ASME BPVC.II.A-2023

SECTION II
MATERIALS

2023 ASME Boiler and Pressure Vessel Code
An International Code

Part A
Ferrous Material Specifications
(SA-451 to End)

ASME
SETTING THE STANDARD

AN INTERNATIONAL CODE

2023 ASME Boiler & Pressure Vessel Code

2023 Edition July 1, 2023

II

MATERIALS

Part A

Ferrous Material Specifications (SA-451 to End)

ASME Boiler and Pressure Vessel Committee on Materials

The American Society of Mechanical Engineers

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FOREWORD[*]

In 1911, The American Society of Mechanical Engineers established the Boiler and Pressure Vessel Committee to formulate standard rules for the construction of steam boilers and other pressure vessels. In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees:

(a) Committee on Power Boilers (I)
(b) Committee on Materials (II)
(c) Committee on Construction of Nuclear Facility Components (III)
(d) Committee on Heating Boilers (IV)
(e) Committee on Nondestructive Examination (V)
(f) Committee on Pressure Vessels (VIII)
(g) Committee on Welding, Brazing, and Fusing (IX)
(h) Committee on Fiber-Reinforced Plastic Pressure Vessels (X)
(i) Committee on Nuclear Inservice Inspection (XI)
(j) Committee on Transport Tanks (XII)
(k) Committee on Overpressure Protection (XIII)
(l) Technical Oversight Management Committee (TOMC)

Where reference is made to "the Committee" in this Foreword, each of these committees is included individually and collectively.

The Committee's function is to establish rules of safety relating only to pressure integrity, which govern the construction[**] of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. The Committee also interprets these rules when questions arise regarding their intent. The technical consistency of the Sections of the Code and coordination of standards development activities of the Committees is supported and guided by the Technical Oversight Management Committee. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks, or nuclear components, or the inservice inspection of nuclear components or transport tanks. Users of the Code should refer to the pertinent codes, standards, laws, regulations, or other relevant documents for safety issues other than those relating to pressure integrity. Except for Sections XI and XII, and with a few other exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of pressure vessels. The objective of the rules is to afford reasonably certain protection of life and property, and to provide a margin for deterioration in service to give a reasonably long, safe period of usefulness. Advancements in design and materials and evidence of experience have been recognized.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities and inservice inspection and testing activities. The Code does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable engineers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code neither requires nor prohibits the use of computers for the design or analysis of components constructed to the

[*] The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Code.

[**] *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and overpressure protection.

requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and the application of these programs to their design.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design, or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code Cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees). Proposed revisions to the Code resulting from inquiries will be presented to the Committee for appropriate action. The action of the Committee becomes effective only after confirmation by ballot of the Committee and approval by ASME. Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute (ANSI) and published at http://go.asme.org/BPVCPublicReview to invite comments from all interested persons. After public review and final approval by ASME, revisions are published at regular intervals in Editions of the Code.

The Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the Committee. ASME is to be notified should questions arise concerning improper use of the ASME Single Certification Mark.

When required by context in this Section, the singular shall be interpreted as the plural, and vice versa, and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

The words "shall," "should," and "may" are used in this Standard as follows:

– *Shall* is used to denote a requirement.
– *Should* is used to denote a recommendation.
– *May* is used to denote permission, neither a requirement nor a recommendation.

STATEMENT OF POLICY ON THE USE OF THE ASME SINGLE CERTIFICATION MARK AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use the ASME Single Certification Mark for marking items or constructions that have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the ASME Single Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the ASME Single Certification Mark who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the ASME Single Certification Mark, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications that might so indicate. An organization holding the ASME Single Certification Mark and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code." An ASME corporate logo shall not be used by any organization other than ASME.

The ASME Single Certification Mark shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of the ASME Single Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the ASME Single Certification Mark.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the ASME Single Certification Mark described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the ASME Single Certification Mark shall not be used on any item that is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME that tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

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(23) # CORRESPONDENCE WITH THE COMMITTEE

General

ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Section of the ASME Boiler and Pressure Vessel Code (BPVC) should be sent to the staff secretary noted on the Section's committee web page, accessible at https://go.asme.org/CSCommittees.

NOTE: See ASME BPVC Section II, Part D for guidelines on requesting approval of new materials. See Section II, Part C for guidelines on requesting approval of new welding and brazing materials ("consumables").

Revisions and Errata

The committee processes revisions to this Code on a continuous basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Code. Approved revisions will be published in the next edition of the Code.

In addition, the committee may post errata and Special Notices at http://go.asme.org/BPVCerrata. Errata and Special Notices become effective on the date posted. Users can register on the committee web page to receive e-mail notifications of posted errata and Special Notices.

This Code is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Code

(4) to permit use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Code.

(c) The committee will consider proposed cases concerning the following topics only:

(1) equipment to be marked with the ASME Single Certification Mark, or

(2) equipment to be constructed as a repair/replacement activity under the requirements of Section XI

(d) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Code Section and the paragraph, figure, or table number(s) to which the proposed case applies

(4) the edition(s) of the Code to which the proposed case applies

(e) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Cases that have been approved will appear in the next edition or supplement of the Code Cases books, "Boilers and Pressure Vessels" or "Nuclear Components." Each Code Cases book is updated with seven Supplements. Supplements will be sent or made available automatically to the purchasers of the Code Cases books until the next edition of the Code. Annulments of Code Cases become effective six months after the first announcement of the annulment in a Code Case Supplement or Edition of the appropriate Code Case book. The status of any case is available at http://go.asme.org/BPVCCDatabase. An index of the complete list of Boiler and Pressure Vessel Code Cases and Nuclear Code Cases is available at http://go.asme.org/BPVCC.

Interpretations

(a) Interpretations clarify existing Code requirements and are written as a question and reply. Interpretations do not introduce new requirements. If a revision to resolve conflicting or incorrect wording is required to support the interpretation, the committee will issue an intent interpretation in parallel with a revision to the Code.

(b) Upon request, the committee will render an interpretation of any requirement of the Code. An interpretation can be rendered only in response to a request submitted through the online Interpretation Submittal Form at http://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic e-mail confirming receipt.

(c) ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Code requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers may track the status of their requests at http://go.asme.org/Interpretations.

(d) ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

(e) Interpretations are published in the ASME Interpretations Database at http://go.asme.org/Interpretations as they are issued.

Committee Meetings

The ASME BPVC committees regularly hold meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the applicable committee. Information on future committee meetings can be found at http://go.asme.org/BCW.

PREFACE

The American Society of Mechanical Engineers (ASME) and the American Society for Testing and Materials (ASTM) have cooperated for more than fifty years in the preparation of material specifications adequate for safety in the field of pressure equipment for ferrous and nonferrous materials, contained in Section II (Part A — Ferrous and Part B — Nonferrous) of the ASME Boiler and Pressure Vessel Code.

The evolution of this cooperative effort is contained in Professor A. M. Greene's "History of the ASME Boiler Code," which was published as a series of articles in *Mechanical Engineering* from July 1952 through August 1953 and is now available from ASME in a special bound edition. The following quotations from this history, which was based upon the minutes of the ASME Boiler and Pressure Vessel Committee, will help focus on the cooperative nature of the specifications found in Section II, Material Specifications.

"General discussion of material specifications comprising Paragraphs 1 to 112 of Part 2 and the advisability of having them agree with ASTM specifications," (1914).

"ASME Subcommittee appointed to confer with ASTM," (1916).

"Because of this cooperation the specifications of the 1918 Edition of the ASME Boiler Code were more nearly in agreement with ASTM specifications. In the 1924 Edition of the Code, 10 specifications were in complete agreement with ASTM specifications, 4 in substantial agreement and 2 covered materials for which ASTM had no corresponding specifications."

"In Section II, Material Specifications, the paragraphs were given new numbers beginning with S-1 and extending to S-213," (1925).

"Section II was brought into agreement with changes made in the latest ASTM specifications since 1921," (1932).

"The Subcommittee on Material Specifications arranged for the introduction of the revisions of many of the specifications so that they would agree with the latest form of the earlier ASTM specifications...," (1935).

From the preceding, it is evident that many of the material specifications were prepared by the Boiler and Pressure Vessel Code Committees, then subsequently, by cooperative action, modified and identified as ASTM specifications. Section II, Parts A and B, currently contain many material specifications that are identical with the corresponding ASTM specifications and some that have been modified for Code usage. Many of these specifications are published in dual format. That is, they contain both U.S. Customary units and SI units. The metrication protocols followed in the specifications are those adopted by ASTM, and are usually to the rules of IEEE/ASTM SI 10-1997, Standard for the Use of the International System of Units (SI): The Modern Metric System.

In 1969, the American Welding Society began publication of specifications for welding rods, electrodes, and filler metals, hitherto issued by ASTM. The Boiler and Pressure Vessel Committee has recognized this new arrangement, and is now working with AWS on these specifications. Section II, Part C, contains the welding material specifications approved for Code use.

In 1992, the ASME Board of Pressure Technology Codes and Standards endorsed the use of non-ASTM material for Boiler and Pressure Vessel Code applications. It is the intent to follow the procedures and practices currently in use to implement the adoption of non-ASTM materials.

All identical specifications are indicated by the ASME/originating organization symbols. The specifications prepared and copyrighted by ASTM, AWS, and other originating organizations are reproduced in the Code with the permission of the respective Society. The ASME Boiler and Pressure Vessel Committee has given careful consideration to each new and revised specification, and has made such changes as they deemed necessary to make the specification adaptable for Code usage. In addition, ASME has furnished ASTM with the basic requirements that should govern many proposed new specifications. Joint action will continue an effort to make the ASTM, AWS, and ASME specifications identical.

To assure that there will be a clear understanding on the part of the users of Section II, ASME publishes both the identical specifications and those amended for Code usage every 2 years.

The ASME Boiler and Pressure Vessel Code has been adopted into law by 50 states and many municipalities in the United States and by all of the Canadian provinces.

SPECIFICATIONS LISTED BY MATERIALS

Corrosion-Resisting and Heat-Resisting Steels

Methods

Steel Bars

Steel Billets and Forgings

Steel Bolting Materials

Steel Castings

Steel Flanges, Fittings, Valves, and Parts

Steel Pipe

Steel Plate, Sheet, and Strip

Steel Plates, Sheets, and Strip for Pressure Vessels

Steel Tubes

Structural Steel

Wrought Iron, Cast Iron, and Malleable Iron

SPECIFICATION REMOVAL (23)

From time to time, it becomes necessary to remove specifications from this Part of Section II. This occurs because the sponsoring society (e.g., ASTM, AWS, CEN) has notified ASME that the specification has either been replaced with another specification, or that there is no known use and production of a material. Removal of a specification from this Section also results in concurrent removal of the same specification from Section IX and from all of the ASME Boiler and Pressure Vessel Construction Codes that reference the material. This action effectively prohibits further use of the material in ASME Boiler and Pressure Vessel construction.

The following specifications will be dropped from this Section in the next Edition, unless information concerning current production and use of the material is received before December 1 of this year:

SA-557
SA-731 (withdrawn by ASTM; see SA-268/SA-268M)

If you are currently using and purchasing new material to this specification for ASME Boiler and Pressure Vessel Code construction, and if discontinuance of this specification would present a hardship, please notify the Secretary of the ASME Boiler and Pressure Vessel Committee, at the address shown below:

Secretary
ASME Boiler and Pressure Vessel Committee
Two Park Avenue
New York, NY 10016-5990

SUMMARY OF CHANGES

Changes listed below are identified on the pages by a margin note, **(23)**, placed next to the affected area.

Page	*Location*	*Change*
xi	List of Sections	*(1)* Under Section III, Division 4 added *(2)* Title of Section XI and subtitle of Section XI, Division 2 revised *(3)* Information on interpretations and Code cases moved to "Correspondence With the Committee"
xv	Personnel	Updated
xxxvii	ASTM Personnel	Updated
xxxviii	Correspondence With the Committee	Added (replaces "Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees")
xlix	Specification Removal	Updated
liii	Cross-Referencing in the ASME BPVC	Updated
1	Statement of Policy on the Use of ASME Material Specifications	Added
3	SA-6/SA-6M	Revised in its entirety
67	SA-20/SA-20M	Revised in its entirety
101	SA-29/SA-29M	Revised in its entirety
125	SA-36/SA-36M	Revised in its entirety
139	SA-53/SA-53M	Revised in its entirety
163	SA-105/SA-105M	Revised in its entirety
169	SA-106/SA-106M	Revised in its entirety
201	SA-179/SA-179M	Revised in its entirety
211	SA-182/SA-182M	Revised in its entirety
229	SA-192/SA-192M	Revised in its entirety
233	SA-193/SA-193M	Revised in its entirety
247	SA-194/SA-194M	Revised in its entirety
279	SA-213/SA-213M	Revised in its entirety
295	SA-214/SA-214M	Revised in its entirety
355	SA-249/SA-249M	Revised in its entirety
393	SA-266/SA-266M	Revised in its entirety
399	SA-268/SA-268M	Revised in its entirety
407	SA-276/SA-276M	Revised in its entirety
423	SA-283/SA-283M	Revised in its entirety
465	SA-320/SA-320M	Revised in its entirety

Page	*Location*	*Change*
539	SA-351/SA-351M	Revised in its entirety
565	SA-358/SA-358M	Revised in its entirety
581	SA-370	Revised in its entirety
631	SA-372/SA-372M	Revised in its entirety
637	SA-376/SA-376M	Revised in its entirety
665	SA-401/SA-401M	Added
671	SA-403/SA-403M	Revised in its entirety
683	SA-409/SA-409M	Revised in its entirety
691	SA-414/SA-414M	Revised in its entirety
705	SA-423/SA-423M	Revised in its entirety
715	SA-437/SA-437M	Revised in its entirety
719	SA-439/SA-439M	Added
735	SA-450/SA-450M	Revised in its entirety
753	SA-453/SA-453M	Revised in its entirety
773	SA-479/SA-479M	Revised in its entirety
809	SA-484/SA-484M	Revised in its entirety
823	SA-487/SA-487M	Revised in its entirety
831	SA-508/SA-508M	Revised in its entirety
885	SA-524/SA-524M	Revised in its entirety
893	SA-530/SA-530M	Revised in its entirety
911	SA-540/SA-540M	Revised in its entirety
929	SA-542/SA-542M	Revised in its entirety
951	SA-557/SA-557M	Deleted
1017	SA-572/SA-572M	Revised in its entirety
1075	SA-656/SA-656M	Revised in its entirety
1137	SA-691/SA-691M	Revised in its entirety
1159	SA-703/SA-703M	Revised in its entirety
1195	SA-727/SA-727M	Revised in its entirety
1201	SA-731/SA-731M	Deleted
1211	SA-738/SA-738M	Revised in its entirety
1243	SA-751	Revised in its entirety
1319	SA-813/SA-813M	Revised in its entirety
1329	SA-814/SA-814M	Revised in its entirety
1357	SA-836/SA-836M	Revised in its entirety
1381	SA-941	Revised in its entirety
1391	SA-960/SA-960M	Revised in its entirety

Page	*Location*	*Change*
1403	SA-961/SA-961M	Revised in its entirety
1413	SA-962/SA-962M	Revised in its entirety
1427	SA-965/SA-965M	Revised in its entirety
1481	SA-995/SA-995M	Revised in its entirety
1539	SA-1058	Added
1565	SA/CSA-G40.21	Revised in its entirety
1567	SA/EN 10025-2	Revised in its entirety
1571	SA/EN 10028-2	Revised
1575	SA/EN 10028-3	Revised
1577	SA/EN 10028-4	Revised
1593	SA/EN 10222-2	Revised
1597	SA/IS 2062	Revised in its entirety
1599	SA/JIS G3118	Revised in its entirety
1608	Mandatory Appendix II	Revised in its entirety
1610	Table II-200-1	Updated
1619	Table II-200-2	Updated

CROSS-REFERENCING IN THE ASME BPVC (23)

Paragraphs within the ASME BPVC may include subparagraph breakdowns, i.e., nested lists. The following is a guide to the designation and cross-referencing of subparagraph breakdowns:

(a) Hierarchy of Subparagraph Breakdowns

(1) First-level breakdowns are designated as (a), (b), (c), etc.

(2) Second-level breakdowns are designated as (1), (2), (3), etc.

(3) Third-level breakdowns are designated as (-a), (-b), (-c), etc.

(4) Fourth-level breakdowns are designated as (-1), (-2), (-3), etc.

(5) Fifth-level breakdowns are designated as (+a), (+b), (+c), etc.

(6) Sixth-level breakdowns are designated as (+1), (+2), etc.

(b) Cross-References to Subparagraph Breakdowns. Cross-references within an alphanumerically designated paragraph (e.g., PG-1, UIG-56.1, NCD-3223) do not include the alphanumerical designator of that paragraph. The cross-references to subparagraph breakdowns follow the hierarchy of the designators under which the breakdown appears. The following examples show the format:

(1) If X.1(c)(1)(-a) is referenced in X.1(c)(1), it will be referenced as (-a).

(2) If X.1(c)(1)(-a) is referenced in X.1(c)(2), it will be referenced as (1)(-a).

(3) If X.1(c)(1)(-a) is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).

(4) If X.1(c)(1)(-a) is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).

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SPECIFICATION FOR CENTRIFUGALLY CAST AUSTENITIC STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

SA-451/SA-451M

(Identical with ASTM Specification A451/A451M-06(2010) except for editorial differences in 15.1.)

Standard Specification for Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service

1. Scope

1.1 This specification covers austenitic alloy steel pipe for use in high-temperature, corrosive, or nuclear pressure service.

1.2 Several grades of austenitic stainless steel are covered as indicated in Table 1.

1.3 Optional supplementary requirements are provided when additional testing may be required.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exactly equivalents; therefore, each system must be used independently of each other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1—This specification is not intended to cover centrifugal pipe made from alloys containing more than 0.20 % carbon, such as are covered by Specification A297/A297M.

2. Referenced Documents

2.1 *ASTM Standards:*

A297/A297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E94 Guide for Radiographic Examination

E165 Practice for Liquid Penetrant Examination for General Industry

E186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (50.8 to 114-mm)) Steel Castings

E280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings

E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness

2.2 *ANSI Standard:*

B46.1 Surface Texture

3. Ordering Information

3.1 Orders for material to this specification shall include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (centrifugally cast pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (outside or inside diameter and minimum wall thickness in inches or millimetres),

3.1.5 Length (specific or random, Specification A999/A999M),

3.1.6 End Finish of Specification A999/A999M,

3.1.7 Optional Requirements (9.4 and Supplementary Requirements S1 through S7),

3.1.8 Test Report Required (Section 14), and

3.1.9 Special Requirements or Additions to Specification.

4. Materials and Manufacture

4.1 *Heat-Treatment*—The pipe shall receive a heat-treatment at the temperature and time specified in Table 2, followed by a quench in water or rapid cool by other means.

4.2 *Machining*—The pipe shall be machined on the inner and outer surfaces to a roughness value no greater than 250-µin. [6.35-µm] arithmetical average deviation (AA) from the mean line, as defined in American National Standard B46.1.

TABLE 1 Chemical Requirements

Grade	Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Columbium	Tantalum, max	Nitrogen
	Composition, %										
CPF3	0.03	1.50	0.040	0.040	2.00	8.0–12.0	17.0–21.0	...	...	...	...
CPF3A	0.03	1.50	0.040	0.040	2.00	8.0–12.0	17.0–21.0	...	...	...	...
CPF8	0.08	1.50	0.040	0.040	2.00	8.0–11.0	18.0–21.0	...	...	...	...
CPF8A	0.08	1.50	0.040	0.040	2.00	8.0–11.0	18.0–21.0	...	...	...	...
CPF3M	0.03	1.50	0.040	0.040	1.50	9.0–13.0	17.0–21.0	2.0–3.0	...	...	...
CPF8M	0.08	1.50	0.040	0.040	1.50	9.0–12.0	18.0–21.0	2.0–3.0	...	...	...
CPF10MC[A]	0.10	1.50	0.040	0.040	1.50	13.0–16.0	15.0–18.0	1.75–2.25	1.2 max, 10 × C min	...	...
CPF8C[A]	0.08	1.50	0.040	0.040	2.00	9.0–12.0	18.0–21.0	...	1 max, 8 × C min	...	...
CPF8C(Ta max)[B]	0.08	1.50	0.040	0.040	2.00	9.0–12.0	18.0–21.0	...	1 max, 8 × C min	0.10	...
CPH8	0.08	1.50	0.040	0.040	1.50	12.0–15.0	22.0–26.0	...	...	...	...
CPH20 or CPH10	0.20[C]	1.50	0.040	0.040	2.00	12.0–15.0	22.0–26.0	...	...	...	...
CPK20	0.20	1.50	0.040	0.040	1.75	19.0–22.0	23.0–27.0	...	...	...	...
CPE20N	0.20	1.50	0.040	0.040	1.50	8.0–11.0	23.0–26.0	...	...	...	0.08–0.20

[A] Grades CPF10MC and CPF8C may have a columbium plus tantalum content maximum of 1.35 %.
[B] No designation as yet assigned by ASTM International or Steel Founders' Society of America.
[C] By agreement between the manufacturer and the purchaser, the carbon content of Grade CPH20 may be restricted to 0.10 % max. When so agreed, the grade designation shall be CPH10.

TABLE 2 Heat-Treatment Requirements

Grade	Temperature, min °F	Temperature, min °C	Hold Time, h/in. of Thickness
CPF3, CPF3A, CPF8, CPF8A, CPF3M, CPF8M	1900	1040	1
CPF10MC, CPF8C, CPF8C (Ta max)	1950	1065	2
CPH8, CPH10, CPH20, CPK20	2100	1150	1
CPE20N	2225	1220	1

TABLE 3 Tensile Requirements

Grade	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min
CPF3	70 [485]	30 [205]	35
CPF3A[A]	77 [535]	35 [240]	35
CPF3M	70 [485]	30 [205]	30
CPF8	70 [485]	30 [205]	35
CPF8A[A]	77 [535]	35 [240]	35
CPF8M	70 [485]	30 [205]	30
CPF10MC	70 [485]	30 [205]	20
CPH10	70 [485]	30 [205]	30
CPF8C (Ta max), CPF8C	70 [485]	30 [205]	30
CPH8	65 [448]	28 [195]	30
CPK20	65 [448]	28 [195]	30
CPH20	70 [485]	30 [205]	30
CPE20N	80 [550]	40 [275]	30

[A] The properties shown are obtained by adjusting the composition within the limits shown in Table 1 to obtain a ferrite-austenite ratio that will result in the higher ultimate and yield strengths indicated. A lowering of impact values may develop in these materials when exposed to service temperature above 800°F [425°C].

5. Chemical Analysis

5.1 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of elements specified in Table 1. The analysis shall be made on a test sample taken preferably during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1.

5.2 *Product Analysis*—A product analysis may be made by the purchaser. The sample for analysis shall be selected so as to be thoroughly representative of the pipe being analyzed. The chemical composition thus determined shall conform to the requirements specified in Table 1.

5.3 To determine conformance with the chemical analysis requirements, an observed value or calculated value shall be rounded in accordance with Practice E29 to the nearest unit in the last right-hand place of values listed in Table 1.

6. Tensile Requirements

6.1 *Test Specimens:*

6.1.1 Test specimens shall be prepared in accordance with Test Methods and Definitions A370. Test bars shall be poured in special blocks from the same heat as the castings represented. Test bars shall be supplied in sufficient number to furnish all specimens required in 6.2 and 6.3 (see Table 3).

6.1.2 Test specimens may be cut from heat-treated castings instead of from test bars when agreed upon between the manufacturer and the purchaser.

6.1.3 Tension test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimens shown in Fig. 6 of Test Methods and Definitions A370.

6.2 *Number of Tests:*

6.2.1 One tension test shall be made from each heat. The bar from which the test specimen is taken shall be heat-treated in the same manner as the castings represented.

6.2.2 If a specimen is machined improperly or flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

6.3 *Retests*—If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be reheat-treated and retested, but may not be solution-treated more than twice.

7. Hydrostatic Test

7.1 Each length of pipe shall be hydrostatically tested in accordance with Specification A999/A999M.

7.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work has been performed on the casting. In such cases, the foundry is responsible for the satisfactory performance of the casting when it is tested.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free from cracks and hot tears. Other surface defects shall be judged in accordance with visual acceptance criteria which may be specified in the order.

9. Rework and Retreatment

9.1 Defects as defined in Section 8 shall be removed and their removal verified by visual inspection of the resultant cavities. Defects which are located by inspecting with Supplementary Requirement S6 or S7, or both, shall be removed or reduced to an acceptable size.

9.2 If removal of the defect does not infringe upon the minimum wall thickness, the depression may be blended uniformly into the surrounding surface.

9.3 If the cavity resulting from defect removal infringes upon the minimum wall thickness, weld repair is permitted subject to the purchasers' approval. The composition of the weld rod used shall be suitable for the composition of the metal being welded.

9.3.1 Only operators and procedures qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX, shall be used. All repair welds will be inspected to the same quality standards used to inspect the casting.

9.4 Postweld heat-treatment of the repaired casting is neither required nor prohibited.

10. Permissible Variations in Dimensions

10.1 *Thickness*—The wall thickness shall not vary over that specified by more than ⅛ in. (3 mm). There shall be no variation under the specified wall thickness.

11. General Requirements

11.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M, unless otherwise provided herein.

12. Rejection

12.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the pipe may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

13. Rehearing

13.1 Samples that represent rejected material shall be preserved for 2 weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

15. Product Marking

15.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the letters ASTM, the specification number, and grade. In addition, heat numbers, or serial numbers that are traceable to heat numbers, shall be marked on each length of pipe.

16. Keywords

16.1 austenitic; centrifugally cast; height; high-temperature service; stainless steel; steel castings

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Additional Tension Tests

S1.1 Additional tension tests shall be made at a temperature to be specified by the customer, and the properties to be met are a matter of agreement between purchaser and manufacturer.

S2. Flattening Test

S2.1 The flattening test shall be made on specimens from one or both ends of each length of pipe. If the specimen from any end of any length fails to conform to the requirements of Specification A999/A999M, that length shall be rejected.

S3. Photomicrographs

S3.1 The manufacturer shall furnish one photomicrograph at 100 diameters from one specimen of as-finished pipe from each heat in each heat-treatment lot. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. Such photomicrographs are for information only, to show the actual metal structure of the pipe as furnished. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S4.

S4. Photomicrographs for Individual Pieces

S4.1 The manufacturer shall furnish photomicrographs from one or both ends of each pipe. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S5. Metal Structure and Etching Tests

S5.1 Etching tests (Note S1) shall be made on transverse sections from the pipe and shall reveal the macrostructure of the material. Such tests are for information only.

NOTE S1—Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recommended Practice for a Standard Macroetch Test for Routine Inspection of Iron and Steel be followed.

S6. Radiographic Examination

S6.1 The castings shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Guide E94 and the types and degrees of discontinuities considered shall be judged by Reference Radiographs E446, E186, or E280. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S7. Liquid Penetrant Examination

S7.1 The castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The method of performing the liquid penetrant test shall be in accordance with Test Method E165. The areas to be inspected, the methods and types of liquid penetrants to be used, the developing procedure, and the basis for acceptance shall be as specified on the inquiry or invitation to bid and on the purchase order or contract or both, or as agreed upon between the manufacturer and the purchaser.

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SPECIFICATION FOR HIGH-TEMPERATURE BOLTING, WITH EXPANSION COEFFICIENTS COMPARABLE TO AUSTENITIC STAINLESS STEELS

SA-453/SA-453M

(23)

(Identical with ASTM Specification A453/A453M-17.)

Specification for High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels

1. Scope

1.1 This specification covers five grades of bolting materials with twelve classes of yield strength ranging from 50 to 120 ksi [345 to 827 MPa] for use in high-temperature service for bolting components, such as bolts, screws, nuts, or studs, for pressure vessel and valve flanges. See Specification A962/A962M for the definition of bolting. The material requires special processing and is not intended for general purpose applications.

1.2 The following referenced general requirements are indispensable for application of this specification: Specification A962/A962M.

1.3 Supplementary Requirements are provided for use at the option of the purchaser. The Supplementary Requirements shall only apply when specified individually by the purchaser in the purchase order or contract.

1.4 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable "M" specification designation (SI units), the inch-pound units shall apply.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A193/A193M Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

A962/A962M Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

E292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *heat-treatment charge*—one heat of material heat treated in one batch. If a continuous operation is used, the weight processed as a heat-treatment charge shall not exceed the weights in Table 1.

3.1.2 *lot*—a lot shall consist of the quantities shown in Table 2.

4. Ordering Information

4.1 The inquiry and order shall indicate the following:

4.1.1 Quantity (weight or number of pieces),

4.1.2 Description of item (bars, bolts, nuts, etc.),

4.1.3 Grade and class (see Table 3),

4.1.4 Method of finishing (see 6.1),

4.1.5 Type of thread desired (see 6.1.1),

4.1.6 Alternative test method option (see 8.2.4.3),

4.1.7 Bolt shape option, if any,

4.1.8 Thread option, if any,

4.1.9 Test method for surface quality, if any,

TABLE 1 Continuous Heat-Treatment Charge Sizes

Diameter, in. [mm]	Weight, lb [kg]
To 1¾ [44]	3000 [1400]
Over 1¾ [44] to 2½ [63]	6000 [2700]
Over 2½ [63]	12000 [5400]

TABLE 2 Lot Sizes

Diameter, in. [mm]	Maximum Lot Size, lb [kg]
1½ [38] and under	200 [90]
Over 1½ [38] to 1¾ [44], incl	300 [140]
Over 1¾ [44] to 2½ [63], incl	600 [270]
Over 2½ [63]	20 pieces

4.1.10 Test location option, if any,

4.1.11 Rejection option, if any, and

4.1.12 If stress-rupture testing is not required, except for Grade 660 Class D and Grade 668 (see 8.2.1).

5. Common Requirements

5.1 Bolting materials and bolting components supplied to this specification shall conform to the requirements of Specification A962/A962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A962/A962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A962/A962M, this specification shall prevail.

6. Materials and Manufacture

6.1 *Finishing Process:*

6.1.1 Threads may be formed by machining or rolling. Threads may be formed after precipitation heat treatment or after solution anneal but prior to precipitation heat treatment. Type designations are as follows:

Type M1—threads formed by machining after precipitation heat treatment.

Type M2—threads formed by machining after solution anneal but prior to precipitation heat treatment.

Type R1—threads formed by rolling after precipitation heat treatment.

Type R2—threads formed by rolling after solution anneal but prior to precipitation heat treatment.

When not specified by the purchaser, the type supplied shall be the option of the manufacturer.

6.2 *Heat Treatment*—Each grade and class shall be heat treated as prescribed in Table 4.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 3.

8. Mechanical Properties

8.1 *Tension Test:*

8.1.1 *Requirements*—Bolting material in each heat-treatment charge shall conform to the room-temperature tensile requirements in Table 5.

8.1.2 *Number of Specimens:*

8.1.2.1 *Heat-Treated Bars*—When not more than two sizes of bars are heat treated in the same load, one tension test shall be made from each size in each heat of material in the heat-treatment charge (see 3.1.1). When more than two sizes of bars are treated in the same charge, one tension test shall be made from one bar of each of the two largest diameters from each heat of material in the heat-treating charge.

8.1.2.2 *Finished Bolting Components*—One tension test shall be made if the lot consists of parts of the same nominal diameter. If the lot consists of components of more than one nominal diameter, one tension test shall be made from each nominal diameter of each heat involved in the lot (see Section 3).

8.2 *Stress-Rupture Test:*

8.2.1 *Requirements*—Bolting material shall conform to the stress-rupture requirements prescribed in Table 6 for design temperatures above 800 °F [427 °C]. Bolting material not stress-rupture tested shall be permanently stamped NR. Grade 660 Class D and Grade 668 do not require stress-rupture and shall be stamped NR.

8.2.2 The number of specimens shall be the same as the required number of tension test specimens.

8.2.3 The test location and orientation shall be the same as that required for the tension test specimens.

8.2.4 *Test Method:*

8.2.4.1 The rupture test shall be performed in accordance with Practice E139.

NOTE 1—Fig. 1 is taken from Test Method E292. This is to facilitate detection of notch sensitivity. The specimen found in Practice E139 does not include a notch. The specimen in Fig. 1 is to be used only to determine if the material is notch sensitive. Actual testing is to Practice E139, not Test Method E292, so the additional test data required by Test Method E292 is not to be determined or reported.

8.2.4.2 A combination smooth and notched test specimen, machined to the dimensions prescribed in Fig. 1 and Table 7, shall be tested in accordance with the stress-rupture requirements prescribed in Table 6. The test shall be continued to rupture. The rupture shall occur in the smooth section of the bar.

8.2.4.3 As an alternative procedure and, when specifically approved by the purchaser, separate smooth and notched test specimens, machined from adjacent sections of the same piece, with gage sections conforming to the respective dimensions of Table 7, may be tested under the above conditions. The notched specimen need not be tested to rupture but shall not rupture in less time than the companion smooth specimen.

8.2.4.4 When the minimum specified time to rupture in Table 6 has been achieved, incremental loading may be used to accelerate the time to rupture. At intervals of 8 to 16 h, preferably 8 to 10 h, the stress shall be increased in increments of 5000 psi [34.5 MPa]. Rupture location, and elongation requirements shall be as prescribed in Table 6, 8.2.4.2, and 8.2.4.3.

8.3 *Hardness Test:*

8.3.1 *Requirements*—Bolting material shall conform to the room temperature hardness requirements prescribed in Table 5.

8.3.2 *Number of Tests:*

TABLE 3 Chemical Requirements

	Grade 660		Grade 651	
UNS Number	S66286		S63198	
	Content, %	Product Analysis Variation, Over or Under, %	Content, %	Product Analysis Variation, Over or Under, %
Carbon	0.08 max	0.01 over	0.28–0.35	0.02
Manganese	2.00 max	0.04	0.75–1.50	0.04
Phosphorus	0.040 max	0.005 over	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over	0.030 max	0.005 over
Silicon	1.00 max	0.05	0.30–0.80	0.05
Nickel	24.0–27.0	0.20	8.0–11.0	0.15
Chromium	13.5–16.0	0.20	18.0–21.0	0.25
Molybdenum	1.00–1.50	0.05	1.00–1.75	0.05
Tungsten	...	...	1.00–1.75	0.05
Titanium	1.90–2.35	0.05	0.10–0.35	0.05 over
Columbium[A]	...	...	0.25–0.60	0.05
Aluminum	0.35 max	0.05 over	...	...
Vanadium	0.10–0.50	0.03	...	...
Boron	0.001–0.010	0.0004 under to 0.001 over	...	...
Copper	...	...	0.50 max	0.03 over
	Grade 662		Grade 665	
UNS Number	S66220		S66545	
	Content, %	Product Analysis, Variation Over or Under, %	Content, %	Product Analysis Variation, Over or Under, %
Carbon	0.08 max	0.01 over	0.08 max	0.01 over
Manganese	0.40–1.00	0.03	1.25–2.00	0.04
Phosphorus	0.040 max	0.005 over	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over	0.030 max	0.005 over
Silicon	0.40–1.00	0.05	0.10–0.80	0.05
Nickel	24.0–28.0	0.20	24.0–28.0	0.20
Chromium	12.0–15.0	0.15	12.0–15.0	0.15
Molybdenum	2.0–3.5	0.10	1.25–2.25	0.10
Titanium	1.80–2.10	0.05	2.70–3.3	0.05
Aluminum	0.35 max	0.05 over	0.25 max	0.05 over
Copper	0.50 max	0.03 over	0.25 max	0.03 over
Boron	0.001–0.010	0.0004 under to 0.001 over	0.01–0.07	0.005
	Grade 668			
UNS Number	S66285			
	Content, %	Product Analysis, Variation Over or Under, %		
Carbon	0.08 max	0.01 over		
Manganese	2.00 max	0.04		
Phosphorus	0.040 max	0.005 over		
Sulfur	0.030 max	0.005 over		
Silicon	1.00 max	0.05		
Nickel	17.5 – 21.5	0.20		
Chromium	13.5–16.0	0.20		
Molybdenum	1.50 max	0.05		
Tungsten	...	...		
Titanium	2.2–2.8	0.05		
Columbium[A]	...	...		
Aluminum	0.50 max	0.05 over		
Vanadium	0.50 max	0.03		
Boron	0.001–0.010	0.0004 under to 0.001 over		
Copper	...	...		

[A] Or columbium plus tantalum.

8.3.2.1 *Bars 2 in. [50 mm] and Over*—One test on each mill-treated length.

8.3.2.2 *Bars under 2 in. [50 mm]*—One test on at least 10 % of the mill treated lengths.

8.3.2.3 *Bolting Components*—See Specification A962/A962M for the required number of tests.

8.3.3 *Test Locations*—The hardness test shall be made at the center of the cross section for bars up to 1 in. [25 mm] in diameter, and at the midradius on bars 1 in. [25 mm] and larger in diameter.

TABLE 4 Heat Treatment Requirements[A]

Grade Symbol	Class	Solution Treatment	Hardening Treatment
660	A	1650 ± 25 °F [900 ± 14 °C], hold 2 h, min, and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool
	B	1800 ± 25 °F [980 ± 14 °C], hold 1 h, min, and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool
	C	1800 ± 25 °F [980 ± 14 °C], hold 1 h min, and oil quench	1425 ± 25 °F [775 ± 14 °C] hold 16 h, air cool, followed by 1200 ± 25 °F [650 ± 14 °C] hold 16 h, air cool
	D	1650 ± 25 °F [900 ± 14 °C], hold 2 h min, and liquid quench or 1800 ± 25 °F [980 ± 14 °C], hold 1 h min, and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool If necessary to achieve properties, second age: 1200 ± 25 °F [650 ± 14 °C] hold 16 h, air cool
651	A		hot-cold worked at 1200 °F [650 °C] min with 15 % min reduction in cross-sectional area, stress relieve at 1200 °F [650 °C] min or 4 h, min
	B		hot-cold worked at 1200 °F [650 °C] min with 15 % min reduction of cross-sectional area, stress relieve at 1350 °F [730 °C] min for 4 h, min
662	A	1800 ± 25 °F [980 ± 14 °C], hold 2 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool
	B	1950 ± 25 °F [1065 ± 14 °C], hold 2 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool
665	A	1800 ± 25 °F [980 ± 14 °C], hold 3 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool
	B	2000 ± 25 °F [1095 ± 14 °C], hold 3 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool
668	A	1650 ± 25 °F [900 ± 14 °C], hold 2 h, min and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool
	B	1800 ± 25 °F [980 ± 14 °C], hold 1 h, min and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool

[A] Times refer to the minimum time material is required to be at temperature.

TABLE 5 Mechanical Property Requirements

Grade	Class	Tensile Strength, min		Yield Strength (0.2 % Offset), min		Elongation in 4× Diam, min, %	Reduction of Area, min, %	Brinell Hardness Number	Approximate Rockwell Hardness, B and C	
		ksi	MPa	ksi	MPa				min	max
660	A, B, and C	130	895	85	585	15	18	248–341	24 HRC	37 HRC
	D (≤2½ in. [63.5 mm])	130	895	105	725	15	18	248–321	24 HRC	35 HRC
	D (>2½ in. [63.5 mm])	120	825	95	655	15	18	248–321	24 HRC	35 HRC
651	A	100	690	70[A] 60[B]	485 415	18	35	217–277	95 HRB	29 HRC
	B	95	655	60[A] 50[B]	415 345	18	35	212–269	93 HRB	28 HRC[C]
662	A	130	895	85	585	15	18	248–321	24 HRC	35 HRC[C]
	B	125	860	80	550	15	18	248–321	24 HRC	35 HRC
665	A	170	1170	120	830	12	15	311–388	32 HRC	41 HRC
	B	155	1070	120	830	12	15	311–388	32 HRC	41 HRC
668	A and B	130	895	85	585	15	18	248–341	24 HRC	37 HRC

[A] Bolting material sizes 3 in. [76 mm] and under in diameter.
[B] Bolting material sizes over 3 in. [76 mm] in diameter.
[C] Conversion numbers taken from Specification A193/A193M, Table number 2 (austenitic steels); others by interpolation.

TABLE 6 Stress Rupture Requirements

Grade	Class	Test Temperature, °F [°C]	Stress, min		Time to Rupture, min, h[A]	Elongation, min, %
			ksi	MPa		
660	A, B, and C	1200 [650]	56	385	100	5
651	A and B	1200 [650]	40	275	100	5
662	A and B	1200 [650]	55	380	100	5
665	A	1200 [650]	75	515	100	3
	B	1200 [650]	70	485	100	5

[A] The combination bar specimen shown in Fig. 1 shall be tested continuously at the temperature and at the minimum stress specified or at a greater stress and shall rupture in a time not less than that specified.

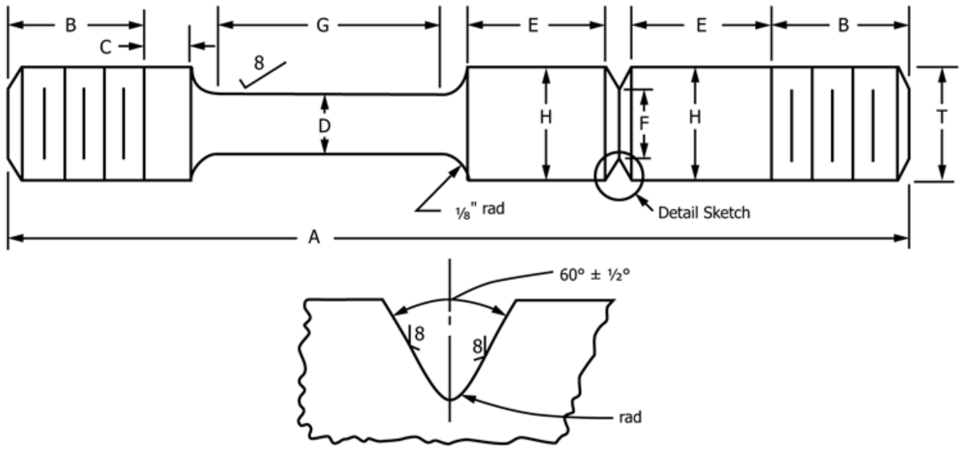

FIG. 1 Combination Smooth-Notch Stress-Rupture Test Specimen (See Table 6)

9. Product Marking

9.1 *Bolts, Nuts, Screws, and Studs*—In addition to the requirements of Specification A962/A962M, the grade symbol and class shown in Table 4 and the type designation (see 6.1.1) shall also appear on all bolting components so processed. Grade 660 Class D and Grade 668 shall be stamped NR in addition to other required markings.

10. Certification

10.1 Certification is required. See Specification A962/A962M.

11. Keywords

11.1 bolts–steel; bolting components–steel; marking; nuts–steel; precipitation hardening steels; pressure vessel service; revision letter; steel bars–alloy; steel bolting; steel flanges; steel values; temperature service applications–high

TABLE 7 Test Specimen Dimensions

NOTE 1— Surfaces marked [8], finish to 8 μin. [0.2 μm] rms or better.

NOTE 2—The difference between dimensions *F* and *D* shall not exceed 0.0005 in. [0.01 mm] for specimens 1 or 2. The difference shall not exceed 0.001 in. [0.02 mm] for specimens 3, 4, 5, or 6.

NOTE 3—Taper the gage length *G* to the center so that the diameter *D* at the ends of the gage length exceeds the diameter at the center of the gage length by not less than 0.0005 in. [0.01 mm] nor more than 0.0015 in. [0.04 mm].

NOTE 4—All sections shall be concentric about the specimen axis within 0.001 in. [0.02 mm].

NOTE 5—Thread size *T* shall be equal to or greater than diameter *H*.

NOTE 6—Dimensions *A* and *B* are not specified.

NOTE 7—Length of shoulder *C*—⅛ + 1⁄32 −0 in. [3.2 + 0.8 mm].

NOTE 8—Length of shoulder *E*—⅜ + 1⁄32 −0 in. [10.0 + 0.8 mm].

Specimen Type	Mid-length Gage Dia *D* and Notch-Root Dia *F*	Gage Length, *G*	Shoulder Diameter, *H*	Notch-Root Radius
	Inches			
1	0.125	0.5	0.177	0.005
2	0.160	0.65	0.226	0.005
3	0.178	0.75	0.250	0.005
4	0.252	1.0	0.375	0.007
5	0.357	1.5	0.500	0.010
6	0.505	2.0	0.750	0.015
Tolerance	±0.001	±0.05	±0.003	±0.0005
	Millimetres			
7	3.17	12.0	4.5	0.13
8	4.06	17.0	5.5	0.13
9	4.52	20.0	6.5	0.13
10	6.40	25.0	9.5	0.18
11	9.07	40.0	12.0	0.25
12	12.8	50.0	19.0	0.38
Tolerance	±0.025	±1.3	±0.1	±0.01

TABLE 8 Permissible Variations in Size of Cold-Finished Bars

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm][A]	
	Over	Under
Over ½ to 1 [13 to 25], excl	0.002 [0.05]	0.002 [0.05]
1 to 1½ [25 to 38], excl	0.0025 [0.06]	0.0025 [0.06]
1½ to 4 [38 to 100], incl[B]	0.003 [0.08]	0.003 [0.08]

[A] When it is necessary to heat treat or heat treat and pickle after cold finishing, because of special hardness or mechanical property requirements, the permissible variations are generally double those shown in the table.
[B] For size tolerances of sizes over 4 in. [100 mm], the manufacturer should be consulted.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, HIGH-STRENGTH MANGANESE

SA-455/SA-455M

(Identical with ASTM Specification A455/A455M-12a(2017).)

Standard Specification for Pressure Vessel Plates, Carbon Steel, High-Strength Manganese

1. Scope

1.1 This specification covers high-tensile strength carbon-manganese steel plates intended for welded pressure vessels.

1.2 This steel is usually made to a semi-killed or capped deoxidation practice; however, at the purchaser's or the steel producer's option, the steel may be made silicon-killed or aluminum-killed.

1.3 The maximum thickness of plates furnished under this specification shall be ¾ in. [20 mm].

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A20/A20M apply.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A20/A20M.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Heat Treatment

4.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5. Chemical Composition

5.1 The steel shall conform to the chemical requirements given in Table 1.

6. Mechanical Properties

6.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

7. Keywords

7.1 carbon steel; high-strength steel plate for pressure purposes; welded pressure vessels

TABLE 1 Chemical Requirements

Elements	Composition, %
Carbon, max[A,B]	0.33
Manganese:[C]	
Heat analysis	0.85–1.20
Product analysis	0.79–1.30
Phosphorus, max[A]	0.025
Sulfur, max[A]	0.025
Silicon:[D]	
Heat analysis	0.10 max
Product analysis	0.13 max

[A] Applies to both heat and product analyses.
[B] When the silicon is higher than 0.10 %, the carbon maximum shall be 0.28 %.
[C] For each reduction of 0.01 percentage point below the specified maximum for carbon, and increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.
[D] At the purchaser's or the producer's option, silicon may be 0.40 % max on heat analysis, 0.45 % max on product analysis.

TABLE 2 Tensile Requirements

	Thickness		
	Up to 0.375 in. [9.5 mm]	Over 0.375 to 0.580 in. [15 mm]	Over 0.580 to 0.750 in. [20 mm]
Tensile strength, ksi [MPa]	75–95 [515–655]	73–93 [505–640]	70–90 [485–620]
Yield strength, min, ksi [MPa]	38 [260]	37 [255]	35 [240]
Elongation in 8 in. [200 mm], min, %[A]	15	15	15
Elongation in 2 in. [50 mm], min, %[A]	22	22	22

[A] See Specification A20/A20M for elongation adjustments.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons.

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SPECIFICATION FOR DUCTILE IRON CASTINGS FOR PAPER MILL DRYER ROLLS

SA-476/SA-476M

(Identical with ASTM Specification A476/A476M-00(2018) except for editorial changes in 4.1.6 and 13.1 to make certification mandatory.)

SPECIFICATION FOR DUCTILE IRON CASTINGS FOR PAPER MILL DRYER ROLLS

SA-476/SA-476M

[Identical with ASTM Specification A 476/A 476M-00(2018) except for editorial changes in 4.1.6 and 13.1 to make certification mandatory.]

1. Scope

1.1 This specification covers ductile iron castings for use in pressure containing paper mill dryer rolls at temperatures up to 450°F [230°C].

1.2 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron (see Appendix X1).

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 644 Terminology Relating to Iron Castings
E 8 Test Methods for Tension Testing of Metallic Materials
E 10 Test Method for Brinell Hardness of Metallic Materials
E 94 Guide for Radiographic Testing
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness

3. Terminology

3.1 Definitions for many terms common to iron castings are found in Terminology A 644.

4. Ordering Information

4.1 Orders for material purchased to the requirements of this specification should include the following information:

4.1.1 Quantity,

4.1.2 Specification number and date of issue,

4.1.3 Description of casting by pattern number or drawing,

4.1.4 Heat treatment, if required (see 5.1),

4.1.5 Type of test coupon (see 9.2),

4.1.6 Certification, is required (see 13.1),

4.1.7 Marking location (see 14.1), and

4.1.8 Additional requirements.

5. Heat Treatment

5.1 The castings may be stress relieved at a temperature not to exceed 1200°F [650°C].

6. Chemical Requirements

6.1 The castings shall conform to the following chemical requirements:

Total carbon, min, %	3.0
Silicon, max, %	3.0
Phosphorus, max, %	0.08
Sulfur, max, %	0.05

6.2 The castings shall have a carbon equivalent of 3.8 to 4.5 inclusive.

NOTE 1 — The carbon content equivalent is calculated as follows:
Total carbon + 0.3 (silicon + phosphorus)

6.3 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or on thin wafers approximately $\frac{1}{32}$ in. [0.8 mm] thick, cut from test coupons. Drillings shall not be used due to attendant loss of graphite.

7. Mechanical Properties

7.1 The iron represented by test coupons shall conform to tensile requirements prescribed in Table 1.

7.2 The yield strength prescribed in Table 1 may be determined by any of the approved procedures described in 7.3 of Test Methods E 8.

7.3 The Brinell hardness of the material shall be a minimum of 201 HB. Hardness tests shall be conducted in accordance with Test Method E 10, using a 3000 kgf load. The test may be made on either the casting or on a test coupon representing the casting.

8. Workmanship, Finish, and Appearance

8.1 The castings shall conform to the dimensions on the drawings furnished by the purchaser, or if no drawing has been provided, to the dimensions predicated by the pattern supplied by the purchaser. Surfaces of the castings shall be free of adhering sand. Runners, risers, fins, and other extraneous metal shall be removed.

9. Sampling

9.1 Test coupons shall be poured from the same iron as the castings represented.

9.2 Test coupons shall be cast either to the "Y" block size and shape shown in Fig. 1 or to the dimensions of the 1 in. [25-mm] keel block shown in Fig. 2. The type of test coupon and, when selected, the size of the "Y" block shall be specified by the purchaser.

9.3 The test coupons shall be cast in open molds made of suitable core sand with a minimum $1\frac{1}{2}$ in. [38 mm] of sand for the 1 in. [25 mm] size and 3 in. [75 mm] of sand for the 3 in. [75 mm] size. The coupons shall be left in the mold until black.

9.4 Table 2 shows the equivalent geometrical shapes with various dimensions and the equivalent "Y" block, based on cooling rates, and may be used as a guide for selection of the proper "Y" block to be specified to represent the casting.

9.5 When the castings are heat treated, the test coupons shall be heat treated with the castings they represent.

10. Tension Test

10.1 Tension test specimens shall be obtained from test coupons shown in either Fig. 1 or Fig. 2, and machined to the dimensions shown in Fig. 3. Test coupons cast as "Y" blocks (Fig. 1) shall be sectioned as shown in Fig. 4.

10.2 One tension test shall be performed for each casting.

10.3 If any specimen shows defective machining or flaws, it may be discarded and another substituted from the same casting represented.

10.4 If an apparently sound test specimen fails to conform to the tensile requirements, two retests may be made. If either retest fails to conform to the requirements specified, the castings shall be rejected.

11. Repairs

11.1 Castings made to this specification that leak on subsequent hydrostatic testing may be repaired by using threaded plugs provided the following requirements are met.

11.1.1 No welding or brazing shall be permitted.

11.1.2 The diameter of the plug shall not exceed the diameter of a standard 2 in. [ISO R2] iron pipe size pipe plug.

11.1.3 The plugs, where practical, shall conform in all dimensions to the standard iron pipe size pipe plugs. In addition, they shall have full thread engagement corresponding to the thickness of the repaired section. Where a tapered plug is impractical because of the excess wall thickness in terms of plug diameter and coincident thread engagement, other types of plugs may be used provided both full thread engagement and effective sealing against pressure are obtained. Where possible the ends of the plugs should be ground smooth after installation to conform to the inside and outside contours of the cylinder.

11.1.4 The material from which the plug is manufactured shall conform in all respects to this specification.

11.1.5 The area adjacent to the drilled hole should be examined radiographically in accordance with Guide E 94. The area examined shall meet the requirements of Severity Level 3 of Reference Radiographs E 446.

11.1.6 The thickness of any repaired section in relation to the size of plug used shall be not less than that given in Table 3.

11.1.7 The minimum radius of curvature of the repaired section of the cylinder in relation to the size of plug used shall be not less than that given in Table 4.

11.1.8 A repaired area may consist of a maximum of three plugs with a spacing such that the distance between adjacent plugs shall not be less than those listed in Table 5. Adjacent areas of repair, in which each contains more than one plug, shall be separated by at least twice the distance required in Table 5 for the two nearest plugs separating the two areas.

11.2 Surface imperfections not exceeding 20% of the thickness of the section and other minor defects may be repaired by plugging provided the diameter of the plug does not exceed its length.

12. Inspection

12.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with this specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture unless otherwise agreed.

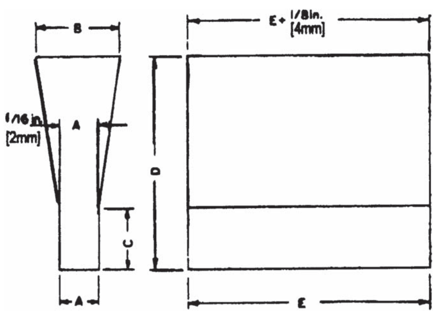
13. Certification

13.1 The manufacturer's certification shall be furnished stating that the material was manufactured, sampled, tested, and inspected in accordance with the requirements of this specification and was found to meet the requirements. In addition to the certification, a test report shall be furnished showing the results of all tests performed.

14. Product Marking

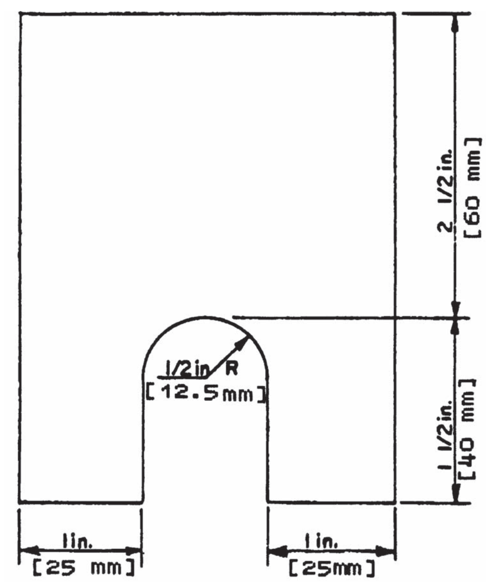
14.1 Castings made in accordance with this specification shall have the name of the manufacturer or his recognized trade mark and this specification number cast on or indelibly stamped on a surface designated by the purchaser.

FIG. 1 "Y" BLOCKS FOR TEST COUPONS



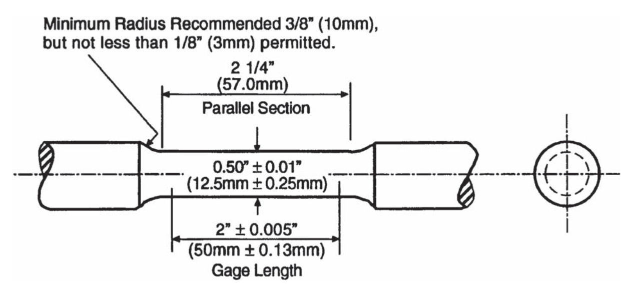
Dimensions	"Y" Block Size	
	For Casting of Thickness ½ in. to 1½ in. [12.5-40 mm]	For Castings of Thickness of 1½ in. [40 mm] and Over
	in. [mm]	in. [mm]
A	1 [25]	3 [75]
B	1⅛ [55]	5 [125]
C	3 [75]	4 [100]
D	6 [150]	8 [200]
E	7 [175] approx	7 [175] approx

FIG. 2 KEEL BLOCK FOR TEST COUPONS



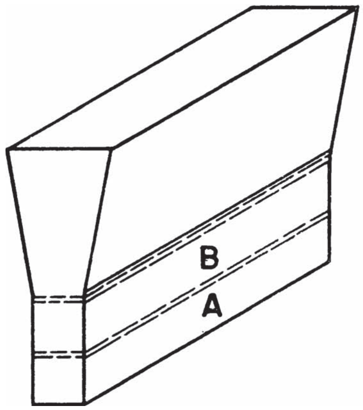
NOTE 1 — The length of keel block shall be 6 in. [150 mm].

FIG. 3 STANDARD ROUND TENSION TEST SPECIMEN WITH 2-IN. [50 MM] GAGE LENGTH

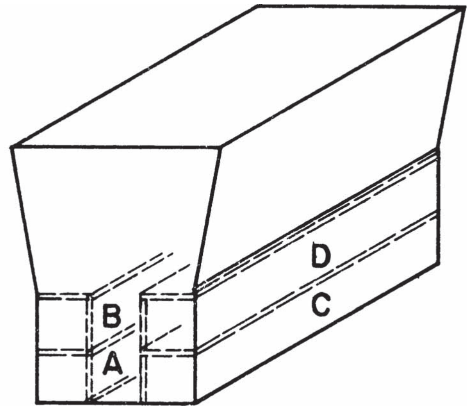


NOTE 1 — The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holder of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. [0.08–0.13 mm] larger in diameter than the center.

FIG. 4 SECTIONING PROCEDURE FOR "Y" BLOCKS



(*a*) *1 in. [25 mm] "Y" Block* — Two blanks for 0.50 in. [12.5 mm] diameter tension test specimens.



(*b*) *3 in. [75 mm] "Y" Block* — Four blanks for 0.50 in. [12.5 mm] diameter tension test specimens.

TABLE 1
TENSILE REQUIREMENTS

Test Coupon Section Thickness	1 in. [25 mm]	3 in. [75 mm]
Tensile strength, min, ksi [MPa]	80 [555]	80 [555]
Yield strength, min, ksi [MPa]	60 [415]	60 [415]
Elongation in 2 in. [50mm], min, %	3.0 [3.0]	1.0 [1.0]

TABLE 2
EQUIVALENT GEOMETRIC SHAPES CORRESPONDING TO "Y" BLOCKS

"Y" Block Size, in. [mm]	Infinite Plate Thickness, in. [mm]	Round Diameter, in. [mm]	Cube Edge, in. [mm]
1 [25]	0.9 [22.5]	1.75 [44]	2.75 [44]
3 [75]	1.6 [40]	3.1 [78]	4.8 [120]

TABLE 3
MINIMUM THICKNESS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in. [ISO Pipe Plug Size]	Minimum Section Thickness, in. [mm]
1/8 [R1/8]	11/32 [8]
1/4 [R1/4]	7/16 [10]
3/8 [R3/8]	1/2 [13]
1/2 [R1/2]	21/32 [17]
3/4 [R3/4]	3/4 [19]
1 [R1]	13/16 [21]
1 1/4 [R1 1/4]	7/8 [23]
1 1/2 [R1 1/2]	15/16 [24]
2 [R2]	1 [26]

TABLE 4
MINIMUM RADIUS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in. [ISO Pipe Plug Size]	Minimum Radius of Curvature, in. [mm]
1/8 [R1/8]	9/16 [15]
1/4 [R1/4]	11/16 [18]
3/8 [R3/8]	1 1/16 [28]
1/2 [R1/2]	1 1/4 [32]
3/4 [R3/4]	2 [52]
1 [R1]	2 1/2 [64]
1 1/4 [R1 1/4]	4 [104]
1 1/2 [R1 1/2]	5 1/4 [136]
2 [R2]	8 1/8 [208]

TABLE 5
MINIMUM DISTANCE BETWEEN PLUG CENTERS
(Based on Ligament Efficiency of 80%)[A]

Adjacent Plug Diameters, in. [ISO Pipe Plug Size]	Minimum Distance Between Plug Centers, in. [mm]			
	1/8 [R1/8], 1/4 [R1/4], 3/8 [R3/8]	1/2 [R1/2], 3/4 [R3/4]	1 [R1], 1 1/4 [R1 1/4]	1 1/2 [R1 1/2], 2 [R2]
1/8 [R1/8], 1/4 [R1/4], 3/8 [R3/8]	2 5/8 [67]	4 1/8 [105]	6 5/8 [169]	9 1/2 [242]
1/2 [R1/2], 3/4 [R3/4]	4 1/8 [105]	4 1/8 [105]	6 5/8 [169]	9 1/2 [242]
1 [R1], 1 1/4 [R1 1/4]	6 5/8 [169]	6 5/8 [169]	6 5/8 [169]	9 1/2 [242]
1 1/2 [R1 1/2], 2 [R2]	9 1/2 [242]	9 1/2 [242]	9 1/2 [242]	9 1/2 [242]

[A] *Example* — Assume three plugs are required for repair, one 1/8 in. [R1/8], one 3/8 in. [R3/8], and one 1 1/2 in. The minimum distance permitted is as follows.

Ligament distance between 1/8 [R1/8] and 3/8 in. [R3/8] plugs = 2 5/8 in. [67 mm]

Ligament distance between 1/8 [R1/8] and 1 1/2 in. [R1 1/2] plugs = 9 1/2 in. [242 mm]

Ligament distance between 3/8 [R3/8] and 1 1/2 in. [R1 1/2] plugs = 9 1/2 in. [242 mm]

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition, by heat treatment, by the design of the casting, by the design and nature of the mold, by the location and effectiveness of gates and risers, and by certain other factors.

X1.2 The cooling rate in the mold and, therefore, the properties developed in any particular section are influenced by the presence of cores, chills and chaplets, changes in section thickness, and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the complexity of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be more closely ascertained by appropriate experimentation.

X1.3 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen, and where experimentation would be unfeasible, the size of the test casting should be so selected as to approximate the thickness of the main or controlling section of the casting.

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SPECIFICATION FOR STAINLESS STEEL BARS AND SHAPES FOR USE IN BOILERS AND OTHER PRESSURE VESSELS

SA-479/SA-479M (23)

(Identical with ASTM Specification A479/A479M-21.)

Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

1. Scope

1.1 This specification covers hot- and cold-finished bars of stainless steel, including rounds, squares, and hexagons, and hot-rolled or extruded shapes such as angles, tees, and channels for use in boiler and pressure vessel construction.[2]

NOTE 1—There are standards covering high nickel, chromium, austenitic corrosion, and heat-resisting alloy materials. These standards are under the jurisdiction of ASTM Subcommittee B02.07 and may be found in *Annual Book of ASTM Standards*, Vol 02.04.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A484/A484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

A751 Test Methods and Practices for Chemical Analysis of Steel Products

E112 Test Methods for Determining Average Grain Size

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *SAE Document:*

SAE J 1086 Recommended Practice for Numbering Metals and Alloys

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A484/A484M.

3.1.1 Definitions,
3.1.2 General requirements for delivery,
3.1.3 Ordering information,
3.1.4 Process,
3.1.5 Special tests,
3.1.6 Heat treatment,
3.1.7 Dimensions and permissible variations,
3.1.8 Workmanship, finish, and appearance,
3.1.9 Number of tests/test methods,
3.1.10 Specimen preparation,
3.1.11 Retreatment,
3.1.12 Inspection,
3.1.13 Rejection and rehearing,
3.1.14 Material test report,
3.1.15 Certification, and
3.1.16 Packaging, marking, and loading.

4. Other Requirements

4.1 In addition to the requirements of this specification, all requirements of the current editions of Specification A484/

A484M shall apply. Failure to comply with the general requirements of Specification A484/A484M constitutes nonconformance with this specification.

5. Chemical Composition

5.1 Chemical composition shall be reported to the purchaser, or his representative, and shall conform to the requirements specified in Table 1.

5.2 When a product analysis is performed or requested by the purchaser, the tolerance limits as described in Specification A484/A484M apply unless Supplementary Requirement S3 is invoked.

5.3 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A751.

6. Grain Size for Austenitic Grades

6.1 All austenitic grades shall be tested for average grain size by Test Methods E112.

6.2 The H grades shall conform to an average grain size as follows:

6.2.1 ASTM No. 6 or coarser for Types 304H, 309H, 310H, and 316H, and

6.2.2 ASTM No. 7 or coarser for Types 321H, 347H, and 348H.

6.3 For S32615, the grain size as determined in accordance with Test Methods E112, comparison method, Plate 11, shall be No. 3 or finer.

6.4 For N08810 and N08811, the average grain size as determined in accordance with Test Methods E112 shall be No. 5 or coarser.

6.5 Supplementary Requirement S1 shall be invoked when non-H grade austenitic stainless steels are ordered for ASME Code applications for service above 1000 °F [540 °C].

7. Mechanical Properties Requirements

7.1 The material shall conform to the mechanical property requirements specified in Table 2 for the grade ordered. At least one room-temperature test shall be performed by the manufacturer on a sample from at least one bar or shape from each lot of material.

7.2 The yield strength shall be determined by the offset (0.2 %) method as prescribed in Test Methods and Definitions A370.

7.3 Martensitic material supplied in the annealed condition shall be capable of meeting the hardened and tempered mechanical properties when heat treated.

7.4 Hardness measurements, when required, shall be made at a location midway between the surface and the center of the cross section.

7.5 Martensitic grades shall be capable of meeting the hardness requirements after heat treating as specified in Table 3.

8. Testing for Intermetallic Compounds

8.1 When specified by the purchaser in the purchase order, the manufacturer shall test the austenitic or austenitic-ferritic (duplex) stainless steel material in its final condition in accordance with supplementary test requirements S6.

NOTE 2—Many, if not all, duplex stainless steels and some austenitic stainless steels will form intermetallic phases or compounds such as sigma, chi, and laves phases when exposed to temperatures below the specified annealing temperature or cooled slowly from a higher temperature during casting, welding, or annealing. These phases can have a negative effect on mechanical properties and corrosion resistance. These phases can typically be removed by correct annealing and cooling practices. The presence of these phases can be demonstrated by tests, typically involving metallography, impact toughness, or corrosion resistance, although the testing requirements may be different for different alloy grades. Such testing may or may not be routinely performed by the manufacturer.

9. Certification

9.1 The material manufacturer's certificate of compliance certifying that the material was manufactured and tested in accordance with this specification, together with a report of the results required by this specification and the purchase order, shall be furnished at the time of shipment. The certification shall be positively relatable to the lot of material represented.

10. Product Marking

10.1 In addition to the marking requirements of Specification A484/A484M, materials that have been heat treated or have been strain hardened shall be identified by placement of the following symbols after the grade designation:

10.1.1 *Austenitic Grades:*

10.1.1.1 All grades in the annealed condition—A,

10.1.1.2 Strain hardened Type 316, Level 1—S1,

10.1.1.3 Strain hardened Type 316, Level 2—S2,

10.1.1.4 Hot-rolled Type XM-19—H,

10.1.1.5 Strain hardened Type XM-19—S, and

10.1.1.6 Material meeting Supplementary Requirement S1—ELT (unnecessary for H grades).

10.1.1.7 In addition to all other marking requirements of this specification, when S1 is invoked, all grades in the direct quenched condition shall be marked "D."

10.1.2 *Austenitic-Ferritic Grades*—All grades in the annealed condition—A.

10.1.3 *Ferritic Grades*—All grades in the annealed condition—A.

10.1.4 *Martensitic Grades:*

10.1.4.1 All grades in the annealed condition—*A*.

10.1.4.2 Types 403 and 410—COND 1, COND 2, or COND 3 as appropriate for the tempering temperature employed.

10.1.4.3 Type 414, S41500, and Type XM-30 tempered materials—T.

11. Keywords

11.1 austenitic stainless steel; austenitic-ferritic duplex stainless steel; ferritic stainless steel; high temperature service applications; martensitic stainless steel; pressure vessel service; pressure-containing parts; stainless steel bars; stainless steel shapes

TABLE 1 Chemical Requirements

UNS Designation[A]	Type	Composition, %[B]									
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Nitrogen	Molybdenum	Other Elements[C]
Austenitic Grades											
N08020	Alloy 20	0.07	2.00	0.045	0.035	1.00	19.0–21.0	32.0–38.0	. . .	2.00–3.00	Cu 3.0–4.0; Cb 8xC–1.00
N08367	. . .	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	0.18–0.25	6.0–7.0	Cu 0.75
N08800	800	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	. . .	Fe[K] 39.5 min. Cu 0.75 Al 0.15–0.60 Ti 0.15–0.60
N08810	800H	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	. . .	Fe[K] 39.5 min. Cu 0.75 Al 0.15–0.60 Ti 0.15–0.60
N08811	. . .	0.06–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	. . .	Fe[K] 39.5 min. Cu 0.75 Al[L] 0.25–0.60 Ti[L] 0.25–0.60
N08700	. . .	0.040	2.00	0.040	0.030	1.00	19.0–23.0	24.0–26.0	. . .	4.3–5.0	Cu 0.50; Cb 8xC–0.40
N08904	904L	0.020	2.00	0.045	0.035	1.00	19.0–23.0	23.0–28.0	0.10	4.0–5.0	Cu 1.0–2.0
N08925	. . .	0.020	1.00	0.045	0.030	0.50	19.0–21.0	24.0–26.0	0.10–0.20	6.0–7.0	Cu 0.80–1.50
N08926	. . .	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	0.15–0.25	6.0–7.0	Cu 0.50–1.50
S20161	. . .	0.15	4.0–6.0	0.045	0.030	3.0–4.0	15.0–18.0	4.0–6.0	0.08–0.20	. . .	. . .
S20910	XM-19	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	0.20–0.40	1.50–3.00	Cb 0.10–0.30; V 0.10–0.30
S21600	XM-17	0.08	7.5–9.0	0.045	0.030	1.00	17.5–20.5	5.0–7.0	0.25–0.50	2.00–3.00	. . .
S21603	XM-18	0.03	7.5–9.0	0.045	0.030	1.00	17.5–20.5	5.0–7.0	0.25–0.50	2.00–3.00	. . .
S21800	. . .	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	0.08–0.18	. . .	. . .
S21904	XM-11	0.04	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	0.15–0.40		
S24000	XM-29	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	0.20–0.40	. . .	. . .
S30200	302	0.15	2.00	0.045	0.030	1.00	17.0–19.0	8.0–10.0	0.10	. . .	. . .
S30400	304	0.08[D]	2.00	0.045	0.030	1.00	18.0–20.0	8.0–10.5	. . .	. . .	. . .
S30403	304L	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	. . .	. . .	. . .
S30409	304H	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–10.5	. . .	. . .	. . .
S30451	304N	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	0.10–0.16	. . .	. . .
S30453	304LN	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	0.10–0.16	. . .	. . .
S30600	. . .	0.018	2.00	0.020	0.020	3.7–4.3	17.0–18.5	14.0–15.5	. . .	0.20	Cu 0.50
S30815	. . .	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	0.14–0.20	. . .	Ce 0.03–0.08
S30908	309S	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	. . .	. . .	. . .
S30909	309H	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	. . .	. . .	. . .
S30940	309Cb	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	. . .	. . .	Cb 10×C- 1.10
S30880	ER308[E]	0.08	1.00–2.50	0.030	0.030	0.25–0.60	19.5–22.0	9.0–11.0	. . .	. . .	. . .
S31008	310S	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	. . .	. . .	. . .
S31009	310H	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	. . .	. . .	. . .
S31010[F]	. . .	0.030	5.50–6.50	0.030	0.0010	0.25–0.75	28.5–30.5	14.0–16.0	0.80–0.90	1.5–2.5	Al 0.05 B 0.005
S31040	310Cb	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	. . .	. . .	Cb 10×C-1.10
S31050	. . .	0.025	2.00	0.020	0.015	0.4	24.0–26.0	20.5–23.5	0.09–0.15	1.60–2.60	. . .
S31254	. . .	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	0.18–0.25	6.0–6.5	Cu 0.50–1.00
S31266	. . .	0.030	2.00–4.00	0.035	0.020	1.00	23.0–25.0	21.0–24.0	0.35–0.60	5.2–6.2	Cu 1.00–2.50 W 1.50–2.50
S31600	316	0.08[D]	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	. . .	2.00–3.00	. . .
S31603	316L	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	. . .	2.00–3.00	. . .
S31609	316H	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	. . .	2.00–3.00	. . .
S31635	316Ti	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	0.10	2.00–3.00	Ti 5×(C+N)- 0.70
S31640	316Cb	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	0.10	2.00–3.00	Cb 10×C- 1.10
S31651	316N	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	0.10–0.16	2.00–3.00	. . .
S31653	316LN	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	0.10–0.16	2.00–3.00	. . .
S31700	317	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	. . .	3.0–4.0	. . .
S31725	. . .	0.030	2.00	0.045	0.030	1.00	18.0–20.0	13.5–17.5	0.20	4.0–5.0	. . .
S31726	. . .	0.030	2.00	0.045	0.030	1.00	17.0–20.0	14.5–17.5	0.10–0.20	4.0–5.0	. . .
S31727	. . .	0.030	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	0.15–0.21	3.8–4.5	Cu 2.8–4.0
S32050	. . .	0.030	1.50	0.035	0.020	1.00	22.0–24.0	20.0–23.0	0.21–0.32	6.0–6.8	Cu 0.40
S32053	. . .	0.030	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	0.17–0.22	5.0–6.0	. . .
S32100	321	0.08[D]	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Ti 5×(C+N)- 0.70[G]
S32109	321H	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Ti 4×(C+N)- 0.70[G]
S32615	. . .	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	. . .	0.30–1.50	Cu 1.50–2.50
S32654	. . .	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	0.45–0.55	7.0–8.0	Cu 0.30–0.60
S33228	. . .	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	. . .	. . .	Cb 0.60–1.00; Ce 0.05–0.10; Al 0.025
S34565	. . .	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	0.40–0.60	4.0–5.0	Cb 0.10
S34700	347	0.08[D]	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Cb 10×C–1.10
S34709	347H	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Cb 8×C–1.10

TABLE 1 *Continued*

UNS Designation[A]	Type	Composition, %[B]									
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Nitrogen	Molybdenum	Other Elements[C]
S34752	. . .	0.005–0.02	2.00	0.035	0.010	0.60	17.0–18.0	10.0–13.0	0.06.-0.12	0.02–1.20	Cu 2.50–3.50 Nb 0.20–0.50 Nb/C ration, min 15 B00.001–0.005
S34800	348	0.08[D]	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	(Cb+Ta) 10×C–1.10; Ta 0.10; Co 0.20
S34809	348H	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	(Cb + Ta) 8×C–1.10; Co 0.20; Ta 0.10
S35315	. . .	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.0–26.0	34.0–36.0	0.12–0.18	. . .	Ce 0.03–0.08
S38815	. . .	0.030	2.00	0.040	0.020	5.50–6.50	13.0–15.0	15.0–17.0	. . .	0.75–1.50	Al 0.30; Cu 0.75–1.50
Austenitic-Ferritic Grades											
S31803	. . .	0.030	2.00	0.030	0.020	1.00	21.0–23.0	4.5–6.5	0.08–0.20	2.5–3.5	. . .
S32101	. . .	0.040	4.0–6.0	0.040	0.030	1.00	21.0–22.0	1.35–1.70	0.20–0.25	0.10–0.80	Cu 0.10–0.80
S32202	. . .	0.030	2.00	0.040	0.010	1.00	21.5–24.0	1.00–2.80	0.18–0.26	0.45	. . .
S32205	. . .	0.030	2.00	0.030	0.020	1.00	22.0–23.0	4.5–6.5	0.14–0.20	3.0–3.5	. . .
S32506	. . .	0.030	1.00	0.040	0.015	0.90	24.0–26.0	5.5–7.2	0.08–0.20	3.0–3.5	W 0.05–0.30
S32550	. . .	0.04	1.50	0.040	0.030	1.00	24.0–27.0	4.5–6.5	0.10–0.25	2.9–3.9	Cu 1.50–2.50
S32750[M]	. . .	0.030	1.20	0.035	0.020	0.80	24.0–26.0	6.0–8.0	0.24–0.32	3.0–5.0	Cu 0.50
S32760[H]	. . .	0.030	1.00	0.030	0.010	1.00	24.0–26.0	6.0–8.0	0.20–0.30	3.0–4.0	Cu 0.50–1.00; W 0.50–1.00
S32808	. . .	0.030	1.10	0.030	0.010	0.50	27.0–27.9	7.0–8.2	0.30–0.40	0.80–1.2	W 2.10–2.50
S32906	. . .	0.030	0.80–1.50	0.030	0.030	0.50	28.0–30.0	5.8–7.5	0.30–0.40	1.50–2.60	Cu 0.80
S32950	. . .	0.03	2.00	0.035	0.010	0.60	26.0–29.0	3.5–5.2	0.15–0.35	1.00–2.50	. . .
S39277	. . .	0.025	0.80	0.025	0.002	0.80	24.0–26.0	6.5–8.0	0.23–0.33	3.0–4.0	Cu 1.20–2.00 W 0.80–1.20
S82441	. . .	0.030	2.5–4.0	0.035	0.005	0.70	23.0–25.0	3.0–4.5	0.20–0.30	1.00–2.00	Cu 0.10–0.80
Ferritic Grades											
S40500	405	0.08	1.00	0.040	0.030	1.00	11.5–14.5	0.50	. . .	. . .	Al 0.10–0.30
S43000	430	0.12	1.00	0.040	0.030	1.00	16.0–18.0	. . .	. . .	. . .	. . .
S43035	439	0.07	1.00	0.040	0.030	1.00	17.0–19.0	0.50	0.04	. . .	Ti 0.20 + 4 × (C+N) –1.10; Al 0.15
S44400	444	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00	0.035	1.75–2.50	(Ti+Cb) 0.20 + 4 × (C+N)-0.80
S44627	XM-27	0.010[I]	0.40	0.020	0.020	0.40	25.0–27.5	0.50	0.015[I]	0.75–1.50	Cu 0.20; Cb 0.05–0.20; (Ni+Cu) 0.50
S44700	. . .	0.010	0.30	0.025	0.020	0.20	28.0–30.0	0.15	0.020	3.5–4.2	(C+N) 0.025; Cu 0.15
S44800	. . .	0.010	0.30	0.025	0.020	0.20	28.0–30.0	2.00–2.50	0.020	3.5–4.2	(C+N) 0.025; Cu 0.15
Martensitic Grades											
S40300	403	0.15	1.00	0.040	0.030	0.50	11.5–13.0	. . .	. . .	. . .	. . .
S41000	410	0.15	1.00	0.040	0.030	1.00	11.5–13.5	. . .	. . .	. . .	. . .
S41040	XM-30	0.18	1.00	0.040	0.030	1.00	11.5–13.5	. . .	. . .	. . .	Cb 0.05–0.30
S41400	414	0.15	1.00	0.040	0.030	1.00	11.5–13.5	1.25–2.50	. . .	. . .	. . .
S41425	. . .	0.05	0.50–1.00	0.020	0.005	0.50	12.0–15.0	4.0–7.0	0.06–0.12	1.50–2.00	Cu 0.30
S41500	[J]	0.05	0.50–1.00	0.030	0.030	0.60	11.5–14.0	3.5–5.5	. . .	0.50–1.00	. . .
S43100	431	0.20	1.00	0.040	0.030	1.00	15.0–17.0	1.25–2.50	. . .	. . .	. . .

[A] New designations established in accordance with Practice E527 and SAE J 1086 published jointly by ASTM and SAE. See ASTM DS56C.[2]
[B] Maximum unless otherwise indicated.
[C] Except as required for specific alloy type, molybdenum, titanium, nickel, cobalt, tantalum, nitrogen, and copper need not be reported but shall not be present in other than residual amounts, the intent being to prohibit substitution of one alloy type for another due to absence of control of the above named elements in certain alloys.
[D] See Supplementary Requirement S1.
[E] American Welding Society designation.
[F] UNS S31010 is a highly alloyed austenitic stainless steel type 3b as defined in NACE MR0175/ISO 15156-3.
[G] Nitrogen content is to be reported for this grade.
[H] % Cr + 3.3 × % (Mo + ½ W) + 16 × % N ≥ 41.
[I] Product analysis tolerance over the maximum limit for carbon and nitrogen to be 0.002 %.
[J] Wrought version of CA6NM.
[K] Iron shall be determined arithmetically by difference of 100 minus the sum of specified elements.
[L] (Al+Ti) 0.85–1.20.
[M] % Cr + 3.3 × % Mo + 16 × % N ≥ 41.

TABLE 2 Mechanical Property Requirements

UNS Designation	Type	Condition	Tensile Strength, min, ksi [MPa]	Yield Strength,[A] min, ksi [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %[B,C]	Brinell Hardness, max
Austenitic Grades							
N08020	Alloy 20	stabilized-annealed	80 [550]	35 [240]	30[D]	50	
	Up to 2 in. [50.8 mm], incl	strain-hardened	90 [620]	60 [415]	15	40	
N08367	. . .	annealed	95 [655]	45 [310]	30	. . .	241
N08800	800	annealed	75 [515]	30 [205]	30	. . .	192
N08810	800H	annealed	65 [450]	25 [170]	30	. . .	192
N08811	. . .	annealed	65 [450]	25 [170]	30	. . .	192
N08700	. . .	annealed	80 [550]	35 [240]	30	50	. . .
N08904	904L	annealed	71 [490]	31 [220]	35	. . .	. . .
N08925	. . .	annealed	87 [600]	43 [295]	40	. . .	217
N08926	. . .	annealed	94 [650]	43 [295]	35	. . .	256
S20161	. . .	annealed	125 [860]	50 [345]	40	40	311
S20910	XM-19	annealed	100 [690]	55 [380]	35	55	293
	Up to 2 in. [50.8 mm], incl	hot-rolled	135 [930]	105 [725]	20	50	. . .
	Over 2 to 3 in. [50.8 to 76.2 mm], incl	hot-rolled	115 [795]	75 [515]	25	50	. . .
	Over 3 to 8 in. [76.2 to 203.2 mm], incl	hot-rolled	100 [690]	60 [415]	30	50	. . .
	Up to 1½ in. [38.1 mm], incl	strain-hardened	145 [1000]	125 [860]	12	40	. . .
	Over 1½ to 2¼ in. [38.1 to 57.2 mm], incl	strain-hardened	120 [825]	105 [725]	15	45	. . .
S21600, S21603	XM-17, XM-18	annealed	90 [620]	50 [345]	40	50	212
S21800	. . .	annealed	95 [655]	50 [345]	35	55	241
S21904	XM-11	annealed	90 [620]	50 [345]	45	60	. . .
S24000	XM-29	annealed	100 [690]	55 [380]	30	50	. . .
S30200, S30400, S30409, S30453, S30880, S30908, S30909, S30940, S31008, S31009, S31040, S31600, S31609, S31635, S31640, S31653, S31700, S32100, S32109, S34700, S34709, S34800, S34809	302, 304, 304H, 304LN, ER308,[E] 309S, 309H, 309Cb, 310S, 310H, 310Cb, 316, 316H, 316Ti, 316Cb, 316LN, 317, 321, 321H, 347, 347H, 348, 348H	annealed	75 [515][F]	30 [205]	30	40	. . .
S30403, S31603	304L, 316L	annealed	70 [485]	25 [170]	30	40	. . .
S31600, S31603, S30400, S30403	316, 316L, 304, 304L	strain-hardened level 1	85 [585]	65 [450][G]	30	40	. . .
	2 in. and under	strain-hardened level 2	95 [655]	75 [515]	25	40	. . .
	Over 2 to 2½ in. [50.8 to 63.5 mm], incl.	strain-hardened level 2	90 [620]	65 [450]	30	40	. . .
	Over 2½ to 3 in. [63.5 to 76.2 mm], incl	strain-hardened level 2	80 [550]	55 [380]	30	40	. . .
S30451, S31651	304N, 316N	annealed	80 [550]	35 [240]	30	40	. . .
S30600	. . .	annealed	78 [540]	35 [240]	40	. . .	. . .
S30815	. . .	annealed	87 [600]	45 [310]	40	50	. . .
S31010	. . .	annealed	110 [760]	75 [515]	40	50	330
S31050	0.25 in. [6 mm] and under	annealed	84 [580]	39 [270]	25	40	. . .
	Over 0.25 in. [6 mm]	annealed	78 [540]	37 [255]	25	40	
S31254	. . .	annealed	95 [655]	44 [305]	35	50	. . .
S31266	. . .	annealed	109 [750]	61 [420]	35	. . .	. . .
S31725	. . .	annealed	75 [515]	30 [205]	40	. . .	. . .
S31726	. . .	annealed	80 [550]	35 [240]	40	. . .	. . .
S31727	. . .	annealed	80 [550]	36 [245]	35	. . .	217
S32050	. . .	annealed	98 [675]	48 [330]	40	. . .	. . .
S32053	. . .	annealed	93 [640]	43 [295]	40	. . .	217
S32615	. . .	annealed	80 [550]	32 [220]	25	40	. . .
S32654	. . .	annealed	109 [750]	62 [430]	40	40	250
S33228	. . .	annealed	73 [500]	27 [185]	30	. . .	. . .
S34565	. . .	annealed	115 [795]	60 [415]	35	40	230
S34752	. . .	annealed	75 [515]	30 [205]	35	. . .	. . .
S35315	. . .	annealed	94 [650]	39 [270]	40	. . .	. . .
S38815	. . .	annealed	78 [540]	37 [255]	30	. . .	. . .
Austenitic-Ferritic Grades							
S31803	. . .	annealed	90 [620]	65 [450]	25	. . .	290
S32101	. . .	annealed	94 [650]	65 [450]	30	. . .	290
S32202	. . .	annealed	94 [650]	65 [450]	30	. . .	290
S32205	. . .	annealed	95 [655]	65 [450]	25	. . .	290
S32506	. . .	annealed	90 [620]	65 [450]	18	. . .	302
S32550	. . .	annealed	110 [760]	80 [550]	15	. . .	297
S32750	2 in. and under	annealed	116 [800]	80 [550]	15	. . .	310
	over 2 in.	annealed	110 [760]	75 [515]	15	. . .	310

TABLE 2 *Continued*

UNS Designation	Type	Condition	Tensile Strength, min, ksi [MPa]	Yield Strength,[A] min, ksi [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %[B,C]	Brinell Hardness, max
Austenitic Grades							
S32760	. . .	annealed	109 [750]	80 [550]	25	. . .	310
S32808	. . .	annealed	101 [700]	72 [500]	15	. . .	310
S32906	. . .	annealed	109 [750]	80 [550]	25	. . .	310
S32950	. . .	annealed	100 [690]	70 [485]	15	. . .	297
S39277	. . .	annealed	118 [820]	85 [585]	25	50	293
S82441	Under 7⁄16 in. [11 mm]	annealed	107 [740]	78 [540]	25	. . .	290
S82441	7⁄16 in. and over [11 mm]	annealed	99 [680]	70 [480]	25	. . .	290
Ferritic Grades							
S40500	405	annealed	60 [415]	25 [170]	20	45	207
S43000, S43035	430, 439	annealed	70 [485]	40 [275]	20[H]	45[H]	192
S44627	XM-27	annealed	65 [450]	40 [275]		45[H]	217
S44401	. . .	annealed	60 [415]	45 [310]	20[I]	45[I]	217
S44700	. . .	annealed	70 [485]	55 [380]	20	40	. . .
S44800	. . .	annealed	70 [485]	55 [380]	20	40	. . .
Martensitic Grades							
S40300, S41000	403, 410	annealed	70 [485]	40 [275]	20[I]	45[I]	223
		1	70 [485]	40 [275]	20[I]	45[I]	223
		2	110 [760]	85 [585]	15	45	269
		3	130 [895]	100 [690]	12	35	331
S41400	414	tempered	115 [795]	90 [620]	15	45	321
S41425	. . .	tempered	120 [825]	95 [655]	15	45	321
S41500	. . .	normalized and tempered	115 [795]	90 [620]	15	45	293
S43100	431[J]	annealed	. . .	. . .	. . .	. . .	277
		tempered	115 [795]	90 [620]	15	45	321
S41040	XM-30	annealed	70 [485]	40 [275]	13[H]	45[H]	235
		quenched and tempered	125 [860]	100 [690]	13	45	302

[A] See Section 7.
[B] Reduction of area does not apply on flat bars 3⁄16 in. [4.80 mm] and under in thickness, as this determination is not generally made in this product size.
[C] The material shall be capable of meeting the required reduction of area where listed, but actual measurement and reporting of the reduction of area are not required unless specified in the purchase order.
[D] Cold-finished shapes require only 15 %, minimum, elongation.
[E] American Welding Society designation.
[F] Tensile strength 70 ksi [485 MPa] minimum permitted for extruded shapes.
[G] For bars greater than 2 in. [51 mm], a cross section, 60 ksi [415 MPa] minimum, shall be permitted.
[H] Elongation in 2 in. or 50 mm of 12 % minimum and reduction of area of 35 % minimum permitted for cold-finished bars.
[I] Elongation in 2 in. of 12 % minimum and reduction of area of 35 % minimum permitted for cold-drawn or cold-rolled bars.
[J] Annealed bars shall be capable of meeting the tempered condition requirements when heat treated.

TABLE 3 Response To Heat Treatment

Type[A]	Heat Treatment Temperature[B] °F (°C), min	Quenchant	Hardness HRC, min
403	1750 [955]	Air	35
410	1750 [955]	Air	35
414	1750 [955]	Oil	42

[A] Samples for testing shall be in the form of a section not exceeding 3⁄8 in. [9.50 mm] in thickness.
[B] Temperature tolerance is ±25 °F [15 °C].

SUPPLEMENTARY REQUIREMENTS

The following may be made requirements when the purchaser specifies them to be applicable.

S1. Materials for High-temperature Service

S1.1 Unless an H grade has been ordered, this supplementary requirement shall be specified for ASME Code applications for service above 1000 °F [540 °C].

S1.2 The user is permitted to use an austenitic stainless steel as the corresponding H grade when the material meets all requirements of the H grade including chemistry, annealing temperature, and grain size (see Section 6).

S1.3 The user is permitted to use an L grade austenitic stainless steel for service above 1000 °F [540 °C], subject to the applicable allowable stress table of the ASME Code, when the material meets all requirements of this specification and the grain size is ASTM No. 7 or coarser as determined in accordance with Test Methods E112. The grain size shall be reported on a Certified Test Report.

S2. Corrosion Tests

S2.1 Intergranular corrosion tests shall be performed by the manufacturer on sensitized specimens of Types 304L, 316L, 321, 347, and 348, and for the other austenitic grades, on specimens representative of the as-shipped condition. All austenitic stainless steels shall be capable of passing intergranular corrosion tests in the as-shipped condition. Tests shall be performed in accordance with Practice E of Practices A262.

S3. Product Analysis

S3.1 An analysis shall be made by the manufacturer on a sample from one bar in each lot as defined in Specification A484/A484M. The analysis shall meet the requirements of Table 1. In the event of failure, the lot represented shall be rejected except that, at the option of the manufacturer, each bar in the lot may be tested for acceptance. Product analysis tolerance provisions do not apply.

S4. Material for High Cycle Fatigue Service

S4.1 The mechanical properties of bars furnished in lengths under 20 ft [6 m] shall be determined by testing one end of each bar. Bars furnished in lengths of 20 ft [6 m] and over shall be tested at each end.

S5. Material for Optimum Resistance to Stress Corrosion Cracking

S5.1 This supplementary requirement is to be referenced when austenitic stainless steels are to be purchased with solution-annealing as the final operation and with no subsequent cold drawing permitted. Straightening is permitted as a final operation to meet the straightness requirements of Specification A484/A484M unless specifically prohibited by the purchaser.

S6. Demonstration of the Absence of Detrimental Intermetallic Phase in Austenitic and Austenitic-Ferritic (Duplex) Grades

S6.1 This supplementary requirement is to be referenced when the austenitic or duplex stainless steels are to be purchased with testing to demonstrate the absence of detrimental intermetallic phases that can have negative effects on mechanical properties or corrosion resistance of the material. The test method(s), reporting requirements, and acceptance criteria shall be agreed upon by the manufacturer and purchaser in the purchase agreement.

APPENDIX

(Nonmandatory Information)

X1. RATIONALE REGARDING DEFINITION OF SOLUTION ANNEALING

X1.1 It is generally recognized that austenitic stainless steels are solution annealed by heating to a temperature that dissolves (takes into solution) chromium carbides and quenching rapidly so that the chromium carbides will not precipitate in the grain boundaries, which could cause susceptibility to intergranular corrosion in a critically corrosive environment. Thus, solution annealing also can be accomplished for non-stabilized grades by taking advantage of hot rolling temperatures (which always exceed solution annealing temperature requirements), maintaining hot rolling finishing temperatures well above minimum solution annealing requirements, and immediately quenching integral with hot rolling. Stabilized grades (with columbium or titanium added) cannot be handled this way, since they would become destabilized due to columbium or titanium carbide solution, without subsequent reheating.

X1.2 For Boiler Code applications involving temperatures at which optimum resistance to creep is desired, the larger grain size of material solution annealed by reheating is generally desired. For that reason, a minimum grain size has been required of the H grades (created for optimum elevated temperature properties), and a mandatory grain size test and report has been added for the non-H grades so that the information is available for those desiring to reclassify a non-H grade to H grade.

X1.3 To satisfy the concerns of inadvertent assignment of fine grained material to elevated temperature applications, special marking has been added for material that meets the requirements of Supplementary Requirement S1.

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SPECIFICATION FOR GENERAL REQUIREMENTS FOR FLAT-ROLLED STAINLESS AND HEAT-RESISTING STEEL PLATE, SHEET, AND STRIP

SA-480/SA-480M

(Identical with ASTM Specification A480/A480M-17.)

Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

1. Scope

1.1 This specification covers a group of general requirements that, unless otherwise specified in the purchase order or in an individual specification, shall apply to rolled steel plate, sheet, and strip, under each of the following specifications issued by ASTM: Specifications A240/A240M, A263, A264, A265, A666, A693, A793, and A895.

1.2 In the case of conflict between a requirement of a product specification and a requirement of this specification, the product specification shall prevail. In the case of conflict between a requirement of the product specification or a requirement of this specification and a more stringent requirement of the purchase order, the purchase order shall prevail. The purchase order requirements shall not take precedence if they, in any way, violate the requirements of the product specification or this specification; for example, by waiving a test requirement or by making a test requirement less stringent.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets, except that when A480M is specified, Annex A3 shall apply for the dimensional tolerances and not the bracketed SI values in Annex A2. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 This specification and the applicable material specifications are expressed in both inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation [SI units], the material shall be furnished in inch-pound units.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A263 Specification for Stainless Chromium Steel-Clad Plate
A264 Specification for Stainless Chromium-Nickel Steel-Clad Plate
A265 Specification for Nickel and Nickel-Base Alloy-Clad Steel Plate
A342/A342M Test Methods for Permeability of Weakly Magnetic Materials
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A666 Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
A693 Specification for Precipitation-Hardening Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels
A793 Specification for Rolled Floor Plate, Stainless Steel
A895 Specification for Free-Machining Stainless Steel Plate, Sheet, and Strip

A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels

E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

2.2 *AIAG Standard:*

B-5 Primary Metals Identification Tag Application Standard

2.3 *ANSI Standard:*

Accredited Standards Committee X12 (ANSI ASC X12)

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.5 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

3. Terminology

3.1 *Definitions:*

3.1.1 Plate, sheet, strip, and cold work as used in this specification apply to the following:

3.1.2 *cold work, n*—the changing of mechanical properties by work hardening.

3.1.3 *plate, n*—material 3⁄16 in. [5.00 mm] and over in thickness and over 10 in. [250 mm] in width. Finishes for *plate* are actually shown in Section 13.

3.1.4 *sheet, n*—material under 3⁄16 in. [5.00 mm] in thickness and 24 in. [600 mm] and over in width. Finishes for *sheet* are actually shown in Section 11.

3.1.5 *strip, n*—cold-rolled material under 3⁄16 in. [5.00 mm] in thickness and under 24 in. [600 mm] in width. Finishes are detailed in Section 12 for *strip*, and strip edges in Section 14 for Cold-Rolled Strip.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight and number of pieces),

4.1.2 Name of material (stainless steel),

4.1.3 Condition (hot-rolled, cold-rolled, annealed, heat-treated),

4.1.4 Finish (see Section 11 for Sheet, Section 12 for Strip, and Section 13 for Plates). In the case of polished finishes, specify whether one or both sides are to be polished,

4.1.5 Temper (if the applicable material specification requires this detail),

4.1.6 Form (plate, sheet, or strip),

4.1.7 Dimensions (thickness, width, length),

4.1.7.1 Thickness shall be ordered to decimal or fractional thickness. The use of the gauge number is discouraged as being an archaic term of limited usefulness not having general agreement on meaning. The gauge number shall not be a basis for rejection.

4.1.7.2 Thickness, width, and length, when applicable, should be ordered in the same units, for example, 0.060 by 48 by 120 in. [1.52 by 1219 by 3048 mm].

4.1.8 Edge, strip only (see Section 14 for Cold-Rolled Strip),

4.1.9 Type or UNS designation, refer to the applicable material specification,

4.1.10 Specification designation and date of issue,

4.1.11 Additions to specification or special requirements,

4.1.12 Restrictions (if desired) on methods for determining yield strength (see appropriate footnote to mechanical properties table of the basic material specification),

4.1.13 Marking requirements (see Section 25),

4.1.14 Preparation for delivery (see Section 25), and

4.1.15 Magnetic permeability test (when required). Refer to Section 19.

5. Process

5.1 The steel shall be manufactured/produced by the following or as specified in the applicable material specification.

5.1.1 The steel shall be made by one of the following processes: electric-arc, electric-induction, or other suitable processes.

5.1.2 If a specific type of melting is required by the purchaser, it shall be so specified on the purchase order.

6. Heat Analysis

6.1 Methods and practices relating to chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

6.2 An analysis of each heat shall be made by the steel producer to determine the percentages of the elements specified in the applicable material specification. This analysis shall be made from a test sample taken during the pouring of the melt, or from the in-process product later in the manufacturing flow.

6.2.1 The heat analysis shall conform to the chemical requirements for each of the specified elements for the grade ordered, as listed in the applicable product specification.

6.2.2 All commercial metals contain small amounts of elements other than those which are specified. It is neither practical nor necessary to specify limits for unspecified elements that can be present. The producer is permitted to analyze for unspecified elements and is permitted to report such analyses. The presence of an unspecified element and the reporting of an analysis for that element shall not be a basis for rejection, unless the presence of that element causes the loss of a property typically expected for that metal, for the type and quality ordered.

6.2.3 The purchaser is permitted to require in the purchase order a maximum limit for an individual element not specified in the product specification. Such a requirement for an element not listed in the product specification, when acknowledged in the order acceptance, shall be treated as a specified element, with determination of chemical analysis and reporting of that analysis.

6.2.4 The purchaser is permitted to make the requirements for any element more stringent, that is, require higher minimums for elements having minimum requirements or ranges with minimum requirements, or requiring lower maximums for elements having specified maximums, or ranges with maximums. The purchaser is not permitted to make chemical requirements less stringent.

6.2.5 Analysis limits shall be established for specific elements rather than groups of elements, including but not limited to *all others*, *rare earths*, and *balance*, unless all elements in such a group are similar in technical effect and are associated in typical methods of chemical analysis.

6.3 Except as permitted in 6.3.1, the steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within this specification or any specification listed within the scope as being covered by the specification.

6.3.1 Unless otherwise specified to lower maximum limits on the purchase order, maximum allowances for unspecified elements will be established for Cu, Mo, Ti, and Nb for the specified grade if the amount of that element present in the material conforms with composition limits for that element in another grade. These allowances are: Cu, 0.75 %; Mo, 0.75 %; Ti, 0.10 %; and Nb, 0.10 %.

6.3.2 If any allowance in 6.3.1 is used to demonstrate non-substitution, then the element involved must be reported as if it were a specified element.

6.4 The producer is not permitted to certify that material is in compliance with an ASTM product specification when the purchase order has required that the material contain as a minimum or range an element that is neither a specified element nor an intentionally added unspecified element for the ordered grade in accordance with the definitions of Test Methods, Practices, and Terminology A751.

7. Product Analysis

7.1 The purchaser is permitted to perform a product analysis (formerly check analysis) to verify the identity of the finished material representing each heat or lot. Such analysis shall be made by any of the commonly accepted methods that will positively identify the material.

7.2 The chemical composition determined in accordance with 7.1 shall conform to the limits of the material specification within the tolerances of Table A1.1, unless otherwise specified in the applicable material specification or the purchase order. The allowable variation of a particular element in a single sample for product analysis is permitted to be either above or below the specified range. However, percentages must exhibit the same tendencies in all samples; that is, the several determinations of any individual element in a heat shall not vary both above and below the specified range.

8. Material Test Report and Certification

8.1 A report of the results of all tests required by the product specification shall be supplied to the purchaser. This material test report shall reference the product specification designation and year date indicating that the material was manufactured, sampled, tested, and inspected in accordance with requirements of the product specification and has been found to meet those requirements. The material test report shall report the melting process when the purchase order requires either a specific type of melting or requires that the melting process used is to be reported.

8.1.1 The report shall indicate the type of steel. If certifying that the material conforms to the requirements for more than one type of steel, the manufacturer may indicate each type of steel on the report, or may issue a separate report for each type of steel.

8.2 A signature is not required on the report. However, the document shall clearly identify the organization submitting the report. Not withstanding the absence of a signature, the organization submitting the document is responsible for its content.

8.3 A material test report, certificate of inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifiers' facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

8.4 When finished material is supplied to a purchase order specifying the product specification, the organization supplying that material shall provide the purchaser with a copy of the original manufacturer's test report.

NOTE 1—Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

NOTE 2—The industry definition as invoked here is: EDI is the computer-to-computer exchange of business information in a standard format such as ANSI ASC X 12.

8.4.1 When the original manufacturer's test report was provided by EDI to the organization supplying the finished material to the purchaser, the organization supplying the finished material shall provide to the purchaser a printed form of the original test report or shall retransmit the test report by EDI to the purchaser. In either case, the test report shall be complete with the full identification of the original manufacturer and with all data provided on the test report of the original manufacturer.

9. Permitted Variations in Dimensions and Weight

9.1 Sheet, strip, and plate shall conform to the permitted variations in thickness, width, length and flatness, and other properties when specified, as listed in Annex A2 and Annex A3 for A480 and A480M respectively, for the ordered product form, or as agreed upon by seller and user and specified in the purchase order.

10. Workmanship

10.1 The material shall be of uniform quality consistent with good manufacturing and inspection practices. The steel shall have no imperfections of a nature or degree, for the type and quality ordered, that will adversely affect the stamping, forming, machining, or fabrication of finished parts.

10.2 *Sheet, Strip, and Plate*—For sheet and strip, restricted only to material ordered to have a No. 1 finish in accordance with 11.1.1 and 12.1.1 respectively, and for plate restricted to material ordered to hot-rolled and annealed or hot-rolled, annealed, and pickle finish in accordance with 13.1.1 and 13.1.2 respectively, it is permitted to grind to remove surface imperfections, provided such grinding does not reduce the thickness or width at any point beyond the permissible variations in dimensions. An iron free abrasive wheel shall be used for such grinding and shall be operated at a speed ample to ensure that defective areas are cleanly cut out.

11. Finish for Sheet

11.1 The types of finish available on sheet products are:

11.1.1 *No. 1 Finish*—Hot-rolled, annealed, and descaled.

11.1.2 *No. 2D Finish*—Cold-rolled, dull finish.

11.1.3 *No. 2B Finish*—Cold-rolled, bright finish.

11.1.3.1 *Bright Annealed Finish*—A bright cold-rolled finish retained by final annealing in a controlled atmosphere furnace.

11.1.4 *No. 3 Finish*—Intermediate polished finish, one or both sides.

11.1.5 *No. 4 Finish*—General purpose polished finish, one or both sides.

11.1.6 *No. 6 Finish*—Dull satin finish, Tampico brushed, one or both sides.

11.1.7 *No. 7 Finish*—High luster finish.

11.1.8 *No. 8 Finish*—Mirror finish.

11.1.9 *TR Finish*—Cold-worked to obtain specified properties.

NOTE 3—*Explanation of Sheet Finishes:*

No. 1—Commonly referred to as hot-rolled annealed and pickled or descaled. This is a dull, nonreflective finish.

No. 2D—A smooth, nonreflective cold-rolled annealed and pickled or descaled finish. This nondirectional finish is favorable for retention of lubricants in deep drawing applications.

No. 2B—A smooth, moderately reflective cold-rolled annealed and pickled or descaled finish typically produced by imparting a final light cold-rolled pass using polished rolls. This general-purpose finish is more readily polished than No. 1 or 2D finishes. Product with 2B finish is normally supplied in the annealed plus lightly cold-rolled condition unless a tensile-rolled product is specified.

Bright Annealed Finish—A smooth, bright, reflective finish typically produced by cold rolling followed by annealing in a protective atmosphere so as to prevent oxidation and scaling during annealing.

No. 3—A linearly textured finish that may be produced by either mechanical polishing or rolling. Average surface roughness (R_a) may generally be up to 40 µin. A skilled operator can generally blend this finish. Surface roughness measurements differ with different instruments, laboratories, and operators. There may also be overlap in measurements of surface roughness for both No. 3 and No. 4 finishes.

No. 4—A linearly textured finish that may be produced by either mechanical polishing or rolling. Average surface roughness (R_a) may generally be up to 25 µin. A skilled operator can generally blend this finish. Surface roughness measurements differ with different instruments, laboratories, and operators. There may also be overlap in measurements of surface roughness for both No. 3 and No. 4 finishes.

No. 6—This finish has a soft, satin appearance typically produced by tampico brushing a No. 4 finish.

No. 7—Has a high degree of reflectivity. It is produced by buffing a finely ground surface, but the grit lines are not removed. It is chiefly used for architectural or ornamental purposes.

No. 8—This is a highly reflective, smooth finish typically produced by polishing with successively finer grit abrasives, then buffing. Typically, very faint buff of polish lines may still be visible on the final product. Blending after part assembly may be done with buffing.

TR Finish—The finish resulting from the cold-rolling of an annealed and descaled or bright annealed product to obtain mechanical properties higher than that of the annealed condition. Appearance will vary depending upon the starting finish, amount of cold work, and the alloy.

Architectural Finishes—Sometimes described as a No. 5 finish, these are a separate category and may be negotiated between buyer and seller, as there are many techniques and finish variations available throughout the world.

11.1.10 Architectural finish, No. 5, or other proprietary names are special finishes.

11.1.11 Note 3 is not meant to be restrictive or to be used as a basis for rejection but is intended to give general guidelines. Various production methods may be used to obtain these finishes.

11.1.12 Sheets can be produced with one or two sides polished. When polished on one side only, it is permitted to rough grind the other side in order to obtain the necessary flatness.

12. Finish for Strip

12.1 The various types of finish procurable on cold-rolled strip products are:

12.1.1 *No. 1 Finish*—Cold-rolled to specified thickness, annealed, and descaled.

12.1.2 *No. 2 Finish*—Same as No. 1 Finish, followed by a final light cold-roll pass, generally on highly polished rolls.

12.1.3 *Bright Annealed Finish*—A bright cold-rolled finish retained by final annealing in a controlled atmosphere furnace.

12.1.4 *TR Finish*—Cold-worked to obtain specified properties.

12.1.5 *Polished Finish*—Stainless steel strip is also available in polished finishes such as No. 3 and No. 4, which are explained in Note 3.

NOTE 4—*Explanation of Strip Finishes:*

No. 1—Appearance of this finish varies from dull gray matte finish to a fairly reflective surface, depending largely upon composition. This finish is used for severely drawn or formed parts, as well as for applications where the brighter No. 2 Finish is not required, such as parts for heat resistance.

No. 2—This finish has a smoother and more reflective surface, the appearance of which varies with composition. This is a general purpose finish, widely used for household and automotive trim, tableware, utensils, trays, and so forth.

Bright Annealed Finish—See Note 3.

TR Finish—See Note 3.

13. Finish for Plates

13.1 The types of finish available on plates are:

13.1.1 *Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated*—Scale not removed, an intermediate finish. Use of plates in this condition is generally confined to heat-resisting applications. Scale impairs corrosion resistance.

13.1.2 *Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated, and Blast Cleaned or Pickled*—Condition and finish commonly preferred for corrosion-resisting and most heat-resisting applications, essentially a No. 1 Finish.

13.1.3 *Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated, and Surface Cleaned and Polished*—Polish finish is generally No. 4 Finish.

13.1.4 *Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated, and Descaled, and Temper Passed*—Smoother finish for specialized applications.

13.1.5 *Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated, and Descaled; and Cold-Rolled, and Annealed or Heat Treated, and Descaled, and Optionally Temper Passed*—Smooth finish with greater freedom from surface imperfections than in 13.1.4.

14. Edges for Cold-Rolled Strip

14.1 The types of edges available on strip products are:

14.1.1 *No. 1 Edge*—A rolled edge, either round or square as specified.

14.1.2 *No. 3 Edge*—An edge produced by slitting.

14.1.3 *No. 5 Edge*—An approximately square edge produced by rolling or filing after slitting.

15. Heat Treatment

15.1 The heat treatments shown in this section are to be followed unless otherwise specified in the applicable material specification. Heat treatment thermal cycles shall be separate from other thermal processing cycles; for example, in-process thermal cycles are not permitted as a substitute for the separate annealing cycle.

15.2 *Austenitic Types:*

15.2.1 The austenitic types shall be annealed in accordance with Table A1.2.

15.2.2 The material shall be annealed to meet the mechanical property requirements of the applicable material specification unless otherwise stated in the material specification.

15.2.3 Except as indicated in Table A1.2, Series 300, XM-15, N08800, S30415, S30815, S31725, S31726, and S32615 austenitic chromium-nickel steels, when specified on the purchase order, shall be capable of meeting the test for resistance to intergranular corrosion specified in 18.2.

15.2.4 For grades stabilized with titanium or columbium, refer to Note 5.

NOTE 5—Solution-annealing temperatures above 1950°F [1066°C] can impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the stabilized grades, Types 309Cb, 309HCb, 310Cb, 310HCb, 316Ti, 316Cb, 321, 321H, 347, 347H, 348, 348H, S21640, S33425, S35140, S35135, and S35125. When intergranular corrosion is of concern, the purchaser should specify the corrosion test of 18.2 (to be conducted on sensitized specimens). The manufacturer is permitted, if necessary, use a lower temperature resolution anneal or a stabilization anneal after a high temperature solution anneal in order to meet corrosion test requirements. Consideration should be given to the corrosive media before using a stabilization anneal at less than 1800°F [982°C], as such treatment is not equally effective for all media.

15.2.5 For the stabilized H types, it is noted that the heat treatment requirements shown in Table A1.2 differ as a function of whether the material was cold worked or hot finished.

15.2.6 The chromium-manganese-nickel types (201, 202, S20103, S20400, S20153, S21800, S21640, XM-11, XM-17, XM-18, XM-19, XM-29, and XM-31) shall be solution annealed to meet the mechanical property requirements of the applicable material specification and to exhibit adequate resistance to intergranular corrosion (see 18.2). For S20161, the heat treatment is specified in Table A1.2. For S21640, see Note 5.

15.2.6.1 Note that some of these types contain high carbon content that can adversely affect resistance to intergranular corrosion.

15.3 *Duplex Types*—The duplex types shall be solution annealed in accordance with Table A1.2.

15.4 *Martensitic and Ferritic Types:*

15.4.1 The chromium steels (S32803, 400 Series, S40945, S41045, S41050, S41500, S43932, S44400, S44537, S44635, S44660, S44700, S44735, S44800, XM-27, and XM-33) shall be heat treated in such a manner as to satisfy all the requirements for mechanical and bending properties specified in the applicable material specification and (except for 400 Series, S41050, and S41500) to provide for adequate resistance to intergranular attack.

15.4.2 For S41500, heat to 1750°F [955°C] minimum, air cool to 200°F [93°C] or lower prior to any optional intermediate temper and prior to final temper. The final temper shall be between 1050°F [566°C] and 1150°F [621°C].

16. Number of Tests

16.1 Unless otherwise specified by the applicable material specification or by agreement between the seller and the purchaser to perform a greater number of tests, the following number of tests are to be performed.

16.1.1 In the case of plate, sheet, and strip produced in coil form, two or more hardness tests (one from each end of the coil); one bend test, when required; one permeability test, when required; and one or more tension tests shall be made on specimens taken from each coil. If the hardness difference between the two ends of the coil exceeds 5 HRB, or equivalent, or if the material is temper rolled, tensile properties must be determined on both coil ends.

16.1.2 In the case of plate, sheet, or strip produced in cut lengths, one tension test; two tension tests if the material is temper rolled (one tension test for single piece lots); one bend test when required, and one or more hardness tests shall be made on each 100 or less pieces of the same heat and nominal thickness rolled separately or continuously and heat treated within the same operating period, either as a lot or continuously.

NOTE 6—The term continuously, as applied to heat treatment, is meant to describe a heat-treating operation in which one cut length follows another through the furnace. Interspersement of different melts is permissible if they are of approximately the same nominal thickness and are heat treated in the same operating period and under the same conditions (time and temperature).

16.1.3 One intergranular corrosion test, when required, shall be selected from each heat and thickness subjected to the same heat treatment practice. It is permitted to obtain such specimens from specimens selected for mechanical testing.

17. Test Specimens

17.1 *Tension Test:*

17.1.1 Tension test specimens shall be taken from finished material and shall be selected in either or both longitudinal and transverse direction. The tension test specimen shall conform to the appropriate sections of Test Methods and Definitions A370, unless otherwise specified in the applicable material specification or agreed upon by the seller and the purchaser.

17.1.2 The testing speed between the yield strength and the fracture of the specimen, shall be conducted at a constant strain rate between ⅛ in. [3.18 mm] and ½ in. [12.70 mm] inclusive, per inch [25.40 mm] of gauge length per minute, or at a crosshead speed that will give a strain rate within this range. For the purposes of this specification, the rate of strain shall be determined by a strain-rate pacer, indicator, or controller, or by dividing the unit elongation by the elapsed time from yield strength to fracture.

17.2 *Hardness Test*—It is permitted to perform hardness tests on the grip ends of the tension specimens before they are subjected to the tension test.

17.2.1 Unless otherwise specified in the purchase order, the manufacturer may use an alternate hardness test procedure when material size or form dictates. Hardness conversion shall be done using the applicable tables in Test Methods and Definitions A370. When the material is too thin to allow hardness testing using any of the Rockwell superficial hardness tests, the hardness requirement is waived.

17.3 *Bend Test:*

17.3.1 Bend test specimens (when required) shall be taken from finished material and shall be selected in the transverse direction or as indicated in the applicable material specification or as agreed upon by the seller and the purchaser. In the case of transverse bend test specimens, the axis of bend shall be parallel to the direction of rolling.

17.3.2 Bend test specimens from sheet and strip product shall be the full thickness of the material and approximately 1 in. [25.4 mm] in width. It is permitted to round the edges of the test specimen to a radius equal to one half the specimen thickness.

17.3.3 The width of strip for which bend tests can be made is subject to practical limitations on the length of the bend test specimen. For narrow strip, the following widths can be tested:

Strip thickness, in. [mm]	Minimum Strip Width and Minimum Specimen Length for Bend Tests, in. [mm]
0.100 [2.5] and under	½ [12.7]
Over 0.100 [2.5] to 0.140 [3.5], excl.	1 [25.4]
0.140 [3.5] and over	1½ [38.1]

Bend test specimens shall be of any suitable length over the specified minimum length.

17.3.4 Bend test specimens taken from plates shall be in full thickness of the material up to and including ½ in. [12.7 mm] in thickness, of suitable length, and between 1 and 2 in. [25.4 and 50.8 mm] in width. It is permitted to remove the sheared edges to a depth of at least ⅛ in. [3.2 mm] and it is permitted to smooth the sides with a file. It is permitted to break the corners of the cross section of the specimen with a file, but no appreciable rounding of the corners is permitted.

17.3.5 In the case of plates over ½ in. [12.7 mm] in thickness, it is permitted to use bend test specimens, machined to 1 in. [25.4 mm] nominal width by ½ in. [12.7 mm] nominal thickness and at least 6 in. [152.4 mm] in length. One surface, to be the outside surface in bending, shall be the original surface of the plate; however, surface preparation by light grinding is permitted. It is permitted to round the edges to a 1⁄16 in. [1.6 mm] radius. When agreed by the seller and the purchaser, it is permitted to modify the cross section to ½ in. [12.7 mm] nominal square.

17.3.6 In the case of plates over 1 in. [25.4 mm] in thickness, bend tests must be agreed upon between the seller and the purchaser.

17.3.7 The bend test specimen shall withstand cold bending through the angle specified in the applicable material specification without cracking on the outside of the bent portion.

17.4 The bend shall be made over a diameter equal to the number of thicknesses of flat stock shown in the applicable material specification or over a single piece of flat stock equal to the number of thicknesses shown in the applicable material specification; or as follows:

17.4.1 Material up to and including ⅜ in. [9.5 mm] in thickness shall be bent over a piece (or pieces) of flat stock that has the same nominal thickness of the material being tested (1T), allowing the test material to form its natural curvature.

17.4.2 Material over ⅜ in. [9.5 mm] and up to and including 1 in. [25.4 mm] in thickness shall be bent over a piece (or pieces) of flat stock equalling two times the thickness of the material being tested (2T), allowing the test material to form its natural curvature.

18. Special Tests

18.1 If other tests are required, the methods and acceptance criteria shall be agreed upon between the seller and the purchaser and specified on the purchase order.

18.2 *Resistance to Intergranular Corrosion:*

18.2.1 The intergranular corrosion test, Practice E of Practices A262, is not required unless it is specified on the purchase order. All austenitic chromium-nickel types except the H types are expected to be capable of passing this test. However, it is not necessary to actually run the test unless it is specified on the purchase order. Note that Practices A262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum in their specified composition, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser. When specified, all flat rolled products of the chromium-nickel series (300 series) in thickness up to and including 2 in. [50.8 mm] nominal size shall be capable of passing the intergranular corrosion test in the as shipped condition. In the case of heavier plates of types other than 304L, 304LN, 309Cb, 310Cb, 316Cb, 316L, 316LN, 316Ti, 317L, 321, 347, 348, S31725, and S31726, the applicability of this test shall be a matter for negotiation between the seller and the purchaser.

18.2.2 The H types are not normally subject to intergranular corrosion tests. However, it is permitted to specify Practice E of Practices A262 for Type 321H when intergranular corrosion is of concern. In this case, the purchaser shall inform the seller and agree upon the requirements and these requirements shall be so stated on the purchase order.

18.2.3 Austenitic chromium-manganese-nickel types (201, 202, XM-17, XM-18, XM-19, XM-29, XM-31, S20400, S21640, and S21800) are to be heat treated for intergranular corrosion resistance. When intergranular corrosion tests are required, they shall be as agreed upon between the seller and the purchaser.

18.2.4 N08800 shall be heat treated for intergranular corrosion resistance. When intergranular corrosion tests are required, they shall be as agreed upon between the seller and purchaser.

18.2.5 Corrosion tests are not normally required for the 400 series types. Lower-carbon corrosion-resistant types (S44400, S44635, S44660, S44700, S44800, S44735, XM-27, and XM-33) are heat treated for resistance to corrosion. For S44400, S44635, S44660, S44700, S44800, S44735, XM-27, and XM-33, intergranular corrosion testing of Practices A763, Practice X, Y, or Z shall be specified as agreed upon between the seller and the purchaser.

18.3 *Detrimental Intermetallic Phases in Duplex Stainless Steels*—The tests for detrimental intermetallic phases in wrought duplex stainless steels, Methods A, B, or C of Test Methods A923, are not required unless it is specified on the purchase order. All duplex (austenitic-ferritic) types that are listed in Test Methods A923 are expected to be capable of passing these tests. However, it is not necessary to actually run the tests unless specified on the purchase order. The applicability of these tests to duplex stainless steels not listed in Test Methods A923 shall be a matter for negotiation between the seller and the purchaser.

19. Test Methods

19.1 The properties enumerated in applicable specifications shall be determined in accordance with the following ASTM standards.

19.1.1 *Tension Tests*—Test Methods and Definitions A370.

19.1.2 *Brinell Tests*—Test Methods and Definitions A370.

19.1.3 *Rockwell Hardness*—Test Methods and Definitions A370.

19.1.4 *Hardness Equivalents*—Tables E140.

19.1.5 *Intergranular Corrosion* (*when specified*)—Practices A262, Practices A763.

19.1.6 *Permeability Test* (*when required*)—Test Methods A342/A342M.

19.1.7 *Charpy Impact Testing (when required)*—Test Methods and Definitions A370.

19.1.8 *Intermetallic Phases (when specified)*—Test Methods A923.

20. Retests and Retreatment

20.1 Retests are permitted in accordance with the provisions of Test Methods and Definitions A370.

20.2 If any test specimen shows defective machining or develops flaws, it is permitted to discard the flawed specimen and substitute another specimen.

20.2.1 If the percentage of elongation of any tension specimen is less than that specified and any part of the fracture is more than ¾ in. [19.1 mm] from the center of the gauge length of the 2 in. [50.8 mm] specimen or is outside the middle half of the gauge length of an 8-in. [203.2-mm] specimen, as indicated by scribe marks placed on the specimen before testing, a retest shall be allowed.

20.3 If a bend test specimen fails, due to conditions of bending more severe than required by the specification, a retest shall be permitted, either on a duplicate specimen or on a remaining portion of the failed specimen.

20.4 If the results of any test lot are not in conformance with the requirements of the applicable material specification, the producer is permitted the option of retreating such lots. The material shall be accepted if the results of retests on retreated material are within the specified requirements.

20.5 If any specimens selected to represent any heat fail to meet any of the test requirements as specified in the applicable material specification, it is permitted to reheat treat the material represented and resubmit it for testing.

20.6 If the product analysis fails to conform to the specified limits, analysis shall be made on a new sample. The results of this retest shall be within the specified requirements.

21. Repair of Plate by Welding

21.1 Repair of surface defects of plate, by welding, is permitted unless prohibited by other specifications or purchase order requirements.

21.2 Defect depth shall not exceed ⅓ of the nominal thickness, and the total area shall not exceed 1 % of the plate surface area, unless prior approval from the purchaser is obtained.

21.3 Unacceptable imperfections shall be suitably prepared for welding by grinding or machining. Open clean defects, such as pits or impressions, will not necessarily require preparation.

21.4 The welding procedure and the welders or welding operators shall be qualified in accordance with Section IX of the ASME Code.[2]

21.5 The welding consumables shall be suitable with the plate.

21.6 After repair welding, the welded area shall be ground smooth and blended uniformly to the surrounding surface.

22. Inspection

22.1 Inspection of the material by the purchaser's representative at the producing plant shall be made as agreed upon between the purchaser and the seller as part of the purchase order.

22.2 Unless otherwise specified in the contract or purchase order: (*1*) the seller is responsible for the performance of all the inspection and test requirements in this specification, (*2*) the seller is permitted to use own or other suitable facilities for the performance of the inspection and testing, and (*3*) the purchaser shall have the right to perform any of the inspection and tests set forth in this specification. The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy the inspector that the material is being furnished in accordance with the specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer.

23. Rejection

23.1 Unless otherwise specified, any rejection based on tests made in accordance with this specification shall be reported to the seller within 60 working days from the receipt of the material by the purchaser.

23.2 Material that shows injurious imperfections as described in Section 10 subsequent to its acceptance at the purchaser's works will be rejected and the seller shall be notified.

24. Rehearing

24.1 Samples tested in accordance with this specification that represent rejected material shall be retained for three weeks from the date of the notification to the seller of the rejection. In case of dissatisfaction with the results of the test, the seller is permitted to make claim for a rehearing within that time.

25. Packaging, Marking, and Loading

25.1 *For Commercial Procurement:*

25.1.1 *Marking*—Unless otherwise specified in the applicable material specification or the purchase order, marking shall be conducted as follows:

25.1.1.1 Sheet, strip, and plate shall be marked on one face, in the location indicated below with the specification designation number, type of steel (type or UNS designation), material identification number, and the name or mark of the manufacturer. For sheet, strip, and plate whose length and width dimensions are both less than 24 in., each piece shall be marked with the type of steel and material identification number. The specification and designation number, and name or mark of the manufacturer shall be marked on the piece(s) or attached to the item or bundle. The characters shall be of such size as to be clearly legible. The marking shall be sufficiently stable to withstand normal handling. Unless otherwise specified by the purchaser, the marking, at the producers option, is permitted to be done with *(a)* marking fluid (if a specific maximum impurity limit of designated elements in the marking fluid is required by the purchaser, it shall be so stated on the purchase order), *(b)* low-stress blunt-nosed continuous or low-stress blunt-nosed-interrupted-dot die stamp, *(c)* a vibratory tool with a minimum tip radius of 0.005 in. [0.1 mm], or *(d)* electrochemical etching.

25.1.1.2 Flat sheet, strip in cut lengths, and plate shall be marked in two places near the ends or shall be continuously line marked along one edge. For flat sheet, strip in cut lengths, and plate whose length and width dimensions are both less than 48 in., it is permitted to mark such pieces in only one place.

25.1.1.3 Sheet, strip, and plate in coil form shall be marked near the outside end of the coil. The inside of the coil shall also be marked or shall have a tag or label attached and marked with the information of 25.1.1.1.

25.1.1.4 Material less than ¼ in. [6.4 mm] in thickness shall not be marked with die stamps.

25.1.1.5 The manufacturer's test identification number shall be legibly stamped on each test specimen, if to be shipped to the customer.

25.1.1.6 Material that conforms completely with the requirements of two types of steel within the ordering specification is permitted to be marked as both types of steel provided that the manufacturer is certifying the material as meeting the requirements of each of the types of steel. Such marking, if used, shall be part of the same marking as used for a single type of steel, or shall be a separate but similar marking immediately adjacent to the marking used for a single type of steel.

25.1.1.7 The AIAG primary metals identification tag (AIAG B-5) is permitted to be used as an auxiliary method of identification in cases where a bar-coded identification tag is desired. Use of this method shall be by agreement between purchaser and supplier.

25.1.2 *Packaging and Loading*—Unless otherwise specified in the applicable material specification or the purchase order, packaging and loading shall be in accordance with the procedures recommended by Practices A700.

25.2 *For U.S. Government Procurement:*

25.2.1 When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

25.2.2 When specified in the contract or order, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract or order.

26. Keywords

26.1 austenitic stainless steel; duplex stainless steel; ferritic stainless steel; martensitic stainless steel; stainless steel; stainless steel plate; stainless steel sheet; stainless steel strip

ANNEXES

(Mandatory Information)

A1. PRODUCT ANALYSIS TOLERANCES AND HEAT TREATMENT REQUIREMENTS

A1.1 Listed in Annex A1 are tables showing the permitted variations of composition for product analysis relative to specified chemical requirements (Table A1.1) and the heat treatment requirements for types of stainless steel covered by product specifications that reference Specification A480/A480M (Table A1.2).

TABLE A1.1 Chemical Requirements (Product Analysis Tolerances)[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit	Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	to 0.010, incl	0.002	Titanium	to 1.00, incl	0.05
	over 0.010 to 0.030, incl	0.005		over 1.00 to 3.00, incl	0.07
	over 0.030 to 0.20, incl	0.01			
	over 0.20 to 0.60, incl	0.02	Cobalt	over 0.05 to 0.50, incl	0.01[B]
	over 0.60 to 1.20, incl	0.03		over 0.50 to 2.00, incl	0.02
				over 2.00 to 5.00, incl	0.05
Manganese	to 1.00, incl	0.03			
	over 1.00 to 3.00, incl	0.04	Columbium plus tantalum	to 1.50, incl	0.05
	over 3.00 to 6.00, incl	0.05			
	over 6.00 to 10.00, incl	0.06			
	over 10.00 to 15.00, incl	0.10			
	over 15.00 to 20.00, incl	0.15	Tantalum	to 0.10, incl	0.02
Phosphorus	to 0.040, incl	0.005	Copper	to 0.50, incl	0.03
	over 0.040 to 0.20, incl	0.010		over 0.50 to 1.00, incl	0.05
				over 1.00 to 3.00, incl	0.10
Sulfur	to 0.040, incl	0.005		over 3.00 to 5.00, incl	0.15
	over 0.040 to 0.20, incl	0.010		over 5.00 to 10.00, incl	0.20
	over 0.20 to 0.50, incl	0.020			
			Aluminum	to 0.15, incl	−0.005, +0.01
Silicon	to 1.00, incl	0.05		over 0.15 to 0.50, incl	0.05
	over 1.00 to 3.00, incl	0.10		over 0.50 to 2.00, incl	0.10
	over 3.00 to 7.00, incl	0.15			
Chromium	over 4.00 to 10.00, incl	0.10			
	over 10.00 to 15.00, incl	0.15	Nitrogen	to 0.02, incl	0.005
	over 15.00 to 20.00, incl	0.20		over 0.02 to 0.19, incl	0.01
	over 20.00 to 30.00, incl	0.25		over 0.19 to 0.25, incl	0.02
				over 0.25 to 0.35, incl	0.03
Nickel	to 1.00, incl	0.03		over 0.35 to 0.45, incl	0.04
	over 1.00 to 5.00, incl	0.07		over 0.45 to 0.55, incl	0.05
	over 5.00 to 10.00, incl	0.10	Tungsten	to 1.00, incl	0.03
	over 10.00 to 20.00, incl	0.15		over 1.00 to 2.00, incl	0.05
	over 20.00 to 30.00, incl	0.20		over 2.00 to 5.00, incl	0.07
	over 30.00 to 40.00	0.25		over 5.00 to 10.00, incl	0.10
	over 40.00	0.30		over 10.00 to 20.00, incl	0.15
			Vanadium	to 0.50, incl	0.03
Molybdenum	over 0.20 to 0.60, incl	0.03		over 0.50 to 1.50, incl	0.05
	over 0.60 to 2.00, incl	0.05			
	over 2.00 to 8.00, incl	0.10	Selenium	all	0.03

[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05 % have not been established, and the manufacturer should be consulted for those limits.

TABLE A1.2 Heat Treatment Requirements

Designation/Type	Temperature[A]	Cooling/Testing Requirements
Austenitic (Chromium-Nickel) (Chromium-Nickel-Manganese)		
All Cr-Ni steels except as listed below	1900°F [1040°C]	[B]
302, 308, 309, 309Cb, 310, 310Cb, S21640, S30215, S30452, S30615, S32615, S33228, S33425, S35140, S38100	1900°F [1040°C]	[C]
304H, 309H, 310H, 316H	1900°F [1040°C]	[C]
309HCb, 310HCb, 321H, 347H, 348H		
Cold Worked	2000°F [1095°C]	[C]
Hot Finished	1925°F [1050°C]	[C]
N08020	1700° to 1850°F [925° to 1010°C]	[C]
N08367	2025°F [1105°C]	[C]
N08700	2000°F [1095°C]	[C]
N08810	2050°F [1120°C]	[C]
N08811	2100°F [1150°C]	[C]
N08904	2000°F [1095°C]	[C]
N08925	2100°F [1150°C]	[C]
N08926	2010°F [1100°C]	[C]
S20161	1900° to 2000°F [1040° to 1095°C]	[C]
S20431	1900° to 2010°F [1040° to 1100°C]	[C]
S20432	1900° to 2010°F [1040° to 1100°C]	[C]
S20433	1900° to 2010°F [1040° to 1100°C]	[C]
S30530	1900° to 2100°F [1040° to 1150°C]	[C]
S30600, S30601	2010° to 2140°F [1100° to 1170°C]	[C]
S30616	1920 to 2100°F [1050° to 1150°C]	[C]
S31060	1975° to 2160°F [1080° to 1180°C]	[C]
S31254, S31266, S32050, S32654	2100°F [1150°C]	[C]
S31277	2050°F [1120°C]	[C]
S31727	1975 to 2155°F [1080 to 1180°C]	[C]
S32053	1975 to 2155°F [1080 to 1180°C]	[C]
S33228	2050 to 2160°F [1120 to 1180°C]	[C]
S33550	2065 to 2155°F [1130 to 1180°C]	[C]
S34565	2050° to 2140°F [1120° to 1170°C]	[C]
S35115	2000°F [1095°C]	[C]
S35315	2010°F [1100°C]	[C]
Duplex (Austenitic-Ferritic)		
S31200, S31803, S32001, S32550	1900°F [1040°C]	[C]
S31260	1870° to 2010°F [1020° to 1100°C]	[C]
S32003	1850°F [1010°C]	[C]
S32101	1870°F [1020°C]	[C]
S32202	1800° to 1975°F [980° to 1080°C]	[C]
S32205	1900°F [1040°C]	[D]
S32304	1800°F [980°C]	[C]
S32506	1870 to 2050°F [1020 to 1120°C]	[C]
S32520	1975 to 2050°F [1080 to 1120°C]	[C]
S32750[E]	1880° to 2060°F [1025° to 1125°C]	[C]
S32760	2010°F [1100°C]	[C]
S32808	1925 to 2100°F [1050 to 1150°C]	[C]
S32900	1750° ± 25°F [955° ± 15°C]	[C]
S32906	1900° to 2100°F [1040° to 1150°C]	[C]
S32950	1850° ± 25°F [1010° ± 15°C]	[C]
S39274	1925 to 2100°F [1050 to 1150°C]	[C]
S44537	1922°F [1050°C]	[C]
S81921	1760 to 2010°F [960° to 1100°C]	[C]
S82011	1850°F [1010°C]	[C]
S82012	1830°F [1000°C]	[C]
S82031	1830°F [1000°C]	[C]
S82121	1830 to 2010°F [1000 to 1100°C]	[C]
S82122	1725°F [940°C]	[C]
S82441	1830°F [1000°C]	[C]

[A] Minimum, unless otherwise indicated.
[B] Quenched in water or rapidly cooled by other means at a rate sufficient to prevent reprecipitation of carbides, as demonstrable by the capability of passing the test for resistance to intergranular corrosion specified in 18.2.
[C] Quenched in water or rapidly cooled by other means.
[D] Quenched in water, except that coiled product heat treated in a continuous annealing line shall be water quenched or rapidly cooled by other means.
[E] Temperatures above 2060°F are permissible if the resulting microstructure provides the properties required by this specification or any additional requirements of the purchase order.

A2. PERMITTED VARIATIONS IN DIMENSIONS, ETC.—INCH-POUND UNITS

A2.1 Listed in Annex A2 are tables showing the permissible variations in dimensions expressed in inch-pound units of measurement. These requirements, including the SI units shown in brackets within Annex A2, shall apply to A480, but shall not apply to A480M. Requirements for A480M are given in Annex A3.

A2.1.1 The dimensional tolerances are grouped by production method (hot rolling or cold rolling, with or without coiling), product width (narrow (<24 in. [610 mm]) or wide (≥24 in. [610 mm])), and by product dimension addressed.

A2.2 *Cold-Rolled Narrow (<24 in. [610 mm] width) Coil-Processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A2.1-A2.4.

A2.3 *Cold-Rolled Wide (≥24 in. [610 mm] width) Coil-Processed Product*— For thickness, width, length, and flatness tolerance tables, refer to Tables A2.5-A2.8.

A2.4 *Hot-Rolled Narrow (<24 in. [610 mm] width) Coil-Processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A2.9-A2.12.

A2.5 *Hot-Rolled Wide (≥24 in. [610 mm] width) Coil-Processed Product*— For thickness, width, length, and flatness tolerance tables, refer to Tables A2.13-A2.16.

A2.6 *Hot-Rolled Product Processed Without Coiling*—For thickness, width, length, and flatness tolerance tables, refer to Tables A2.17-A2.20.

A2.7 *Cold-Rolled Product Processed Without Coiling*—For thickness, width, length, and flatness tolerance tables, refer to Table A2.21.

A2.8 *Tolerances for Other Dimensional Characteristics*—For other tolerance tables, refer to Tables A2.22-A2.30.

TABLE A2.1 Permitted Variations in Thickness for Cold-Rolled, Narrow, Coil-Processed Product as Coils and Cut Lengths

NOTE 1—Thickness measurements are taken at least ⅜ in. [9.52 mm] in from the edge of the product, except on widths less than 1 in. [25.4 mm] the measurements should be taken at least ⅛ in. [3.18 mm] from the product edge.

NOTE 2—The tolerances in this table include crown tolerances.

Specified Thickness, in. [mm]	Thickness Tolerances, for the Thickness and Widths Given, Over and Under, in. [mm]		
	Width (w), in. [mm]		
	3⁄16 [4.76] to 6 [152], incl $w \le 6$ [152]	Over 6 [152] to 12 [305], incl 6 [152] < $w \le 12$ [305]	Over 12 [305] to 24 [610], excl 12 [305] < $w \le 24$ [610]
	Thickness Tolerances[A]		
0.002 [0.05] to 0.005 [0.13], excl	10 %	10 %	10 %
0.005 [0.13] to 0.010 [0.25] , incl.	0.0006 [0.015]	0.0008 [0.020]	0.001 [0.025]
Over 0.010 [0.25] to 0.012 [0.30], incl	0.001 [0.025]	0.001 [0.025]	0.001 [0.025]
Over 0.012 [0.30] to 0.015 [0.40], incl	0.001 [0.025]	0.0015 [0.04]	0.0015 [0.04]
Over 0.015 [0.40] to 0.020 [0.50], incl	0.001 [0.025]	0.0015 [0.04]	0.0015 [0.04]
Over 0.020 [0.50] to 0.029 [0.74], incl	0.0015 [0.04]	0.0015 [0.04]	0.002 [0.050]
Over 0.029 [0.74] to 0.035 [0.89], incl	0.0015 [0.04]	0.002 [0.050]	0.002 [0.050]
Over 0.035 [0.89] to 0.050 [1.27], incl	0.0025 [0.060]	0.003 [0.070]	0.003 [0.070]
Over 0.050 [1.27] to 0.069 [1.75], incl	0.003 [0.070]	0.003 [0.070]	0.003 [0.070]
Over 0.069 [1.75] to 0.100 [2.54], incl	0.003 [0.070]	0.003 [0.070]	0.004 [0.10]
Over 0.100 [2.54] to 0.125 [2.98], incl	0.004 [0.10]	0.004 [0.10]	0.005 [0.12]
Over 0.125 [2.98] to 0.161 [4.09], incl	0.005 [0.12]	0.005 [0.12]	0.005 [0.12]
Over 0.161 [4.09] to under 3⁄16 [4.76]	0.005 [0.12]	0.005 [0.12]	0.006 [0.15]

[A] Thickness tolerances given in in. [mm] unless otherwise indicated.

TABLE A2.2 Permitted Variations in Width for Cold-Rolled, Narrow, Coil-Processed Product as Coils and Cut Lengths for Edge No. 3[A]

Specified Thickness[B], in. [mm]	Width Tolerance, Over and Under, for Thickness and Width Given, in. [mm]			
	$w \leq$ 1.60 [40]	1.60 [40] < $w \leq$ 6 [150]	6 [150] < $w \leq$ 12 [305]	12 [300] < $w \leq$ 24 [610]
0.010 [0.25]	0.003 [0.085]	0.004 [0.10]	0.005 [0.125]	0.020 [0.50]
0.020 [0.50]	0.005 [0.125]	0.005 [0.125]	0.010 [0.25]	0.020 [0.50]
0.040 [1.00]	0.005 [0.125]	0.005 [0.125]	0.010 [0.25]	0.020 [0.50]
0.060 [1.50]	0.005 [0.125]	0.006 [0.15]	0.010 [0.25]	0.020 [0.50]
0.100 [2.50]	. . .	0.010 [0.25]	0.016 [0.40]	0.020 [0.50]
0.120 [3.00]	. . .	0.010 [0.25]	0.016 [0.40]	0.024 [0.60]
0.160 [4.00]	. . .	0.016 [0.40]	0.016 [0.40]	0.024 [0.60]
0.200 [4.99]	. . .	0.030 [0.80]	0.030 [0.80]	0.030 [0.80]

[A] For tolerances applicable to narrow product with Edge No. 1 or No. 5, see Table A3.22.
[B] For specified thickness other than those shown, the tolerances for the next higher thickness shall apply.

TABLE A2.3 Permitted Variations in Length for Cold-Rolled, Narrow, Coil-Processed Product as Cut Lengths

Specified Length, ft [mm]	Tolerances, in. [mm]
≤6 [1830]	+⅛ [3], −0
>6 [1830] to ≤12 [3660]	+0.2 [5], −0
>12 [3660] to ≤20 [6096]	+0.3 [8], −0

TABLE A2.4 Permitted Variations in Flatness of Cold-Rolled, Narrow, Coil-Processed Product as Cut Lengths

Tolerances for variations of flatness cold-rolled products, narrow, coil-processed product as cut lengths shall be identical to the tolerances for cold-rolled, wide, coil-processed product as listed in Table A2.8 unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.5 Permitted Variations in Thickness of Cold-Rolled, Wide, Coil-Processed Product as Coil and Cut Lengths

Specified Thickness[A,B], in. [mm]	Permitted Variation, Over and Under, in [mm], for specified width (w), w in inches		
	$w \leq$ 40 [1000]	40 [1000] < $w \leq$ 50 [1300]	50 [1300] < $w \leq$ 84 [2100]
0.012 [0.30]	0.001 [0.030]	. . .	. . .
0.016 [0.40]	0.0015 [0.04]	0.0015 [0.04]	. . .
0.020 [0.50]	0.0015 [0.04]	0.0015 [0.04]	. . .
0.024 [0.60]	0.002 [0.05]	0.002 [0.05]	. . .
0.032 [0.80]	0.002 [0.05]	0.002 [0.05]	. . .
0.040 [1.00]	0.0025 [0.06]	0.0025 [0.06]	0.003 [0.08]
0.047 [1.20]	0.003 [0.08]	0.003 [0.08]	0.003 [0.08]
0.059 [1.50]	0.003 [0.08]	0.003 [0.08]	0.004 [0.10]
0.079 [2.00]	0.004 [0.10]	0.004 [0.10]	0.0045 [0.11]
0.098 [2.50]	0.004 [0.10]	0.004 [0.10]	0.005 [0.13]
0.118 [3.00]	0.005 [0.13]	0.005 [0.13]	0.006 [0.15]
0.157 [4.00]	0.007 [0.17]	0.007 [0.17]	0.007 [0.17]
0.197 [5.00]	0.007 [0.17]	0.007 [0.17]	0.0075 [0.19]
0.236 [6.00]	0.007 [0.17]	0.008 [0.20]	0.009 [0.23]
0.3125 [8.00]	0.007 [0.17]	0.009 [0.23]	0.010 [0.25]

[A] Thickness measurements are taken at least ⅜ in. [9.52 mm] from the edge of the sheet.
[B] For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

TABLE A2.6 Permissible Variations in Width for Cold-Rolled Wide, Coil-Processed Product as Cut Lengths (Not Resquared) and Coil

Specified Thickness, in. [mm][A]	Permitted Variation in Width (w), in. [mm], for Specified Width (w), in. [mm]				
	$w \le 6$ [150]	6 [125] < $w \le 12$ [300]	12 [300] < $w \le 24$ [600]	24 [600] < w < 48 [1200]	48 [1000] ≥ w
0.040 [1.00]	+0.02 [0.5], –0	+0.02 [0.5], –0	+0.03 [0.7], –0	+1/16 [1.6], –0	+⅛ [3.2], –0
0.059 [1.50]	+0.03 [0.7], –0	+0.03 [0.7], –0	+0.04 [1.0], –0	+1/16 [1.6], –0	+⅛ [3.2], –0
0.098 [2.50]	+0.04 [1.0], –0	+0.04 [1.0], –0	+0.05 [1.2], –0	+1/16 [1.6], –0	+⅛ [3.2], –0
0.138 [3.50]	+0.05 [1.2], –0	+0.05 [1.2], –0	+0.06 [1.5], –0	+1/16 [1.6], –0	+⅛ [3.2], –0
0.3125 [8.00]	+0.08 [2.0], –0	+0.08 [2.0], –0	+0.08 [2.0], –0	+0.16 [4.0], –0	+0.16 [4.0], –0

[A] For specified thicknesses and other than those shown, the tolerances for the next higher thickness shall apply.

TABLE A2.7 Permitted Variations in Length for Cold-Rolled, Wide, Coil-Processed Product as Cut Lengths Not Resquared

Specified Length (L), ft [mm]	Tolerances, in. [mm]	
	Over	Under
Up to 6 [1830], incl	3/16 [4.8]	0
Over 6 [1830]	0.03 × L [0.0025 × L]	0

TABLE A2.8 Permitted Variations in Flatness of Cold-Rolled, Wide, Coil-Processed Product as Cut Lengths

Not Specified to Stretcher-Leveled Standard of Flatness[A]		
Specified Thickness, in. [mm]	Width, in. [mm]	Flatness Tolerance,[B] in. [mm]
<0.062 [1.57]	≤60 [1524]	0.40 [10]
	>60 [1524]	0.50 [12]
≥0.062 [1.57]	≤60 [1524]	0.40 [10]
	>60 [1524]	0.50 [12]

Stretcher-Leveled Standard of Flatness[C]			
Specified Thickness, in. [mm]	Width, in. [mm]	Length, in. [mm]	Flatness Tolerance,[B] in. [mm]
<3/16 [4.76]	<48 [1219]	<96 [2438]	⅛ [3.2]
	<48 [1219]	≥96 [2438]	¼ [6.4]
<3/16 [4.76]	≥48 [1219]	<96 [2438]	¼ [6.4]
	≥48 [1219]	≥96 [2438]	¼ [6.4]

2xx and 3xx Series Specified to ¼ and ½ Hard Tempers			
Specified Thickness, in. [mm]	Width, in. [mm]	Flatness Tolerance,[B] in. [mm]	
		¼ Hard	½ Hard
<0.016 [0.41]	24 [610] to <36 [914]	½ [12.70]	¾ [19.05]
0.016 [0.41] to 0.030 [0.76]		⅝ [15.88]	⅞ [22.22]
>0.030 [0.76]		¾ [19.05]	⅞ [22.22]
≤0.016 [0.41]	36 [914] to <48 [1219]	⅝ [15.88]	1 [25.40]
>0.016 [0.41] to 0.030 [0.76]		¾ [19.05]	⅛ [28.58]
>0.030 [0.76]		1 [25.40]	1⅛ [28.58]

[A] Not specified to stretcher-leveled standard of flatness, and not including hard tempers of 2xx and 3xx Series, dead-soft sheets, and deep-drawing sheets.
[B] Maximum deviation from a horizontal flat surface.
[C] Not including hard tempers of 2xx and 3xx Series, dead-soft sheets, and deep-drawing sheets.

TABLE A2.9 Permitted Variations in Thickness of Hot-Rolled, Narrow, Flat-Rolled, Coil-Processed Product as Cut Lengths and Coil

Tolerances for variations of thickness of hot-rolled, narrow, coil-processed product as cut lengths and coil shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A2.13, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.10 Permitted Variations in Width of Hot-Rolled, Narrow, Flat-Rolled, Coil-Processed Product as Cut Lengths and Coil

Tolerances for variations of width of hot-rolled, narrow, coil-processed product as cut lengths and coil shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A2.14 unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.11 Permitted Variations in Length of Hot-Rolled, Narrow, Coil-Processed Product as Cut Lengths

Tolerances for variations of length of hot-rolled, narrow, coil-processed product as cut lengths shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A2.15 unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.12 Permitted Variations in Flatness of Hot-Rolled, Narrow, Coil-Processed Product as Cut Lengths

Tolerances for variations of flatness of hot-rolled, narrow, coil-processed product as cut lengths shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A2.16 unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.13 Permitted Variations in Thickness of Hot-Rolled, Wide, Coil-Processed Product as Coil and Cut Lengths

Specified Thickness[A], in. [mm]	Permitted Variations, in. [mm], Over and Under, Except as Indicated Otherwise, for Specified Width (w) in. [mm]	
	$w \leq$ 60 [1525]	w > 60 [1525]
0.072 [1.83]	0.006 [0.15]	0.009 [0.22]
>0.072 [1.83] to 0.083 [2.11]	0.007 [0.18]	0.010 [0.25]
>0.083 [2.11] to 0.098 [2.49]	0.008 [0.20]	0.011 [0.27]
>0.098 [2.49] to 0.114 [2.90]	0.009 [0.23]	0.012 [0.30]
>0.114 [2.90] to 0.130 [3.30]	0.011 [0.27]	0.013 [0.33]
>0.130 [3.30] to 0.145 [3.68]	0.012 [0.30]	0.013 [0.33]
>0.145 [3.68] to 0.1875 [4.76]	0.013 [0.33]	0.014 [0.35]
>0.1875 [4.76] to 0.250 [6.35]	–0.010 [0.25], +0.020 [0.50]	–0.010 [0.25], +0.020 [0.50]
>0.250 [6.35] to 0.3125 [7.94]	–0.010 [0.25], +0.022 [0.55]	–0.010 [0.25], +0.022 [0.55]
>0.3125 [7.94]	–0.010 [0.25], +0.030 [0.75]	–0.010 [0.25], +0.030 [0.75]

[A] Thickness measurements are taken at least ⅜ in. [9.52 mm] from the edge of the sheet.

TABLE A2.14 Permitted Variations in Width of Hot-Rolled, Wide, Coil-Processed Product as Cut Lengths (Not Resquared) and Coil

Specified Thickness, t, in. [mm]	Width (w), in. [mm]	Tolerances on Width, in. [mm], for Trimmed Edges
t < 3⁄16 [4.76]	w < 48 [1219]	+1⁄16 [1.59], –0
	$w \geq$ 48 [1219]	+¼ [6.35], –0
3⁄16 [4.76] ≤ t < ⅜ [9.5]	w < 48 [1219]	+5⁄32 [3.97], –0
	$w \geq$ 48 [1219]	+⅜ [9.5], –0
$t \geq$ ⅜ [9.5]	w < 48 [1219]	+¼ [6.35], –0
	$w \geq$ 48 [1219]	+7⁄16 [11.1], –0

TABLE A2.15 Permitted Variations in Length of Hot-Rolled, Wide, Coil-Processed Product as Cut Lengths Not Resquared

Specified Thickness, t, in. [mm]	Length (L), ft [mm]	Tolerances, in. [mm], Over and Under
t < 3⁄16 [4.76]	$L \leq$ 10 [3048]	+¼ [6.35], –0
	10 [3048] < $L \leq$ 20 [6096]	½ [12.7] , –0
t ≥ 3⁄16 [4.76]	$L \leq$ 10 [3048]	+½ [12.7], –0
	10 [3048] < $L \leq$ 20 [6096]	+⅝ [15.9], –0

TABLE A2.16 Permitted Variations in Flatness of Hot-Rolled, Wide, Coil-Processed Product as Cut Lengths

Not Specified to Stretcher-Leveled Standard of Flatness		
Specified Thickness (t), in. [mm]	Width (w), in. [mm]	Flatness Tolerance,[A] in. [mm]
t < 3⁄16 [4.76]	$w \le$ 36 [914]	0.50 [12.7]
	36 [914] < $w \le$ 60 [1524]	0.75 [19.1]
	w > 60 [1524]	1.00 [25.4]
$t \ge$ 3⁄16 [4.76]	$w \le$ 60 [1524]	0.90 [23]
	60 [1524] < $w \le$ 72 [1829]	1.20 [30]
	w > 72 [1829]	1.50 [38]

Stretcher-Leveled Standard of Flatness			
Specified Thickness (t), in. [mm]	Specified Width (w), in. [mm]	Specified Length (L), in. [mm]	Flatness Tolerance,[A] in. [mm]
t < 3⁄16 [4.76]	$w \le$ 48 [1219]	$L \le$ 96 [2438]	1⁄8 [3.18]
	$w \le$ 48 [1219]	L > 96 [2438]	1⁄4 [6.35]
t < 3⁄16 [4.76]	w > 48 [1219]	$L \le$ 96 [2438]	1⁄4 [6.35]
	w > 48 [1219]	L > 96 [2438]	1⁄4 [6.35]

[A] Maximum deviation from a horizontal flat surface.

TABLE A2.17 Permitted Variations in Thickness of Hot-Rolled Mill Plate (Quarto Plate)[A,B]

Specified Thickness (t), in. [mm]	Width (w), in. [mm]			
	$w \le$ 84 [2134]	84 [2134] < $w \le$ 120 [3048]	120 [3048] < $w \le$ 144 [3658]	w > 144 [3658]
	Tolerance Over Specified Thickness,[C,D] in. [mm]			
t < 3⁄16 [4.76]	0.055 [1.35]	0.070 [1.78]	. . .	. . .
3⁄16 [4.76] $\le t$ < 3⁄8 [9.52]	0.045 [1.14]	0.050 [1.27]	0.085 [2.16]	. . .
3⁄8 [9.52] $\le t$ < 3⁄4 [19.05]	0.055 [1.40]	0.060 [1.52]	0.085 [2.16]	0.090 [2.29]
3⁄4 [19.05] $\le t$ < 1 [25.40]	0.060 [1.52]	0.065 [1.65]	0.085 [2.16]	0.100 [2.54]
1 [25.40] $\le t$ < 2 [50.80]	0.070 [1.78]	0.075 [1.90]	0.095 [2.41]	0.115 [2.92]
2 [50.80] $\le t$ < 3 [76.20]	0.125 [3.20]	0.150 [3.80]	0.175 [4.45]	0.200 [5.08]
3 [76.20] $\le t$ < 4 [101.6]	0.150 [3.81]	0.160 [4.06]	0.200 [5.08]	0.225 [5.72]
4 [101.6] $\le t$ < 6 [152.4]	0.180 [4.57]	0.200 [5.08]	0.335 [8.50]	0.355 [9.02]
6 [152.4] $\le t$ < 8 [203.2]	0.235 [6.00]	0.255 [6.48]	0.355 [9.02]	0.435 [11.0]
8 [203.2] $\le t$ < 10 [254.0]	0.315 [8.00]	0.335 [8.50]	0.435 [11.0]	0.550 [14.0]

[A] Thickness is measured along the original longitudinal edges of the as-produced plate at least 3⁄8 in. [9.52 mm], but not more than 3 in. [76.20 mm], from the edge.
[B] For plates up to 10 in. [254.0 mm], excl, in thickness, the tolerance under the specified thickness is 0.010 in. [0.25 mm].
[C] For circles, the over thickness tolerances in this table apply to the diameter of the circle corresponding to the width ranges shown. For plates of irregular shape, the over thickness tolerances apply to the greatest width corresponding to the width ranges shown.
[D] The tolerance over specified thickness in the area more than 3 inches in from the longitudinal edges of the plate at the mill produced width shall not exceed twice the tabular tolerance.

TABLE A2.18 Permitted Variations in Width for Hot-Rolled Rectangular Sheared Plate Mill Plates (Quarto Plates)

Specified Width (w), in. [mm]	Tolerances, over specified width, in. [mm][A]
$w \le$ 84 [2135]	5⁄8 [15.9]
84 [2135] < $w \le$ 108 [2745]	3⁄4 [19.1]
w > 108 [2745]	1 [25.4]

[A] The tolerance under specified width is 1⁄4 in. [6.35 mm].

TABLE A2.19 Permitted Variations in Length for Hot-Rolled Sheared Rectangular Plate Mill Plates (Quarto Plates)

Nominal Length (L), in. [mm]	Tolerances, over and under, in. [mm][A]
L < 160 [4064]	3⁄4 [19.1]
160 [4064] $\le L$ < 240 [6096]	1 1⁄4 [31.8]
240 [6000] $\le L$ < 315 [8000]	1 5⁄8 [41.3]
315 [8000] $\le L$ < 394 [10 008]	2 [50.8]
394 [10 008] $\le L$ < 590 [15 000]	2 1⁄4 [57.2]
590 [15 000] $\le L$ < 790 [20 066]	2 1⁄4 [57.2]

[A] The tolerance under specified length is 1⁄4 in. [6.35 mm].

TABLE A2.20 Permitted Variations in Flatness of Plate Mill Plate (Quarto Plate)

NOTE 1—Tolerances in this table apply to any length, not necessarily the rolling direction, up to 36 in. [914 mm] and to any 36 in. [914 mm] of longer lengths in the plane of the plate measured while the plate rests on a flat surface with the concavity of the curvature upward.

NOTE 2—If the longer dimension is under 36 in. [914 mm], the tolerance is not greater than ¼ in. [6.4 mm].

NOTE 3—For plates with specified minimum yield strengths of 35 ksi [240 MPa] or more, the permitted variations are increased to 1½ times the amounts shown.

Specified Thickness (t), in. [mm]	Flatness Tolerance for Thicknesses Given, in. [mm]
t < ¼ [6.35]	7⁄16 [11]
¼ [6.35] ≤ t < ⅜ [9.52]	⅜ [9.5]
⅜ [9.52] ≤ t < ½ [12.70]	5⁄16 [7.9]
½ [12.70] ≤ t < ¾ [19.05]	5⁄16 [7.9]
¾ [19.05] ≤ t < 1 [25.40]	5⁄16 [7.9]
1 [25.40] ≤ t < 1½ [38.10]	¼ [6.4]
1½ [38.10] ≤ t < 4 [101.60]	¼ [6.4]
t ≥ 4 [101.60]	¼ [6.4]

TABLE A2.21 Cold-Rolled Products, Processed Without Coiling

Tolerances for cold-rolled products processed without coiling shall be identical to the tolerances for hot-rolled products processed without coiling as listed in Table A2.17, Table A2.18, Table A2.19, and Table A2.20 unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.22 Permitted Variations in Width for Cold-Rolled Narrow, Coil-Processed Product in Coils and Cut Lengths for Edge No. 1 or 5

Specified Edge No.	Width, in. [mm]	Thickness, in. [mm]	Width Tolerance for Thickness and Width Given in. [mm]	
			Over	Under
1 and 5	9⁄32 [7.14] and under	1⁄16 [1.59] and under	0.005 [0.13]	0.005 [0.13]
1 and 5	over 9⁄32 [7.14] to ¾ [19.05], incl	3⁄32 [2.38] and under	0.005 [0.13]	0.005 [0.13]
1 and 5	over ¾ [19.05] to 5 [127.00], incl	⅛ [3.18] and under	0.005 [0.13]	0.005 [0.13]
5	over 5 [127.00] to 9 [228.60], incl	0.008 [0.20] to ⅛ [3.18], incl	0.010 [0.25]	0.010 [0.25]
5	over 9 [228.60] to 20 [508.00], incl	0.015 [0.38] to 0.105 [2.67]	0.010 [0.25]	0.010 [0.25]
5	over 20 [508.00] to 24 [610], excl	0.023 [0.58] to 0.080 [2.03]	0.015 [0.38]	0.015 [0.38]

TABLE A2.23 Permitted Variations in Width and Length for Hot-Rolled and Cold-Rolled Resquared Coil-Processed Product (Stretcher Leveled Standard of Flatness)

Specified Dimensions, in. [mm]	Tolerances		
	Over		Under
	in.	mm	
For thicknesses under 0.131 [3.33]:			
Widths up to 48 [1219] excl	1⁄16	1.59	0
Widths 48 [1219] and over	⅛	3.18	0
Lengths up to 120 [3048] excl	1⁄16	1.59	0
Lengths 120 [3048] and over	⅛	3.18	0
For thicknesses 0.131 [3.33] up to 3⁄16, excl:			
All widths and lengths	¼	6.35	0

TABLE A2.24 Permitted Variations in Width and Length for Hot-Rolled Product by Abrasive Cutting

Specified Thickness, in. [mm]	Tolerance over Specified Width and Length[A]	
	Width	Length
Up to 1 [25.40], incl	⅛ [3.18]	⅛ [3.18]
1 [25.40] to 2 [50.80], incl	3⁄16 [4.76]	3⁄16 [4.76]
2 [50.80] to 3 [76.20], incl	¼ [6.35]	¼ [6.35]
3 [76.20] to 4 [101.6], incl[B]	5⁄16 [7.94]	5⁄16 [7.94]

[A] The tolerances under specified width and length are ⅛ in. [3.18 mm].
[B] Width and length tolerances for abrasive cut plates over 4 in. [101.6 mm] thick are not included in the table; consult producer.

TABLE A2.25 Permitted Variations in Diameter for Hot-Rolled and Cold-Rolled Coil-Processed Product as Sheared Circles

Specified Thickness, in. [mm]	Tolerance Over Specified Diameter (No Tolerance Under), in. [mm]		
	Diameters Under 30 in. [762 mm]	Diameters 30 to 48 in. [762 to 1219 mm]	Diameters Over 48 in. [1219 mm]
Up to 0.0567 [1.45], include	1⁄16 [1.59]	1⁄8 [3.18]	3⁄16 [4.76]
0.0568 to 0.0971 [1.45 to 2.46], incl	3⁄32 [2.38]	5⁄32 [3.97]	7⁄32 [5.56]
0.0972 up to 3⁄16 [2.46 up to 4.76], excl	1⁄8 [3.18]	3⁄16 [4.76]	1⁄4 [6.35]

TABLE A2.26 Permitted Variations in Diameter for Hot-Rolled and Cold-Rolled Coil-Processed Product as Sheared Circles

Specified Thickness, in. [mm]	Tolerance Over Specified Diameter (No Tolerance Under), in. [mm]		
	Diameter and Thickness,[A] in. [mm]		
	To 3⁄8 in. [9.52 mm], excl, in Thickness	3⁄8 to 5⁄8 in. [9.52 to 15.88 mm], excl, in Thickness	5⁄8 in. [15.88 mm] and Over in Thickness[B]
To 60 [1524], excl	1⁄4 [6.35]	3⁄8 [9.52]	1⁄2 [12.70]
60 to 84 [1524 to 2134], excl	5⁄16 [7.94]	7⁄16 [11.11]	9⁄16 [14.29]
84 to 108 [2134 to 2743], excl	3⁄8 [9.52]	1⁄2 [12.70]	5⁄8 [15.88]
108 to 180 [2743 to 4572], excl	7⁄16 [11.11]	9⁄16 [14.29]	11⁄16 [17.46]

[A] No tolerance under.
[B] Circular and sketch plates over 5⁄8 in. [15.88 mm] in thickness are not commonly sheared but are machined or flame cut.

TABLE A2.27 Torch Cutting Tolerances[A] and Recommended Cleanup Allowance for Rectangular Plates, Circles, Rings, and Sketches

Specified Thickness, in.	Tolerance, in.		Cleanup Allowance[B] per Edge, in.
	Outside Dimension	Inside Dimension	
2 and under	+3⁄8 , –0	–3⁄8 , +0	±1⁄4
Over 2 to 3 incl	+1⁄2 , –0	–1⁄2 , +0	±3⁄8
Over 3 to 6 incl	+3⁄4 , –0	–3⁄4 , +0	±1⁄2

[A] Tolerances to apply unless otherwise agreed. Note that for some applications user may wish to specify minus rather than plus tolerance or vice versa.
[B] Recommended cleanup allowance which, unless otherwise specified, will be applied by supplier to purchasers ordered size.

TABLE A2.28 Permitted Variations in Weight for Hot-Rolled or Cold-Rolled Coil Processed Product with Thickness less than 3⁄16 in. [4.76 mm]

Any item of five sheets or less, or any item estimated to weigh 200 lb [90.72 kg] or less, may actually weigh as much as 10 % over the theoretical weight	weigh 200 lb [90.72 kg] or less
Any item of more than five sheets and estimated to weigh more than 200 lb [90.72 kg], may actually weigh as much as 7½ % over the theoretical weight	weigh more than 200 lb [90.72 kg]
Chromium-manganese-nickel	40.7 lb/ft^2·in. thickness [7.82 kg/m^2·mm thick]
Chromium-nickel	42.0 lb/ft^2·in. thickness [8.07 kg/m^2·mm thick]
Chromium	41.2 lb/ft^2·in. thickness [7.92 kg/m^2·mm thick]

TABLE A2.29 Permitted Variations in Camber for Cold-Rolled Coil Processed Product in Coils and Cut Lengths[A]

Specified Width, in. [mm]	Tolerance per Unit Length of Any 8 ft [2438 mm], in. [mm]
To 1½ [38.10], incl	½ [12.70]
Over 1½ [38.10] to 24 [609.60], excl	¼ [6.35]

[A] Camber is the deviation of a side edge from a straight line and measurement is taken by placing an 8-ft [2438-mm] straightedge on the concave side and measuring the greatest distance between the strip edge and the straightedge.

TABLE A2.30 Permitted Variations in Camber for Sheared Mill and Universal Mill Plates[A]

Maximum camber	= ⅛ in. in any 5 ft = 3.18 mm in any 1.524 m

[A] Camber is the deviation of a side edge from a straight line, and measurement is taken by placing a 5-ft straightedge on the concave side and measuring the greatest distance between the plate and the straightedge.

A3. PERMITTED VARIATIONS IN DIMENSIONS, ETC.—SI UNITS

A3.1 Listed in Annex A3 are tables showing the permitted variations in dimensions expressed in SI units of measurement. These requirements shall apply to A480M but shall not apply to A480. Requirements for A480 are given in Annex A2.

A3.1.1 The dimensional tolerances are grouped by production method (hot rolling or cold rolling, with or without coiling), product width (narrow (<600 mm) or wide (≥600 mm)), and by product dimension addressed.

A3.2 *Cold-Rolled Narrow (<600 mm width) Coil-Processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A3.1-A3.4.

A3.3 *Cold-Rolled Wide (≥600 mm width) Coil-Processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A3.5-A3.8.

A3.4 *Hot-Rolled Narrow (<600 mm width) Coil-Processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A3.9-A3.12.

A3.5 *Hot-Rolled Wide (≥600 mm width) Coil-Processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A3.13-A3.16.

A3.6 *Hot-Rolled Product Processed Without Coiling*—For thickness, width, length, and flatness tolerance tables, refer to Tables A3.17-A3.20.

A3.7 *Cold-Rolled Product Processed Without Coiling*—For thickness, width, length, and flatness tolerance tables, refer to Table A3.21.

A3.8 *Tolerances for Other Dimensional Characteristics*—For other tolerance tables, refer to Tables A3.22-A3.30.

TABLE A3.1 Permitted Variations in Thickness of Cold-Rolled, Narrow, Coil-Processed Product as Coil and Cut Lengths

NOTE 1—Thickness measurements are taken at least 10 mm in from the edge of the product, except that on widths less than 26 mm, the tolerances are applicable for measurements at all locations.

NOTE 2—The tolerances in this table include crown tolerances.

NOTE 3—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness, mm	Thickness Tolerances, for the Thickness and Widths Given, Over and Under, mm — Width (w), mm		
	50 to 150, incl $w \le 125$	Over 150 to 300, incl $125 < w \le 250$	Over 300 to 600, excl $250 < w < 600$
	Thickness Tolerances[A]		
0.15	0.010	0.015	0.020
0.25	0.015	0.020	0.025
0.50	0.025	0.030	0.035
0.75	0.030	0.040	0.050
1.00	0.030	0.040	0.050
1.25	0.035	0.045	0.050
1.50	0.040	0.050	0.060
1.75	0.050	0.060	0.070
2.00	0.050	0.060	0.070
2.50	0.050	0.070	0.080
3.00	0.060	0.070	0.090
4.00	0.070	0.070	0.090
4.99	0.070	0.070	0.090

[A] Thickness tolerances given in mm unless otherwise indicated.

TABLE A3.2 Permitted Variations in Width of Cold-Rolled, Narrow, Coil-Processed Product in Coils and Cut Lengths for Edge No. 3[A]

Specified Thickness[B], mm	Width Tolerance, Over and Under, for Thickness and Width Given, mm			
	$w \le 40$	$40 < w \le 125$	$125 < w \le 250$	$250 < w \le 600$
0.25	0.085	0.10	0.125	0.50
0.50	0.10	0.125	0.15	0.50
1.00	0.125	0.125	0.20	0.50
1.50	0.125	0.15	0.25	0.50
2.50	. . .	0.20	0.30	0.50
3.00	. . .	0.25	0.30	0.60
4.00	. . .	0.25	0.40	0.60
4.99	. . .	0.40	0.50	0.80

[A] For tolerances applicable to narrow product with Edge No. 1 or No. 5, see Table A3.22.
[B] For specified thickness other than those shown, the tolerances for the next higher thickness shall apply.

TABLE A3.3 Permitted Variations in Length of Cold-Rolled, Narrow, Coil-Processed Products as Cut Lengths

Specified Length, mm	Tolerances, mm
≤1500	+3, −0
>1500, ≤4000	+5, −0
>4000, ≤6000	+8, −0

TABLE A3.4 Permitted Variations in Flatness of Cold-Rolled, Narrow, Coil-Processed Product as Cut Lengths

Tolerances for variations of flatness cold-rolled products, narrow, coil-processed product as cut lengths shall be identical to the tolerances for cold-rolled, wide, coil-processed product as listed in Table A3.8, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.5 Permitted Variations in Thickness of Cold-Rolled, Wide, Coil-Processed Product as Coil and Cut Lengths

NOTE 1—Thickness measurements are taken at least 15 mm from the edge of the product in the case of slit edges and at least 25 mm from the edge of the product in the case of mill edges.

NOTE 2—Cold-rolled sheets in cut lengths and coils are produced in some type numbers and some widths and thickness to tolerances less than those shown in the table.

NOTE 3—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness, mm	Permitted Variation, Over and Under, mm, for specified width (w), w in mm		
	$w \le 1000$	$1000 < w \le 1300$	$1300 < w \le 2100$
0.30	0.03	. . .	. . .
0.40	0.04	0.04	. . .
0.50	0.045	0.05	. . .
0.60	0.05	0.05	. . .
0.80	0.05	0.05	. . .
1.00	0.055	0.06	0.07
1.20	0.08	0.08	0.08
1.50	0.08	0.08	0.10
2.00	0.10	0.10	0.11
2.50	0.10	0.11	0.13
3.00	0.13	0.13	0.15
4.00	0.17	0.17	0.17
5.00	0.17	0.17	0.19
6.00	0.17	0.20	0.23
8.00	0.17	0.22	0.25

TABLE A3.6 Permitted Variations in Width of Cold-Rolled, Wide, Coil-Processed Product as Cut Lengths (Not Resquared) and Coil

Specified Thickness, mm[A]	Permitted Variation in Width, mm, for Specified Width (w), mm				
	$w \le 125$	$125 < w \le 250$	$250 < w \le 600$	$600 < w \le 1000$	$1000 < w \le 2100$
1.00	+0.5, –0	+0.5, –0	+0.7, –0	+1.5, –0	+2.0, +0
1.50	+0.7, –0	+0.7, –0	+1.0, –0	+1.5, –0	+2.0, +0
2.50	+1.0, –0	+1.0, –0	+1.2, –0	+2.0, –0	+2.5, –0
3.50	+1.2, –0	+1.2, –0	+1.5, –0	+3.0, –0	+3.0, –0
8.00	+2.0, –0	+2.0, –0	+2.0, –0	+4.0, –0	+4.0, –0

[A] For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

TABLE A3.7 Permitted Variations in Length of Cold-Rolled, Wide, Coil-Processed Product as Cut Lengths Not Resquared

Specified Length (L), mm	Tolerance, mm	
	Over	Under
≤2000	5	0
>2000	$0.0025 \times L$	0

TABLE A3.8 Permitted Variations in Flatness of Cold-Rolled, Wide, Coil-Processed Product as Cut Lengths

Not Specified to Stretcher-Leveled Standard of Flatness[A]		
Specified Thickness, mm	Specified Width, mm	Flatness Tolerance[B], mm
<1.50	<1500	10
	≥1500	12
≥1.50	<1500	10
	≥1500	12

Stretcher-Leveled Standard of Flatness[C]			
Specified Thickness, mm	Specified Width, mm	Specified Length, mm	Flatness Tolerance,[B] mm
≤4.99	<1200	<2400	4
		≥2400	7
	≥1200	<2400	7
		≥2400	7

2xx and 3xx Series Specified to ¼ and ½ Hard Tempers			
Specified Thickness, mm	Specified Width, mm	Flatness Tolerance,[B] mm	
		¼ Hard	½ Hard
≤0.04	600 to 900, excl	19	23
>0.04 to ≤0.80		16	23
>0.80		13	19
≤0.04	900 to 1200, incl	26	29
>0.04 to ≤0.80		19	29
>0.80		16	26

[A] Not specified to stretcher-leveled standard of flatness, and not including hard tempers of 2xx and 3xx series, dead-soft sheets, and deep-drawing sheets.
[B] Maximum deviation from a horizontal flat surface.
[C] Not including hard tempers of 2xx and 3xx series, dead-soft sheets, and deep-drawing sheets.

TABLE A3.9 Permitted Variations in Thickness of Hot-Rolled, Narrow, Flat-Rolled, Coil-Processed Product as Cut Lengths and Coil

Tolerances for variations of thickness of hot-rolled, narrow, coil-processed product as cut lengths and coil shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A3.13, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.10 Permitted Variations in Width of Hot-Rolled, Narrow, Flat-Rolled, Coil-Processed Product as Cut Lengths and Coil

Tolerances for variations of width of hot-rolled, narrow, coil-processed product as cut lengths and coil shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A3.14, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.11 Permitted Variations in Length of Hot-Rolled, Narrow, Coil-Processed Product as Cut Lengths

Tolerances for variations of length of hot-rolled, narrow, coil-processed product as cut lengths shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A3.15, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.12 Permitted Variations in Flatness of Hot-Rolled, Narrow, Flat-Rolled, Coil-Processed Product as Cut Lengths

Tolerances for variations of flatness of hot-rolled, narrow, coil-processed product as cut lengths shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A3.16, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.13 Permitted Variations in Thickness of Hot-Rolled, Wide, Coil-Processed Product as Coil and Cut Lengths

NOTE 1—Thickness measurements are taken at least 10 mm from the edge of the product.

NOTE 2—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness, mm	Permitted Variations of Thickness, mm, Over and Under, Except as Indicated Otherwise, for Specified Width (*w*)	
	$w \leq 1500$	$w > 1500$
2.0	0.18	0.25
2.25	0.20	0.27
2.5	0.23	0.30
3.0	0.25	0.33
3.5	0.30	0.33
5.0	–0.25, +0.47	–0.25, +0.51
6.0	–0.25, +0.51	–0.25, +0.51
8.0	–0.25, +0.75	–0.25, +0.75
>8.0	–0.25, +0.75	–0.25, +0.75

TABLE A3.14 Permitted Variations in Width of Hot-Rolled, Wide, Coil-Processed Product as Cut Lengths (Not Resquared) and Coil

Specified Dimension, mm		Tolerance on Width, mm, for Trimmed Edges	
Thickness (t), mm	Width (w), mm	Over	Under
<5.00	w < 1200	2	0
	w ≥ 1200	6	0
5.00 < t ≤ 10.00	w < 1200	4	0
	w ≥ 1200	9	0
>10.00	w < 1200	6	0
	w ≥ 1200	12	0

TABLE A3.15 Permitted Variations in Length of Hot-Rolled, Wide, Coil-Processed Product as Cut Lengths Not Resquared

Specified Length (L), mm	Tolerance, mm	
	Over	Under
L < 3000	12	0
3000 ≤ L ≤ 6000	(0.005 × L)	0

TABLE A3.16 Permitted Variations in Flatness of Hot-Rolled, Wide, Coil-Processed Product as Cut Lengths

Not Specified to Stretcher-Leveled Standard of Flatness			
Specified Thickness (t), mm	Specified Width (w), mm		Flatness Tolerance,[A] mm
t < 5	w < 900		13
	900 ≤ w < 1500		19
	w ≥ 1500		26
t ≥ 5	w < 1500		23
	1500 ≤ w < 1800		30
	w ≥ 1800		38
Stretcher-Leveled Standard of Flatness			
Specified Thickness (t), mm	Specified Width (w), mm	Specified Length (L), mm	Flatness Tolerance,[A] mm
t ≤ 13	w < 1200	L < 2400	4
		L ≥ 2400	7
	w ≥ 1200	L < 2400	7
		L ≥ 2400	7

[A] Maximum deviation from a horizontal flat surface.

TABLE A3.17 Permitted Variations in Thickness of Hot-Rolled Plate Mill Plate (Quarto Plate)[A,B]

NOTE 1—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness, mm	Width (w), mm			
	w < 2100	2100 ≤ w < 3000	3000 ≤ w < 3600	w ≥ 3600
	Tolerance Over Specified Thickness,[C] mm			
5	1.35	1.75	. . .	. . .
8	1.15	1.30	2.15	. . .
10	1.15	1.30	2.15	. . .
20	1.40	1.55	2.15	2.30
25	1.55	1.65	2.15	2.55
50	1.80	1.90	2.40	2.95
75	3.20	3.80	4.45	5.10
100	3.75	4.00	5.00	5.70
150	4.50	5.00	8.50	9.00
200	6.00	6.50	9.00	11.0
250	8.00	8.50	11.0	14.0

[A] Thickness is measured along the original longitudinal edges of the as-produced plate at least 10 mm but not more than 75 mm from the edge.
[B] For circles, the over thickness tolerances in this table apply to the diameter of the circle corresponding to the width ranges shown. For plates of irregular shape, the over thickness tolerances apply to the greatest width corresponding to the width ranges shown. For plates up to 250 mm, incl, in thickness, the tolerance under the specified thickness is 0.30 mm.
[C] The tolerance over specified thickness in the area more than 75 mm in from the longitudinal edges of the plate at the mill produced width shall not exceed twice the tabular tolerance.

TABLE A3.18 Permitted Variations in Width for Hot-Rolled Rectangular Sheared Plate Mill Plates (Quarto Plates)

Specified Width (w), mm	Tolerances, over and under, mm
w < 2000	+15, −0
2000 ≤ w < 3000	+20, −0
w ≥ 3000	+25, −0

TABLE A3.19 Permitted Variations in Length for Hot-Rolled Sheared Rectangular Plate Mill Plates (Quarto Plates)

Nominal Length (L), mm	Tolerances, Over and Under, mm
L < 4000	+20, −0
4000 ≤ L < 6000	+30, −0
6000 ≤ L < 8000	+40, −0
8000 ≤ L < 10 000	+50, −0
10 000 ≤ L < 15 000	+75, −0
15 000 ≤ L < 20 000	+100, −0

TABLE A3.20 Permitted Variations in Flatness of Plate Mill Plate (Quarto Plate)

NOTE 1—Tolerances in this table apply to any length, not necessarily the rolling direction, up to 36 in. [914 mm] and to any 36 in. [914 mm] of longer lengths in the plane of the plate measured while the plate rests on a flat surface with the concavity of the curvature upward.

NOTE 2—If the longer dimension is under 36 in. [914 mm], the tolerance is not greater than ¼ in. [6.4 mm].

NOTE 3—For plates with specified minimum yield strengths of 35 ksi [240 MPa] or more, the permitted variations are increased to 1½ times the amounts shown.

NOTE 4—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness (t), in. [mm]	Flatness Tolerance for Thicknesses Given, in. [mm]
5	0.40 [10]
10	⅜ [9.5]
15	5⁄16 [7.9]
20	5⁄16 [7.9]
25	5⁄16 [7.9]
50	¼ [6.4]
150	¼ [6.4]
>150	¼ [6.4]

TABLE A3.21 Cold-Rolled Products, Processed Without Coiling

Tolerances for cold-rolled products processed without coiling shall be identical to the tolerances for hot-rolled products processed without coiling as listed in Table A3.17, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.22 Permitted Variations in Width for Cold-Rolled Narrow, Coil-Processed Product in Coils and Cut Lengths for Edge No. 1 or 5

Specified Edge No.	Width, mm	Thickness, mm	Width Tolerance for Thickness and Width Given, mm	
			Over	Under
1 and 5	under 10	1.50 and under	0.13	0.13
1 and 5	10 to 20, excl	2.50 and under	0.13	0.13
1 and 5	20 to 100, excl	3.00 and under	0.13	0.13
5	100 to 300, excl	0.20 to 3.00, incl	0.25	0.25
5	300 to 600, excl	0.40 to 2.60, incl	0.25	0.25
5	600 and over	0.60 to 2.00, incl	0.40	0.40

TABLE A3.23 Permitted Variations in Width and Length for Hot-Rolled and Cold-Rolled Resquared Coil-Processed Product (Stretcher Leveled Standard of Flatness)

NOTE 1—Polished sheets with Finishes No. 4 and higher are produced to tolerances given in this table.

Specified Dimensions, mm			Width and Length Tolerance, mm	
Thickness	Width	Length	Over	Under
Under 3.30	Up to 1200	Up to 3000	2	0
	1200 and over	3000 and over	3	0
3.30 and over	All	All	7	0

TABLE A3.24 Permitted Variations in Abrasive Cutting Width and Length for Plates

Specified Thickness, [mm]	Tolerance over Specified Width and Length,[A] mm	
	Width	Length
Up to 25, incl	3.2	3.2
25 to 50, incl	4.8	4.8
50 to 75, incl	6.4	6.4
75 to 100, incl[B]	7.9	7.9

[A] The tolerances under specified width and length are 3.2 mm.
[B] Width and length tolerances for abrasive cut plates over 100 mm thick are not included in the table; consult producer.

TABLE A3.25 Permitted Variations in Diameter for Hot-Rolled and Cold-Rolled Coil-Processed Product as Sheared Circles

Specified Thickness, mm	Tolerance Over Specified Diameter (No Tolerance Under), mm		
	Diameters Under 600	Diameters 600 to 1200 incl	Diameters Over 1200
Under 1.50	2	3	5
1.50 to 2.50 excl	3	4	6
2.50 and thicker	4	5	7

TABLE A3.26 Permitted Variations in Diameter for Circular Plates Taken From Hot-Rolled Product Processed With or Without Coiling

NOTE 1—For specific diameters other than those shown, the tolerance for the next higher diameter shall apply.

Specified Diameter, mm	Tolerance Over Specified Diameter for Given Diameter and Thickness,[A] mm		
	Thickness of Plate		
	To 10, excl	10 to 15, excl	15 and over
1500 and under	7	10	13
2100	8	13	16
2700	10	11	15
4500	11	15	18

[A] No tolerance under.

TABLE A3.27 Torch Cutting Tolerances[A] and Recommended Cleanup Allowance for Rectangular Plates, Circles, Rings, and Sketches

Specified Thickness, mm	Tolerance, mm		Cleanup Allowance[B]
	Outside Diameter	Inside Diameter	Per Edge, mm
51 and under	+10, –0	–10, +0	±6
Over 51 to 76 incl	+13, –0	–13, +0	±10
Over 76 to 152 incl	+19, –0	–19, +0	±13

[A] Tolerances to apply unless otherwise agreed. Note that for some applications user may wish to specify minus rather than plus tolerance or vice versa.
[B] Recommended cleanup allowance which, unless otherwise specified, will be applied by supplier to purchasers ordered size.

TABLE A3.28 Permitted Variations in Weight for Hot-Rolled and Cold-Rolled Sheets

Any item of five sheets or less, and estimated to weigh 100 kg or less, may actually weigh 10 % over the theoretical weight	weigh 100 kg or less
Any item of more than five sheets and estimated to weigh more than 100 kg, may actually weigh 7 ½ % over the theoretical weight	weigh more than 100 kg
Chromium-manganese-nickel	7.82 kg/m^2/mm thick
Chromium-nickel	8.07 kg/m^2/mm thick
Chromium	7.92 kg/m^2/mm thick

TABLE A3.29 Permitted Variations in Camber for Cold-Rolled Narrow Coil-Processed Product in Coils and Cut Lengths[A]

Specified Width, mm	Tolerance Per Unit Length Of Any 2400 mm
To 40, incl	13
Over 40 to 600, incl	7

[A] Camber is the deviation of a side edge from a straight line and measurement is taken by placing a 2400-mm straightedge on the concave side and measuring the greatest distance between the strip edge and the straightedge.

TABLE A3.30 Permitted Variations in Camber for Hot-Rolled and Cold-Rolled Wide Coil-Processed Product as Cut Lengths Not Resquared and Cold-Rolled Wide Coil-Processed Product as Coils[A]

Specified Width, mm	Tolerance per Unit Length of Any 2400 mm, mm
600 to 900, excl	4
900 and over	3

[A] Camber is the greatest deviation of a side edge from a straight line and measurement is taken by placing an 8-ft [2438-mm] straightedge on the concave side and measuring the greatest distance between the sheet edge and the straightedge.

A4. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A4.1 New materials may be proposed for inclusion in specifications referencing this specification subject to the following conditions:

A4.1.1 Application for the addition of a new grade to a specification shall be made to the Chair of the subcommittee that has jurisdiction over that specification.

A4.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A4.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A4.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A4.1.5 The application shall state whether the new grade is covered by patent.

A5. REQUIREMENTS FOR THE INTRODUCTION OF MATERIALS FROM OTHER A01 OR B02.07 SPECIFICATIONS

A5.1 Wrought materials that are already covered by another A01 or B02.07 specification may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A5.1.1 Application for the addition of a grade that is already covered in another A01 or A01.17 specification shall be made to the chair of the subcommittee that has jurisdiction over that the specification to which the grade is to be added.

A5.1.2 The chemical requirements, the specified mechanical properties, and the heat treatment requirements of the grade being added shall be the same as those for the grade in the A01 or A01.17 specification in which the grade is presently covered.

A5.1.3 The application shall provide recommendations for all requirements appearing in the applicable specification.

A5.1.4 The application shall state whether or not the grade is covered by patent.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR STAINLESS STEEL BARS, BILLETS, AND FORGINGS

SA-484/SA-484M (23)

(Identical with ASTM Specification A484/A484M-21.)

Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

1. Scope

1.1 This specification covers general requirements that shall apply to wrought stainless steel bars, shapes, forgings, and billets or other semi-finished material (except wire) for forging, under each of the following specifications issued by ASTM: Specifications A276/A276M, A314, A458, A477, A479/A479M, A564/A564M, A565/A565M, A582/A582M, A638/A638M, A705/A705M, and A831/A831M.

1.2 In the case of conflict between a requirement of a product specification and a requirement of this specification, the product specification shall prevail. In the case of conflict between a requirement of the product specification or a requirement of this specification and a more stringent requirement of the purchase order, the purchase order shall prevail. The purchase order requirements shall not take precedence if they, in any way, violate the requirements of the product specification or this specification; for example, by waiving a test requirement or by making a test requirement less stringent.

1.3 The requirements for introduction of new materials in specifications referencing this specification are given in Annex A1.

1.4 General requirements for flat-rolled stainless steel products other than bar are covered in Specification A480/A480M.

1.5 General requirements for wire products in coils are covered in Specification A555/A555M.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined

1.7 Unless the order specifies an "M" designation, the material shall be furnished to inch-pound units.

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A276/A276M Specification for Stainless Steel Bars and Shapes

A314 Specification for Stainless Steel Billets and Bars for Forging

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A458 Specification for Hot-Worked, Hot-Cold-Worked, and Cold-Worked Alloy Steel Bars for High Strength at Elevated Temperatures (Withdrawn 1988)

A477 Specification for Hot-Worked, Hot-Cold Worked and Cold-Worked Alloy Steel Forgings and Forging Billets for High Strength at Elevated Temperatures (Withdrawn 1988)[4]

A479/A479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A555/A555M Specification for General Requirements for Stainless Steel Wire and Wire Rods

A564/A564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes

A565/A565M Specification for Martensitic Stainless Steel Bars for High-Temperature Service
A582/A582M Specification for Free-Machining Stainless Steel Bars
A638/A638M Specification for Precipitation Hardening Iron Base Superalloy Bars, Forgings, and Forging Stock for High-Temperature Service
A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A705/A705M Specification for Age-Hardening Stainless Steel Forgings
A751 Test Methods and Practices for Chemical Analysis of Steel Products
A831/A831M Specification for Austenitic and Martensitic Stainless Steel Bars, Billets, and Forgings for Liquid Metal Cooled Reactor Core Components (Withdrawn 2005)
E112 Test Methods for Determining Average Grain Size
E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

2.2 *Federal Standards:*
Fed Std. No. 123 Marking for Shipment (Civil Agencies)
Fed Std. No. 183 Continuous Marking of Iron and Steel Products

2.3 *Military Standards:*
MIL-STD-129 Marking for Shipment and Storage
MIL-STD-163 Preservation of Steel Products for Shipment (Storage and Overseas Shipment)

2.4 *Other Standard:*
Primary Metals Bar Code Standard

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bars, n*—straight lengths that are produced by processing that includes hot deformation, such as rolling, forging, or extrusion; the permitted cross-sections include round, rectangular, and complex shapes; shall include shapes with all dimensions under 5 in. [125 mm]; shall include hot-rolled flats with width of 10 in. [250 mm] or less, and with thickness 0.125 in. [3.00 mm] or greater; shall include flats with width of 10 in. [250 mm] or less, and with thickness 0.125 in. [3.00 mm] or greater, cut from strip or plate provided that the long direction of the cut bar is parallel to the final rolling direction of the strip or plate.

3.1.1.1 *Discussion*—All cold-reduced flat material with thickness less than 0.1875 in. [5.00 mm] and width 0.375 in. [9.50 mm] and over is classified as strip.

3.1.2 *billets, n*—semi-finished products, typically produced by rolling, forging, or continuous casting, that require subsequent hot working by rolling, forging, or extrusion; typically have a cross-section area of 36 in.^{2} [230 cm^2] or less and shape that is square or rectangular with width less than twice the thickness; rectangular cross sections with width equal to or greater than twice the thickness are classified as slabs or sheet bars.

3.1.3 *blooms, n*—semi-finished products, typically produced by rolling or continuous casting, that require subsequent hot working by rolling or forging; typically have a cross section area of greater than 36 in.^{2} [230 cm^2] and shape that is square or rectangular with width less than twice the thickness; rectangular cross sections with width equal to or greater than twice the thickness are classified as slabs or sheet bars.

3.1.4 *condition, n*—identification of the final step or steps thermomechanical processing as required to describe the metallurgical state of the material as delivered (examples include hot-worked; hot-worked and annealed; hot-worked, annealed, and cold-worked for increased mechanical properties; and hot-worked, quenched, and tempered).

3.1.5 *dead lengths or exact lengths, n*—bars, typically hot-sheared, hot-sawed, or machine-cut after machine-straightening, meeting the permitted variations in length as listed in the tolerance tables of this specification.

3.1.6 *finish, n*—description of the surface finish and applicable dimensional tolerances of the product as delivered, most typically by identification of the process applied to the product, and identification of the applicable category of product dimensional tolerances; examples of finishing operations include blasting, pickling, rough turning, machine straightening, centerless grinding, polishing, and light cold drawing for surface finish but not for increased mechanical properties; see also 8.1.1 for *hot-finished* bars and 8.1.3 for *cold-finished* bars.

3.1.7 *forgings, n*—parts, including bars, billets, semi-finished products, or complex shapes, produced by hot mechanical working using hammers, presses, or forging machines.

3.1.8 *multiple lengths, n*—lengths that are specified as containing a predetermined number of units of length associated with production of a particular part, commonly including an allowance of ¼ in. [6.5 mm] per unit for cutting to insure obtaining the required number of pieces.

3.1.9 *random lengths, n*—a length range not less than 24 in. [1 m]; for example, 10 to 12 ft [3 to 4 m], 14 to 17 ft [4 to 5 m], or 15 to 20 ft [5 to 6 m].

3.1.10 *shapes, n*—bar having a cross section other than circular, rectangular, or hexagonal.

3.1.11 *slabs or sheet bars, n*—products, typically produced by blooming, slabbing, or sheet bar mills or by continuous casting, that are shipped without further hot working to be further processed into plate, sheet, or strip; it is permitted to heat treat, cut to shape, or surface condition a slab or sheet bar.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements to be considered include, but are not limited to, the following:

4.1.1 Quantity (weight or number of pieces), 4.1.2 Dimensions, including shape or form with diameter or width and thickness as applicable, length, and prints or sketches as applicable,

4.1.3 Type or UNS designation,

4.1.4 ASTM specification designation and edition year if other than the latest edition,

4.1.5 Condition,

4.1.6 Finish,

4.1.7 Supplementary Requirements when invoked,

4.1.8 Whether bars are to be rolled as bars or cut from strip or plate, when applicable,

4.1.9 Preparation for delivery,

4.1.10 Marking requirements,

4.1.11 Surface preparation, for shapes, and

4.1.12 Special requirements.

NOTE 1—A typical ordering description is as follows: 5000 lb [2000 kg]; 1.000 in. [25 mm] round bar by 10 to 12 ft [3 to 4 m]; Type 304 or S30400; Specification A479/A479M; annealed, centerless ground; plus optional requirements, such as special marking instructions.

5. Materials and Manufacture

5.1 The material shall be made by any process.

5.2 The material shall be furnished in one of the conditions detailed in the applicable product specification, for example, hot-worked; hot-worked and annealed; hot-worked, annealed, and cold-worked; or hot-worked, annealed, and heat-treated.

5.3 The material shall be furnished in one of the finishes as detailed in Section 8 or further described in the applicable product specification, for example, hot-finished or cold-finished.

6. Chemical Composition

6.1 *Heat or Cast Analysis*—The chemical analysis of each heat shall be determined in accordance with the applicable materials specification and Test Methods, Practices, and Terminology A751.

6.1.1 The analysis of each heat shall be made from a test sample taken during the pouring of the melt or from the in-process product later in the manufacturing flow.

6.1.2 The heat analysis shall conform to the chemical requirements for each of the specified elements for the grade ordered, as listed in the applicable product specification.

6.1.3 All commercial metals contain small amounts of elements other than those which are specified. It is neither practical nor necessary to specify limits for unspecified elements that can be present. The producer is permitted to analyze for unspecified elements and is permitted to report such analyses. The presence of an unspecified element and the reporting of an analysis for that element shall not be a basis for rejection unless the presence of that element cause the loss of a property typically expected for that metal, for the type and quality ordered.

6.1.4 The purchaser is permitted to require in the purchase order a maximum limit for an individual element not specified in the product specification. Such a requirement for an element not listed in the product specification, when acknowledged in the order acceptance, shall be treated as a specified element, with determination of chemical analysis and reporting of that analysis.

6.1.5 The purchaser is permitted to make the requirements for any element more stringent, that is, require higher minimums for elements having minimum requirements or ranges with minimum requirements, or requiring lower maximums for elements having specified maximums, or ranges with maximums. The purchaser is not permitted to make chemical requirements less stringent.

6.1.6 Analysis limits shall be established for specific elements rather than groups of elements, including but not limited to *all others*, *rare earths*, and *balance*, unless all elements in such a group are similar in technical effect and are associated in typical methods of chemical analysis.

6.2 *Product Analysis*—When required, a product analysis shall be determined in accordance with Test Methods, Practices, and Terminology A751. The chemical composition thus determined shall conform to the tolerances shown in Table 1.

6.2.1 When the product requirement includes a ratio requirement that is the quotient of two, or more, elements, the minimum required ratio determined from product analysis shall be at least 0.90× the minimum in the product specification.

6.3 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade in the referencing product specification, and any of the product specifications within the scope of this general requirements specification, for which that element has a specified minimum.

7. Heat Treatment

7.1 The heat treatments shown in this section are to be followed unless otherwise specified in the applicable product specification.

7.2 *Austenitic Grades:*

7.2.1 Except for strain-hardened grades (see 7.2.4), hot-rolled grades (see 7.2.5), and UNS N08020 (see 7.2.6), all austenitic stainless steels shall be furnished in the solution annealed condition in accordance with Table 2, with subsequent light cold drawing for cold finishing and straightening permitted.

7.2.2 Except as indicated in Table 2, the austenitic grades shall be annealed, at the option of the manufacturer, by a separate annealing treatment or by process annealing.

7.2.2.1 The separate annealing treatment shall consist of heating the material to the minimum annealing temperature for the grade as listed in Table 2, holding for a sufficient time to permit grain boundary carbides to enter into solution, and cooling rapidly enough to prevent unacceptable grain boundary carbide precipitation. Except as indicated in Table 2, austenitic stainless steels solution annealed by a separate annealing treatment shall be capable of meeting the requirements of Practice E of Practices A262. Practice E of Practices A262 is not required unless specified on the purchase order.

7.2.2.2 Process annealing shall consist of completing hot working above the minimum annealing temperature required

TABLE 1 Product Analysis Tolerances

NOTE 1—This table specifies tolerances over the maximum limits or under the minimum limits of the chemical requirements of the applicable material specification (see 1.1); it does not apply to heat analysis.

Element	Upper Limit of Maximum of Specified Range, %	Tolerances over the Maximum (Upper Limit) or Under the Minimum (Lower Limit)	Element	Upper Limit or Maximum of Specified Range, %	Tolerances over the Maximum (Upper Limit) or Under the Minimum (Lower Limit)
Carbon	to 0.010, incl	0.002	Cobalt	over 0.05 to 0.50, incl	0.01
	over 0.010 to 0.030, incl	0.005		over 0.50 to 2.00, incl	0.02
	over 0.030 to 0.20, incl	0.01		over 2.00 to 5.00, incl	0.05
	over 0.20 to 0.60, incl	0.02		over 5.00 to 10.00, incl	0.10
	over 0.60 to 1.20, incl	0.03		over 10.00 to 15.00, incl	0.15
				over 15.00 to 22.00, incl	0.20
Manganese	to 1.00, incl	0.03		over 22.00 to 30.00, incl	0.25
	over 1.00 to 3.00, incl	0.04			
	over 3.00 to 6.00, incl	0.05	Columbium[A] + Tantalum	to 1.50, incl	0.05
	over 6.00 to 10.00, incl	0.06		over 1.50 to 5.00, incl	0.10
	over 10.00 to 15.00, incl	0.10		over 5.00	0.15
	over 15.00 to 20.00, incl	0.15			
			Tantalum	to 0.10, incl	0.02
Phosphorus	to 0.040, incl	0.005			
	over 0.040 to 0.20, incl	0.010	Copper	to 0.50, incl	0.03
				over 0.50 to 1.00, incl	0.05
Sulfur	to 0.040, incl	0.005		over 1.00 to 3.00, incl	0.10
	over 0.040 to 0.20, incl	0.010		over 3.00 to 5.00, incl	0.15
	over 0.20 to 0.50, incl	0.020		over 5.00 to 10.00, incl	0.20
Silicon	to 1.00, incl	0.05	Aluminum	to 0.15, incl	−0.005, +0.01
	over 1.00 to 3.00, incl	0.10		over 0.15 to 0.50, incl	0.05
	over 3.00 to 7.00 incl	0.15		over 0.50 to 2.00, incl	0.10
				over 2.00 to 5.00, incl	0.20
Chromium	over 4.00 to 10.00, incl	0.10		over 5.00 to 10.00, incl	0.35
	over 10.00 to 15.00, incl	0.15			
	over 15.00 to 20.00, incl	0.20	Nitrogen	to 0.02, incl	0.005
	over 20.00 to 30.00, incl	0.25		over 0.02 to 0.19, incl	0.01
				over 0.19 to 0.25, incl	0.02
Nickel	to 1.00, incl	0.03		over 0.25 to 0.35, incl	0.03
	over 1.00 to 5.00, incl	0.07		over 0.35 to 0.45, incl	0.04
	over 5.00 to 10.00, incl	0.10		over 0.45	0.05
	over 10.00 to 20.00, incl	0.15			
	over 20.00 to 30.00, incl	0.20	Tungsten	to 1.00, incl	0.03
	over 30.00 to 40.00, incl	0.25		over 1.00 to 2.00, incl	0.05
	over 40.00	0.30		over 2.00 to 5.00, incl	0.07
				over 5.00 to 10.00, incl	0.10
Molybdenum	over 0.20 to 0.60, incl	0.03		over 10.00 to 20.00, incl	0.15
	over 0.60 to 2.00, incl	0.05			
	over 2.00 to 7.00, incl	0.10	Vanadium	to 0.50, incl	0.03
	over 7.00 to 15.00, incl	0.15		over 0.50 to 1.50, incl	0.05
	over 15.00 to 30.00, incl	0.20			
			Selenium	all	0.03
Titanium	to 1.00, incl	0.05			
	over 1.00 to 3.00, incl	0.07			
	over 3.00	0.10			

[A] Columbium (Cb) and niobium (Nb) are considered interchangeable names for element 41 in the periodic table and both names are acceptable for use.

for each grade as indicated in Table 2, and cooling rapidly enough to prevent unacceptable grain boundary carbide precipitation. Except as indicated in Table 2, austenitic stainless steels solution annealed by process annealing shall be capable of meeting the requirements of Practice E of Practices A262. Practice E of Practices A262 is not required unless specified on the purchase order.

7.2.3 For the stabilized grades, Types 321, 321H, 347, 347H, 348, and 348H, the manufacturer is permitted, if necessary, to use a lower temperature resolution anneal or a stabilization anneal after a high temperature anneal in order to maximize resistance to intergranular corrosion.

NOTE 2—Solution annealing temperatures above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions for the stabilized grades. When intergranular corrosion is of concern, the purchaser should specify Practice E of Practices A262 (to be conducted on specimens exposed to a sensitizing treatment). Consideration should be given to the corrosive media before using a stabilization anneal at less than 1800 °F [980 °C], as such a treatment may not be fully effective for all media.

7.2.4 *Strain-hardened Austenitic Grades*—When a particular austenitic grade is desired with increased mechanical properties, the purchaser is permitted to specify a strain hardened condition. This condition is produced by solution annealing the product in accordance with Table 2, followed by strain hardening sufficient to meet the required mechanical properties. Annealing in accordance with Table 2 is permitted between strain hardening steps. The solution annealed and strain hardened material shall be capable of meeting the intergranular corrosion test requirements of Practice E of

TABLE 2 Annealing Requirements

Designation/Type	Temperature[A]	Cooling/Testing Requirements	Permitted Annealing[B]	
			Separate	Process
Austenitic (Chromium-Nickel) (Chromium-Nickel-Manganese)				
All austenitic grades except as listed below	1900 °F [1040 °C]	C	x	x[D]
All Cr-Ni-Mn grades, 302, S30215, S30452, S30600, S30615, 308, S30815, S30880, 309, 309S, 310, 310S, 314, 317, S31725, S31726, S32615, S38100	1900 °F [1040 °C]	E	x	x[D]
309Cb, 310Cb, 316Cb, 316Ti, 321, 347, 348	1900 °F [1040 °C]	E	x	
304H, 309H, 310H, 316H	1900 °F [1040 °C]	E	x	
321H, 347H, 348H				
Hot-worked	1925 °F [1050 °C]	E	x	
Cold-worked	2000 °F [1095 °C]	E	x	
S31254, S32050	2100 °F [1150 °C]	E	x	
S31727, S32053	1975 to 2155 °F [1080° to 1180 °C]	E	x	
S33228	2050 to 2140 °F [1120° to 1170 °C]	E	x	
S34565	2050 to 2140 °F [1120° to 1170 °C]	E	x	
S34752	1940 to 2140 °F [1060° to 1170 °C]	E	x	
S35315	2010 °F [1100 °C]	E	x	
N08367	2025 °F [1105 °C]	E	x	
N08700	2000 °F [1095 °C]	E	x	
N08020	1700 to 1850 °F [930 to 1010 °C]	E	x	
N08810	2050 °F [1120 °C]	E	x	
N08811	2100 °F [1150 °C]	E	x	
N08904	2000 °F [1095 °C]	E	x	
N08925, N08926	2010 to 2100 °F [1100 to 1150 °C]	E	x	
Austenitic-Ferritic (Duplex)				
S32100	1900 °F [1040 °C]	E	x	x[F]
S31260	1870° to 2010 °F [1020° to 1100 °C]	E	x	x[F]
S31266	2100 °F [1150 °C]	E	x	
S31803	1900 °F [1040 °C]	E	x	x[F]
S32101	1870 °F [1020 °C]	E	x	x[F]
S32202	1800 to 1975 °F [980 to 1080 °C]	E	x	x[F]
S32205	1900 °F [1040 °C]	G	x	x[F]
S32304	1800 °F [980 °C]	E	x	x[F]
S32506	1870° to 2050 °F [1020° to 1120 °C]	E	x	x[F]
S32550	1900 °F [1040 °C]	E	x	x[F]
S32750	1880 °F [1025 °C]	E	x	x[F]
S32760	2010 °F [1100 °C]	E	x	x[F]
S32808	1925 to 2100 °F [1050 to 1150 °C]	E	x	x[F]
S32900	1750° ± 25 °F [955°± 15 °C]	E	x	x[F]
S32906	1830° to 2100 °F [1000° to 1150 °C]	E	x	x[F]
S32950	1850° ± 25 °F [1010°± 15 °C]	E	x	x[F]
S82441	1830 °F [1000 °C]	E	x	x[F]

[A] Minimum annealing temperature unless otherwise specified.
[B] Permitted annealing procedure, see 7.2.2.
[C] Quenched in water or rapidly cooled by other means at a rate sufficient to prevent reprecipitation of carbides, as demonstrable by the capability of passing Practice E of Practices A262. Performance of the test is not required unless specified in the purchase order.
[D] Minimum temperature at which hot rolling is completed shall be 1850 °F [1010 °C].
[E] Quenched in water or rapidly cooled by other means.
[F] Minimum temperature at which hot rolling is completed shall be the minimum temperature for separate annealing.
[G] Quenched in water.

Practices A262. Practice E of Practices A262 is not required unless specified on the purchase order.

7.2.4.1 Individual product specifications are permitted to define particular strain hardened conditions as functions of grade, size, and degree of strain hardening.

7.2.5 *Hot-rolled Austenitic Grades*—Individual product specifications are permitted to define requirements for particular hot-rolled austenitic grades without annealing.

7.2.6 Except when strain-hardened (see 7.2.4), UNS N08020 shall be furnished in the stabilized annealed condition in accordance with Table 2, with subsequent light cold drawing for cold finishing and straightening permitted.

7.3 *Austenitic-Ferritic (Duplex) Grades:*

7.3.1 The austenitic-ferritic (duplex) grades shall be furnished in the solution annealed condition in accordance with Table 2, with subsequent light cold drawing for cold finishing and straightening permitted.

7.3.2 Except as indicated in Table 2, the duplex grades shall be annealed, at the option of the manufacturer, by a separate annealing treatment or by process annealing.

7.3.2.1 The separate annealing treatment shall consist of heating the material to the minimum annealing temperature for the grade as listed in Table 2, holding for a sufficient time to permit dissolution of intermetallic phases, and cooling rapidly enough to prevent unacceptable precipitation of intermetallic phases.

7.3.2.2 Process annealing shall consist of completing hot working above the minimum annealing temperature required for each grade as indicated in Table 2, and cooling rapidly enough to prevent unacceptable precipitation of intermetallic phases.

7.4 *Ferritic Grades*—Ferritic grades shall be annealed to meet their respective mechanical testing requirements as shown in the applicable product specification.

7.5 *Martensitic Grades:*

7.5.1 All martensitic grades shall be supplied in either the annealed condition or in the tempered condition as specified by the purchaser. Tempered material shall be normalized, or shall be liquid quenched from 1700 °F [925 °C], minimum, followed by tempering in accordance with 7.5.2, 7.5.3, or 7.5.4.

7.5.2 Types 403 and 410 tempered material shall be held at the tempering temperature for at least 1 h/in. [25.4 mm] of cross section as follows:

7.5.2.1 *Condition 1*—1250 °F [675 °C] minimum, 1400 °F [760 °C] maximum.

7.5.2.2 *Condition 2*—1100 °F [595 °C] minimum, 1400 °F [760 °C] maximum.

7.5.2.3 *Condition 3*—1050 °F [565 °C] minimum, 1400 °F [760 °C] maximum.

7.5.3 Types XM-30, 414, and 431 tempered materials shall be held at 1100 °F [595 °C], minimum for at least 1 h/in. [25 mm] of cross section. Maximum tempering temperature shall be 1400 °F [760 °C].

7.5.4 S41500 shall be heated to 1750 °F [955 °C] minimum, air cooled to 200 °F [95 °C] or lower prior to any optional intermediate temper and prior to the final temper. The final temper shall be between 1050 and 1150 °F [565 and 620 °C].

7.5.5 When the purchaser elects to perform the hardening and tempering heat treatment, martensitic materials shall be supplied by the manufacturer in the annealed condition (see 7.5.1). In this case the purchaser shall be responsible to apply the proper heat treatment and to conduct the tests deemed necessary to assure that the required properties are obtained.

8. Finish

8.1 The following types of finishes are permitted, as applicable to the product ordered:

8.1.1 *Hot-finished Bars*—Hot-finished bars shall have the surface finish that results from hot processing, with or without certain additional surface modification. Hot-finished bars are commonly produced by hot rolling, forging, pressing, extruding, or similar hot working procedures applied to ingots, blooms, or billets. The resulting products are typically subject to various additional operations affecting the surface of the bars, including but not limited to one or more of the following: annealing or other heat treatment; cleaning by blasting, pickling, or other descaling methods; rough turning; and machine straightening. The producer is permitted to use centerless grinding, polishing, or other operations commonly associated with cold finishing in order to provide improved dimensional tolerances or surface condition for the hot-finished bar. The dimensional tolerances applicable to hot-finished bars are less stringent than those applicable to cold-finished bars.

8.1.2 *Bars Cut from Strip or Plate*—Bars cut from flat-rolled stainless steel products shall have two surfaces that are pickled or descaled, and two cut surfaces, except when the bar is heat treated subsequent to cutting, in which case all surfaces shall be descaled or pickled.

8.1.3 *Cold-finished Bar*—Cold-finished bars shall have the surface finish that results from hot-finished bars being further processed by additional mechanical operations on the surface of the bar, including but not limited to light cold drawing, burnishing, centerless grinding, and polishing to provide closer tolerances and improved surface finish. The dimensional tolerances applicable to cold-finished bars are more stringent than those applicable to hot-finished bars.

8.1.4 *Bars and Billets or Other Semi-finished Material for Reforging*—Material intended for reforging shall be delivered in the hot-finished condition or in the cold-drawn condition. The cold-drawn condition alternative is only permitted for austenitic and austenitic-ferritic stainless steel forgings. When delivered in the hot-finished condition, it is permitted to condition the surface by removing surface defects provided that the depth of the conditioning does not exceed that which affects the surface condition or dimensions of the article to be forged from the bar or billet. When delivered in the cold-drawn condition, it is permitted to hot forge forgings from cold-drawn bar provided this bar has been cold-drawn from material in the solution-annealed condition.

8.1.5 *Shapes*—Shapes shall be descaled by machining, grinding, blasting, or pickling.

8.1.5.1 Shapes shall be subject to either Class A or Class C surface preparation as specified on the purchase order. Class A consists of grinding for the removal of imperfections of a hazardous nature, such as fins, tears, and jagged edges, provided the underweight tolerance is not exceeded and the maximum depth of grinding at any one point does not exceed 10 % of the thickness of the section. Class C consists of grinding for the removal of all visible surface imperfections, provided that the underweight tolerance is not exceeded and the maximum depth of grinding at any point does not exceed 10 % of the thickness of the section.

8.1.6 *Forgings*—Forgings shall be descaled by machining, blasting, or pickling. The selection of the descaling methods shall be at the option of the producer unless a particular descaling method is specified in the purchase order.

9. Dimensions, Mass, and Permissible Variations

9.1 Unless otherwise specified on the purchase order, the material shall conform to the permitted variations in dimensions as specified in the following:

9.1.1 *Bars*—Tables 3-12.

9.1.2 *Shapes*—Tables 13-19 and Figs. 1 and 2.

9.1.3 *Forgings*—As specified in the purchase order, or in prints or sketches accompanying the purchase order.

9.1.4 *Billets or Other Semi-finished Material for Reforging*—Billets and other semi-finished material shall conform to the shape and dimensions specified by the purchaser within a permitted variation of ±5 %.

TABLE 3 Permitted Variations in Size of Hot-finished Round, Turned,[A] and Square Bars

Specified Size, in. [mm]	Permitted Variations from Specified Size, in. [mm] Over	Permitted Variations from Specified Size, in. [mm] Under	Out-of-Round[B] or Out-of-Square,[C] in. [mm]
5/16 to 7/16 [8.00 to 11.00], incl[D]	0.006 [0.15]	0.006 [0.15]	0.009 [0.23]
Over 7/16 to 5/8 [11.00 to 15.50], incl[D]	0.007 [0.18]	0.007 [0.18]	0.010 [0.26]
Over 5/8 to 7/8 [15.50 to 22.00], incl	0.008 [0.20]	0.008 [0.20]	0.012 [0.30]
Over 7/8 to 1 [22.00 to 25.00], incl	0.009 [0.23]	0.009 [0.23]	0.013 [0.34]
Over 1 to 1 1/8 [25.00 to 28.00], incl	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over 1 1/8 to 1 1/4 [28.00 to 31.50], incl	0.011 [0.28]	0.011 [0.28]	0.016 [0.42]
Over 1 1/4 to 1 3/8 [31.50 to 34.50], incl	0.012 [0.30]	0.012 [0.30]	0.018 [0.46]
Over 1 3/8 to 1 1/2 [34.50 to 38.00], incl	0.014 [0.35]	0.014 [0.35]	0.021 [0.53]
Over 1 1/2 to 2 [38.00 to 50.00], incl	1/64 [0.40]	1/64 [0.40]	0.023 [0.60]
Over 2 to 2 1/2 [50.00 to 63.00], incl	1/32 [0.80]	0	0.023 [0.60]
Over 2 1/2 to 3 1/2 [63.00 to 90.00], incl	3/64 [1.20]	0	0.035 [0.90]
Over 3 1/2 to 4 1/2 [90.00 to 115.00], incl	1/16 [1.60]	0	0.046 [1.20]
Over 4 1/2 to 5 1/2 [115.00 to 140.00], incl	5/64 [2.00]	0	0.058 [1.50]
Over 5 1/2 to 6 1/2 [140.00 to 165.00], incl	1/8 [3.00]	0	0.070 [1.80]
Over 6 1/2 to 8 [165.00 to 200.00], incl	5/32 [4.00]	0	0.085 [2.20]
Over 8 to 12 [200.00 to 300.00], incl[A]	3/16 [4.80]	0	3/32 [2.40]
Over 12 to 15 [300.00 to 400.00], incl[A]	7/32 [5.50]	0	7/64 [2.80]
Over 15 to 25 [400.00 to 625.00], incl[A]	1/4 [6.50]	0	1/8 [3.20]

[A] Turned bars are generally available from 2 to 25 in. [50 to 625 mm] in diameter, over 8 in. [200 mm] only turned bars are available.
[B] Out-of-round is the difference between the maximum and minimum diameters of the bar measured at the same cross section.
[C] Out-of-square section is the difference in the two dimensions at the same cross section of a square bar, each dimension being the distance between opposite faces.
[D] Size tolerances have not been evolved for round sections in the size range of 5/16 in. [8.00 mm] to approximately 5/8 in. [15.5 mm] in diameter which are produced on rod mills in coils.

TABLE 4 Permitted Variations in Size of Hot-finished Hexagonal and Octagonal Bar

Specified Sizes Measured Between Opposite Sides, in. [mm]	Permitted Variations from Specified Size, in. [mm] Over	Permitted Variations from Specified Size, in. [mm] Under	Maximum Difference in 3 Measurements for Hexagons Only, in. [mm]
1/4 to 1/2 [6.50 to 13.00], incl	0.007 [0.18]	0.007 [0.18]	0.011 [0.28]
Over 1/2 to 1 [13.00 to 25.00], incl	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over 1 to 1 1/2 [25.00 to 38.00], incl	0.021 [0.53]	0.021 [0.53]	0.025 [0.64]
Over 1 1/2 to 2 [38.00 to 50.00], incl	1/32 [0.80]	1/3 [0.80]	1/32 [0.80]
Over 2 to 2 1/2 [50.00 to 63.00], incl	3/64 [1.20]	3/64 [1.20]	3/64 [1.20]
Over 2 1/2 to 3 1/2 [63.00 to 90.00], incl	1/16 [1.60]	1/16 [1.60]	1/16 [1.60]

TABLE 5 Permitted Variations in Thickness and Width for Hot-finished Flat Bars Rolled as Bars

Specified Width, in. [mm]	Permitted Variations in Thickness for Thicknesses Given, in. [mm]												Permitted Variations in Width, in. [mm]	
	1/8 to 1/2 [3.2 to 13], incl		Over 1/2 to 1 [13 to 25], incl		Over 1 to 2 [25 to 50], incl		Over 2 to 4 [50 to 100], incl		Over 4 to 6 [100 to 150], incl		Over 6 to 8 [150 to 200], incl			
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
To 1	0.008	0.008	0.010	0.010	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.015	0.015
[25.00], incl	[0.20]	[0.20]	[0.25]	[0.25]									[0.40]	[0.40]
Over 1 to 2	0.012	0.012	0.015	0.015	0.031	0.031	. . .	. . .	. . .	. . .	. . .	. . .	0.031	0.031
[25.00 to 50.00], incl	[0.30]	[0.30]	[0.40]	[0.40]	[0.80]	[0.80]							[0.80]	[0.80]
Over 2 to 4	0.015	0.015	0.020	0.020	0.031	0.031	0.062	0.031	. . .	. . .	. . .	. . .	0.062	0.031
[50.00 to 100.00], incl	[0.40]	[0.40]	[0.50]	[0.50]	[0.80]	[0.80]	[1.60]	[0.80]					[1.60]	[0.80]
Over 4 to 6	0.015	0.015	0.020	0.020	0.031	0.031	0.062	0.031	0.093	0.062	. . .	. . .	0.093	0.062
[100.00 to 150.00], incl	[0.40]	[0.40]	[0.50]	[0.50]	[0.80]	[0.80]	[1.60]	[0.80]	[2.40]	[1.60]			[2.40]	[1.60]
Over 6 to 8	0.016	0.016	0.025	0.025	0.031	0.031	0.062	0.031	0.093	0.062	0.125	0.156	0.125	0.156
[150.00 to 200.00], incl	[0.40]	[0.40]	[0.65]	[0.65]	[0.80]	[0.80]	[1.60]	[0.80]	[2.40]	[1.60]	[3.20]	[4.00]	[3.20]	[4.00]
Over 8 to 10	0.020	0.020	0.031	0.031	0.031	0.031	0.062	0.031	0.093	0.062	0.125	0.156	0.156	0.187
[200.00 to 250.00], incl	[0.50]	[0.50]	[0.80]	[0.80]	[0.80]	[0.80]	[1.60]	[0.80]	[2.40]	[1.60]	[3.20]	[4.00]	[4.00]	[4.80]

10. Workmanship, Finish, and Appearance

10.1 The material shall be of uniform quality consistent with good manufacturing and inspection practices. Imperfections shall be of such a nature or degree for the type and quality ordered, that they shall not adversely affect the forming, machining, or fabrication of finished parts.

TABLE 6 Permitted Variations in Dimensions for Flat Bars Cut from Strip or Plate

Order Thickness	Permitted Variation in Thickness, in. [mm]		Permitted Variation^{A} in Width				Permitted Variation in Length^{B}	
			Widths to 4 [100]		Widths Over 4 [100]			
	Over	Under	Over	Under	Over	Under	Over	Under
Over 0.114 to 0.130 [2.90 to 3.30], incl	0.010 [0.25]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
Over 0.130 to 0.145 [3.30 to 3.70], incl	0.012 [0.30]	0.012 [0.30]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
Over 0.145 to less than 3⁄16, [3.70 to 4.80]	0.014 [0.35]	0.014 [0.35]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
3⁄16 to 3⁄8 [4.80 to 9.00], excl	0.050 [1.25]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
3⁄8 to 3⁄4 [9.00 to 19.00], excl	0.060 [1.50]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
3⁄4 to 1 [19.00 to 25.00], excl	0.065 [1.65]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
1 to 2 [25.00 to 50.00], excl	0.075 [1.90]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
2 to 3 [50.00 to 75.00], excl	0.150 [3.80]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
3 to 4 [75.00 to 100.00], excl	0.210 [5.30]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
4 to 6 [100.00 to 150.00], excl	0.300 [7.60]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
6 to 8 [150.00 to 200.00], excl	0.420 [10.65]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
8 to 10 [200.00 to 250.00], excl	0.540 [13.70]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0

^{A} By agreement between purchaser and seller, tolerances can be shifted as desired to any combination of plus-minus tolerance between all minus and all plus.
^{B} Not applicable when bars are ordered random length.

TABLE 7 Permitted Variations in Size of Cold-finished Round Bars

Specified Size, in. [mm]	Permitted Variations from Specified Size, in. [mm]^{A,B}	
	Over	Under
1⁄16 to 5⁄16 [1.50 to 8.00], excl	0.001 [0.03]	0.001 [0.03]
5⁄16 to 1⁄2 [8.00 to 13.00], excl	0.0015 [0.04]	0.0015 [0.04]
1⁄2 to 1 [13.00 to 25.00], excl	0.002 [0.05]	0.002 [0.05]
1 to 1½ [25.00 to 38.00], excl	0.0025 [0.06]	0.0025 [0.06]
1½ to 3¼ [38.00 to 83.00], incl^{C}	0.003 [0.08]	0.003 [0.08]
3¼ to 4 [83.00 to 100], incl^{C}	0.005 [0.13]	0.005 [0.13]

^{A} Unless otherwise specified, size tolerances are over and under as shown in the above table. When required, however, they may be specified all over and nothing under, or all under and nothing over, or any combination of over and under, if the total spread in size tolerance for a specified size is not less than the total spread shown in the table.
^{B} When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.
^{C} Cold-finished bars over 4 in. [100 mm] in diameter are produced; size tolerances for such bars are not included herein.

TABLE 8 Permitted Variations in Size of Cold Finished Hexagonal, Octagonal, and Square Bars

Specified Size,^{A} in. [mm]	Permitted Variations from Specified Size, in. [mm]^{B}	
	Over	Under
1⁄8 to 5⁄16 [3.00 to 8.00], excl	0	0.002 [0.05]
5⁄16 to 1⁄2 [8.00 to 13.00], excl	0	0.003 [0.08]
1⁄2 to 1 [13.00 to 25.00], incl	0	0.004 [0.10]
Over 1 to 2 [25.00 to 50.00], incl	0	0.006 [0.15]
Over 2 to 3 [50.00 to 75.00], incl	0	0.008 [0.20]
Over 3 [75.00]	0	0.010 [0.25]

^{A} Distance across flats.
^{B} When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

11. Sampling

11.1 A lot for product analysis shall consist of all bars, shapes, or forgings made from the same heat.

11.2 For other tests required by the product specification, a lot shall consist of all bar products of the same size, or forgings weighing less than 1000 lb [500 kg] each, from the same heat, and produced under the same processing conditions. All austenitic, ferritic, austenitic-ferritic, and free-machining grades, martensitic grades annealed to Condition A, and precipitation or age-hardening grades when solution treated are permitted to be heat treated in the same furnace or in several furnaces utilizing controlled processing and equipment (see Appendix X1). When heat treating martensitic stainless steels to Condition T or H, and when age hardening the precipitation hardening grades, a lot shall consist of the same size, same heat, and the same heat treat charge in a batch-type furnace or under the same conditions in a continuous furnace.

11.2.1 For forgings weighing from 1000 lb [500 kg] to 5000 lb [2500 kg] each, a lot shall consist of one size classification from each heat and each heat-treating charge. Where continuous heat-treating furnaces are used, a lot shall consist of one size classification from each heat, heated in a period of 8 h or less.

11.2.2 For all classes of forgings weighing from 5000 to 7000 lb [2300 to 3200 kg], each unit shall be considered a lot.

11.2.3 For all classes of forgings weighing more than 7000 lb [3200 kg], each unit shall be considered a double lot, and two tension tests shall be required, one from each end of each forging. In the case of ring forgings, the tension test specimens shall be removed from each of two locations on the

TABLE 9 Permitted Variations in Width and Thickness of Cold-finished Flat Bars

Width, in. [mm]	Permitted Variations in Width, Over and Under, in. [mm][A]	
	For Thicknesses ¼ in. [6.5] and Under	For Thicknesses Over ¼ in. [6.5]
1⁄16 to 3⁄8 [1.50 to 9.50], incl	0.005 [0.12]	0.005 [0.12]
Over 3⁄8 to 1 [9.50 to 25.00], incl	0.004 [0.10]	0.004 [0.10]
Over 1 to 2 [25.00 to 50.00], incl	0.006 [0.15]	0.004 [0.10]
Over 2 to 3 [50.00 to 75.00], incl	0.008 [0.20]	0.004 [0.10]
Over 3 to 4½ [75.00 to 115.00], incl	0.010 [0.25]	0.005 [0.13]
Thickness, in. [mm]	**Permitted Variations in Thickness, Over and Under, in. [mm][A]**	
Up to .029 [0.70], incl	0.001 [0.03]	
Over .029 to .035 [0.70 to 1.00], incl	0.0015 [0.04]	
Over .035 to 1 [1.00 to 25.00], incl	0.002 [0.05]	
Over 1 to 2 [25.00 to 50.00], incl	0.003 [0.08]	
Over 2 to 3 [50.00 to 75.00], incl	0.004 [0.10]	
Over 3 to 4½ [75.00 to 115.00], incl[B]	0.005 [0.13]	

[A] When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.
[B] Cold-finished flat bars over 4½ in. [115 mm] wide or thick are produced; width and thickness tolerances for such bars are not included herein.

TABLE 10 Permitted Variations in Length of Hot-finished or Cold-finished Bars

Specified Size of Rounds, Squares, Hexagons, Octagons, and Widths of Flats,[A] in. [mm]	Permitted Variations in Length, in. [mm][B]			
	For Lengths up to 12 ft[C] [4 m], incl		For Lengths Over 12 to 25 ft [4 to 8 m], incl	
	Over	Under	Over	Under
Up to 6 [150.00], incl	1 [25]	0	1¼ [31.50]	0
Over 6 to 9 [150.00 to 225.00], incl	1¼ [31.5]	0	1½ [38.00]	0
Over 9 to 12 [225.00 to 300.00], incl	1½ [38]	0	2 [50.00]	0

[A] The maximum width of bar flats is 10 in. [250 mm].
[B] Random Lengths—When ordered as random lengths, permissible variation is 2 ft [0.6 m] over and under the specified length. When ordered as random lengths subject to a minimum length requirement, permissible variation is 2 ft [0.6 m] over and nothing under the specified length.
[C] For lengths under 3 ft [1 m] and sizes up to ½ in. [13.00 mm] incl., the permissible variation in length is 1⁄32 in. [0.80 mm] over and nothing under.

TABLE 11 Permitted Variations in Length of Hot-finished or Cold-finished Bars Machine Cut After Machine Straightening[A]

NOTE 1—These tolerances are not applicable when bars are ordered random length.

Specified Size of Rounds, Squares, Hexagons, Octagons, and Width of Flats,[B] in. [mm]	Permitted Variations in Length, in. [mm]			
	For Lengths up to 12 ft [4 m], incl		For Lengths Over 12 to 25 ft [4 to 8 m], incl	
	Over	Under	Over	Under
To 3 [75], incl		0		0
Over 3 [75] to 12 [225 to 300], incl	½ [13.0]	0	½ [13.0]	0

[A] Table 11 does not apply to product produced on coil to bar equipment.
[B] The maximum width of bar flats is 10 in. [250 mm].

TABLE 12 Permitted Variations in Straightness of Machine Straightened Hot-finished or Cold-finished Bars[A]

NOTE 1—Measurement is taken on the concave side of the bar with a straightedge. Unless otherwise specified, hot-finished or cold-finished bars for machining purposes are furnished machine straightened to the following tolerances.

Hot-finished
⅛ in. [3.00 mm] in any 5 ft [1.50 m]; but may not exceed ⅛ in. [3.00 mm] × (length in ft/5) [m/1.50]
Cold-finished
1⁄16 in. [1.5 mm] in any 5 ft [1.5 m]; but may not exceed 1⁄16 in. [1.5 mm] × (length in ft/5) [m/1.50]

[A] Straightness tolerances have not been established for sizes less than ½ in. [13.00 mm].

TABLE 13 Permitted Variations for Hot-finished Angles

NOTE 1—For unequal leg angles, the longer leg determines the tolerance for the length of each leg.

Weight[A]
For angles of 6 lb/ft [9.0 kg/m] or less, the weight tolerances shall not exceed ±7½ %. For angles over 6 lb/ft [9 kg/m], the weight tolerance shall not exceed ±4½ %.
Length of Legs
For angles having legs or flanges up to 6 in. [150 mm], incl, the length tolerance shall not exceed ±⅛ in. [3.00 mm]. For angles having legs or flanges over 6 in., the length tolerance shall not exceed +3⁄16 in. [5.00 mm] and –⅛ in.
Squareness of Legs
The tolerance for the right angle between the legs is ±2°.

[A] For equal leg angles, the theoretical weight per foot is:

$$\text{weight/foot} = (24\ W \times t - 12t^2)\ (0.2871\ \text{lb/ft})$$

where:

W = specified length of the leg, in inches, and
t = specified thickness, in inches.

For unequal leg angles, the theoretical weight per foot is:

$$\text{weight/foot} = [12\ W1 \times t + 12\ W2 \times t - 12t^2]\ (0.2871\ \text{lb/ft})$$

where:

$W1$ and $W2$ = specified leg lengths, in inches, and
t = specified leg thickness, in inches.

periphery, approximately 180° apart, and insofar as practicable, from opposite ends of the forging.

12. Number of Tests and Retests

12.1 Unless otherwise specified in the product specification, one sample per heat shall be selected for chemical analysis and one mechanical test sample shall be selected from each lot of bars and shapes and from each lot of forgings. Except for bars cut from strip or plate, tension tests of bars and shapes shall be made in the longitudinal direction or, at the manufacturer's option unless otherwise specified in the purchase order, in the transverse (through thickness) direction. Material tensile tested in the transverse direction and meeting the specified tensile property requirements need not be tested in the longitudinal direction. Testing for bars cut from strip or plate shall conform to the requirements of the applicable product specification for the strip or plate and to Specification A480/A480M. Hardness tests on bars shall be conducted midway between the center and surface of the product. Tension tests on forgings shall be prepared from suitable prolongations, or at the option of the supplier, excess forgings may be provided for test. All tests shall conform to the chemical and mechanical requirements of the product specification.

12.2 One intergranular corrosion test, when required, and one grain size test, when required shall be made on each lot. Often, it is convenient to obtain test material from the specimen selected for mechanical testing.

TABLE 14 Permitted Variations in Size of Hot-finished Channels

Specified Size of Channel, in. [mm]	Size Tolerances, Over and Under, in. [mm]				
	Depth of Section^A	Width of Flanges	Thickness of Web for Thickness Given: To 3/16 incl [5.00 mm]	Thickness of Web for Thickness Given: Over 3/16 [5.00 mm]	Out-of-Square^B of Either Flange, in./in. [mm/ mm] of Flange Width
To 1½ [38.00], incl	3/64 [1.20]	3/64 [1.20]	0.015 [0.41]	0.023 [0.60]	3/64 [1.20]
Over 1½ to 3 [38.00 to 75.00], excl	3/32 [2.40]	3/32 [2.40]	0.023 [0.60]	0.030 [0.80]	3/64 [1.20]

^{A} Channel depth is measured at back of web.
^{B} For channels 5/8 in. [15.50 mm] and under in depth, the out-of-square tolerance is 5/64 in./in. [2.00 mm/mm] of depth. Out-of-squareness is determined by placing a square against the bottom surface of the web and measuring the amount of toe-in or toe-out of either flange. Measurements for depth of section and width of flanges are over-all.

TABLE 15 Permitted Variations in Size of Hot-finished Tees

Specified Size of Tee, in. [mm]^A	Width or Depth, in.^{B}		Thickness of Flange, in. [mm]		Thickness of Stem, in. [mm]		Stem Out-of-Square^C in. [mm]
	Over	Under	Over	Under	Over	Under	
To 1½ [38.00], incl.	5/64 [2.00]	5/64 [2.00]	0.015 [0.38]	0.015 [0.38]	0.008 [0.20]	0.030 [0.75]	3/64 [1.20]
Over 1½ to 2 [38.00 to 50.00], incl	3/32 [2.40]	3/32 [2.40]	0.018 [0.46]	0.018 [0.46]	0.015 [0.38]	0.030 [0.75]	3/32 [2.40]
Over 2 to 3 [50.00 to 75.00], excl	9/64 [3.60]	9/64 [3.60]	0.023 [0.60]	0.023 [0.60]	0.023 [0.60]	0.030 [0.75]	9/64 [3.60]

^{A} The longer member of an unequal tee determines the size for tolerances.
^{B} Measurements for both width and depth are over-all.
^{C} Stem out-of-square is the variation from its true position of the center line of stem measured at the point.

TABLE 16 Permitted Variations in Size of Hot-extruded Shapes

Specified Size, in [mm]	Section Tolerances, in. [mm]	
	Over	Under
Dimensions under 1 [25]	0.020 [0.50]	0.020 [0.50]
Dimensions 1 to 3 [25 to 75], excl	0.031 [0.80]	0.031 [0.80]
Dimensions 3 to 4 [75 to 100], incl	0.046 [1.20]	0.046 [1.20]
Over 4 [100]	0.062 [1.60]	0.062 [1.60]

TABLE 17 Angularity Tolerance for Extruded Shapes

Plus and minus	max 2°

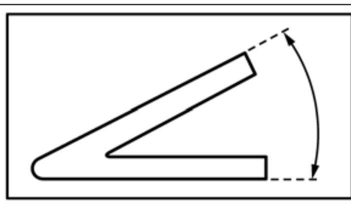


TABLE 18 Length Tolerances for Extruded Shape Length^{A,B}

Specified Size	For Lengths up to 12 ft [4 m], incl.		For Lengths over 12 ft [4 m]	
	Over	Under	Over	Under
Up to 3 in. [75 mm], excl	3/16 in. [4.8 mm]	0	¼ in. [6.5 mm]	0

^{A} *Multiple Lengths*—Unless otherwise specified, ¼ in. [6.5 mm] is added to the total length of each piece for each multiple contained.
^{B} *Random Lengths*—When ordered as random lengths, permissible variation is 2 ft [0.6 m] over and under the specified length. When ordered as random lengths subject to a minimum length requirement, permissible variation is 2 ft [0.6 m] over and nothing under the specified length.

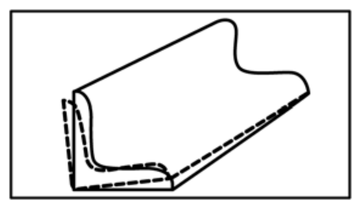
12.3 If any test specimen shows defective machining or flaws, it is permitted to discard the specimen and to substitute another specimen.

12.4 If the results of any test are not in conformance with the requirements of this specification or the requirements of the applicable product specification, it is permitted to retest a new sample of two specimens, to replace the original failed sample. If one of the retest specimens fails, the lot shall be rejected.

TABLE 19 Twist Tolerances

NOTE 1—The amount of spiraling in an extruded shape is called twist. It can be measured by the height of the high corner from a flat reference base (established rise).

NOTE 2—Using the following calculation the twist tolerance must not exceed what is shown in the table.



$$\text{rise in 5 ft} = \frac{\text{established rise} \times \text{number of ft in length}}{5}$$

Section Width	Rise in 5 ft
½ to 1½ in. [13 to 39 mm]	0.125 in. [3.00 mm]
Over 1½ to 4 in. [39 to 100 mm]	0.188 in. [4.80 mm]
Over 4 in. [100 mm]	0.250 in. [6.50 mm]

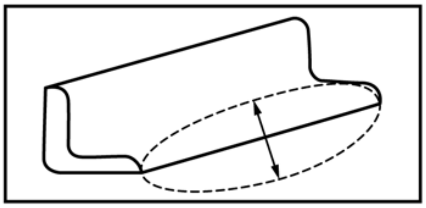
13. Retreatment

13.1 Where the failure of a lot is attributable to inadequate heat treatment, the producer may reheat treat the material and submit the retreated material for test.

14. Test Methods

14.1 The properties enumerated in the applicable product specification shall be tested in accordance with the following ASTM methods:

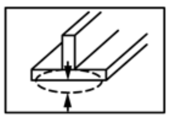
14.1.1 *Chemical Analysis*—Test Methods, Practices, and Terminology A751.



NOTE 1—Camber or bow tolerances shall not exceed 0.025 in. [0.60 mm] × length in ft [m/3].

Camber tolerances for hot finished or extruded shapes camber (or bow) is the greatest deviation of a side from a straight line. Measurement is taken on the concave side of the shapes with a straight edge.

FIG. 1 Camber or Bow Tolerances



NOTE 1—Allowable deviation from flat is max 0.010 in. [0.25 mm] per 1 in. [25 mm] of width. Maximum deviation on dimensions of less than 1 in. [25 mm] is 0.010 in. [0.250 mm].

The transverse flatness tolerance is the maximum deviation from a reference base across any cross-section flat surface.

FIG. 2 Transverse Flatness Tolerances

14.1.2 *Tension Tests*—Test Methods and Definitions A370.

14.1.3 *Stress Rupture*—Test Methods E139.

14.1.4 *Brinell Hardness*—Test Methods and Definitions A370.

14.1.5 *Rockwell Hardness*—Test Methods and Definitions A370.

14.1.6 *Intergranular Corrosion*—Practice E of Practices A262.

14.1.7 *Grain Size*—Test Methods E112.

14.1.8 *Charpy V-notch Impact Test*—Test Methods and Definitions A370.

15. Inspection

15.1 *Civilian Procurement*—Inspection of the material shall be as agreed upon between the purchaser and the supplier as part of the purchase contract.

15.2 *Government Procurement*—Unless otherwise specified in the contract or purchase order, the seller is responsible for the performance of all inspection and test requirements in this specification, the seller is permitted to use their own facilities or other suitable facilities for the performance of the inspection and testing, and the purchaser shall have the right to perform any of the inspection and tests set forth in this specification. The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy purchaser that the material is being furnished in accordance with the specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer.

16. Rejection and Rehearing

16.1 The purchaser is permitted to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the producer or supplier promptly, preferably in writing. In case of dissatisfaction with the results of a test, the producer or supplier is permitted to make claim for a rehearing.

17. Certification

17.1 A report of the results of all tests required by the product specification shall be supplied to the purchaser. This material test report shall reference the product specification designation and year date indicating that the material was manufactured, sampled, tested, and inspected in accordance with requirements of the product specification and has been found to meet those requirements. The material test report shall report the melting process when the purchase order requires either a specific type of melting or requires that the melting process used is to be reported.

17.1.1 The report shall indicate the type of steel. If certifying that the material conforms to the requirements for more than one type of steel, the manufacturer may indicate each type of steel on the report, or may issue a separate report for each type of steel.

17.2 A signature is not required on the report. However, the document shall clearly identify the organization submitting the report. Not withstanding the absence of a signature, the organization submitting the document is responsible for its content.

17.3 A document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Not withstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

NOTE 3—The industry definition of EDI invoked herein is the computer-to-computer exchange of business information in a standard format such as ANSI ASC X12.

17.4 When finished material is supplied to a purchase order specifying the product specification, the organization supplying that material shall provide the purchaser with a copy of the original manufacturer's test report.

17.4.1 When the original manufacturer's test report was provided by EDI to the organization supplying the finished material to the purchaser, the organization supplying the finished material shall provide to the purchaser a printed form of the original test report or shall retransmit the test report by EDI to the purchaser. In either case, the test report shall be complete with the full identification of the original manufacturer and with all data provided on the test report of the original manufacturer.

18. Product Marking

18.1 *Civilian Procurement:*

18.1.1 Bars and shapes shall be marked or tagged with the name of manufacturer, purchaser's name and order number, ASTM specification designation, heat number, grade or type, condition, finish, and where appropriate, the size, length, and weight. Unless otherwise specified, the method of marking is at the option of the manufacturer. Marking shall be made by hot stamping, cold stamping, or painting of bars, or by marking tags attached to bundles, lifts, or boxes.

18.1.2 Forgings shall be legibly die stamped with the manufacturer's symbol or name, material specification designation, grade or type, and heat identification. When die stamping is not permitted by the purchaser, electric pencil or electro-etching shall be used.

18.2 *Government Procurement:*

18.2.1 When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment, in addition to any requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

18.2.2 For government procurement by the Defense Supply Agency, bars and shapes shall be marked continuously for identification in accordance with Fed. Std. No. 183.

19. Packaging and Package Marking

19.1 Unless otherwise specified, the bars and shapes shall be packaged and loaded in accordance with Practices A700.

19.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

20. Keywords

20.1 general delivery requirements; stainless steel bars; stainless steel billets; stainless steel forgings; stainless steel shapes

ANNEXES

(Mandatory Information)

A1. REQUIREMENTS FOR INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in specifications referencing this specification, subject to the following conditions:

A1.1.1 The application for the addition of a new grade to a specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A1.1.5 The application shall state whether the new grade is covered by patent.

A2. REQUIREMENTS FOR INTRODUCTION OF MATERIALS FROM OTHER A01 OR B02.07 SPECIFICATIONS

A2.1 Wrought materials that are already covered by another A01 or B02.07 specification may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A2.1.1 Application for the addition of a grade that is already covered in another A01 or B02.07 specification shall be made to the chair of the subcommittee that has jurisdiction over that the specification to which the grade is to be added.

A2.1.2 The chemical requirements, the specified mechanical properties, and the heat treatment requirements of the grade being added shall be the same as those for the grade in the A01 or B02.07 specification in which the grade is presently covered.

A2.1.3 The application shall provide recommendations for all requirements appearing in the applicable specification.

A2.1.4 The application shall state whether or not the grade is covered by patent.

APPENDIXES

(Nonmandatory Information)

X1. RATIONALE REGARDING DEFINITION OF LOT FOR MECHANICAL PROPERTIES AND CORROSION TESTING

X1.1 It is generally recognized that material described as a lot must be "produced under the same processing conditions," which means the same manufacturing order number, same size, same heat, same heat-treating procedure, and same subsequent processing. Under those conditions, single samples can be selected to be representative of the total lot, with at least one sample for each 20 000 pounds of material.

X1.2 Following the principle described in X1.1 generally requires that the producer control each of several furnace loads constituting the same lot so that:

X1.2.1 Set point temperature and process tolerance match,

X1.2.2 Time at temperature for all thermal treatment shall match within 10 %,

X1.2.3 All furnaces used be similar in size and meet the uniformity requirements of a documented furnace quality assurance program, and

X1.2.4 The quench systems are the same with respect to volume, type of quenchant, and circulation rate.

X1.2.5 Further, it would be expected that grouped loads be handled within a relatively short time period, and that hardness testing be performed on at least one sample per charge.

X1.3 The old definition of a lot for mechanical testing based on simply the words "same size, heat, and heat treatment charge in a batch furnace" assumes that heat treating is the only process affecting properties. This kind of definition ignores the effects of other processing, prior to and subsequent to heat treating. Moreover, it assumes that each heat-treated batch will be uniform and unique rather than reproducible. In reality, heat treating is a process which can be controlled easily throughout a batch and from batch to batch, with the net result that multiple batches can be considered part of a single lot if equipment and processing parameters meet the mandates of X1.1 and X1.2.

X1.4 The sampling specified for mechanical properties is not a statistical sampling plan. Therefore, it provides only typical data. Assurance of uniformity within the lot can be obtained only by the producer adequately controlling the processing parameters.

X2. BAR CODING

X2.1 Bar coding to identify steel is not specifically addressed in Committee A01 specifications. Committee A01 endorses the AIAG bar code standard for primary metals for steel products and proposes that this bar coding standard be considered as a possible auxiliary method of identification.

SPECIFICATION FOR STEEL CASTINGS SUITABLE FOR PRESSURE SERVICE

SA-487/SA-487M

(23)

(Identical with ASTM Specification A487/A487M-21 except no welding for Grade 17 per Table 4.)

Specification for Steel Castings Suitable for Pressure Service

1. Scope

1.1 This specification covers low-alloy steels and martensitic stainless steels in the normalized and tempered, or quenched and tempered, condition suitable for pressure-containing parts. The weldability of the classes in this specification varies from readily weldable to weldable only with adequate precautions, and the weldability of each class should be considered prior to assembly by fusion welding.

1.2 Selection will depend on design, mechanical, and service conditions. Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtained.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3.1 Within the text, the SI units are shown in brackets.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

A985/A985M Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts

E165/E165M Practice for Liquid Penetrant Testing for General Industry

E709 Guide for Magnetic Particle Testing

2.2 *American Society of Mechanical Engineers:*

ASME Boiler and Pressure Vessel Code, Section IX

2.3 *Manufacturers Standardization Society of the Valve and Fittings Industry Standards:*

SP-55 Quality Standard for Steel Castings—Visual Method

3. General Conditions for Delivery

3.1 Except for investment castings, castings furnished to this specification shall conform to the requirements of Specification A703/A703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A703/A703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A703/A703M, this specification shall prevail.

3.2 Investment castings furnished to this specification shall conform to the requirements of Specification A985/A985M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A985/A985M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A985/A985M, Specification A985/A985M shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 ASTM designation and year of issue,

4.1.3 Grade and class of steel,

4.1.4 Options in the specification, and

4.1.5 The supplementary requirements desired, including the standard of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment indicated in Table 1. Preliminary heat treatment prior to final heat treatment, as well as multiple tempering, is permitted.

5.2 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

5.3 The furnace temperature for heat treating shall be effectively controlled by use of recording-type pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2. Except for investment castings, product analysis tolerance shall conform to the product analysis tolerance shown in Specification A703/A703M. For investment castings, the product analysis tolerance shall conform to the product analysis tolerance shown in Specification A985/A985M.

7. Tensile Requirements

7.1 Tensile properties of steel used for the castings shall conform to the requirements prescribed in Table 3.

TABLE 1 Heat Treat Requirement

Grade	Class	Austenitizing Temperature, min, °F [°C]	Media[A]	Quenching Cool Below °F [°C]	Tempering Temperature,[B] °F [°C]
1	A	1600 [870]	A	450 [230]	1100 [595]
1	B	1600 [870]	L	500 [260]	1100 [595]
1	C	1600 [870]	A or L	500 [260]	1150 [620]
2	A	1600 [870]	A	450 [230]	1100 [595]
2	B	1600 [870]	L	500 [260]	1100 [595]
2	C	1600 [870]	A or L	500 [260]	1150 [620]
4	A	1600 [870]	A or L	500 [260]	1100 [595]
4	B	1600 [870]	L	500 [260]	1100 [595]
4	C	1600 [870]	A or L	500 [260]	1150 [620]
4	D	1600 [870]	L	500 [260]	1150 [620]
4	E	1600 [870]	L	500 [260]	1100 [595]
6	A	1550 [845]	A	500 [260]	1100 [595]
6	B	1550 [845]	L	500 [260]	1100 [595]
7	A	1650 [900]	L	600 [315]	1100 [595]
8	A	1750 [955]	A	500 [260]	1250 [675]
8	B	1750 [955]	L	500 [260]	1250 [675]
8	C	1750 [955]	L	500 [260]	1250 [675]
9	A	1600 [870]	A or L	500 [260]	1100 [595]
9	B	1600 [870]	L	500 [260]	1100 [595]
9	C	1600 [870]	A or L	500 [260]	1150 [620]
9	D	1600 [870]	L	500 [260]	1150 [620]
9	E	1600 [870]	L	500 [260]	1100 [595]
10	A	1550 [845]	A	500 [260]	1100 [595]
10	B	1550 [845]	L	500 [260]	1100 [595]
11	A	1650 [900]	A	600 [315]	1100 [595]
11	B	1650 [900]	L	600 [315]	1100 [595]
12	A	1750 [955]	A	600 [315]	1100 [595]
12	B	1750 [955]	L	400 [205]	1100 [595]
13	A	1550 [845]	A	500 [260]	1100 [595]
13	B	1550 [845]	L	500 [260]	1100 [595]
14	A	1550 [845]	L	500 [260]	1100 [595]
16	A	1600 [870][C]	A	600 [315]	1100 [595]
17	A	1590 [865][C]	L	500 [260]	1095 [590][F,G]
CA15	A	1750 [955]	A or L	400 [205]	900 [480]
CA15	B	1750 [955]	A or L	400 [205]	1100 [595]
CA15	C	1750 [955]	A or L	400 [205]	1150 [620][D,E]
CA15	D	1750 [955]	A or L	400 [205]	1150 [620][D,E]
CA15M	A	1750 [955]	A or L	400 [205]	1100 [595]
CA6NM	A	1850 [1010]	A or L	200 [95]	1050–1150 [565–620]
CA6NM	B	1850 [1010]	A or L	200 [95]	1225–1275 [665–690][E,F] 1050–1150 [565–620][G]

[A] A = air, L = liquid.
[B] Minimum temperature unless a range is specified.
[C] Double austenitize.
[D] Double temper with the final temper at a lower temperature than the intermediate temper.
[E] Air cool to below 200 °F [95 °C] after first temper.
[F] Intermediate.
[G] Final.

TABLE 2 Chemical Composition Requirements[A,B]

Grade Class Type (UNS Number)	Element, %											
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Copper	Vanadium	Boron	Tungsten
1 ABC V (J13002)	0.30	1.00	0.035	0.035	0.80	0.50[D]	0.35[D]	[C,D]	0.50[D]	0.04–0.12	. . .	[C,D]
2 ABC Mn-Mo (J13005)	0.30	1.00–1.40	0.035	0.035	0.80	0.50[D]	0.35[D]	0.10–0.30	0.50[D]	0.03[D]	. . .	0.10[D]
4 ABCDE Ni-Cr-Mo (J13047)	0.30	1.00	0.035	0.035	0.80	0.40–0.80	0.40–0.80	0.15–0.30	0.50[E]	0.03[E]	. . .	0.10[E]
6 AB Mn-Ni-Cr-Mo (J13855)	0.05–0.38	1.30–1.70	0.035	0.035	0.80	0.40–0.80	0.40–0.80	0.30–0.40	0.50[E]	0.03[E]	. . .	0.10[E]
7 A Ni-Cr-Mo-V[F] (J13084)	0.05–0.20	0.60–1.00	0.035	0.035	0.80	0.70–1.00	0.40–0.80	0.40–0.60	0.15–0.50	0.03–0.10	0.002–0.006	0.10
8 ABC Cr-Mo (J22091)	0.05–0.20	0.50–0.90	0.035	0.035	0.80	. . .	2.00–2.75	0.90–1.10	0.50[E]	0.03[E]	. . .	0.10[E]
9 ABCDE Cr-Mo (J13345)	0.05–0.33	0.60–1.00	0.035	0.035	0.80	0.50[D]	0.75–1.10	0.15–0.30	0.50[D]	0.03[D]	. . .	0.10[D]
10 AB Ni-Cr-Mo (J23015)	0.30	0.60–1.00	0.035	0.035	0.80	1.40–2.00	0.55–0.90	0.20–0.40	0.50[E]	0.03[E]	. . .	0.10[E]
11 AB Ni-Cr-Mo (J12082)	0.05–0.20	0.50–0.80	0.035	0.035	0.60	0.70–1.10	0.50–0.80	0.45–0.65	0.50[G]	0.03[G]	. . .	0.10[G]
12 AB Ni-Cr-Mo (J22000)	0.05–0.20	0.40–0.70	0.035	0.035	0.60	0.60–1.00	0.50–0.90	0.90–1.20	0.50[G]	0.03[G]	. . .	0.10[G]
13 AB Ni-Mo (J13080)	0.30	0.80–1.10	0.035	0.035	0.60	1.40–1.75	0.40[H]	0.20–0.30	0.50[H]	0.03[H]	. . .	0.10[H]

TABLE 2 *Continued*

Grade Class Type (UNS Number)	Element, %											
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Copper	Vanadium	Boron	Tungsten
14 A Ni-Mo (J15580)	0.55	0.80–1.10	0.035	0.035	0.60	1.40–1.75	0.40[H]	0.20–0.30	0.50[H]	0.03[H]	. . .	0.10[H]
16 A Low C-Mn-Ni (J31200)	0.12[I]	2.10[I]	0.02	0.02	0.50	1.00–1.40	0.20[G]	0.10[G]	0.20[G]	0.02[G]	. . .	0.10[G]
17 A Ni-Cr-Mo	0.05–0.20	0.55–0.70	0.01	0.005	0.20–0.50	3.0–3.80	1.35–1.60	0.35–0.60	0.20	0.03	. . .	. . .
CA15 ABCD Martensitic Cr (J91150)	0.15	1.00	0.035	0.035	1.50	1.00	11.5–14.0	0.50	0.50[G]	0.05[G]	. . .	0.10[G]
CA15M A Martensitic Cr (J91151)	0.15	1.00	0.035	0.035	0.65	1.00	11.5–14.0	0.15–1.0	0.50[G]	0.05[G]	. . .	0.10[G]
CA6NM AB Martensitic Cr-Ni (J91540)	0.06	1.00	0.035	0.03	1.00	3.5–4.5	11.5–14.0	0.4–1.0	0.50[G]	0.05[G]	. . .	0.10[G]

[A] All values are maximums unless a range is provided.
[B] Where ellipses (…) appear in this table, there is no requirement and the element need not be analyzed for or reported.
[C] The Mo + W content shall not exceed 0.25 %.
[D] Specified Residual Elements—the total content of these elements is 1.00 % maximum.
[E] Specified Residual Elements—the total content of these elements is 0.60 % maximum.
[F] Proprietary steel composition.
[G] Specified Residual Elements—the total content of these elements is 0.50 % maximum.
[H] Specified Residual Elements—the total content of these elements is 0.75 % maximum.
[I] For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted up to a maximum of 2.30 %.

TABLE 3 Required Mechanical Properties

Previous Designation	Grade	Class	Tensile Strength,[A] ksi [MPa]	Yield Strength,[A] ksi [MPa], at 0.2 % Offset	Elongation,[A] 2 in. [50 mm] or 4*d*, %	Reduction of Area,[A] %	Maximum Hardness, HRC [HB]	Thickness, in. [mm]
1N	1	A	85–110 [585–760]	55 [380]	22	40		
1Q	1	B	90–115 [620–795]	65 [450]	22	45		
	1	C	90 [620]	65 [450]	22	45	22 [235]	
2N	2	A	85–110 [585–760]	53 [365]	22	35		
2Q	2	B	90–115 [620–795]	65 [450]	22	40		
	2	C	90 [620]	65 [450]	22	40	22 [235]	
4N	4	A	90–115 [620–795]	60 [415]	18	40		
4Q	4	B	105–130 [725–895]	85 [585]	17	35		
	4	C	90 [620]	60 [415]	18	35	22 [235]	
	4	D	100 [690]	75 [515]	17	35	22 [235]	
4QA	4	E	115 [795]	95 [655]	15	35		
6N	6	A	115 [795]	80 [550]	18	30		
6Q	6	B	120 [825]	95 [655]	12	25		
7Q	7	A	115 [795]	100 [690]	15	30		2.5 [63.5] max
8N	8	A	85–110 [585–760]	55 [380]	20	35		
8Q	8	B	105 [725]	85 [585]	17	30		
	8	C	100 [690]	75 [515]	17	35	22 [235]	
9N	9	A	90 [620]	60 [415]	18	35		
9Q	9	B	105 [725]	85 [585]	16	35		
	9	C	90 [620]	60 [415]	18	35	22 [235]	
	9	D	100 [690]	75 [515]	17	35	22 [235]	
	9	E	115 [795]	95 [655]	15	35		
10N	10	A	100 [690]	70 [485]	18	35		
10Q	10	B	125 [860]	100 [690]	15	35		
11N	11	A	70–95 [484–655]	40 [275]	20	35		
11Q	11	B	105–130 [725–895]	85 [585]	17	35		
12N	12	A	70–95 [485–655]	40 [275]	20	35		
12Q	12	B	105–130 [725–895]	85 [585]	17	35		
13N	13	A	90–115 [620–795]	60 [415]	18	35		
13Q	13	B	105–130 [725–895]	85 [585]	17	35		
14Q	14	A	120–145 [825–1000]	95 [655]	14	30		
16N	16	A	70–95 [485–655]	40 [275]	22	35		
	17	A	113 [780]	97 [670]	15	30		up to 6.0 [150], incl.
	17	A	110 [760]	94 [650]	15	30		over 6.0 [150] to 8.0 [200], incl.
	17	A	106 [730]	91 [625]	15	30		over 8.0 [200] to 12.0 [300], incl.
	17	A	102 [705]	88 [605]	15	30		over 12.0 [300] to 14.0 [360], incl.
CA15A	CA15	A	140–170 [965–1170]	110–130 [760–895]	10	25		
CA15	CA15	B	90–115 [620–795]	65 [450]	18	30		
	CA15	C	90 [620]	60 [415]	18	35	22 [235]	
	CA15	D	100 [690]	75 [515]	17	35	22 [235]	
CA15M	CA15M	A	90–115 [620–795]	65 [450]	18	30		
CA6NM	CA6NM	A	110–135 [760–930]	80 [550]	15	35		
CA6NM	CA6NM	B	100 [690]	75 [515]	17	35	23 [255][B]	

[A] Minimum value, unless a range is provided.
[B] Test Methods and Definitions A370, Table 2 does not apply to CA6NM. The conversion given is based on CA6NM test coupons. (For example, see ASTM STP 756.)

8. Quality

8.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperatures are used in the removal and repair of discontinuities, the casting shall be preheated to at least the minimum temperature in Table 4.

8.2 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair By Welding

9.1 For castings other than those intended for use under ASME Boiler and Pressure Vessel Code, repairs shall be made using procedures and welders qualified under Practice A488/A488M.

9.2 On castings intended for use under the ASME Boiler and Pressure Vessel Code, repairs shall be made by procedures and welders qualified under Section IX of that code.

9.3 After repair welding, all castings shall be post-weld heat treated in accordance with Table 4 or reheat treated in accordance with Table 1.

9.4 Weld repairs shall be inspected using the same quality standards as are used to inspect the castings. Re-examination of

TABLE 4 Minimum Preheat and Post-Weld Heat Treat Requirements

Grade	Class	Minimum Preheat Temperature, °F [°C]	Post-Weld Heat Treat, °F [°C]
1	A, B	200 [95]	1100 [595][A] minimum
1	C	200 [95]	1150 [620][A] minimum
2	A, B	200 [95]	1100 [595][A] minimum
2	C	200 [95]	1150 [620][A] minimum
4	A, B, E	200 [95]	1100 [595][A] minimum
4	C, D	200 [95]	1150 [620][A] minimum
6	A, B	300 [150]	1100 [595][A] minimum
7	A	300 [150]	1100 [595][A] minimum
8	A, B, C	300 [150]	1250 [675][A] minimum
9	A, B, E	300 [150]	1100 [595][A] minimum
9	C, D	300 [150]	1150 [620][A] minimum
10	A, B	300 [150]	1100 [595][A] minimum
11	A, B	300 [150]	1100 [595][A] minimum
12	A, B	300 [150]	1100 [595][A] minimum
13	A, B	400 [205]	1100 [595][A] minimum
14	A	400 [205]	1100 [595][A] minimum
16	A	50 [10]	1100 [595][A] minimum
17	A	...	No welding
CA15	A	400 [205]	1750 [955] air cool or liquid quench below 400 [205] temper at 900 [480] minimum
CA15	B	400 [205]	1100 [595][A] minimum
CA15	C, D	400 [205]	1150 [620][A] minimum
CA15M	A	400 [205]	1100 [595][A] minimum
CA6NM	A	50 [10]	Final temper between 1050 [565] and 1150 [620]
CA6NM	B	50 [10]	Intermediate PWHT between 1225 [665] and 1275 [690] Final temper PWHT 1050 [565] and 1150 [620][B]

[A] Post-weld heat treat temperature must be at or below the final tempering temperature.
[B] The intermediate and final PWHT temperatures shall be the same as the intermediate and final tempering temperatures, respectively, as the original heat treatment of the castings. Cool to below 200 °F [95 °C] between the intermediate and final PWHT.

the weld repair by radiography when Supplementary Requirement S5 has been specified will not be necessary when an applicable surface inspection method was used to locate the discontinuity except for the following:

9.4.1 Weld repairs on castings which have leaked on hydrostatic test.

9.4.2 Weld repairs on castings in which the depth of any cavity prepared for repair welding is more than 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller.

9.4.3 Weld repairs on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2].

10. Product Marking

10.1 Castings shall be marked for material identification with the grade and class symbols (1-A, 4-C, CA15-A).

11. Keywords

11.1 alloy steel; martensitic stainless steel; pressure-containing parts; stainless steel; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specifications A703/A703M and A985/A985M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specifications A703/A703M and A985/A985M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S8. Charpy Impact Test

S8.1 In addition to the requirements listed in S8 of Specifications A703/A703M and A985/A985M, the following specific requirements apply to this specification:

S8.1.1 When S8 is specified for Grades 1B, 2B, 4B, 6B, 7A, 8B, 9B, or 10B, impact properties shall be determined by performing a Charpy V-notch impact test at −50 °F [−46 °C] with a specific minimum average value of 15 ft-lb [20 J] and a specified minimum single value of 10 ft-lb [14 J]. Other temperatures may be used upon agreement between the manufacturer and the purchaser, in which case S8.1.3 shall apply. Other higher specified minimum average and single values may be used upon agreement between the manufacturer and the purchaser.

S8.1.2 Impact requirements for grades other than 1B, 2B, 4B, 6B, 7A, 8B, 9B, and 10B shall be agreed upon between the manufacturer and the purchaser.

S8.1.3 When an impact test temperature other than −50 °F [−46 °C] is used for those grades listed in S8.1.1, the lowest test temperature at which the material meets the impact requirements shall be stamped with low-stress stamps immediately ahead of the material symbol on the raised pad (for example, 25 10B for +25 °F [−4 °C] and 025 10B for −25 °F [−32 °C]).

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Guide E709 or Practice E165/E165M.

S26. Alternate Tension Test Coupons and Specimen Locations for Castings

S27. Hot Isostatic Pressing (HIPing)

SPECIFICATION FOR QUENCHED AND TEMPERED VACUUM-TREATED CARBON AND ALLOY STEEL FORGINGS FOR PRESSURE VESSELS

SA-508/SA-508M

(**23**)

(Identical with ASTM Specification A508/A508M-18.)

Specification for Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels

1. Scope

1.1 This specification covers quenched and tempered vacuum-treated carbon and alloy steel forgings for pressure vessels such as those used in reactor systems. Specifically, it covers forgings for vessel closures, shells, flanges, tube sheets, rings, heads, and similar parts.

1.2 All grades are considered weldable under proper conditions. Welding technique is of fundamental importance, and it is presupposed that welding procedure and inspection will be in accordance with approved methods for the grade of material used.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

NOTE 1—Grades 1 and 1A are composed of different chemistries but have the same mechanical requirements.

NOTE 2—Designations have been changed as follows:

Current	Formerly
Grade 1	Class 1
Grade 1A	Class 1A
Grade 2 Class 1	Class 2
Grade 2 Class 2	Class 2A
Grade 3 Class 1	Class 3
Grade 3 Class 2	Class 3A
Grade 4N Class 1	Class 4
Grade 4N Class 2	Class 4A
Grade 4N Class 3	Class 4B
Grade 5 Class 1	Class 5
Grade 5 Class 2	Class 5A
Grade 22 Class 3	Class 22B
Grade 22 Classes 4, 5, 6, and 7	
Grade 3V	Class 3V

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

A788/A788M Specification for Steel Forgings, General Requirements

A966/A966M Practice for Magnetic Particle Examination of Steel Forgings Using Alternating Current

E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E428 Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing

2.2 *American Society of Mechanical Engineers Standard:*
Boiler and Pressure Vessel Code—Section III, Articles NB 2300, NC 2300, ND 2300, NE 2300, NF 2300, NG 2300

3. Terminology

3.1 *Definitions:*
3.1.1 *controlling cross section thickness (T_C)*—the diameter of the largest theoretical sphere which can be inscribed within the volume of the forging.

4. Ordering Information

4.1 *Purchase Order*—In addition to the ordering information required by Specification A788/A788M, the purchaser shall include with the inquiry and order a detailed drawing that locates the areas of significant loading in the forging (when required), the method of selecting test locations (see 7.1.5 and 7.1.6), and purchase options (see 5.2.2, 7.2, and 11.1) and any supplementary requirements desired.

4.2 *Forging Drawing*—Each forging shall be manufactured in accordance with a purchaser-approved drawing showing the prequenched dimensions, the finished dimensions, the surfaces that will be subjected to significant loading, and the locations of mechanical test specimens.

4.3 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

4.3.1 When specified by the purchaser, it is permissible to perform Magnetic particle examination using the AC yoke in accordance with Practice A966/A966M instead of using Practice A275/A275M (see 9.2.1).

4.4 The optional minimum silicon content as expressed in Footnote B to Table 1, if required.

4.5 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, the requirements of this specification shall prevail.

5. Materials and Manufacture

5.1 *Melting Process:*
5.1.1 The steel shall be made by the basic electric-furnace process except when secondary ladle refining or the remelting process is employed, in which case the melting processes of Specification A788/A788M are permitted.
5.1.2 The molten steel shall be vacuum treated in accordance with the methods described in Specification A788/A788M, prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen.
Grade 22 Classes 4, 5, 6, and 7 liquid steel shall be produced to a fine grain melting practice which has been shown to result in a prior austenitic grain size of five or finer.
5.1.3 *Discard*—Sufficient discard shall be made from each ingot to secure freedom from piping and excessive segregation.

5.2 *Heat Treatment:*
5.2.1 *Preliminary Heat Treatment*—After forging and before reheating, the forgings shall be cooled to provide substantially complete transformation of austenite. Preliminary heat treatment may be applied to improve machinability and to enhance subsequent heat treatments.
5.2.2 *Heat Treatment for Mechanical Properties*—The forgings shall be heated to a temperature which produces an austenitic structure and then quenched in a suitable liquid medium by spraying or immersion. For Grade 4N, Classes 1

TABLE 1 Chemical Requirements

	Composition, %									
	Grade 1	Grade 1A	Grade 2	Grade 3	Grade 4N	Grade 5	Grade 22[A]	Grade 3V	Grade 3VCb	Grade 6
Carbon	0.35 max	0.30 max	0.27 max	0.25 max	0.23 max	0.23 max	0.11–0.15	0.10–0.15	0.10–0.15	0.28–0.33
Manganese	0.40–1.05	0.70–1.35	0.50–1.00	1.20–1.50	0.20–0.40	0.20–0.40	0.30–0.60	0.30–0.60	0.30–0.60	0.75–1.15
Phosphorus	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.020 max	0.015 max	0.020 max	0.020 max	0.025 max
Sulfur	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.020 max	0.015 max	0.020 max	0.010 max	0.025 max
Silicon[B]	0.40 max	0.40 max	0.40 max	0.40 max	0.40 max	0.30 max	0.35 max	0.10 max	0.10 max	0.35 max
Nickel	0.40 max	0.40 max	0.50–1.00	0.40–1.00	2.8–3.9	2.8–3.9	0.25 max	. . .	0.25 max	0.75–0.95
Chromium	0.25 max	0.25 max	0.25–0.45	0.25 max	1.50–2.00	1.50–2.00	2.00–2.50	2.8–3.3	2.7–3.3	0.70–1.00
Molybdenum	0.10 max	0.10 max	0.55–0.70	0.45–0.60	0.40–0.60	0.40–0.60	0.90–1.10 max	0.90–1.10	0.90–1.10	0.30–0.45
Vanadium	0.05 max	0.05 max	0.05 max	0.05 max	0.03 max	0.08 max	0.02 max	0.20–0.30	0.20–0.30	0.05 max
Columbium[C]	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.015–0.070	0.01 max
Copper	0.20 max	0.20 max	0.20 max	0.20 max	0.25 max	0.25 max	0.25 max	0.25 max	0.25 max	0.25 max
Calcium	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.0005–0.0150	0.015 max
Boron	0.003 max	0.003 max	0.003 max	0.003 max	0.003 max	0.003 max	0.003 max	0.001–0.003	0.003 max	0.003 max
Titanium	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015–0.035	0.015 max	0.015 max
Aluminum[D]	0.030 max	0.030 max	0.030 max	0.030 max	0.025 max	0.025 max	0.025 max	0.015 max	0.015 max	0.025 max

[A] For Grade 22 Classes 5, 6, and 7 with section thickness at heat treat of 8 in. or greater, the carbon and manganese shall be held to 0.13 to 0.15 and 0.50 to 0.60, respectively.
[B] When required by the purchaser a minimum silicon content of 0.15 % shall apply for Grades 1, 1A, 2, 3, and 4N.
[C] Columbium (Cb) and Niobium (Nb) are alternate names for Element 41 in the Periodic Table of the Elements.
[D] Aluminum content reported shall be the combined total soluble and insoluble aluminum.

and 3, the austenitizing temperature shall be 1540 °F [840 °C] min to 1640 °F [895 °C] max. Quenching shall be followed by tempering at a subcritical temperature and holding at this temperature for a minimum time of one-half hour per inch of maximum section thickness. Except when Supplementary Requirement S 13 is specified for Grades 2 and 3, the minimum tempering temperatures shall be as follows:

Grades 1, 1A, 2 Class 2, and 3 Class 2	1150 °F [620 °C]
Grades 2 Class 1 and 3 Class 1	1200 °F [650 °C]
Grades 4N Classes 1 and 2, and 5 Classes 1 and 2	1100 °F [595 °C]
Grade 4N Class 3	1125 °F [605 °C]
Grades 3V and 3VCb	1250 °F [675 °C]
Grade 22, Class 3	1200 °F [650 °C]
Grade 22, Classes 4, 5, 6, and 7	1100 °F [593 °C]

Specific cooling rates from the tempering temperature shall be applied if Supplementary Requirement S14 is specified.

5.3 For Grades 1, 1A, 2, 2A, 3, or 3A, a multiple stage austenitizing procedure may be used whereby the forging is first fully austenitized and liquid quenched, followed by reheating within the intercritical temperature range to partially reaustenitize and again liquid quenched. On completion of the austenitizing/quenching cycles, the forgings shall be tempered at a subcritical temperature as described in 5.2.2.

6. Chemical Composition

6.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A788/A788M shall comply with Table 1 except that the additional features of Supplementary Requirements S7, S8, S9, and S11 shall also apply as individually specified in the ordering information.

6.2 *Product Analysis*—The manufacturer shall use the product analysis provision of Specification A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat. The permissible variations provided in the table on Permissible Variations in Product Analysis for Killed Steel in Specification A788/A788M apply for manganese, nickel, chromium, molybdenum, and vanadium only. Boron is not subject to product analysis. The purchaser may also make this determination in accordance with Specification A788/A788M.

7. Mechanical Properties

7.1 *Tension Test:*

7.1.1 The steel shall conform to the requirements of Table 2.

7.1.2 The location and number of tension test specimens for each forging or multiple forging shall be as follows:

7.1.2.1 *Individual Forgings with Weights Not Exceeding 1000 lb [455 kg] or Multiple Forgings Separated into Identical Individual Forgings with Weights not Exceeding 1000 lb [455 kg] Prior to Quenching and Tempering Treatment*—At least one individual forging from each heat and each heat-treating lot shall be tested using the test specimen locations of 7.1.5 or 7.1.6 as specified on the purchase orders, except that test specimens located at midlength may be closer to the ends of the production forging than the specified distance to the second surfaces. All forgings shall be quenched and tempered in the same furnace charge. All forgings from the multiple shall be Brinell hardness tested after heat treatment and forgings not tested for mechanical properties shall have a Brinell Hardness within 20 points of the Brinell Hardness of the forging that has been tested for mechanical properties.

7.1.2.2 *Forgings or Multiple Forgings (Note 3) with Weight at Time of Heat Treatment Not Exceeding 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongation) of 80 in. [2032 mm] or Less*—A test prolongation (Note 4) shall be located at one end. One tension test specimen shall be taken from the test prolongation.

7.1.2.3 *Forgings or Multiple Forgings with Weight at Time of Heat Treatment Not Exceeding 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongations) Exceeding 80 in. [2032 mm]*—A test prolongation shall be located at each end. One tension test specimen shall be taken from each test prolongation. An orientation of 180° shall be established between the two tension test specimens.

7.1.2.4 *Forgings or Multiple Forgings with Weight at Time of Heat Treatment Over 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongation) of 80 in. [2032 mm] or Less*—A test prolongation shall be located at one end. Two tension test specimens shall be taken from the test prolongation and shall be oriented 180° apart.

7.1.2.5 *Forgings or Multiple Forgings with Weight at Time of Heat Treatment Over 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongations) Exceeding 80 in. [2032 mm]*—A test prolongation shall be located at each end. The tension test specimens oriented 180° apart from each other shall be taken from each test prolongation. The two tension specimens located in one test prolongation shall be oriented 90° in relation to the two tension specimens located in the other test prolongation.

NOTE 3—Multiple forgings in 7.1.2.2 through 7.1.2.5 are those which will be separated after the quench and temper treatment.

NOTE 4—A test prolongation is defined as that integral test metal located at an end of the forging or forging multiples.

7.1.3 Samples for mechanical test specimen shall be removed from forgings after the quenching and tempering heat treatment. The sample material shall be subjected to a simulated post weld heat treatment if Supplementary Requirement S1 is specified.

7.1.4 For upset disk forgings, the longitudinal axis of the test specimens shall be in the tangential direction. For all other parts, the longitudinal axis of the specimens shall be parallel to the direction of major working of the forging.

7.1.5 Each forging shall be manufactured in accordance with a purchaser-approved drawing, showing the prequenched dimensions, the finished dimensions, the surfaces that will be subjected to critical stresses, and the location of mechanical test specimens.

7.1.6 The tension test specimens shall be positioned so that the longitudinal axis and mid-length is in accordance with one of the following methods:

7.1.6.1 *Method 1—t* by 2*t*, where *t* is the distance from the area of significant loading (see 4.1) to the nearest quenched surface. Specimens shall be removed at least 2*t* from the nearest second surface. However, they shall not be nearer to one quenched surface than ¾ in. [20 mm] and to the second quenched surface than 1½ in. [40 mm].

TABLE 2 Tensile Requirements

	Grades 1 and 1a	Grades 2 Class 1 and 3 Class 1	Grades 2 Class 2 and 3 Class 2	Grades 4N Class 1 and 5 Class 1	Grades 4N Class 2 and 5 Class 2	Grade 4N Class 3	Grade 22 Class 3	Grades 3V and 3VCb	Grade 6 Class 1	Grade 6 Class 2	Grade 6 Class 3	Grade 6 Class 4	Grade 22 Class 4	Grade 22 Class 5	Grade 22 Class 6	Grade 22 Class 7
Tensile strength, ksi [MPa]	70–95 [485–655]	80–105 [550–725]	90–115 [620–795]	105–130 [725–895]	115–140 [795–965]	90–115 [620–795]	85–110 [585–760]	85–110 [585–760]	85–110 [585–760]	95–120 [655–825]	100–125 [690–860]	105–130 [725–895]	85–110 [585–760]	95–120 [655–825]	100–125 [690–860]	105–130 [725–895]
Yield strength, min [0.2 % offset], ksi [MPa]	36 [250]	50 [345]	65 [450]	85 [585]	100 [690]	70 [485]	55 [380]	60 [415]	60 [415]	75 [515]	80 [550]	85 [585]	60 [415]	75 [515]	80 [550]	85 [585]
Elongation in 2 in. or 50 mm, min, %	20	18	16	18	16	20	18	18	20	18	18	18	20	18	18	18
Reduction of area, min, %	38	38	35	45	45	48	45	45	35	35	35	35	35	35	35	35

7.1.6.2 *Method 2—¼ T_C by T_C*. Specimens shall be removed ¼ T_C from the nearest quenched surface and at least T_C from all other surfaces exclusive of the T_C dimension surfaces. Where this method of testing is employed, the following limitations for T_C shall generally apply:

Grades 1 and 1a	3 in. [75 mm], max
Grades 2 Class 2 and 3 Class 2	6 in. [150 mm], max
Grades 2 Class 1 and 3 Class 1	8 in. [205 mm], max
Grade 4N Class 2 and 5 Class 2	16 in. [405 mm], max
Grade 4N Class 1 and 5 Class 1	30 in. [760 mm], max
Grade 4N Class 3	40 in. [1015 mm], max
Grades 3V and 3VCb	20 in. [510 mm], max
Grade 22 Class 3	20 in. [510 mm], max
Grade 22 Classes 4, 5, 6, and 7	12 in. [305 mm], max

7.1.6.3 *Method 3*—Test specimens shall be taken from a representative separate test forging made from the same heat of steel and shall receive substantially the same reduction and type of hot working as the production forgings that it represents and shall have the same T_C as the as-quenched production forgings. The separate test forging shall be heat treated in the same furnace charge and under the same conditions as the production forgings. Test specimens shall be removed from the region midway between the mid-thickness and the surface, and not closer than T_C to a second heat treated surface with the same limitation on forging thickness as in 7.1.6.2. Alternatively, an extra production forging of the same configuration (right and left handed configurations being considered equivalent) as that ordered, may be tested as described in Method 2.

7.1.6.4 *Method 4*—A thermal buffer ring, at least T_C by T_C in cross section, or segments of such a ring at least 3 T_C in length, shall be welded to the test end of a forging prior to heat treatment for mechanical properties. The buffer material may be any weldable carbon or low-alloy steel and shall be joined to the forging with a partial-penetration type weld which completely seals the buffered surface. The test coupons shall be removed from the forging in the region buffered by the ring or ring segments. If ring segments are used, the test coupons shall be removed from the forging in the area under the buffer ring segment at a minimum distance of T_C from each end of that segment. In either case, the test specimens shall be located at a minimum distance of ½ in. [13 mm] from the buffered surface of the forging, and at least ¼ T_C from a quenched surface of the forging. Where this method of testing is employed, the limitations for T_C given in 7.1.6.2 shall generally apply.

NOTE 5—For forgings with a maximum T_C of 2 in. [50 mm], the specimens shall be taken at midthickness and at least 2 in. from a second surface. This provision is applicable to all four methods in 7.1.6.

7.1.7 Tension specimens shall be the standard 0.5 in. [12.5 mm] round by 2 in. [50 mm] gauge length, as shown in Test Methods and Definitions A370.

7.2 *Impact Test*—The steel shall conform to the requirements of Table 3, or Supplementary Requirement S10 may be specified instead of these requirements.

7.2.1 *Number, Location, and Orientation of Specimens:*

7.2.1.1 One set of three Charpy V-notch specimens shall be taken from each tensile specimen location required in 7.1.2. Orientation shall be the same as in 7.1.4. When S10 is specified, the required number of tests shall be governed by NB, NC, ND, NE, NF, or NG 2300, as applicable.

7.2.1.2 The requirements of 7.1.3 also apply to impact specimens.

7.2.1.3 The longitudinal axis and mid-length of the impact specimen shall be located similarly to the longitudinal axis of the tension test specimens as defined in 7.1.6. The axis of the notch shall be normal to the nearest heat-treated surface of the forging. When Supplementary Requirement S10 is specified the orientation shall be governed by NB, NC, ND, NE, NF, or NG 2300.

7.2.2 Impact specimens shall be Charpy V-notch as shown in Test Methods and Definitions A370.

8. Workmanship and Quality Level Requirements

8.1 See requirements in 9.1, 9.2.2, 9.3.1.1, and 9.3.2.2.

9. Nondestructive Inspection Requirements

9.1 *General Requirements*—Dimensional and visual inspections, and magnetic particle and ultrasonic inspection shall be conducted by the manufacturer. Forgings shall be free of cracks, thermal ruptures, or other injurious indications.

9.2 *Magnetic Particle Inspection:*

9.2.1 Following final machining by the manufacturer all accessible surfaces of each forging shall be examined by the continuous current magnetic particle method. This examination shall be in accordance with Practice A275/A275M unless the purchaser has required the use of the AC yoke in accordance with Practice A966/A966M instead (see 4.3.1).

9.2.2 The following conditions are subject to rejection or removal:

9.2.2.1 Indications with major dimension exceeding 3⁄16 in. [4.8 mm].

9.2.2.2 Four or more indications exceeding 1⁄16 in. [1.6 mm] in major dimensions that are aligned and separated by 1⁄16 in. [1.6 mm] or less end to end.

9.2.2.3 Ten or more indications exceeding 1⁄16 in. [1.6 mm] in major dimensions contained in any 6 in.^{2} [39 cm^2] of surface, with the major dimension of this area not to exceed 6 in. [150 mm]. The area shall be taken in the most unfavorable location relative to the indications being evaluated.

9.3 *Ultrasonic Inspection*—Forgings shall be ultrasonically inspected in accordance with the procedures of Practice A388/A388M.

9.3.1 *Longitudinal Wave Inspection:*

9.3.1.1 Unless otherwise specified by Supplementary Requirement S2, the back reflection method of tuning shall be used in accordance with 7.2.2.1 of Practice A388/A388M. In addition to the reportable conditions in Section 7 of Practice A388/A388M, indications exceeding the resultant back reflection shall be recorded. The following conditions are considered rejectable:

9.3.1.2 Complete loss of back reflection not associated with forging configuration or surface and accompanied by an indication of a discontinuity. For this purpose, a back reflection less than 5 % of full screen height shall be considered complete loss of back reflection.

TABLE 3 Charpy Impact Requirements

	Grades 1 and 1a at +40 °F [4.4 °C]	Grades 2 Class 1 and 3 Class 1 at +40 °F [4.4 °C]	Grades 2 Class 2 and 3 Class 2 at +70 °F [21 °C]	Grades 4N (all classes) and 5 (all classes) at −20 °F [−29 °C]	Grade 22, Class 3, and Grades 3V and 3VCb at 0 °F [−18 °C]	Grade 6 Classes 1, 2, 3, and 4 at −75 °F [−59 °C]	Grade 22 Classes 4, 5, 6, and 7 at −75 °F [−60 °C]
Minimum average value of set of three specimens, ft·lbf [J][A]	15 [20]	30 [41]	35 [48]	35 [48]	40 [54]	20 [27]	40 [55]
Minimum value of one specimen, ft lbf [J]	10 [14]	25 [34]	30 [41]	30 [41]	35 [50]	15 [20]	35 [50]

[A] Not more than one specimen from a set may be below this value.

9.3.1.3 Indications whose amplitude equals or exceeds that of the back reflection established in an indication-free area of the forging.

9.3.2 *Angle Beam Inspection:*

9.3.2.1 Calibration notches shall be cut into the inside- and outside-diameter surfaces with a depth equal to 3 % of the nominal section thickness (or ⅜ in. [9.5 mm], max), a length of approximately 1 in. [25 mm], and a width not greater than twice its depth. Adjust instrument controls to obtain an indication from the inside-diameter notch approximately 75 % of full screen height. Measure the amplitude of indication from the outside-diameter notch. Draw a straight line on the shield in front of the cathode ray tube from this peak to that of the inside-diameter notch and continue it as a horizontal line to the initial pulse. This line constitutes the angle beam reference line.

9.3.2.2 A forging containing a discontinuity which results in an indication exceeding the amplitude of the reference line is subject to rejection.

NOTE 6—Signals from discontinuities within approximately ¼ in. [6.4 mm] of inside and outside surfaces are reinforced by wave trapping during angle beam inspection; they are therefore amplified in respect to internal discontinuities.

9.3.3 The report of the ultrasonic inspection shall be in compliance with Section 8 of Practice A388/A388M.

9.3.4 Additional nondestructive inspection or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious indications which will not be removed in final machining.

10. Repair Welding

10.1 Repair welding of forgings may be permitted, but only at the option of the purchaser.

10.2 If repair welding is performed, welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

11. Certification and Reports

11.1 In addition to items to be reported by Specification A788/A788M, the following items shall also be reported:

11.1.1 Product chemical analysis,

11.1.2 The method used for locating test specimens, and

11.1.3 Sketches showing the locations of all recordable indications in the report of all nondestructive examinations.

11.1.3.1 If Practice A966/A966M has been used, this also shall be recorded in the certification.

11.1.4 Details of the heat treatment cycle, as listed in Specification A788/A788M.

12. Product Marking

12.1 The purchaser may specify additional identification marking and the location of the stamping. The type of stamps to be used when impression stamping is performed shall be round-nosed or "interrupted-dot" die stamps having a minimum radius of ¹⁄₃₂ in. [0.8 mm].

13. Keywords

13.1 chromium-molybdenum steel; nickel-chromium-molybdenum alloy steels; pressure vessel service; quenched and tempered steels; steel forgings—alloy; steel forgings—carbon; vacuum-treated steels

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S1.1 All test coupons shall be subjected to single or multiple heat treatments at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, timers, and cooling rates.

S2. Ultrasonic Testing-Reference Block Calibration (for examining sections 24-in. [610 mm] thick or less)

S2.1 Reference blocks of acoustically similar metal shall be used for calibration. Blocks shall meet one of the following requirements:

S2.1.1 A comparison of the back reflections between equivalent thicknesses of the reference block material and the actual forging to be tested, without change in instrument setting shall not show a variation in excess of 25 %.

S2.1.2 The reference blocks shall be manufactured from steel that is similar in chemistry and processing history to the production forging being tested. The reference blocks shall be fabricated in accordance with the procedures of Practice E428.

S2.2 For test sections up to 12 in. [305 mm] thick, the reference blocks shall contain a ¼-in. [6.4-mm] diameter flat-bottom hole; for over 12 to 18 in. [305 to 457 mm], the hole diameter shall be ⅜ in. [9.5 mm]; and for over 18 to 24 in. [457 to 610 mm], it shall be ½ in. [13 mm].

S2.3 A distance-amplitude correction curve shall be established for the proper grade of steel and specified hole size.

S2.4 A forging containing one or more indications equal in amplitude to that of the applicable reference hole, when properly corrected for distance, is subject to rejection.

S3. Charpy V-Notch Impact Transition Curve

S3.1 Sufficient impact tests shall be made from the forging test material to establish a temperature-absorbed energy curve. The test-temperature range shall be wide enough to establish the upper and lower shelf foot-pound energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S4. Additional Charpy Data

S4.1 The percent shear fracture and mils of lateral expansion, defined in Test Methods and Definitions A370, shall be reported for each Charpy specimen tested.

S4.2 Acceptance values for percent shear fracture and/or lateral expansion values shall be as specified by the purchaser.

S5. Alternative Impact Test

S5.1 Charpy impact tests shall be made in accordance with the provisions of 7.2 of the specification except that the test temperature shall be lower than specified in Table 3. This test shall be instead of that specified in 7.2.

S6. Drop-Weight Test

S6.1 Drop-weight tests shall be conducted in accordance with the requirements of Test Method E208. The fracture plane of the specimens shall coincide with the location required for other mechanical test specimens as specified by the purchaser in accordance with 7.1.6. However, since the drop weight specimen can be taken in any orientation, the fracture plane of the specimen when tested to Method 1 (7.1.6.1) shall be a minimum distance of 7⁄16 in. [11 mm] from the nearest quenched surface, and 1½ in. [38 mm] from any second surface. The purchaser may specify either duplicate no-break performance when tested 10 °F [6 °C] warmer than a specified temperature or request a determination of the NDT temperature.

S7. Restrictive Chemistry for Grades 4N and 5

S7.1 Phosphorus and sulfur limits for Grades 4N and 5 shall be 0.015 % maximum heat and 0.018 % maximum product.

S8. Additional Vanadium

S8.1 The vanadium content for Grade 5 forgings shall be 0.05 to 0.15 %.

S9. Restrictive Chemistry for Grades 2, 3, or 4N

S9.1 Grades 2, 3, or 4N shall be specified with restricted phosphorus and copper limits, as follows:

S9.1.1 P 0.012 maximum heat and 0.015 maximum product; Cu 0.10 maximum heat and product, or

S9.1.2 P 0.015 maximum heat and 0.018 maximum product; Cu 0.15 maximum heat and product.

S9.2 Grades 2, 3, 4N shall be specified with restricted sulfur of 0.015 heat and 0.018 product.

S10. Alternative Fracture Toughness Requirements

S10.1 The fracture toughness requirements (drop weight and Charpy impact tests) for materials of the ASME Boiler and Pressure Vessel Code, Section III, Articles NB 2300, NC 2300, ND 2300, NE 2300, NF 2300, or NG 2300, as specified, shall be used instead of the Charpy impact test requirements of this specification.

S11. Vacuum Carbon-Deoxidized Steels

S11.1 Material made to Grades 1, 1a, 2, 3, 4N, or 5 shall be vacuum carbon-deoxidized, in which case the silicon content shall be 0.10 % max. The test report shall indicate that the steel was vacuum carbon-deoxidized.

S12. Vacuum-Treated Basic Oxygen Furnace Steels

S12.1 For Grades 1, 1a, 2, or 3 material, vacuum-treated basic oxygen furnace steel shall be used.

S13. Minimum Tempering Temperature

S13.1 For Grades 2 Class 1 and 3 Class 1 the minimum tempering temperature shall be 1175 °F [635 °C] and the simulated post weld heat treatment temperature shall not exceed 1150 °F [620 °C] when S1 is required.

S14. Cooling from the Tempering Temperature

S14.1 The purchaser shall provide specific cooling rates from the tempering temperature.

S15. Product Analysis

S15.1 More than one forging per heat shall be subject to product analysis by either the manufacturer or purchaser. The purchaser shall indicate in the ordering information the number of forgings to be tested, and whether the manufacturer, purchaser, or both shall perform the additional analyses.

S16. Silicon Content

S16.1 The silicon content shall be 0.05 to 0.15 % as a result of ladle refining with aluminum as the deoxidizer. Use of Vacuum Ladle Degassing is optional.

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SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON AND ALLOY STEEL MECHANICAL TUBING

SA-513

(Identical with ASTM Specification A513-00 except that Supplementary Requirements S6 and either S7 or S8 at the manufacturer's option are mandatory.)

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON AND ALLOY STEEL MECHANICAL TUBING

SA-513

(Identical with ASTM Specification A 513-00 except that Supplementary Requirements S6 and either S7 or S8 at the manufacturer's option are mandatory.)

1. Scope

1.1 This specification covers electric-resistance-welded carbon and alloy steel tubing for use as mechanical tubing.

1.2 This specification covers mechanical tubing made from hot- or cold-rolled steel.

1.3 This specification covers round, square, rectangular, and special shape tubing.

Type	Size Range (Round Tubing)
Electric-Resistance-Welded Tubing from Hot-Rolled Steel	outside diameter from $\frac{1}{2}$ to 15 in. (19.0 to 381.0 mm) wall from 0.065 to 0.650 in. (1.65 to 16.50 mm)
Electric-Resistance-Welded Tubing from Cold-Rolled Steel	outside diameter from $\frac{3}{8}$ to 12 in. (9.92 to 304.8 mm) wall from 0.022 to 0.134 in. (0.71 to 3.40 mm)

1.4 Optional supplementary requirements are provided and when desired, shall be so stated in the order.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ANSI Standard:*

B 46.1 Surface Texture

2.3 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

3. Ordering Information

3.1 Orders for material under this specification should include the following as required to adequately describe the desired material:

3.1.1 Quantity (feet or number of lengths),

3.1.2 Name of material (electric resistance-welded carbon or alloy steel mechanical tubing),

3.1.3 Type, description and code letters, (Section 1 and 12.1),

3.1.4 Thermal condition, (12.2),

3.1.5 Flash condition, (12.3),

3.1.6 Grade designation, if required, (Section 5),

3.1.7 Report chemical analysis and product analysis, if required (Sections 6 and 7),

3.1.8 Individual supplementary requirements, if required (S1 to S10, inclusive),

3.1.9 Cross section (round, square, rectangular and special shapes),

3.1.10 Dimensions, round, outside and inside and wall thickness (see 8.1 and 8.2) or square and rectangular, outside dimension and wall thickness and corner radii, if required (see 9.1 and 9.2),

3.1.11 Surface finish (see 11.2),

3.1.12 Length, round, mill lengths or definite cut length (see 8.3), square and rectangular, specified length (see 9.4),

3.1.13 Squareness of cut, round tubing, if required, (see 8.4),

3.1.14 Burrs removed, if required (see 11.3),

3.1.15 Protective coating (see 14.1),

3.1.16 Special packaging (see 17.1),

3.1.17 Specification designation,

3.1.18 End use,

3.1.19 Special requirements,

3.1.20 Special marking (Section 16), and

3.1.21 Straightness Test Method (see 8.5 and 9.6).

4. Materials and Manufacture

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting, such as electroslag or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

4.5 Tubes shall be made by the electric-resistance-welded process and shall be made from hot- or cold-rolled steel as specified.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Tables 1 and 2. If no grade is specified, Grades MT 1010 to MT 1020 may be furnished. Analyses of steels other than those listed are available. To determine their availability, the purchaser should contact the producer.

5.2 When a carbon steel grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Tables 1 and 2 is not permitted.

6. Heat Analysis

6.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified; if secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The heat analysis shall conform to the requirements specified, except that where the heat identity has not been maintained or where the analysis is not sufficiently complete to permit conformance to be determined, the chemical composition determined from a product analysis made by the tubular manufacturer shall conform to the requirements specified for heat analysis. When requested in the order or contract, a report of such analysis shall be furnished to the purchaser.

7. Product Analysis

7.1 When requested on the purchase order, a product analysis shall be made by the supplier. The number and source of samples for such product analysis shall be based on the individual heat or lot identity of one of the following forms of material:

7.1.1 *Heat Identity Maintained* —One product analysis per heat shall be made on either the flat-rolled stock or tube.

7.1.2 *Heat Identity Not Maintained* —A product from one tube per 2000 ft (610 m) or less for sizes over 3 in. (76.2 mm), and one tube per 5000 ft (150 m) or less for sizes 3 in. and under.

7.2 Samples for product analysis except for spectrochemical analysis shall be taken in accordance with Practice E 1806. The composition thus determined shall correspond to the requirements of Tables 1-3.

7.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise, all remaining material in the heat or lot shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

8. Permissible Variations in Dimensions for Round Tubing

8.1 *Diameter and Wall Thickness (Hot-Rolled Steel)* — Variations from specified outside diameter for "as-welded" and “as-welded and annealed” tubing made from hot-rolled steel shall not exceed the amounts prescribed in Table 4. Permissible variations in outside diameter for tubing that has been sink-drawn for closer tolerance on outside diameter are shown in Table 5. Permissible variations in wall thickness for tubing that has been sink-drawn for closer tolerances on outside diameters are ±10% of the nominal wall or ±0.010 in. (0.25 mm), whichever is greater. Permissible variations in wall thickness for tubing made from hot-rolled steel are shown in Table 6. Permissible variation in outside and inside diameter for tubing made from hot-rolled steel that has been mandrel drawn for closer tolerances are shown in Table 5 with wall tolerances shown in Table 7.

8.2 *Diameter and Wall Thickness (Cold-Rolled Steel)* — Variations in outside diameter and inside diameter of “as-welded” and “as-welded and annealed” tubing made from cold-rolled steel are shown in Table 8. Outside diameter tolerances for cold-rolled steel tubing, sink drawn and mandrel drawn, are shown in Table 5. Wall thickness tolerances for “as-welded” tubing made from cold-rolled steel are shown in Table 9. Permissible variations in wall thickness for round tubing, mandrel drawn for closer tolerances, are shown in Table 7. Permissible variations in wall thickness for tubing that has been sink-drawn for closer tolerances on outside diameter are ±10% of the nominal wall or ±0.010 in. (0.25 mm), whichever is greater.

8.3 *Length (Hot- and Cold-Rolled Steel)* —Mechanical tubing is commonly furnished in mill lengths 5 ft (1.5 m) and over. Definite cut lengths are furnished when specified by the purchaser. Tolerances for definite cut lengths round tubing shall be as given in Tables 10 and 11.

8.4 *Squareness of Cut (Hot- and Cold-Rolled Steel)* — When specified, tolerance for squareness of cut of round tubing shall be as given in Table 12. Measurements are made with use of an “L” square and feeler gage. Side leg of square to be equal to tube diameter except minimum length of 1 in. (25.4 mm) and maximum length of 4 in. (101.6 mm). Outside diameter burr to be removed for measurement.

8.5 *Straightness* —The straightness tolerance for round tubing is 0.030 in./3 ft (0.76 mm/1 m) lengths to 8.000 in. (203 mm) outside diameter. For 8.000 in. outside diameter and above, straightness tolerance is 0.060 in./3 ft (1.52 mm/1 m) lengths. For lengths under 1 ft the straightness tolerance shall be agreed upon between the purchaser and producer. The test method for straightness measurement is at the manufacturer’s option, unless a specific test method is specified in the purchase order.

8.6 *Ovality (Hot- and Cold-Rolled Steel)* —The ovality shall be within the tolerances except when the wall thickness is less than 3% of the outside diameter.

8.6.1 In such cases for Types 1 and 2 (A.W.H.R. and A.W.C.R.) the ovality may be 50% greater than the outside tolerances but the mean outside diameter shall be within the specified tolerance.

8.6.2 For Types 3, 4, 5, and 6 (S.D.H.R., S.D.C.R., M.D., and S.S.I.D.) the additional ovality shall be as follows but the mean outside diameter shall be within the specified tolerance:

Outside Diameter, in. (mm)	Additional Ovality Tolerance, in. (mm)
Up to 2 (50.8), incl.	0.010 (0.25)
Over 2 to 3 (50.8 to 76.2), incl.	0.015 (0.38)
Over 3 to 4 (76.2 to 101.6), incl.	0.020 (0.51)
Over 4 to 5 (101.6 to 127.0), incl.	0.025 (0.64)
Over 5 to 6 (127.0 to 152.4), incl.	0.030 (0.76)
Over 6 to 7 (152.4 to 177.8), incl.	0.035 (0.89)
Over 7 to 8 (177.8 to 203.2), incl.	0.040 (1.02)
Over 8 to 9 (203.2 to 228.6), incl.	0.045 (1.14)
Over 9 to 10 (228.6 to 254.0), incl.	0.050 (1.27)
Over 10 to 11 (254.0 to 279.4), incl.	0.055 (1.40)
Over 11 to 12 (279.4 to 304.8), incl.	0.060 (1.52)
Over 12 to 12.500 (304.8 to 317.5), incl.	0.065 (1.65)

9. Permissible Variations in Dimensions of Square and Rectangular Tubing

9.1 *Diameter and Wall Thickness* —Permissible variations in outside dimensions for square and rectangular tubing shall be as given in Table 13. The wall thickness tolerance is ±10% of the nominal wall thickness.

9.2 *Corner Radii* —Unless otherwise specified, the corners of square and rectangular tubing shall be slightly rounded inside and outside, consistent with wall thickness. The outside corners may be slightly flattened. The radii of corners shall be as given in Table 14.

9.3 *Squareness* —Permissible variations for squareness shall be determined by the following equation:

$$\pm b = c \times 0.006 \text{ in.}$$

where:

b = tolerance for out-of-square, and
c = largest external dimension across flats

The squareness of sides is commonly determined by one of the following methods.

9.3.1 A square with two adjustable contact points on each arm, is placed on two sides. A fixed feeler gage is then used to measure the maximum distance between the free contact point and the surface of the tubing.

9.3.2 A square equipped with a direct reading vernier, may be used to determine the angular deviation which, in turn, may be related to distance in inches.

9.4 *Length* —Variations from the specified length shall not exceed the amount prescribed in Table 15.

9.5 *Twist* —Twist tolerances are shown in Table 16. The twist in square and rectangular tubing may be measured by holding one end of the tubing on a surface plate and noting the height of either corner of the opposite end of same side above the surface plate. Twist may also be measured by the use of a beveled protractor equipped with a level, and noting the angular deviation on opposite ends, or at any point throughout the length.

9.6 *Straightness* —The straightness tolerance is $\frac{1}{16}$ in./ 3 ft (1.7 mm/1 m). The test method for straightness measurement is at the manufacturer's option, unless a specific test method is specified in the purchase order.

10. Tubing Sections Other Than Square and Rectangular

10.1 In addition to square and rectangular tubing, many producers supply a variety of special sections, such as oval, streamlined, hexagonal, octagonal, round inside and hexagonal or octagonal outside, ribbed inside or out, triangular, rounded rectangular and D shapes. Manufacturing practices limit the size range and section available from the various producers. These special sections may be made through turkshead rolls or through a die with or without use of a mandrel. Since the sections are special, dies and other tools are not held available. Therefore, when inquiring for shapes other than square and rectangular, it is essential to give full details as to dimensions and finish.

11. Workmanship, Finish, and Appearance

11.1 The tubing shall be free of injurious defects and shall have a workmanlike finish.

11.2 Unless otherwise specified in the purchase order, the tubing shall be free of scale. In the case of thermally treated tubing a slight amount of color will not be considered cause for rejection.

11.3 When burrs must be removed from one or both ends, it shall be specified in the purchase order.

12. Condition

12.1 The types and conditions of tubing covered by this specification are:

Type Number	Code Letters	Description
1	A.W.H.R.	"as-welded" from hot-rolled steel
2	A.W.C.R.	"as-welded" from cold-rolled steel
3	S.D.H.R.	"sink-drawn" hot-rolled steel
4	S.D.C.R.	"sink-drawn," cold-rolled steel
5	M.D.	mandrel drawn
6	S.S.I.D.	special smooth inside diameter

12.2 Thermal conditions under which tubing may be furnished are: no final thermal treatment, stress relieved, and annealed or normalized.

12.3 Flash conditions under which tubing may be furnished are as follows. The flash shall be removed from the outside diameter of tubing covered by this specification. Tubing furnished to this specification may have the following conditions of welding flash on the inside diameter.

12.3.1 *Flash-In* —Tubing in which the inside diameter welding flash does not exceed the wall thickness or $\frac{3}{32}$ in. (2.4 mm), whichever is less. This condition is available in Types 1, 2, 3, and 4.

12.3.2 *Flash Controlled to 0.010 in. (0.25 mm), Maximum* —Tubing in which the height of the remaining welding flash is controlled so as not to exceed 0.010 in. This condition is available in Types 1 and 2 over $1\frac{1}{8}$ in. (28.5 mm) outside diameter and Types 3 and 4.

12.3.3 *Flash Controlled to 0.005 in. (0.13 mm), Maximum* —Tubing produced to outside diameter and wall thickness, inside diameter and wall thickness, or outside diameter and inside diameter tolerances which are so controlled that the height of the remaining inside diameter flash does not exceed 0.005 in. Any remaining inside diameter flash is part of the applicable inside diameter tolerance. This condition is available in Types 1, 2, 3, and 4.

12.3.4 *No Flash* —Tubing further processed for closer tolerances with mandrel tubing produced to outside diameter and wall thickness, inside diameter and wall thickness, or outside diameter and inside diameter to tolerances with no dimensional indication of inside diameter flash. This condition is available in Types 5 and 6.

12.4 Tubes shall be furnished in the following shapes, as specified by the purchaser: round, square, rectangular, or special shapes (as negotiated).

13. Surface Finish

13.1 Tubes shall have a surface finish compatible with the conditions (Section 12) to which they are ordered (see Appendix X1).

14. Coating

14.1 When specified, tubing shall be coated with a film of oil before shipping to retard rust. Should the order specify that tubing be shipped without rust retarding oil, the film of oils incidental to manufacture will remain on the surface. If the order specifies no oil, the purchaser assumes responsibility for rust in transit.

14.2 Special surface preparations as may be required for specific applications are not within the scope of this section. Such requirements shall be considered under the supplementary or basis of purchase provisions of this specification and details shall be provided in the purchase order.

15. Rejection

15.1 Tubes that fail to meet the requirements of this specification shall be set aside and the producer shall be notified.

16. Product and Package Marking

16.1 *Civilian Procurement* —Each box, bundle, lift, or piece shall be identified by a tag or stencil with manufacturers name or brand, specified size, type, purchaser's order number, and this specification number. Bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

16.2 *Government Procurement* —When specified in the contract or order, and for direct procurement by or direct shipment to the Government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for Military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

16.3 *Bar Coding* —In addition to the requirements in 16.1 and 16.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

17. Packaging

17.1 *Civilian Procurement* —On tubing 16 gage (1.29 mm) and lighter, the producer will determine whether or not the tubing will be boxed, crated, cartoned, packaged in secured lifts, or bundled to ensure safe delivery unless otherwise instructed. Tubing heavier than 16 gage will normally be shipped loose, bundled, or in secured lifts. Special packaging requiring extra operations other than those normally used by a producer must be specified on the order.

17.2 *Government Procurement* —When specified in the contract or order, and for direct procurement by or direct shipment to the Government when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

18. Keywords

18.1 alloy steel tube; carbon steel tube; mechanical tubing; resistance welded steel tube; steel tube; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS FOR STANDARD LOW-CARBON STEELS [A]

	Chemical Composition Limits, %			
Grade Designation	Carbon	Manganese	Phosphorus, Max.	Sulfur, Max.
MT[B] 1010	0.05–0.15	0.30–0.60	0.035	0.035
MT 1015	0.10–0.20	0.30–0.60	0.035	0.035
MT X 1015	0.10–0.20	0.60–0.90	0.035	0.035
MT 1020	0.15–0.25	0.30–0.60	0.035	0.035
MT X 1020	0.15–0.25	0.70–1.00	0.035	0.035

NOTE 1—Chemistry represents heat analysis. Product analysis, except for rimmed or capped steel, is to be in accordance with usual practice as shown in Table 3.

NOTES:

[A] Rimmed or capped steels which may be used for the above grades are characterized by a lack of uniformity in their chemical composition, and for this reason product analysis is not technologically appropriate unless misapplication is clearly indicated.

[B] The letters MT under grade designation indicate Mechanical Tubing.

TABLE 2
CHEMICAL REQUIREMENTS FOR OTHER CARBON AND ALLOY STEELS [A]

Grade Designation	Chemical Composition Limits, %							
	Carbon	Manganese	Phosphorus, Max.	Sulfur, Max.	Silicon	Nickel	Chromium	Molybdenum
1008	0.10 max.	0.50 max.	0.035	0.035	. . .	. . .	. . .	. . .
1010	0.08–0.13	0.30–0.60	0.035	0.035	. . .	. . .	. . .	. . .
1012	0.10–0.15	0.30–0.60	0.035	0.035	. . .	. . .	. . .	. . .
1015	0.12–0.18	0.30–0.60	0.035	0.035	. . .	. . .	. . .	. . .
1016	0.12–0.18	0.60–0.90	0.035	0.035	. . .	. . .	. . .	. . .
1017	0.14–0.20	0.30–0.60	0.035	0.035	. . .	. . .	. . .	. . .
1018	0.14–0.20	0.60–0.90	0.035	0.035	. . .	. . .	. . .	. . .
1019	0.14–0.20	0.70–1.00	0.035	0.035	. . .	. . .	. . .	. . .
1020	0.17–0.23	0.30–0.60	0.035	0.035	. . .	. . .	. . .	. . .
1021	0.17–0.23	0.60–0.90	0.035	0.035	. . .	. . .	. . .	. . .
1022	0.17–0.23	0.70–1.00	0.035	0.035	. . .	. . .	. . .	. . .
1023	0.19–0.25	0.30–0.60	0.035	0.035	. . .	. . .	. . .	. . .
1024	0.18–0.25	1.30–1.65	0.035	0.035	. . .	. . .	. . .	. . .
1025	0.22–0.28	0.30–0.60	0.035	0.035	. . .	. . .	. . .	. . .
1026	0.22–0.28	0.60–0.90	0.035	0.035	. . .	. . .	. . .	. . .
1027	0.22–0.29	1.20–1.55	0.035	0.035	. . .	. . .	. . .	. . .
1030	0.27–0.34	0.60–0.90	0.035	0.035	. . .	. . .	. . .	. . .
1033	0.29–0.36	0.70–1.00	0.035	0.035	. . .	. . .	. . .	. . .
1035	0.31–0.38	0.60–0.90	0.035	0.035	. . .	. . .	. . .	. . .
1040	0.36–0.44	0.60–0.90	0.040	0.050	. . .	. . .	. . .	. . .
1050	0.47–0.55	0.60–0.90	0.040	0.050	. . .	. . .	. . .	. . .
1060	0.55–0.66	0.60–0.90	0.040	0.050	. . .	. . .	. . .	. . .
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15–0.35	. . .	. . .	. . .
1524	0.18–0.25	1.35–1.65	0.040	0.050	. . .	. . .	. . .	. . .
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	. . .	0.40–0.60	0.08–0.15
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.15–0.35	. . .	0.80–1.10	0.15–0.25
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.15–0.35	. . .	0.80–1.10	0.15–0.25
5130	0.23–0.33	0.70–0.90	0.035	0.040	0.15–0.35	. . .	0.80–1.10	. . .
8620	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8630	0.28–0.33	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25

NOTE 1— Chemistry represents heat analysis. Product analysis, except for rimmed or capped steel, is to be in accordance with usual practice as shown in Table 3.

NOTE:
[A] Where the ellipsis (. . .) appears in this table, there is no requirement.

TABLE 3
TOLERANCES FOR PRODUCT ANALYSYS FOR STEELS SHOWN IN TABLES 1 AND 2[A, B]

Element	Limit, or Maximum of Specified Range, %	Variation, Over the Maximum Limit or Under the Minimum Limit	
		Under Min., %	Over Max., %
Carbon	to 0.15, incl.	0.02	0.03
	over 0.15 to 0.40, incl.	0.03	0.04
	over 0.40 to 0.55, incl.	0.03	0.05
Manganese	to 0.60, incl.	0.03	0.03
	over 0.60 to 1.15, incl.	0.04	0.04
	over 1.15 to 1.65, incl.	0.05	0.05
Phosphorus		. . .	0.01
Sulfur		. . .	0.01
Silicon	to 0.30, incl.	0.02	0.03
	over 0.30 to 0.60	0.05	0.05
Nickel	to 1.00, incl.	0.03	0.03
Chromium	to 0.90, incl.	0.03	0.03
	over 0.90 to 2.10, incl.	0.05	0.05
Molybdenum	to 0.20, incl.	0.01	0.01
	over 0.20 to 0.40, incl.	0.02	0.02

NOTES:
[A] Individual determinations may vary from the specified heat limits or ranges to the extent shown in this table, except that any element in a heat may not vary both above and below a specified range.
[B] Where the ellipsis (. . .) appears in this table, there is no requirement.

TABLE 4
DIAMETER TOLERANCES FOR TYPE I (A.W.H.R.) ROUND TUBING

Outside Diameter Range, in.[A]	Wall Thickness Bwg[F]	Wall Thickness In.[A]	Flash-in-Tubing[B, C] Outside Diameter, ±	Flash Controlled to 0.010 in. Max. Tubing[C, D] Outside Diameter, ±	Flash Controlled to 0.005 in. Max. Tubing[E, D] Outside Diameter, ±	Flash Controlled to 0.005 in. Max. Tubing[E, D] Inside Diameter, ±
			Tolerance, in.[A, G]			
½ to 1⅛, incl.	16 to 10	0.065 to 0.134	0.0035	0.0035	0.0035	0.020
Over 1⅛ to 2, incl.	16 to 14	0.065 to 0.083	0.005	0.005	0.005	0.021
Over 1⅛ to 2, incl.	13 to 7	0.095 to 0.180	0.005	0.005	0.005	0.025
Over 1⅛ to 2, incl.	6 to 5	0.203 to 0.220	0.005	0.005	0.005	0.029
Over 1⅛ to 2, incl.	4 to 3	0.238 to 0.259	0.005	0.005	0.005	0.039
Over 2 to 2½, incl.	16 to 14	0.065 to 0.083	0.006	0.006	0.006	0.022
Over 2 to 2½, incl.	13 to 5	0.095 to 0.220	0.006	0.006	0.006	0.024
Over 2 to 2½, incl.	4 to 3	0.238 to 0.259	0.006	0.006	0.006	0.040
Over 2½ to 3, incl.	16 to 14	0.065 to 0.083	0.008	0.008	0.008	0.024
Over 2½ to 3, incl.	13 to 5	0.095 to 0.220	0.008	0.008	0.008	0.026
Over 2½ to 3, incl.	4 to 3	0.238 to 0.259	0.008	0.008	0.008	0.040
Over 2½ to 3, incl.	2 to 0.320	0.284 to 0.320	0.010	0.010	0.010	0.048
Over 3 to 3½, incl.	16 to 14	0.065 to 0.083	0.009	0.009	0.009	0.025
Over 3 to 3½, incl.	13 to 5	0.095 to 0.220	0.009	0.009	0.009	0.027
Over 3 to 3½, incl.	4 to 3	0.238 to 0.259	0.009	0.009	0.009	0.043
Over 3 to 3½, incl.	2 to 0.360	0.284 to 0.360	0.012	0.012	0.012	0.050
Over 3½ to 4, incl.	16 to 14	0.065 to 0.083	0.010	0.010	0.010	0.026
Over 3½ to 4, incl.	13 to 5	0.095 to 0.220	0.010	0.010	0.010	0.028
Over 3½ to 4, incl.	4 to 3	0.238 to 0.259	0.010	0.010	0.010	0.044
Over 3½ to 4, incl.	2 to 0.500	0.284 to 0.500	0.015	0.015	0.015	0.053
Over 4 to 5, incl.	16 to 14	0.065 to 0.083	0.020	0.020	0.020	0.036
Over 4 to 5, incl.	13 to 5	0.095 to 0.220	0.020	0.020	0.020	0.045
Over 4 to 5, incl.	4 to 3	0.238 to 0.259	0.020	0.020	0.020	0.054
Over 4 to 5, incl.	2 to 0.500	0.284 to 0.500	0.020	0.020	0.020	0.058
Over 5 to 6, incl.	16 to 10	0.065 to 0.134	0.020	0.020	0.020	0.036
Over 5 to 6, incl.	9 to 5	0.148 to 0.220	0.020	0.020	0.020	0.040
Over 5 to 6 incl.	4 to 3	0.238 to 0.259	0.020	0.020	0.020	0.054
Over 5 to 6, incl.	2 to 0.500	0.284 to 0.500	0.020	0.020	0.020	0.058
Over 6 to 8, incl.	11 to 10	0.120 to 0.134	0.025	0.025	0.025	0.043
Over 6 to 8, incl.	9 to 5	0.148 to 0.220	0.025	0.025	0.025	0.045
Over 6 to 8, incl.	4 to 3	0.238 to 0.259	0.025	0.025	0.025	0.059
Over 6 to 8, incl.	2 to 0.500	0.284 to 0.500	0.025	0.025	0.025	0.063
Over 8 to 10, incl.	14 to 12	0.083 to 0.109	0.030	0.030	0.030	0.041
Over 8 to 10, incl.	11 to 10	0.120 to 0.134	0.030	0.030	0.030	0.043
Over 8 to 10, incl.	9 to 5	0.148 to 0.220	0.030	0.030	0.030	0.045
Over 8 to 10, incl.	4 to 3	0.238 to 0.259	0.030	0.030	0.030	0.059
Over 8 to 10, incl.	2 to 0.500	0.248 to 0.500	0.030	0.030	0.030	0.063
Over 10 to 12, incl.	14 to 12	0.083 to 0.109	0.035	0.035	0.035	0.041
Over 10 to 12, incl.	11 to 10	0.120 to 0.134	0.035	0.035	0.035	0.043
Over 10 to 12, incl.	9 to 5	0.148 to 0.220	0.035	0.035	0.035	0.045
Over 10 to 12, incl.	4 to 3	0.238 to 0.259	0.035	0.035	0.035	0.059
Over 10 to 12, incl.	2 to 0.500	0.284 to 0.500	0.035	0.035	0.035	0.063

NOTE 1—Measurements for diameter are to be taken at least 2 in. from the ends of the tubes.

NOTES:

[A] 1 in. = 25.4 mm.

[B] Flash-In-Tubing is produced only to outside diameter tolerances and wall thickness tolerances and the inside diameter welding flash does not exceed the wall thickness or 3⁄32 in., whichever is less.

[C] Flash Controlled to 0.010 in. maximum tubing consists of tubing which is commonly produced only to outside diameter tolerances and wall thickness tolerances, in which the height of the remaining welding flash is controlled not to exceed 0.010 in.

[D] No Flash tubing is further processed for closer tolerances with mandrel-tubing produced to outside diameter and wall, inside diameter and wall, or outside diameter and inside diameter to tolerances with no dimensional indication of inside diameter flash. This condition is available in Types 5 and 6.

[E] Flash Controlled to 0.005 in. maximum tubing is produced to outside diameters and wall thickness tolerance, inside diameter and wall thickness tolerances, or outside diameters and inside diameter tolerances, in which the height of the remaining flash is controlled not to exceed 0.005 in. Any remaining flash is considered to be part of the applicable inside diameter tolerances.

[F] Birmingham Wire Gage.

[G] The ovality shall be within the above tolerances except when the wall thickness is less than 3% of the outside diameter, in such cases see 8.6.1.

TABLE 5
DIAMETER TOLERANCES FOR TYPES 3, 4, 5, AND 6 (S.D.H.R., S.D.C.R., M.D. AND S.S.I.D) ROUND TUBING

NOTE 1—Measurements for diameter are to be taken at least 2 in. from the ends of the tubes.

OD Size Range [A]	Wall % of OD	Types 3, 4, (Sink Drawn)[A,B] and 5, 6, (Mandrel Drawn)[B,C] OD, in.		Types 5 and 6 (Mandrel Drawn)[B,C,D] ID in.	
		Over	Under	Over	Under
Up to 0.499	all	0.004	0.000	. . .	. . .
0.500 to 1.699	all	0.005	0.000	0.000	0.005
1.700 to 2.099	all	0.006	0.000	0.000	0.006
2.100 to 2.499	all	0.007	0.000	0.000	0.007
2.500 to 2.899	all	0.008	0.000	0.000	0.008
2.900 to 3.299	all	0.009	0.000	0.000	0.009
3.300 to 3.699	all	0.010	0.000	0.000	0.010
3.700 to 4.099	all	0.011	0.000	0.000	0.011
4.100 to 4.499	all	0.012	0.000	0.000	0.012
4.500 to 4.899	all	0.013	0.000	0.000	0.013
4.900 to 5.299	all	0.014	0.000	0.000	0.014
5.300 to 5.549	all	0.015	0.000	0.000	0.015
5.550 to 5.999	under 6	0.010	0.010	0.010	0.010
	6 and over	0.009	0.009	0.009	0.009
6.000 to 6.499	under 6	0.013	0.013	0.013	0.013
	6 and over	0.010	0.010	0.010	0.010
6.500 to 6.999	under 6	0.015	0.015	0.015	0.015
	6 and over	0.012	0.012	0.012	0.012
7.000 to 7.499	under 6	0.018	0.018	0.018	0.018
	6 and over	0.013	0.013	0.013	0.013
7.500 to 7.999	under 6	0.020	0.020	0.020	0.020
	6 and over	0.015	0.015	0.015	0.015
8.000 to 8.499	under 6	0.023	0.023	0.023	0.023
	6 and over	0.016	0.016	0.016	0.016
8.500 to 8.999	under 6	0.025	0.025	0.025	0.025
	6 and over	0.017	0.017	0.017	0.017
9.000 to 9.499	under 6	0.028	0.028	0.028	0.028
	6 and over	0.019	0.019	0.019	0.019
9.500 to 9.999	under 6	0.030	0.030	0.030	0.030
	6 and over	0.020	0.020	0.020	0.020
10.000 to 10.999	all	0.034	0.034	0.034	0.034
11.000 to 11.999	all	0.035	0.035	0.035	0.035
12.000 to 12.999	all	0.036	0.036	0.036	0.036
13.000 to 13.999	all	0.037	0.037	0.037	0.037
14.000 to 14.999	all	0.038	0.038	0.038	0.038

NOTES:

[A] Tubing, flash in or flash controlled which is further processed without mandrel to obtain tolerances closer than those shown in Tables 4 and 8.

[B] The ovality shall be within the above tolerances except when the wall thickness is less than 3% of the outside diameter, in such cases see 8.6.2.

[C] Tubing produced to outside diameter and wall thickness, or inside diameter and wall thickness, or outside diameter and inside diameter, with mandrel to obtain tolerances closer than those shown in Tables 4 and 8 and no dimensional indication of inside diameter flash.

[D] Where the ellipsis (. . .) appears in this table, the tolerance is not addressed.

TABLE 6
WALL THICKNESS TOLERANCE FOR TYPE I (A.W.H.R.) ROUND TUBING

Wall Thickness		Outside Diameter, in.[A]															
		¾ to 1, Incl.		Over 1 to 1$^{15}/_{16}$, Incl.		Over 1$^{15}/_{16}$, to 3¾, Incl.		Over 3¾, to 4½, Incl.		Over 4½, to 6, Incl.		Over 6 to 8, Incl.		Over 8 to 10, Incl.		Over 10 to 12, Incl.	
		Wall Thickness Tolerances, in., ±[C]															
in.[A]	Bwg[B]	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
0.065	16	0.005	0.009	0.004	0.010	0.003	0.011	0.002	0.012	0.002	0.012	0.002	0.012	. . .	. . .	. . .	. . .
0.072	15	0.005	0.009	0.004	0.010	0.003	0.011	0.002	0.012	0.002	0.012	0.002	0.012	0.003	0.013	. . .	. . .
0.083	14	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.095	13	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.109	12	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.120	11	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.134	10	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.148	9	. . .	. . .	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.165	8	. . .	. . .	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.180	7	. . .	. . .	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.203	6	. . .	. . .	. . .	. . .	0.007	0.015	0.006	0.016	0.005	0.017	0.005	0.017	0.005	0.017	0.005	0.017
0.220	5	. . .	. . .	. . .	. . .	0.007	0.015	0.006	0.016	0.005	0.017	0.005	0.017	0.005	0.017	0.005	0.017
0.238	4	. . .	. . .	. . .	. . .	0.012	0.020	0.011	0.021	0.010	0.022	0.010	0.022	0.010	0.022	0.010	0.022
0.259	3	. . .	. . .	. . .	. . .	0.013	0.021	0.012	0.022	0.011	0.023	0.011	0.023	0.011	0.023	0.011	0.023
0.284	2	. . .	. . .	. . .	. . .	0.014	0.022	0.013	0.023	0.012	0.024	0.012	0.024	0.012	0.024	0.012	0.024
0.300	1	. . .	. . .	. . .	. . .	0.015	0.023	0.014	0.024	0.013	0.025	0.013	0.025	0.013	0.025	0.013	0.025
0.320		. . .	. . .	. . .	. . .	0.016	0.024	0.015	0.025	0.014	0.026	0.014	0.026	0.014	0.026	0.014	0.026
0.344		. . .	. . .	. . .	. . .	0.017	0.025	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.360		. . .	. . .	. . .	. . .	0.017	0.025	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.375		. . .	. . .	. . .	. . .	. . .	. . .	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.406		. . .	. . .	. . .	. . .	. . .	. . .	0.017	0.027	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.438		. . .	. . .	. . .	. . .	. . .	. . .	0.017	0.027	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.469		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.500		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028

NOTES:

[A] 1 in. = 25.4 mm.

[B] Birmingham Wire Gage.

[C] Where the ellipsis (. . .) appears in this table, the tolerance is not addressed.

TABLE 7
WALL THICKNESS TOLERANCES OF TYPES 5 AND 6 (M.D. AND S.S.I.D.) ROUND TUBING

Wall thickness		Outside Diameter, in.[A] $\frac{3}{8}$ to $\frac{7}{8}$, Incl.		Over $\frac{7}{8}$ to $1\frac{7}{8}$, Incl.		Over $1\frac{7}{8}$ to $3\frac{3}{4}$, Incl.		Over $3\frac{3}{4}$ to 15, Incl.	
		Wall Thickness Tolerances, in.,[A, C] ±							
in.[A]	Bwg[B]	+	−	+	−	+	−	+	−
0.035	20	0.002	0.002	0.002	0.002	0.002	0.002	...	...
0.049	18	0.002	0.002	0.002	0.003	0.002	0.003	...	...
0.065	16	0.002	0.002	0.002	0.003	0.002	0.003	0.004	0.004
0.083	14	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.005
0.095	13	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.005
0.109	12	0.002	0.003	0.002	0.004	0.003	0.003	0.005	0.005
0.120	11	0.003	0.003	0.002	0.004	0.003	0.003	0.005	0.005
0.134	10	...	...	0.002	0.004	0.003	0.003	0.005	0.005
0.148	9	...	...	0.002	0.004	0.003	0.003	0.005	0.005
0.165	8	...	...	0.003	0.004	0.003	0.004	0.005	0.006
0.180	7	...	...	0.004	0.004	0.003	0.005	0.006	0.006
0.203	6	...	...	0.004	0.005	0.004	0.005	0.006	0.007
0.220	5	...	...	0.004	0.006	0.004	0.006	0.007	0.007
0.238	4	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.259	3	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.284	2	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.300	1	...	...	0.006	0.006	0.006	0.006	0.008	0.008
0.320		...	...	0.007	0.007	0.007	0.007	0.008	0.008
0.344		...	...	0.008	0.008	0.008	0.008	0.009	0.009
0.375		...	...	...	...	0.009	0.009	0.009	0.009
0.400		...	...	...	...	0.010	0.010	0.010	0.010
0.438		...	...	...	...	0.011	0.011	0.011	0.011
0.460		...	...	...	...	0.012	0.012	0.012	0.012
0.480		...	...	...	...	0.012	0.012	0.012	0.012
0.531		...	...	...	...	0.013	0.013	0.013	0.013
0.563		...	...	...	...	0.013	0.013	0.013	0.013
0.580		...	...	...	...	0.014	0.014	0.014	0.014
0.600		...	...	...	...	0.015	0.015	0.015	0.015
0.625		...	...	...	...	0.016	0.016	0.016	0.016
0.650		...	...	...	0.017	0.017	0.017	0.017	...

NOTES:
[A] 1 in. = 25.4 mm.
[B] Birmingham Wire Gage.
[C] Where the ellipsis (. . .) appears in this table, the tolerance is not addressed.

TABLE 8
DIAMETER TOLERANCES FOR TYPE 2 (A.W.C.R.) ROUND TUBING

Outside Diameter Range, in.[A]	Wall Thickness: Bwg[A]	Wall Thickness: in.[E]	Flash-In-Tubing [B]: Outside Diameter, ±	Flash Controlled to 0.010 in. Max. Tubing [C]: Outside Diameter, ±	Flash Controlled[D] to 0.005 in. Max. Tubing: Outside Diameter, ±	Flash Controlled[D] to 0.005 in. Max. Tubing: Inside Diameter, ±
			Tolerance, in.[F, G]			
3/8 to 5/8, incl.	24 to 16	0.022 to 0.065	0.003	. . .	. . .	. . .
Over 5/8 to 1 1/8, incl.	24 to 19	0.022 to 0.042	0.0035	0.0035	0.0035	0.013
Over 5/8 to 1 1/8, incl.	18	0.049	0.0035	0.0035	0.0035	0.015
Over 5/8 to 1 1/8, incl.	16 to 14	0.065 to 0.083	0.0035	0.0035	0.0035	0.019
Over 3/4 to 1 1/8, incl.	13	0.095	0.0035	0.0035	0.0035	0.019
Over 7/8 to 1 1/8, incl.	12 to 11	0.109 to 0.120	0.0035	0.0035	0.0035	0.021
Over 1 1/8 to 2, incl.	22 to 18	0.028 to 0.049	0.005	0.005	0.005	0.015
Over 1 1/8 to 2, incl.	16 to 13	0.065 to 0.095	0.005	0.005	0.005	0.019
Over 1 1/8 to 2, incl.	12 to 10	0.109 to 0.134	0.005	0.005	0.005	0.022
Over 2 to 2 1/2, incl.	20 to 18	0.035 to 0.049	0.006	0.006	0.006	0.016
Over 2 to 2 1/2, incl.	16 to 13	0.065 to 0.095	0.006	0.006	0.006	0.020
Over 2 to 2 1/2, incl.	12 to 10	0.109 to 0.134	0.006	0.006	0.006	0.023
Over 2 1/2 to 3, incl.	20 to 18	0.035 to 0.049	0.008	0.008	0.008	0.018
Over 2 1/2 to 3, incl.	16 to 13	0.065 to 0.095	0.008	0.008	0.008	0.022
Over 2 1/2 to 3, incl.	12 to 10	0.109 to 0.134	0.008	0.008	0.008	0.025
Over 3 to 3 1/2, incl.	20 to 18	0.035 to 0.049	0.009	0.009	0.009	0.019
Over 3 to 3 1/2, incl.	16 to 13	0.065 to 0.095	0.009	0.009	0.009	0.023
Over 3 to 3 1/2, incl.	12 to 10	0.109 to 0.134	0.009	0.009	0.009	0.026
Over 3 1/2 to 4, incl.	20 to 18	0.035 to 0.049	0.010	0.010	0.010	0.020
Over 3 1/2 to 4, incl.	16 to 13	0.065 to 0.095	0.010	0.010	0.010	0.024
Over 3 1/2 to 4, incl.	12 to 10	0.109 to 0.134	0.010	0.010	0.010	0.027
Over 4 to 6, incl.	16 to 13	0.065 to 0.095	0.020	0.020	0.020	0.034
Over 4 to 6, incl.	12 to 10	0.109 to 0.134	0.020	0.020	0.020	0.037
Over 6 to 8, incl.	14 to 13	0.083 to 0.095	0.025	0.025	0.025	0.039
Over 6 to 8, incl.	12 to 10	0.109 to 0.134	0.025	0.025	0.025	0.042
Over 8 to 10, incl.	16 to 13	0.065 to 0.095	0.030	0.030	0.030	0.044
Over 8 to 10, incl.	12 to 10	1.109 to 0.134	0.030	0.030	0.030	0.049
Over 10 to 12, incl.	14 to 13	0.083 to 0.095	0.035	0.035	0.035	0.049
Over 10 to 12, incl.	12 to 10	0.109 to 0.134	0.035	0.035	0.035	0.054

NOTE 1 — Measurements for diameter are to be taken at least 2 in. from the ends of the tubes.[A]

NOTES:

[A] 1 in. = 25.4 mm.

[B] Flash-In-Tubing is produced to outside diameter tolerances and wall thickness tolerances only, and the height of the inside welding flash does not exceed the wall thickness or 3/32 in., whichever is less.

[C] Flash Controlled to 0.010 in. maximum tubing consists of tubing over 5/8 in. outside diameter which is commonly produced to outside diameter tolerances and wall thickness tolerances only, in which the height of the remaining inside welding flash is controlled not to exceed 0.010 in.

[D] Flash Controlled to 0.005 in. maximum tubing is produced to outside diameter tolerances and wall thickness tolerances, inside diameter tolerances and wall thickness tolerances, or outside diameter tolerances and inside diameter tolerances, in which the height of the remaining inside welding flash is controlled not to exceed 0.005 in. Any remaining flash is considered to be part of the applicable inside diameter tolerances.

[E] Birmingham Wire Gage.

[F] The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in such cases see 8.6.1.

[G] Where the ellipsis (. . .) appears in this table, the tolerance is not addressed.

TABLE 9
WALL THICKNESS TOLERANCES FOR TYPE 2 (A.W.C.R.) ROUND TUBING

Wall thickness		Outside Diameter, in. [A]															
		$\frac{3}{8}$ to $\frac{7}{8}$, Incl.		Over $\frac{7}{8}$ to $1\frac{7}{8}$, Incl.		Over $1\frac{7}{8}$, to $3\frac{3}{4}$, Incl.		Over $3\frac{3}{4}$, to 5, Incl.		Over 5, to 6, Incl.		Over 6 to 8, Incl.		Over 8 to 10, Incl.		Over 10 to 12, Incl.	
		Wall Thickness Tolerances, in., [A, C] ±															
in.[A]	Bwg[B]	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
0.022	24	0.001	0.005	0.001	0.005	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .				
0.028	22	0.001	0.005	0.001	0.005	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
0.035	20	0.002	0.005	0.001	0.005	0.001	0.005	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
0.042	19	0.002	0.006	0.001	0.006	0.001	0.006	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
0.049	18	0.003	0.006	0.002	0.006	0.002	0.006	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
0.065	16	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	. . .	. . .	0.004	0.008	. . .	. . .
0.083	14	0.006	0.007	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.008	0.004	0.008	0.004	0.008	0.004	0.008
0.095	13	0.006	0.007	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.008	0.004	0.008	0.004	0.008	0.004	0.008
0.109	12	. . .	. . .	0.006	0.008	0.005	0.008	0.005	0.008	0.005	0.009	0.005	0.009	0.005	0.009	0.005	0.009
0.120	11	. . .	. . .	0.007	0.008	0.006	0.008	0.005	0.008	0.005	0.009	0.005	0.009	0.005	0.009	0.005	0.009
0.134	10	. . .	. . .	0.007	0.008	0.006	0.008	0.005	0.008	0.005	0.009	0.005	0.009	0.005	0.009	0.005	0.009

NOTES:

[A] 1 in. = 25.4 mm.

[B] Birmingham Wire Gage.

[C] Where the ellipsis appears in this table, the tolerance is not addressed.

TABLE 10
CUT-LENGTH TOLERANCES FOR LATHE-CUT ROUND TUBING

Outside Diameter Size, in.[A]	6 in. and Under 12 in.	12 in. and Under 48 in.	48 in. and Under 10 ft	10 ft to 24 ft Incl.[B]
$^3/_8$ to 3 incl.	± $^1/_{64}$ in.	± $^1/_{32}$ in.	± $^3/_{64}$ in.	± $^1/_8$ in.
Over 3 to 6, incl.	± $^1/_{32}$ in.	± $^3/_{64}$ in.	± $^1/_{16}$ in.	± $^1/_8$ in.
Over 6 to 9, incl.	± $^1/_{16}$ in.	± $^1/_{16}$ in.	± $^1/_8$ in.	± $^1/_8$ in.
Over 9 to 12, incl.	± $^3/_{32}$ in.	± $^3/_{32}$ in.	± $^1/_8$ in.	± $^1/_8$ in.

NOTES:
[A] 1 in. = 25.4 mm.
[B] For each additional 10 ft or fraction thereof over 24 ft, an additional allowance should be made of plus or minus $^1/_{16}$ in.

TABLE 11
LENGTH TOLERANCES FOR PUNCH-, SAW-, or DISC-CUT ROUND TUBING

Outside Diameter Size, in.[A]	6 in. and Under 12 in.	12 in. and Under 48 in.	48 in. and Under 10 ft	10 ft to 24 ft Incl.
$^3/_8$ to 3, incl.	± $^1/_{16}$ in.	± $^1/_{16}$ in.	± $^1/_8$ in.	± $^1/_4$ in.
Over 3 to 6, incl.	± $^1/_{16}$ in.	± $^1/_{16}$ in.	± $^1/_8$ in.	± $^1/_4$ in.
Over 6 to 9, incl.	± $^1/_{16}$ in.	± $^1/_{16}$ in.	± $^1/_8$ in.	± $^1/_4$ in.
Over 9 to 12, incl.	± $^1/_{16}$ in.	± $^1/_{16}$ in.	± $^1/_8$ in.	± $^1/_4$ in.

NOTE:
[A] 1 in. = 25.4 mm.

TABLE 12
TOLERANCE (INCH) FOR SQUARENESS OF CUT (EITHER END) WHEN SPECIFIED FOR ROUND TUBING[A, B]

Length of Tube, ft[C]	Outside Diameter, in.[D] Under 1	1 to 2, Incl.	Over 2 to 3, Incl.	Over 3 to 4, Incl.	Over 4
Under 1	0.006	0.008	0.010	0.015	0.020
1 to 3, incl.	0.008	0.010	0.015	0.020	0.030
Over 3 to 6, incl.	0.010	0.015	0.020	0.025	0.040
Over 6 to 9, incl.	0.015	0.020	0.025	0.030	0.040

NOTES:
[A] Actual squareness normal to length of tube, not parallelness of both ends.
[B] Values given are "go" value of feeler gage. "No go" value is 0.001 in. greater in each case.
[C] 1 ft = 0.3 m.
[D] 1 in. = 25.4 mm.

TABLE 13
TOLERANCES, OUTSIDE DIMENSIONS[A] SQUARE AND RECTANGULAR TUBING

Largest Nominal Outside Dimension, in.[B]	Wall Thickness, in.[B]	Outside Tolerance at All Sides at Corners ± in.[B]
$\frac{3}{16}$ to $\frac{5}{8}$, incl.	0.020 to 0.083, incl.	0.004
Over $\frac{5}{8}$ to $1\frac{1}{8}$, incl.	0.022 to 0.156, incl.	0.005
Over $1\frac{1}{8}$ to $1\frac{1}{2}$, incl.	0.025 to 0.192, incl.	0.006
Over $1\frac{1}{2}$ to 2, incl.	0.032 to 0.192, incl.	0.008
Over 2 to 3, incl.	0.035 to 0.259, incl.	0.010
Over 3 to 4, incl.	0.049 to 0.259, incl.	0.020
Over 4 to 6, incl.	0.065 to 0.259, incl.	0.020
Over 6 to 8, incl.	0.185 to 0.259, incl.	0.025

NOTES:

[A] Measured at corners at least 2 in. from the cut end of the tubing. Convexity and concavity: Tubes having two parallel sides are also measured in the center of the flat sides for convexity and concavity. This tolerance applies to the specific size determined at the corners, and is measured on the following basis:

[B] 1 in. = 25.4 mm.

Largest Nominal Outside Dimension, in.	Tolerance ±, in.
$2\frac{1}{2}$ and under	0.010
Over $2\frac{1}{2}$ to 4	0.015
Over 4 to 8	0.025

TABLE 14
RADII OF CORNERS OF ELECTRIC-RESISTANCE-WELDED SQUARE AND RECTANGULAR TUBING[A]

Squares and Rectangles Made from Tubes of the Following Diameter Ranges, in.[B]	Wall Thickness in Bwg and in.[B]	Radius Tolerances, in.[C]
1/2 to 1 1/2, incl.	24 (0.022)	1/64 to 3/64
1/2 to 1 1/2, incl.	22 (0.028)	1/32 to 1/16
1/2 to 2 1/2, incl.	20 (0.035)	1/32 to 1/16
1/2 to 2 1/2, incl.	19 (0.042)	3/64 to 5/64
1/2 to 4, incl.	18 (0.049)	3/64 to 5/64
1/2 to 4 1/8, incl.	16 (0.065)	1/16 to 7/64
3/4 to 4 1/8, incl.	14 (0.083)	5/64 to 1/8
Over 4 1/8 to 6, incl.	14 (0.083)	3/16 to 5/16
1 to 4 1/8, incl.	13 (0.095)	3/32 to 5/32
Over 4 1/8 to 6, incl.	13 (0.095)	3/16 to 5/16
1 1/4 to 4, incl.	12 (0.109)	1/8 to 13/64
Over 4 to 6, incl.	12 (0.109)	3/16 to 5/16
1 1/4 to 4, incl.	11 (0.120)	1/8 to 7/32
Over 4 to 6, incl.	11 (0.120)	7/32 to 7/16
2 to 4, incl.	10 (0.134)	5/32 to 9/32
Over 4 to 6, incl.	10 (0.134)	7/32 to 7/16
2 to 4, incl.	9 (0.148)	3/16 to 5/16
Over 4 to 8, incl.	9 (0.148)	7/32 to 7/16
2 to 8, incl.	8 (0.165)	1/4 to 1/2
2 to 8, incl.	7 (0.180)	1/4 to 1/2
2 1/2 to 4, incl.	6 (0.203)	5/16 to 9/16
Over 4 to 8, incl.	6 (0.203)	5/16 to 9/16
2 1/2 to 8, incl.	5 (0.220)	3/8 to 5/8
2 1/2 to 8, incl.	4 (0.238)	3/8 to 5/8
2 1/2 to 8, incl.	3 (0.259)	3/8 to 5/8

NOTES:
[A] This table establishes a standard radius. The purchaser and producer may negotiate special radii. Slight radius flattening is more pronounced in heavier wall tubing.
[B] 1 in. = 25 mm.
[C] These radius tolerances apply to grades of steel covered in Table 1. The purchaser and producer may negotiate tolerances on other grades of steel.

TABLE 15
LENGTH TOLERANCES—SQUARE AND RECTANGULAR TUBING

Lengths, ft[A]	Tolerances, in.[B]
1 to 3, incl.	± 1⁄16
Over 3 to 12, incl.	± 3⁄32
Over 12 to 20, incl.	± 1⁄8
Over 20 to 30, incl.	± 3⁄16
Over 30 to 40, incl.	± 3⁄8

NOTES:
[A] 1 ft = 0.3 m.
[B] 1 in. = 25.4 mm.

TABLE 16
TWIST TOLERANCES ELECTRIC-RESISTANCE-WELDED FOR SQUARE AND RECTANGULAR-MECHANICAL TUBING

Largest Dimension, in.[A]	Twist Tolerance in 3 ft[B], in.[A]
1⁄2 and under	0.032
Over 1⁄2 to 1 1⁄2, incl.	0.050
Over 1 1⁄2 to 2 1⁄2, incl.	0.062
Over 2 1⁄2 to 4, incl.	0.075
Over 4 to 6, incl.	0.087
Over 6 to 8, incl.	0.100

NOTES:
[A] 1 in. = 25.4 mm.
[B] ix ft = 0.3 m.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order and the necessary tests shall be made at the mill. Mechanical tests shall be performed in accordance with the applicable portions of Test Methods and Definitions A 370. Supplementary Requirement S6 and either S7 or S8 at the manufacturer's option are mandatory.

S1. Tubes for Cylinders

S1.1 Round tubing, mandrel drawn for cylinder applications with inside diameter cleanup allowances is considered to be cylinder tubing. Table S1.1 shows the minimum inside diameter allowance for removal of inside surface imperfections by a honing operation.

S2. Cleanup by Centerless Grinding

S2.1 Round tubing, mandrel drawn for applications with outside diameter allowances is considered to be special smooth outside surface tubing. Table S2.1 shows the minimum outside diameter stock allowance for removal of outside surface imperfections by centerless grinding.

S3. Cleanup by Machining

S3.1 Cleanup is permitted on round tubing, mandrel drawn for applications where machining is required to remove surface imperfections. Table S3.1 shows the minimum stock allowance for removal of surface imperfections from either or both the outside and inside surfaces by machining.

S4. Special Smooth Inside Surface

S4.1 Round tubing, special smooth inside diameter for cylinder applications with microinch finish and inside diameter cleanup allowances is considered to be special smooth inside surface tubing. Table S4.1 shows the maximum average microinch readings on the inside surface. Table S4.2 shows the minimum wall depth allowance for inside surface imperfections.

S5. Hardness and Tensile Requirements

S5.1 When hardness properties are specified on the order, round tubing shall conform to the hardness limits specified in Table S5.1 unless "Tensile Properties Required" is specified in the purchase order. When "Tensile Properties Required" is specified in the purchase order, round tubing shall conform to the tensile requirements and not necessarily the hardness limits shown in Table S5.1. For grades of round tubing not shown in Table S5.1, and for all square and rectangular tubing, tensile or hardness limits shall be upon agreement between the manufacturer and the purchaser.

S5.2 Number of tests and retests shall be as follows: one tension test per lot shall be made (Note S1) and 1% of all tubes per lot but in no case less than 5 tubes shall be tested for hardness. If the results of the mechanical tests do not conform to the requirements shown in the table, retests shall be made on additional tubes double the original number selected, each of which shall conform to the specified requirements.

NOTE S1—A lot shall consist of all tubes, before cutting to length, of the same size and wall thickness which are produced from the same heat of steel and, when heat treated, subjected to the same finishing treatment in a continuous furnace. When final heat treatment is done in a batch-type furnace, the lot shall include all those tubes which are heat treated in the same furnace charge.

S5.3 The yield strength corresponding to a permanent offset of 0.2% of the gage length of the specimen or to a total extension of 0.5% of the gage length under load shall be determined.

S6. Destructive Weld Tests

S6.1 Round tubing and tubing to be formed into other shapes when in the round form shall meet the following destructive weld tests.

S6.2 *Flattening Test* —A test 4 to 6 in. (101.6 to 152.4 mm) in length shall be flattened between parallel plates with the weld 90° from the direction of applied force (at the point of maximum bending) until opposite walls of the tubing meet. Except as allowed in S6.2.1, no opening in the weld shall take place until the distance between the plates is less than two thirds of the original outside diameter of the tubing. No cracks or breaks in the base metal shall occur until the distance between the plates is less than one third of the original outside diameter of the tubing, but in no case less than five times the thickness of the tubing wall. Evidence of lamination or burnt material shall not develop during the flattening process, and the weld shall not show injurious defects.

S6.2.1 When low D-to-t ratio tubing is tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

S6.3 *Flaring Test* —A section of tube approximately 4 in. (101.6 mm) in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded 15% of the inside diameter, without cracking or showing flaws.

S6.4 In order to properly evaluate weld quality, the producer at his option may normalize the test specimen prior to testing.

S6.5 Number of tests and retests: two flattening and two flaring tests shall be made from each lot (Note S1).

S7. Hydrostatic Test Round Tubing

S7.1 All tubing will be given a hydrostatic test calculated as follows:

$$P = \frac{2St}{D}$$

where:

P = hydrostatic test pressure, psi or MPa
S = allowable fiber stress of 14,000 psi or 96.5 MPa
t = specified wall thickness, in. or mm, and
D = specified outside diameter, in. or mm

S8. Nondestructive Electric Test

S8.1 Each tube shall be tested with a nondestructive electric test in accordance with Practice E 213, Practice E 273, Practice E 309, or Practice E 570. It is the intent of this test to reject tubes containing injurious defects.

S8.2 For eddy-current testing, the calibration tube shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection. For welded tubing, they shall be placed in the weld if visible.

S8.2.1 *Drilled Hole* —A hole not larger than 0.031 in. (0.79 mm) in diameter shall be drilled radially and completely through the tube wall, care being taken to avoid distortion of the tube while drilling.

S8.2.2 *Transverse Tangential Notch* —Using a round tool or file with a $\frac{1}{4}$ in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding $12\frac{1}{2}$% of the specified wall thickness of the tube or 0.004 in. (0.102 mm), whichever is greater.

S8.2.3 *Longitudinal Notch* —A notch 0.031 in. (0.79 mm) or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding $12\frac{1}{2}$% of the specified wall thickness of the tube or 0.004 in. (0.102 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

S8.3 For ultrasonic testing, the longitudinal calibration reference notches shall be at the option of the producer, any one of the three common notch shapes shown in Practice E 213 or Practice E 273. The depth of notch shall not exceed $12\frac{1}{2}$% of the specified wall thickness of the tube or 0.004 in. (0.102 mm), whichever is greater. For welded tubing the notch shall be placed in the weld, if visible.

S8.4 For flux leakage testing, each of the longitudinal calibration notches shall be a straight sided notch not over $12\frac{1}{2}$% of the wall thickness in depth and not over 1.0 in. (25 mm) in length. Both outside diameter and inside diameter notches shall be placed in the tube located sufficiently apart to enable separation and identification of the signals.

S8.5 Tubing producing a signal equal to or greater than the calibration defect shall be subject to rejection. The area producing the signal may be examined.

S8.5.1 Test signals produced by imperfections which cannot be identified, or produced by cracks or crack-like defects shall result in rejection of the tube subject to rework and retest.

S8.5.2 Test signals produced by imperfections such as those listed below may be judged as injurious or noninjurious depending on visual observation of their severity or the type of signal they produce on the testing equipment used, or both:

S8.5.2.1 Dinges,

S8.5.2.2 Straightener marks,

S8.5.2.3 Loose inside diameter bead and cutting chips,

S8.5.2.4 Scratches,

S8.5.2.5 Steel die stamps,

S8.5.2.6 Chattered flash trim,

S8.5.2.7 Stop marks, or

S8.5.2.8 Tube reducer ripple.

S8.5.3 Any imperfection of the above type exceeding 0.004 in. (0.102 mm) or $12\frac{1}{2}$% of the specified wall thickness (whichever is greater) in depth shall be considered injurious.

S8.5.3.1 If the imperfection is judged as injurious, the tubes shall be rejected but may be reconditioned and retested providing the dimensional requirements are met.

S8.5.3.2 If the imperfection is explored to the extent that it can be identified as noninjurious, the tubes may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness, after due allowance for cleanup in mandrel drawn tubes.

S9. Certification for Government Orders

S9.1 A producer's or supplier's certification shall be furnished to the Government that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. This certificate shall include a report of heat analysis (product analysis when requested in the purchase order), and when specified in the purchase order or contract, a report of test results shall be furnished.

S10. Rejection Provisions for Government Orders

S10.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the tube may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

S10.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

TABLE S1.1
MINIMUM INSIDE DIAMETER STOCK ALLOWANCE ON DIAMETER[A] FOR REMOVAL OF INSIDE-SURFACE IMPERFECTIONS BY HONING OPERATION (MANDREL-DRAWN TUBING)

Outside Diameter, in.[B]	Wall Thickness, in.[B, C] 0.065 and Under	Over 0.065 to 0.125, Incl.	Over 0.125 to 0.180, Incl.	Over 0.180 to 0.230, Incl.	Over 0.230 to 0.360, Incl.	Over 0.360 to 0.460, Incl.	Over 0.460 to 0.563, Incl.	Over 0.563
Up to and incl. $1\frac{1}{2}$	0.010	0.011	0.013	0.015	0.018	. . .	. . .	. . .
Over $1\frac{1}{2}$ to 3 incl.	0.010	0.012	0.014	0.016	0.018	0.021	0.023	. . .
Over 3 to 4 incl.	0.011	0.013	0.015	0.017	0.019	0.021	0.023	0.025
Over 4 to $4\frac{3}{4}$ incl.	. . .	0.014	0.016	0.018	0.020	0.022	0.024	0.026
Over $4\frac{3}{4}$ to 6 incl.	. . .	0.015	0.017	0.019	0.021	0.023	0.025	0.027
Over 6 to 8 incl.	. . .	0.016	0.018	0.020	0.022	0.024	0.026	0.028
Over 8 to $10\frac{1}{2}$ incl.	. . .	. . .	. . .	0.021	0.023	0.025	0.027	0.029
Over $10\frac{1}{2}$ to $12\frac{1}{2}$ incl.	. . .	. . .	. . .	0.022	0.024	0.026	0.028	0.030
Over $12\frac{1}{2}$ to 14 incl.	. . .	. . .	. . .	0.024	0.025	0.027	0.029	0.031
Over 14 to 15 incl.	. . .	. . .	. . .	0.025	0.026	0.028	0.030	0.032

NOTES:
[A] If a specific size is desired, these allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] 1 in. = 25.4 mm.
[C] Where the ellipsis (. . .) appears in this table, no allowances have been established.

TABLE S2.1
MINIMUM OUTSIDE DIAMETER STOCK ALLOWANCE ON DIAMETER[A] FOR REMOVAL OF OUTSIDE-SURFACE IMPERFECTIONS BY CENTERLESS GRINDING (MANDREL-DRAWN TUBING)

Outside Diameter, in.[B]	Tubing Wall Thickness, in.[B, C] Up to 0.125, Incl.	Over 0.125 to 0.180, Incl.	Over 0.180 to 0.230, Incl.	Over 0.230 to 0.360, Incl.	Over 0.360 to 0.460, Incl.	Over 0.460
Up to 3, incl.	0.012	0.014	0.016	0.020	0.024	0.026
Over 3 to $4\frac{3}{4}$, incl.	0.016	0.018	0.020	0.022	0.024	0.026
Over $4\frac{3}{4}$ to 6, incl.	0.018	0.020	0.022	0.024	0.026	0.028
Over 6 to 7, incl.	0.020	0.022	0.024	0.026	0.028	0.030
Over 7 to 8, incl.	. . .	. . .	0.026	0.027	0.029	0.031
Over 8 to $10\frac{1}{2}$, incl.	. . .	. . .	0.027	0.028	0.030	0.032
Over $10\frac{1}{2}$ to $12\frac{1}{2}$, incl.	. . .	. . .	0.028	0.030	0.032	0.034
Over $12\frac{1}{2}$ to 14 incl.	. . .	. . .	0.030	0.032	0.034	0.036
Over 14	. . .	. . .	0.033	0.035	0.036	0.037

NOTES:
[A] If a specific size is desired, these allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] 1 in. = 25.4 mm.
[C] Where the ellipsis (. . .) appears in this table, no allowances have been established.

TABLE S3.1
MINIMUM DIAMETER STOCK ALLOWANCE FOR OUTSIDE DIAMETER AND INSIDE DIAMETER FOR REMOVAL OF IMPERFECTIONS BY MACHINING (MANDREL-DRAWN TUBING)[A]

	Wall Thickness, in.[B, C]				
Outside Diameter, in.[B]	Up to 0.187	0.187 to 0.230, Incl.	Over 0.230 to 0.360, Incl.	Over 0.360 to 0.460, Incl.	Over 0.460
Up to 1½ incl.	0.015	0.020	0.025	. . .	. . .
Over 1½ to 3 incl.	0.020	0.025	0.030	0.030	0.035
Over 3 to 4¾ incl.	0.025	0.030	0.035	0.035	0.040
Over 4¾ to 6 incl.	0.030	0.035	0.040	0.040	0.045
Over 6 to 7 incl.	0.035	0.040	0.045	0.045	0.050
Over 7 to 8 incl.	. . .	0.045	0.048	0.048	0.053
Over 8 to 10½ incl.	. . .	0.048	0.050	0.050	0.055
Over 10½ to 15 incl.	. . .	0.050	0.055	0.055	0.060

NOTE 1 — Camber — For every foot or fraction thereof over one foot of length, add 0.010 in.[B] for camber.

NOTES:
[A] If a specific size is desired, those allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] 1 in. = 25.4 mm.
[C] Where the ellipsis (. . .) appears in this table, no allowances have been established.

TABLE S4.1
MAXIMUM AVERAGE MICROINCH READINGS ON INSIDE SURFACE (SPECIAL SMOOTH INSIDE DIAMETER TUBING)

	Tubing Wall Thickness, in.[A, B]				
Outside Diameter, in.[A]	0.065 and Under	Over 0.065 to 0.150, Incl.	Over 0.150 to 0.187, Incl.	Over 0.187 to 0.225, Incl.	Over 0.225 to 0.312, Incl.
1 to 2½, incl.	40	45	50	55	70
Over 2½ to 4½, incl.	40	50	60	70	80
Over 4½ to 5½, incl.	. . .	55	70	80	90
Over 5½ to 7, incl.	. . .	55	70	80	90

NOTES:
[A] 1 in. = 25.4 mm.
[B] Where the ellipsis (. . .) appears in this table, there is no requirement.

TABLE S4.2
ALLOWANCE FOR SURFACE IMPERFECTIONS ON INSIDE DIAMETERS OF SPECIAL SMOOTH FINISH TUBES[A]

		Wall Depth Allowance for Inside Diameter Surface Imperfections, in.[B]	
Outside Diameter Size, in.[B]	Wall Thickness, in.[B]	Scores	Pits
Up to 2½, incl.	0.065 to 0.109, incl.	0.001	0.0015
	Over 0.109 to 0.250, incl.	0.001	0.002
	Over 0.250 to 0.312, incl.	0.001	0.0025
Over 2½ to 5½, incl.	0.083 to 0.125, incl.	0.0015	0.0025
	Over 0.125 to 0.187, incl.	0.0015	0.003
	Over 0.187 to 0.312, incl.	0.002	0.004
Over 5½ to 7, incl.	0.125 to 0.187, incl.	0.0025	0.005
	Over 0.187 to 0.312, incl.	0.003	0.006

NOTES:
[A] If a specific size is desired, these allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] 1 in. = 25.4 mm.

TABLE S5.1
HARDNESS LIMITS AND TENSILE PROPERTIES FOR ROUND TUBING

	Yield Strength, ksi (MPa), Min.	Ultimate Strength, ksi (MPa), Min.	Elongation in 2 in. or 50 mm, %, Min.	RB Min.	RB Max.
As-Welded Tubing					
1008	30 (207)	42 (290)	15	50	
1010	32 (221)	45 (310)	15	55	
1015	35 (241)	48 (331)	15	58	
1020	38 (262)	52 (359)	12	62	
1021	40 (276)	54 (372)	12	62	
1025	40 (276)	56 (386)	12	65	
1026	45 (310)	62 (427)	12	68	
1030	45 (310)	62 (427)	10	70	
1035	50 (345)	66 (455)	10	75	
1040	50 (345)	66 (645)	10	75	
1340	55 (379)	72 (496)	10	80	
1524	50 (345)	66 (455)	10	75	
4130	55 (379)	72 (496)	10	80	
4140	70 (485)	90 (621)	10	85	
Normalized Tubing					
1008	23 (159)	38 (262)	30		65
1010	25 (172)	40 (276)	30		65
1015	30 (207)	45 (310)	30		70
1020	35 (241)	50 (345)	25		75
1021	35 (241)	50 (345)	25		78
1025	37 (255)	55 (379)	25		80
1026	40 (276)	60 (414)	25		85
1030	40 (276)	60 (414)	25		85
1035	45 (310)	65 (448)	20		88
1040	45 (310)	65 (448)	20		90
1340	50 (345)	70 (483)	20		100
1524	45 (310)	65 (448)	20		88
4130	50 (345)	70 (483)	20		100
4140	65 (448)	90 (621)	20		105

TABLE S5.1
HARDNESS LIMITS AND TENSILE PROPERTIES FOR ROUND TUBING (CONT'D)

	Yield Strength, ksi (MPa), Min.	Ultimate Strength, ksi (MPa), Min.	Elongation in 2 in. or 50 mm, %, Min.	RB Min.	RB Max.
		Sink-Drawn Tubing			
1008	38 (262)	48 (331)	8	65	
1010	40 (276)	50 (345)	8	65	
1015	45 (310)	55 (379)	8	67	
1020	50 (345)	60 (414)	8	70	
1021	52 (359)	62 (428)	7	70	
1025	55 (379)	65 (448)	7	72	
1026	55 (379)	70 (483)	7	77	
1030	62 (427)	70 (483)	7	78	
1035	70 (483)	80 (552)	7	82	
		Mandrel-Drawn Tubing			
1008	50 (345)	60 (414)	5	73	
1010	50 (345)	60 (414)	5	73	
1015	55 (379)	65 (448)	5	77	
1020	60 (414)	70 (483)	5	80	
1021	62 (427)	72 (496)	5	80	
1025	65 (448)	75 (517)	5	82	
1026	70 (483)	80 (552)	5	85	
1030	75 (517)	85 (586)	5	87	
1035	80 (552)	90 (621)	5	90	
1040	80 (552)	90 (621)	5	90	
1340	85 (586)	95 (655)	5	90	
1524	80 (552)	90 (621)	5	90	
4130	85 (586)	95 (655)	5	90	
4140	100 (690)	110 (758)	5	90	
		Mandrel-Drawn Stress-Relieved Tubing			
1008	45 (310)	55 (379)	12	68	
1010	45 (310)	55 (379)	12	68	
1015	50 (345)	60 (414)	12	72	
1020	55 (379)	65 (448)	10	75	
1021	58 (400)	68 (469)	10	75	
1025	60 (414)	70 (483)	10	77	
1026	65 (448)	75 (517)	10	80	
1030	70 (483)	80 (552)	10	81	
1035	75 (517)	85 (586)	10	85	
1040	75 (517)	85 (586)	10	85	
1340	80 (552)	90 (621)	10	87	
1524	75 (517)	85 (586)	10	85	
4130	80 (552)	90 (621)	10	87	
4140	95 (655)	105 (724)	10	90	

NOTES:

(1) These values are based on normal mill stress relieving temperatures. For particular applications, properties may be adjusted by negotiation between purchaser and producer.

(2) For longitudinal strip tests, the width of the gage section shall be 1 in. (25.4 mm) and a deduction of 0.5 percentage points rom the basic minimum elongation for each $^1/_{32}$ in. (0.8 mm) decrease in wall thickness under $^5/_{16}$ in. (7.9 mm) in wall thickness shall be permitted.

APPENDIX

(Nonmandatory Information)

X1. MEASURING MICROINCH FINISH

X1.1 The procedure for making microinch readings on interior surfaces of cold worked tubing (not polished or ground) $\frac{1}{2}$ in. (12.7 mm) inside diameter and larger is as follows:

X1.1.1 Measurements on tubing with longitudinal or no predominant lay should be circumferential on the inside surface of the straight tube, prior to any fabrication, on a plane approximately perpendicular to the tube axis. Measurements on tubing with circumferential lay should be longitudinal.

X1.1.2 Measurements should be made not less than 1 in. (25.4 mm) from the end.

X1.1.3 Measurements should be made at four positions approximately 90° apart or over a complete circumference if the trace should otherwise overlap.

X1.1.4 The length of trace should be in accordance with the latest revision of Section 4.5 of ANSI B 46.1 (not less than 0.600 in. (15.24 mm) long).

X1.1.5 A minimum of three such measurements should be made spaced not less than $\frac{1}{4}$ in. (6.4 mm) apart along the longitudinal axis.

X1.1.6 The numerical rating shall be the arithmetical average microinch of all readings taken. Each reading to be averaged should be the mean position of the indicator during the trace; any momentary meter excursions occupying less than 10% of the total trace should be ignored.

X1.1.7 A deviation in numerical rating in various parts of a tube may be expected. Experience to date indicates that a variation of about ±35% is normal.

X1.2 Instruments should meet the specifications given in the latest revision of ANSI B 46.1.

X1.3 Mechanical tracing is preferred. If hand tracing is used, the speed of trace should not vary by more than ±20% from the required to give the appropriate cutoff. The 0.030 in. roughness width cutoff should be used.

X1.4 Microinch determinations only refer to roughness of areas that do not contain a defect, injurious or otherwise. Such defects as seams, slivers, pits, laps, etc., are subject to ordinary visual inspection in accordance with applicable specifications or trade customs, and have no relationship to roughness.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, FOR INTERMEDIATE- AND HIGHER-TEMPERATURE SERVICE

SA-515/SA-515M

(Identical with ASTM Specification A515/A515M-17.)

Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service

1. Scope

1.1 This specification covers carbon-silicon steel plates primarily for intermediate- and higher-temperature service in welded boilers and other pressure vessels.

1.2 Plates under this specification are available in three grades having different strength levels as follows:

Grade U.S. [SI]	Tensile Strength, ksi [MPa]
60 [415]	60–80 [415–550]
65 [450]	65–85 [450–585]
70 [485]	70–90 [485–620]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A20/A20M apply.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

3.4 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

TABLE 1 Chemical Requirements

Elements	Composition, %		
	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max:[A, B]			
1 in. [25 mm] and under	0.24	0.28	0.31
Over 1 to 2 in. [25 to 50 mm], incl	0.27	0.31	0.33
Over 2 to 4 in. [50 to 100 mm], incl	0.29	0.33	0.35
Over 4 to 8 in. [100 to 200 mm], incl	0.31	0.33	0.35
Over 8 in. [200 mm]	0.31	0.33	0.35
Manganese,[B] max:			
Heat analysis	0.90	0.90	1.20
Product analysis	0.98	0.98	1.30
Phosphorus, max[A]	0.025	0.025	0.025
Sulfur, max[A]	0.025	0.025	0.025
Silicon:			
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45

[A] Applies to both heat and product analyses.
[B] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.

TABLE 2 Tensile Requirements

	Grade		
	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	60–80 [415–550]	65–85 [450–585]	70–90 [485–620]
Yield strength, min, ksi [MPa]	32 [220]	35 [240]	38 [260]
Elongation in 8 in. [200 mm], min, %[A]	21	19	17
Elongation in 2 in. [50 mm], min, %[A]	25	23	21

[A] See Specification A20/A20M for elongation adjustment.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A20/A20M.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and made to a coarse austenitic grain size practice.

5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Properties

7.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 carbon steel; carbon steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessels

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop-Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below is an additional optional supplementary requirement suitable for this specification:

S61. Austenitic Grain Size

S61.1 The material shall have a carburized austenitic grain size of 1 to 5.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, FOR MODERATE- AND LOWER-TEMPERATURE SERVICE

SA-516/SA-516M

(Identical with ASTM Specification A516/A516M-17.)

Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

1. Scope

1.1 This specification covers carbon steel plates intended primarily for service in welded pressure vessels where improved notch toughness is important.

1.2 Plates under this specification are available in four grades having different strength levels as follows:

Grade U.S. [SI]	Tensile Strength, ksi [MPa]
55 [380]	55–75 [380–515]
60 [415]	60–80 [415–550]
65 [450]	65–85 [450–585]
70 [485]	70–90 [485–620]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results of Specification A20/A20M apply.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this product specification shall conform to Specification A20/A20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

3.4 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

TABLE 1 Chemical Requirements

Elements	Composition, %			
	Grade 55 [Grade 380]	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max:[A,B]				
½ in. [12.5 mm] and under	0.18	0.21	0.24	0.27
Over ½ in. to 2 in. [12.5 to 50 mm], incl	0.20	0.23	0.26	0.28
Over 2 in. to 4 in. [50 to 100 mm], incl	0.22	0.25	0.28	0.30
Over 4 to 8 in. [100 to 200 mm], incl	0.24	0.27	0.29	0.31
Over 8 in. [200 mm]	0.26	0.27	0.29	0.31
Manganese:[B]				
½ in. [12.5 mm] and under:				
Heat analysis	0.60–0.90	0.60–0.90[C]	0.85–1.20	0.85–1.20
Product analysis	0.55–0.98	0.55–0.98[C]	0.79–1.30	0.79–1.30
Over ½ in. [12.5 mm]:				
Heat analysis	0.60–1.20	0.85–1.20	0.85–1.20	0.85–1.20
Product analysis	0.55–1.30	0.79–1.30	0.79–1.30	0.79–1.30
Phosphorus, max[A]	0.025	0.025	0.025	0.025
Sulfur, max[A]	0.025	0.025	0.025	0.025
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45

[A] Applies to both heat and product analyses.
[B] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.
[C] Grade 60 plates ½ in. [12.5 mm] and under in thickness may have 0.85–1.20 % manganese on heat analysis, and 0.79–1.30 % manganese on product analysis.

TABLE 2 Tensile Requirements

	Grade			
	55 [380]	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	55–75 [380–515]	60–80 [415–550]	65–85 [450–585]	70–90 [485–620]
Yield strength, min,[A] ksi [MPa]	30 [205]	32 [220]	35 [240]	38 [260]
Elongation in 8 in. [200 mm], min, %[B]	23	21	19	17
Elongation in 2 in. [50 mm], min, %[B]	27	25	23	21

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[B] See Specification A20/A20M for elongation adjustment.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A20/A20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 Plates 1.50 in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 1.50 in. [40 mm] in thickness shall be normalized.

5.3 When notch-toughness tests are required on plates 1½ in. [40 mm] and under in thickness, the plates shall be normalized unless otherwise specified by the purchaser.

5.4 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible for improvement of the toughness, provided the plates are subsequently tempered in the temperature range 1100 to 1300°F [595 to 705°C].

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Properties

7.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 carbon steel; carbon steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessels

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in ASTM Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,
S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S4.1 Additional Tension Test,
S5. Charpy V-Notch Impact Test,
S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),
S7. High-Temperature Tension Test,
S8. Ultrasonic Examination in accordance with Specification A435/A435M,
S9. Magnetic Particle Examination,
S11. Ultrasonic Examination in accordance with Specification A577/A577M,
S12. Ultrasonic Examination in accordance with Specification A578/A578M, and
S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirement is suitable for this application.

S54. Requirements for Carbon Steel Plate for Hydrofluoric Acid Alkylation Service

S54.1 Plates shall be provided in the normalized heat-treated condition.

S54.2 The maximum carbon equivalent (CE) shall be as follows:

Plate thickness less than or equal to 1 in. [25 mm]:

$$\text{CE maximum} = 0.43$$

Plate thickness greater than 1 in. [25 mm]:

$$\text{CE maximum} = 0.45$$

S54.3 Determine the CE as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S54.4 Vanadium (V) and niobium (Nb) maximum content based on heat analysis shall be:

$$\text{Maximum vanadium} = 0.02\ \%$$

$$\text{Maximum niobium} = 0.02\ \%$$

$$\text{Maximum vanadium plus niobium} = 0.03\ \%$$

(Note: niobium = columbium.)

S54.5 The maximum composition based on heat analysis of nickel (Ni) plus copper (Cu) shall be 0.15 %.

S54.6 The minimum carbon (C) content based on heat analysis shall be 0.18 %. The maximum C content shall be as specified for the ordered grade.

S54.7 Welding consumables for repair welds shall be of the low-hydrogen type. E60XX electrodes shall not be used and the resulting weld chemistry shall meet the same chemistry requirements as the base metal.

S54.8 In addition to the requirements for product marking in the specification, an "HF-N" stamp or marking shall be provided on each plate to identify that the plate complies with this supplementary requirement.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, HIGH-STRENGTH, QUENCHED AND TEMPERED

SA-517/SA-517M

(Identical with ASTM Specification A517/A517M-17 except for the addition of Footnote A to Boron in Table 1.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered

1. Scope

1.1 This specification covers high-strength quenched and tempered alloy steel plates intended for use in fusion welded boilers and other pressure vessels.

1.2 This specification includes a number of grades as manufactured by different producers, but all having the same mechanical properties and general characteristics.

1.3 The maximum thickness of plates furnished under this specification shall be as follows:

Grade	Thickness
A, B	1.25 in. [32 mm]
H, S	2 in. [50 mm]
P	4 in. [100 mm]
F	2.50 in. [65 mm]
E, Q	6 in. [150 mm]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other without combining values in any way.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels
A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates furnished to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 Except as allowed by 5.2, the plates shall be heat treated by heating to not less than 1650°F [900°C], quenching in water or oil and tempering at not less than 1150°F [620°C].

5.2 Plates ordered without the heat treatment specified in 5.1 shall be stress relieved by the manufacturer, and subsequent heat treatment of the plates to conform to 5.1 shall be the responsibility of the purchaser.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with

TABLE 1 Chemical Requirements

NOTE 1—Where " … " appears there is no requirement.

Elements	Composition, %							
	Grade A	Grade B	Grade E	Grade F	Grade H	Grade P	Grade Q	Grade S
Carbon:								
Heat analysis	0.15–0.21	0.15–0.21	0.12–0.20	0.10–0.20	0.12–0.21	0.12–0.21	0.14–0.21	0.10–0.20
Product analysis	0.13–0.23	0.13–0.23	0.10–0.22	0.08–0.22	0.10–0.23	0.10–0.23	0.12–0.23	0.10–0.22
Manganese:								
Heat analysis	0.80–1.10	0.70–1.00	0.40–0.70	0.60–1.00	0.95–1.30	0.45–0.70	0.95–1.30	1.10–1.50
Product analysis	0.74–1.20	0.64–1.10	0.35–0.78	0.55–1.10	0.87–1.41	0.40–0.78	0.87–1.41	1.02–1.62
Phosphorus, max[A]	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Sulfur, max[A]	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Silicon:								
Heat analysis	0.40–0.80	0.15–0.35	0.10–0.40	0.15–0.35	0.15–0.35	0.20–0.35	0.15–0.35	0.15–0.40
Product analysis	0.34–0.86	0.13–0.37	0.08–0.45	0.13–0.37	0.13–0.37	0.18–0.37	0.13–0.37	0.13–0.45
Nickel:								
Heat analysis	. . .	. . .	. . .	0.70–1.00	0.30–0.70	1.20–1.50	1.20–1.50	. . .
Product analysis	. . .	. . .	. . .	0.67–1.03	0.27–0.73	1.15–1.55	1.15–1.55	. . .
Chromium:								
Heat analysis	0.50–0.80	0.40–0.65	1.40–2.00	0.40–0.65	0.40–0.65	0.85–1.20	1.00–1.50	. . .
Product analysis	0.46–0.84	0.36–0.69	1.34–2.06	0.36–0.69	0.36–0.69	0.79–1.26	0.94–1.56	. . .
Molybdenum:								
Heat analysis	0.18–0.28	0.15–0.25	0.40–0.60	0.40–0.60	0.20–0.30	0.45–0.60	0.40–0.60	0.10–0.35
Product analysis	0.15–0.31	0.12–0.28	0.36–0.64	0.36–0.64	0.17–0.33	0.41–0.64	0.36–0.64	0.10–0.38
Boron[A]	0.0025 max	0.0005–0.005	0.001–0.005	0.0005–0.006	0.0005 min	0.001–0.005	. . .	. . .
Vanadium:								
Heat analysis	. . .	0.03–0.08	[B]	0.03–0.08	0.03–0.08	. . .	0.03–0.08	. . .
Product analysis	. . .	0.02–0.09	. . .	0.02–0.09	0.02–0.09	. . .	0.02–0.09	. . .
Titanium:								
Heat analysis	. . .	0.01–0.04	0.01–0.10	0.10 max	0.10 max	0.10 max	. . .	0.06 max
Product analysis	. . .	0.01–0.05	0.005–0.11	0.11 max	0.11 max	0.11 max	. . .	0.07 max
Zirconium:								
Heat analysis	0.05–0.15[C]	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Product analysis	0.04–0.16	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Copper:								
Heat analysis	. . .	. . .	. . .	0.15–0.50	. . .	. . .	. . .	. . .
Product analysis	. . .	. . .	. . .	0.12–0.53	. . .	. . .	. . .	. . .
Columbium (Niobium),[D] max								
Heat analysis	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.06
Product analysis	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.07

[A] Applied to both heat and product analyses.
[B] May be substituted for part or all of titanium content on a one for one basis.
[C] Zirconium may be replaced by cerium. When cerium is added, the cerium/sulfur ratio should be approximately 1.5 to 1, based on heat analysis.
[D] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.

TABLE 2 Tensile Requirements

	2.50 in. [65 mm] and Under	Over 2.50 to 6 in. [65 to 150 mm]
Tensile strength, ksi [MPa]	115–135 [795–930]	105–135 [725–930]
Yield strength, min, ksi [MPa]	100 [690]	90 [620]
Elongation in 2 in. [50 mm], min, %[A]	16	14
Reduction of area, min, %:		
Rectangular specimens	35	. . .
Round specimens	45	45

[A] See Specification A20/A20M for elongation adjustment.

Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M for grades other than Grade A.

7. Mechanical Requirements

7.1 *Tension Tests:*

7.1.1 *Requirements*—The plates as represented by the tension-test specimens shall conform to the requirements given in Table 2.

7.1.2 *Test Methods:*

7.1.2.1 The yield strength may be determined by the 0.2 % offset method or by the total extension under load of 0.5 % method.

7.1.2.2 For plates ¾ in. [20 mm] and under in thickness, the test specimen shall be the 1½ in. [40 mm] wide rectangular-test specimen.

7.1.2.3 For plates over ¾ in. [20 mm], either the full thickness rectangular-test specimen or the ½ in. [12.5 mm] round-test specimen may be used.

7.1.2.4 When the 1½ in. [40 mm] wide rectangular-test specimen is used, the elongation is measured in a 2 in. or [50 mm] gage length which includes the fracture.

7.2 *Impact Properties Requirements:*

7.2.1 Transverse Charpy V-notch impact test specimens shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

7.2.2 The test temperature shall be agreed upon between the manufacturer and the purchaser, but shall not be higher than 32°F [0°C].

8. Keywords

8.1 alloy steel; boilers; high-strength; impact tested; plates; pressure vessels; quenched; tempered

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR FORGED OR ROLLED 8 AND 9% NICKEL ALLOY STEEL FLANGES, FITTINGS, VALVES, AND PARTS FOR LOW-TEMPERATURE SERVICE

SA-522/SA-522M

(Identical with ASTM Specification A522/A522M-07.)

SPECIFICATION FOR FORGED OR ROLLED 8 AND 9% NICKEL ALLOY STEEL FLANGES, FITTINGS, VALVES, AND PARTS FOR LOW-TEMPERATURE SERVICE

SA-522/SA-522M

(Identical with ASTM Specification A 522/A 522M-07.)

1. Scope

1.1 This specification covers 8 and 9% nickel-alloy steel forged or rolled flanges, fittings, valves, and parts intended for use in welded pressure vessels for low-temperature service. The specification is applicable to forgings with maximum section thickness of 3 in. [75 mm] in the double normalized and tempered condition and 5 in. [125 mm] in the quenched and tempered condition. Forgings under this specification are intended for service at operating temperatures not lower than −320°F [−196°C] for Type I or −275°F [−170°C] for Type II or higher than 250°F [121°C].

1.2 Material under this specification is available in two types having different chemical compositions as follows:

Type	Nominal Nickel Content, %
I	9
II	8

1.3 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 788/A 788M Specification for Steel Forgings, General Requirements

A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

3. General Requirements and Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961 constitutes nonconformance with this specification.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to furnish the needed material. Examples of such information include but are not limited to the ordering information in Specification A 961 and following:

3.2.1 Any supplementary requirements, and

3.2.2 Additional requirements, (See 4.5, 5.2, 6.1, 7.2, and 10.3).

4. Materials and Manufacture

4.1 The steel shall be produced in accordance with the melting process section of Specification A 788.

4.2 Material for forgings shall consist of ingots, or either forged or rolled blooms, billets, or bars.

4.3 The finished product shall be a forging as defined in the Terminology Section of Specification A 788.

4.4 Except for flanges of all types, hollow cylindrically shaped parts may be made from hot-rolled or forged bar, provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Except for all types of flanges, elbows, return bends, tees, and header tees, other parts up to and including NPS 4 may be machined from hot-rolled or forged bar.

4.5 When specified in the order, the manufacturer shall submit for purchaser's approval a sketch showing the shape of the rough forging before machining.

5. Chemical Composition

5.1 The steel shall conform to the requirements of Table 1.

5.2 If required by the purchaser, product analysis may be performed in accordance with the requirements of A 961.

6. Heat Treatment

6.1 The forgings shall be heat treated by the manufacturer by either of the following methods as mutually agreed upon between the purchaser and the manufacturer.

6.1.1 *Quenched and Tempered* — Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; quench by immersion in circulating water. Reheat until the forging attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air or water quench, at a rate not less than 300°F [165°C]/h.

6.1.2 *Double Normalized and Tempered* — Heat to a uniform temperature of 1650°F [900°C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air. Reheat until the forging attains a uniform temperature of 1450°F [790°C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air or water quench, at a rate not less than 300°F [165°C]/h.

6.2 When stress relieving is to be performed after fabrication, the recommended stress-relieving treatment is as follows: gradually and uniformly heat the steel to a temperature between 1025 and 1085°F [550 and 585°C]; hold for a minimum of 2 h for thicknesses up to 1 in. [25 mm]. For thicknesses over 1 in. [25 mm], a minimum additional holding time in the ratio of 1 h/in. [2.5 min/mm] of thickness in excess of 1 in. [25 mm] shall be added. Cool at a minimum rate of 300°F [165°C]/h to a temperature not exceeding 600°F [315°C].

7. Mechanical Properties

7.1 *Tension Test* — Forgings to Types 1 and 2 shall conform to the tensile requirements of Table 2.

7.2 *Impact Test* — The Charpy impact test requirements in Table 3 shall be met unless Supplementary Requirement S2 of this specification has been specified.

7.2.1 The values for energy absorption and the fracture appearance in percentage of shear fracture for each specimen shall be recorded and reported for information.

8. Workmanship, Finish, and Appearance

8.1 The forgings shall have a workman-like finish and shall be free of injurious defects.

9. Number of Tests and Retests

9.1 At least one tension test and one set of Charpy V-notch impact tests shall be made from each heat in each heat-treatment charge.

9.2 If the results of the mechanical tests do not conform to the specified requirements, the manufacturer may retreat the forgings, but not more than three additional times. Retreatment involves re-austenitizing the forgings. Retests shall be made in accordance with this section.

9.3 If the lateral expansion result from one Charpy impact specimen falls below 0.015 in. [0.38 mm], but not less than 0.010 in. [0.25 mm], and the average test result equals or exceeds 0.015 mm [0.38 mm], then one retest of three additional specimens may be made. The lateral expansion obtained from each of the three retest specimens shall equal or exceed 0.015 in. [0.38 mm].

10. Test Specimens

10.1 The test specimens shall be located at any point midway between the center and surface of solid forgings, and at any point mid-thickness of the heaviest section of hollow or bored forgings. For solid forgings where test metal is provided on the periphery, test specimens shall be taken at mid-thickness of the test prolongation.

10.2 Tests shall be oriented so that the longitudinal axis of the specimen is parallel to the major direction of grain flow.

10.3 When fabrication requires stress relieving, the purchaser shall specify stress relieving of the test pieces prior to machining of the test specimens. Stress relieving shall be carried out as prescribed in 6.2.

11. Method of Impact Testing

11.1 The impact test shall be made in accordance with the simple beam, Charpy type of test described in the latest issue of Test Methods and Definitions A 370.

11.2 Precaution shall be taken so that when broken, the test specimens shall be within ± 3°F [1.7°C] of the specified test temperature.

12. Inspection

12.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

12.2 The manufacturer shall report to the purchaser or the purchaser's representative the heat treatments applied to the material and to the test blocks and the results of the chemical analysis and mechanical tests made in accordance with this specification and the heat number or his heat identification.

13. Rejection

13.1 Unless otherwise specified, any rejection based on tests made in accordance with Section 5 and 7 shall be reported to the manufacturer within 60 days from the receipt of samples or test reports by the purchaser.

13.2 Each forging in which injurious metal defects are exposed during subsequent machining shall be rejected and the manufacturer notified.

14. Certification

14.1 Test reports, when required, shall include certification that all requirements of this specification have been met. The manufacturer shall provide the following where applicable:

14.1.1 Whether Type 1 or Type 11 material has been supplied and the chemical analysis results in accordance with Section 5,

14.1.2 Type of heat treatment used,

14.1.3 Results of tension and Charpy impact tests (together with absorbed energy and % shear fracture) including the impact test temperature, and test coupon stress relief details if applicable,

14.1.4 Results of any additional or supplementary requirements specified by the purchaser, and

14.1.5 The year date and revision letter, if any, of the specification. Note, this information is not required to be marked on the forgings.

15. Product Marking

15.1 Each forging shall be legibly stamped by the manufacturer with the heat number or his heat identification, the manufacturer's name (see Note 1) or trademark, and this specification number, A 522 or A 522M as applicable, 8NI, or 9NI, and QT or NNT as applicable.

NOTE 1 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

15.2 Forgings impact tested at a temperature other than that specified in Table 3, by the use of Supplementary Requirement S2, shall be marked with the letters LTV following the specification number, as well as the temperature scale used. For forgings to A 522, these letters shall be followed by the impact test temperature in degrees Fahrenheit. A prefix 0 to the test temperature indicates a temperature below 0°F, for example A 522 Type 1 LTV0300F indicates −300°F. For forgings to A 522M, the letters LTV shall be followed by the impact test temperature in degrees Celsius. A prefix 0 to the test temperature indicates a temperature below 0°C, for example A 522M Type 1 LTV0150C indicates −150°C.

15.3 The purchaser may specify additional identification marking and the location of all stamping. The type of stamps shall be round or "interrupted-dot" die stamps having a radius of $\frac{1}{32}$ in. [0.8 mm].

15.4 *Bar Coding* — In addition to the requirements in 15.1, 15.2, and 15.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

16. Keywords

16.1 low temperature applications; nickel alloy steel; pipe fittings; steel; piping applications; pressure containing parts; steel flanges; steel forgings; alloy; steel valves

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %	
	Type I	Type II
Carbon, max	0.13	0.13
Manganese, max	0.90	0.90
Phosphorus, max	0.025	0.025
Sulfur, max	0.025	0.025
Silicon[A]	0.15–0.30	0.15–0.30
Nickel	8.5–9.5	7.5–8.5

[A] When vacuum carbon deoxidation is used, the maximum silicon content shall be 0.10%.

TABLE 2
TENSILE REQUIREMENTS AT ROOM TEMPERATURE

Tensile strength, min., ksi [MPa]	100 [690]
Yield strength, min., (0.2% off-set), ksi [MPa]	75 [515]
Elongation in 2 in. [50 mm], min., %	22
Reduction of area, min., %	45

TABLE 3
CHARPY V-NOTCH LATERAL EXPANSION REQUIREMENTS FOR STANDARD SIZE [10 X 10 MM] SPECIMENS

Type	Lateral Expansion in. [mm]	Temperature °F [°C][A]	Report Absorbed Energy and % Shear Fracture
1	0.015 [0.38]	−320 [−195]	Yes
2	0.015 [0.38]	−275 [−170]	Yes

[A] Except when Supplementary Requirement S2 is specified.

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below may be included in purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Nondestructive Tests

S1.1 *Ultrasonic Tests* — Ultrasonic tests may be made by agreement between manufacturer and purchaser.

S1.2 *Liquid Penetrant Tests* — Liquid penetrant tests may be made by agreement between manufacturer and purchaser.

S2. Other Impact Test Temperatures

S2.1 The purchaser may specify an impact test temperature higher than that in Table 3 but no higher than the minimum intended operating temperature for the forging.

S2.2 Marking shall be in accordance with 15.2.

SPECIFICATION FOR SEAMLESS CARBON STEEL PIPE FOR ATMOSPHERIC AND LOWER TEMPERATURES

SA-524/SA-524M

(23)

(Identical with ASTM Specification A524/A524M-21 except for the deletion of alternate elongation and deletion of SI Units from Table 2 Note on Grade I.)

Specification for Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures

1. Scope

1.1 This specification covers seamless carbon steel pipe intended primarily for service at atmospheric and lower temperatures, NPS ⅛ to 26 [DN 6 to 650] inclusive, with nominal (average) wall thickness as given in ANSI B36.10. Pipe having other dimensions may be furnished, provided such pipe complies with all other requirements of this specification. Pipe ordered to this specification shall be suitable both for welding, and for bending, flanging, and similar forming operations.

1.2 The product is available in two grades (Tables 1 and 2).

1.3 Product may be either of hot finished or cold drawn manufacture (see 5.1.4 and 5.1.5).

1.4 *Units*—This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable M specification designation (SI units), the inch-pound units shall apply. The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard. The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.5 The following hazard caveat applies to the test methods portion, Section 16, only. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *American National Standards Institute Standard:*

B36.10 Welded and Seamless Wrought Steel Pipe

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, meters, or number of lengths),

3.1.2 Name of material (seamless carbon steel pipe),

3.1.3 Grade (Table 1 and Table 2),

3.1.4 Manufacture (hot finished or cold drawn (see 5.1.4 and 5.1.5)),

3.1.5 Size (either nominal NPS [DN] wall thickness and weight class or schedule number, or both, or outside diameter and nominal wall thickness, ANSI B36.10),

3.1.6 Length (Section 17),

3.1.7 Optional requirements (Section 8 and Section 11 of Specification A530/A530M),

3.1.8 Test report required (Material Test Report Section of Specification A530/A530M),

TABLE 1 Chemical Requirements

Element	Grades I and II, Composition, %
Carbon, max	0.21
Manganese	0.90–1.35
Phosphorus, max	0.035
Sulfur, max	0.035
Silicon	0.10–0.40

3.1.9 Specification (A524 or A524M) designation,

3.1.10 Hydrostatic test (see 11.2).

3.1.11 End use of material, and

3.1.12 Special requirements.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A530/A530M unless otherwise provided herein.

5. Materials and Manufacture

5.1 *Process:*

5.1.1 The steel shall be killed steel made by one or more of the following processes: electric-furnace, basic-oxygen, or any other commercially viable process.

5.1.2 The steel shall be made to fine grain practice.

5.1.3 Steel may be cast in ingots or may be strand cast. When steel of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

5.1.4 Pipe NPS 1½ [DN 40] and under may be either hot finished or cold drawn.

5.1.5 Unless otherwise specified, pipe NPS 2 [DN 50] and over shall be furnished hot finished. When agreed upon between the manufacturer and purchaser, cold-drawn pipe may be furnished.

5.2 *Heat Treatment*—All hot-finished and cold-drawn pipe shall be reheated to a temperature above 1550°F [845°C] and followed by cooling in air or in the cooling chamber of a controlled atmosphere furnace.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements prescribed in Table 1.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 6. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 6.

8. Product Analysis

8.1 At the request of the purchaser, analyses of two pipes from each lot (Note 2) shall be made by the manufacturer from the finished pipe. The chemical composition thus determined shall conform to the requirements specified in Section 6.

NOTE 2—A lot shall consist of 400 lengths, or fraction thereof, for each size NPS 2 [DN 50] up to but not including NPS 6 [DN 150], and of 200 lengths, or fraction thereof, for each size NPS 6 [DN 150] and over.

8.2 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in Section 6, analyses shall be made on additional pipe of double the original number from the same lot, each of which shall conform to requirements specified.

9. Physical Properties

9.1 *Tensile Properties*—The material shall conform to the requirements as to tensile properties prescribed in Table 2.

9.2 *Bending Properties:*

9.2.1 For pipe NPS 2 [DN 50] and under, a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the nominal diameter of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the nominal diameter of the pipe, without failure.

9.2.2 For pipe whose diameter exceeds 25 in. [635 mm] and whose diameter to wall thickness ratio is 7.0 or less, bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. [25.4 mm]. This test shall be in place of Section 10.

NOTE 3—Diameter to wall thickness ratio = specified outside diameter/nominal wall thickness.
Example: For 28 in. [710 mm] diameter 5.000 in. [125 mm] thick pipe the diameter to wall thickness ratio = 28/5 = 5.6.

10. Flattening Test Requirements

10.1 For pipe over NPS 2 [DN 50], a section of pipe not less than 2½ in. [63.5 mm] in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A530/A530M, except that in the equation used to calculate the *H* value, the following *e* constants shall be used:

0.07 for Grade I
0.08 for Grade II

10.2 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than ten.

11. Hydrostatic Test Requirements

11.1 Each length of pipe shall be subjected to the hydrostatic pressure, except as provided in 11.2.

11.2 When specified in the order, pipe may be furnished without hydrostatic testing and each length so furnished shall include with the mandatory marking the letters "NH."

11.3 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly

TABLE 2 Tensile Requirements

	Wall Thicknesses			
	Grade I, 0.375 in. [9.52 mm] and under		Grade II, greater than 0.375 in. [9.52 mm]	
Tensile strength, psi [MPa]	60 000–85 000 [415–585]		55 000–80 000 [380–550]	
Yield strength, min, psi [MPa]	35 000 [240]		30 000 [205]	
	Longitudinal	Transverse[A]	Longitudinal	Transverse[A]
Elongation in 2 in. [50 mm], min %:				
Basic minimum elongation for walls 5/16 in. [7.9 mm] and over in thickness, strip tests, and for all small sizes tested in full section	30	16.5	35	25

[A] Transverse elongations may not be calculable for sizes smaller than NPS 6 [DN 150] based on test equipment limitations.
[B] The following table gives the computed minimum values:

Wall Thickness		Elongation in 2 in. [50 mm], min, %	
		Grade I	
in.	mm	Longitudinal	Transverse
5/16 (0.312)	[7.94]	30.0	16.5
9/32 (0.281)	[7.14]	28.5	15.5
1/4 (0.250)	[6.35]	27.0	14.5
7/32 (0.219)	[5.56]	25.5	. . .
3/16 (0.188)	[4.76]	24.0	. . .
5/32 (0.156)	[3.97]	22.5	. . .
1/8 (0.125)	[3.18]	21.0	. . .
3/32 (0.094)	[2.38]	19.5	. . .
1/16 (0.062)	[1.59]	18.0	. . .

Note—The above table gives the computed minimum elongation values for each 1/32-in. decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

Grade	Direction of Test	Equation
I	transverse	E = 32t + 6.50
I	longitudinal	E = 48t + 15.00

where:

E = elongation in 2 in. in % and
t = actual thickness of specimen, in.

state "Not Hydrostatically Tested," and the specification number and grade designation, as shown on the certification, shall be followed by the letters "NH."

12. Dimensions and Weights

12.1 The dimensions and weights of plain-end pipe are included in ANSI B36.10. Sizes and wall thicknesses most generally available are listed in Appendix X1.

13. Dimensions, Weight, and Permissible Variations

13.1 *Weight*—The weight of any length of pipe shall not vary more than 6.5 % over and 3.5 % under that specified for pipe of Schedule 120 (Table X1.2) and lighter nor more than 10 % over and 3.5 % under that specified for pipe heavier than Schedule 120. Unless otherwise agreed upon between the manufacturer and purchaser, pipe in sizes NPS 4 [DN 100] and smaller may be weighed in convenient lots; pipe in sizes larger than NPS 4 [DN 100] shall be weighed separately.

13.2 *Diameter*—Variations in outside diameter shall not exceed those specified in Table 3.

13.3 *Thickness*—The minimum wall thickness at any point shall not be more than 12.5 % under the nominal wall thickness specified.

TABLE 3 Variations in Outside Diameter

Designator		Permissible Variations in Outside Diameter, in. [mm]	
NPS	DN	Over	Under
1/8 to 1½, incl.	6 to 40, incl.	1/64 [0.4]	1/32 [0.8]
Over 1½ to 4, incl.	40 to 100, incl.	1/32 [0.8]	1/32 [0.8]
Over 4 to 8, incl.	100 to 200, incl.	1/16 [1.6]	1/32 [0.8]
Over 8 to 18, incl.	200 to 450, incl.	3/32 [2.4]	1/32 [0.8]
Over 18	Over 450	1/8 [3.2]	1/32 [0.8]

Note 4—The minimum wall thickness on inspection is shown in Appendix X1.

14. Workmanship, Finish, and Appearance

14.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 14.2.

14.2 Surface imperfections that penetrate more than 12½ % of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

14.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

14.2.2 Repaired in accordance with the repair welding provisions of 14.6.

14.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

14.2.4 Rejected.

14.3 To provide a workmanlike finish and basis for evaluating conformance with 14.2, the pipe manufacturer shall remove by grinding the following noninjurious imperfections:

14.3.1 Mechanical marks, abrasions (Note 5), and pits, any of which imperfections are deeper than 1⁄16 in. (1.58 mm).

NOTE 5—Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, and the like.

14.3.2 Visual imperfections, commonly referred to as scabs, seams, laps, tears, or slivers, found by exploration in accordance with 14.1 to be deeper than 5 % of the nominal wall thickness.

14.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 14.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

14.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

14.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

14.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A530/A530M.

14.7 The finished pipe shall be reasonably straight.

15. Number of Tests and Retests

15.1 One of either of the tests specified in 9.1 shall be made on one length of pipe from each lot (Note 2).

15.2 For pipe NPS 2 [DN 50] and under, the bend test specified in 9.2 shall be made on one pipe from each lot (Note 2). The bend tests specified in 9.2.2 shall be made on one end of each pipe.

15.3 The flattening test specified in Section 10 shall be made on one length of pipe from each lot (Note 2).

15.4 Retests shall be in accordance with Specification A530/A530M and as provided in 15.5 and 15.6.

15.5 If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

15.6 Should a crop end of a finished pipe fail in the flattening test, one retest may be made from the broken end.

16. Test Specimens and Methods of Testing

16.1 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

16.2 Test specimens for the bend test specified in 9.2 and for the flattening tests specified in Section 10 shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

16.3 Test specimens for the bend test specified in 9.2.2 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. [12.7 mm] in section or 1 by ½ in. [25.4 by 12.7 mm] in section with the corners rounded to a radius not over 1⁄16 in. [1.6 mm] and need not exceed 6 in. [152 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe respectively.

17. Lengths

17.1 Pipe lengths shall be in accordance with the following regular practice:

17.1.1 The lengths required shall be specified in the order, and

17.1.2 No jointers are permitted unless otherwise specified.

17.2 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft [4.9 to 6.7 m], with 5 % 12 to 16 ft [3.7 to 4.9 m], or in double random lengths with a minimum average of 35 ft [10.7 m] and a minimum length of 22 ft [6.7 m] with 5 % 16 to 22 ft [4.9 to 6.7 m].

18. Rejection

18.1 Each length of pipe that develops injurious defects during shop working or application operations will be rejected, and the manufacturer shall be notified. No rejections under this or any other specifications shall be marked as specified in Section 19 for sale under this specification except where such pipe fails to comply with the weight requirements alone, in which case it may be sold under the weight specifications with which it does comply.

19. Product Marking

19.1 In addition to the marking prescribed in Specification A530/A530M, the marking shall include the hydrostatic test pressure when tested or the letters "NH" when not tested, the length and schedule number, and on pipe sizes larger than NPS 4 [DN 100] the weight shall be given. Length shall be marked in feet and tenths of a foot, or metres to two decimal places, depending on the units to which the material was ordered, or other marking subject to agreement.

19.2 *Bar Coding*—In addition to the requirements in 19.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

APPENDIX

(Nonmandatory Information)

X1. DIMENSIONS AND WALL THICKNESSES

X1.1 Following are Tables X1.1 and X1.2, cited in the text of this standard.

TABLE X1.1 Table of Minimum Wall Thicknesses on Inspection for Nominal (Average) Pipe Wall Thickness

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in. [mm], and
t_m = minimum wall thickness, in. [mm].

NOTE 2—The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with Practice E29. This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.068	[1.73]	0.060	[1.52]	0.281	[7.14]	0.246	[6.25]	0.864	[21.94]	0.756	[19.20]
0.083	[2.11]	0.073	[1.85]	0.294	[7.47]	0.257	[6.53]	0.875	[22.22]	0.766	[19.46]
0.088	[2.24]	0.077	[1.96]	0.300	[7.62]	0.262	[6.65]	0.906	[23.01]	0.793	[20.14]
0.091	[2.31]	0.080	[2.03]	0.307	[7.80]	0.269	[6.83]	0.938	[23.82]	0.821	[20.85]
0.095	[2.41]	0.083	[2.11]	0.308	[7.82]	0.270	[6.86]	0.968	[24.59]	0.847	[21.51]
0.109	[2.77]	0.095	[2.41]	0.312	[7.92]	0.273	[6.93]	1.000	[25.40]	0.875	[22.22]
0.113	[2.87]	0.099	[2.51]	0.318	[8.07]	0.278	[7.06]	1.031	[26.19]	0.902	[22.91]
0.119	[3.02]	0.104	[2.64]	0.322	[8.18]	0.282	[7.16]	1.062	[26.97]	0.929	[23.60]
0.125	[3.18]	0.109	[2.77]	0.330	[8.38]	0.289	[7.34]	1.094	[27.79]	0.957	[24.31]
0.126	[3.20]	0.110	[2.79]	0.337	[8.56]	0.295	[7.49]	1.125	[28.58]	0.984	[24.99]
0.133	[3.38]	0.116	[2.95]	0.344	[8.74]	0.301	[7.64]	1.156	[29.36]	1.012	[25.70]
0.140	[3.56]	0.122	[3.10]	0.358	[9.09]	0.313	[7.95]	1.219	[30.96]	1.066	[27.08]
0.141	[3.58]	0.123	[3.12]	0.365	[9.27]	0.319	[8.10]	1.250	[31.75]	1.094	[27.79]
0.145	[3.68]	0.127	[3.23]	0.375	[9.52]	0.328	[8.33]	1.281	[32.54]	1.121	[28.47]
0.147	[3.73]	0.129	[3.28]	0.382	[9.70]	0.334	[8.48]	1.312	[33.32]	1.148	[29.16]
0.154	[3.91]	0.135	[3.43]	0.400	[10.16]	0.350	[8.89]	1.375	[34.92]	1.203	[30.56]
0.156	[3.96]	0.136	[3.45]	0.406	[10.31]	0.355	[9.02]	1.406	[35.71]	1.230	[31.24]
0.172	[4.37]	0.150	[3.81]	0.432	[10.97]	0.378	[9.60]	1.438	[36.53]	1.258	[31.95]
0.179	[4.55]	0.157	[3.99]	0.436	[11.07]	0.382	[9.70]	1.500	[38.10]	1.312	[33.32]
0.188	[4.78]	0.164	[4.17]	0.438	[11.12]	0.383	[9.73]	1.531	[38.89]	1.340	[34.04]
0.191	[4.85]	0.167	[4.24]	0.469	[11.91]	0.410	[10.41]	1.562	[39.67]	1.367	[34.72]
0.200	[5.08]	0.175	[4.44]	0.500	[12.70]	0.438	[11.13]	1.594	[40.49]	1.395	[35.43]
0.203	[5.16]	0.178	[4.52]	0.531	[13.49]	0.465	[11.81]	1.635	[41.53]	1.431	[36.35]
0.210	[5.33]	0.184	[4.67]	0.552	[14.02]	0.483	[12.27]	1.750	[44.45]	1.531	[38.89]
0.216	[5.49]	0.189	[4.80]	0.562	[14.27]	0.492	[12.50]	1.781	[45.24]	1.558	[39.57]
0.218	[5.54]	0.191	[4.85]	0.594	[15.09]	0.520	[13.21]	1.812	[46.02]	1.586	[40.28]
0.219	[5.56]	0.192	[4.88]	0.600	[15.24]	0.525	[13.34]	1.875	[47.62]	1.641	[41.68]
0.226	[5.74]	0.198	[5.03]	0.625	[15.88]	0.547	[13.89]	1.969	[50.01]	1.723	[43.76]
0.237	[6.02]	0.207	[5.26]	0.656	[16.66]	0.574	[14.58]	2.000	[50.80]	1.750	[44.45]
0.250	[6.35]	0.219	[5.56]	0.674	[17.12]	0.590	[14.99]	2.062	[52.37]	1.804	[45.82]
0.258	[6.55]	0.226	[5.74]	0.688	[17.48]	0.602	[15.29]	2.125	[53.98]	1.859	[47.22]
0.276	[7.01]	0.242	[6.15]	0.719	[18.26]	0.629	[15.98]	2.200	[55.88]	1.925	[48.90]
0.277	[7.04]	0.242	[6.15]	0.750	[19.05]	0.656	[16.66]	2.344	[59.54]	2.051	[52.10]
0.279	[7.09]	0.244	[6.19]	0.812	[20.62]	0.710	[18.03]	2.500	[63.50]	2.188	[55.58]
0.280	[7.11]	0.245	[6.22]	0.844	[21.44]	0.739	[18.77]				

TABLE X1.2 Dimensions, Weights and Test Pressures for Plain End Pipe
(As appears in American National Standard B36.10)

Designator		Wall Thickness	Nominal Weight		Weight Class	Schedule No.	Test Pressure	
NPS	DN						Grade I	Grade II
		in. [mm]	lb/ft	[kg/m]	psi (MPa)	psi (MPa)		
⅛	6	0.068 [1.73]	0.24	[0.36]	std	40	2500 [17.2]	...
		0.095 [2.41]	0.31	[0.46]	XS	80	2500 [17.2]	...
¼	8	0.088 [2.24]	0.42	[0.63]	std	40	2500 [17.2]	...
		0.119 [3.02]	0.54	[0.80]	XS	80	2500 [17.2]	...
⅜	10	0.091 [2.31]	0.57	[0.85]	std	40	2500 [17.2]	...
		0.126 [3.20]	0.74	[1.10]	XS	80	2500 [17.2]	...
½	15	0.109 [2.77]	0.85	[1.27]	std	40	2500 [17.2]	...
		0.147 [3.73]	1.09	[1.62]	XS	80	2500 [17.2]	...
		0.294 [7.47]	1.71	[2.55]	XXS	...	2500 [17.2]	...
¾	20	0.113 [2.87]	1.13	[1.68]	std	40	2500 [17.2]	...
		0.154 [3.91]	1.47	[2.19]	XS	80	2500 [17.2]	...
		0.308 [7.82]	2.44	[3.63]	XXS	...	2500 [17.2]	...
1	25	0.133 [3.38]	1.68	[2.50]	std	40	2500 [17.2]	...
		0.179 [4.55]	2.17	[3.23]	XS	80	2500 [17.2]	...
		0.358 [9.09]	3.66	[5.45]	XXS	...	2500 [17.2]	...
1¼	32	0.140 [3.56]	2.27	[3.38]	std	40	2500 [17.2]	...
		0.191 [4.85]	3.00	[4.47]	XS	80	2500 [17.2]	...
		0.382 [9.70]	5.21	[7.76]	XXS	...	...	2500 [17.2]
1½	40	0.145 [3.68]	2.72	[4.05]	std	40	2500 [17.2]	...
		0.200 [5.08]	3.63	[5.41]	XS	80	2500 [17.2]	...
		0.400 [10.16]	6.41	[9.55]	XXS	...	...	2500 [17.2]
2	50	0.154 [3.91]	3.65	[5.44]	std	40	2500 [17.2]	...
		0.218 [5.54]	5.02	[7.48]	XS	80	2500 [17.2]	...
		0.344 [8.74]	7.46	[11.12]	...	160	2500 [17.2]	...
		0.436 [11.07]	9.03	[13.45]	XXS	...	...	2500 [17.2]
2½	65	0.203 [5.16]	5.79	[8.62]	std	40	2500 [17.2]	...
		0.276 [7.01]	7.66	[11.41]	XS	80	2500 [17.2]	...
		0.375 [9.52]	10.01	[14.91]	...	160	2500 [17.2]	...
		0.552 [14.02]	13.70	[20.41]	XXS	...	...	2500 [17.2]
3	80	0.216 [5.49]	7.58	[11.29]	std	40	2500 [17.2]	...
		0.300 [7.62]	10.25	[15.27]	XS	80	2500 [17.2]	...
		0.438 [11.13]	14.32	[21.34]	...	160	...	2500 [17.2]
		0.600 [15.24]	18.58	[27.67]	XXS	...	...	2500 [17.2]
3½	90	0.226 [5.74]	9.11	[13.57]	std	40	2400 [16.5]	...
		0.318 [8.08]	12.51	[18.63]	XS	80	2800 [19.3]	...
4	100	0.237 [6.02]	10.79	[16.07]	std	40	2200 [15.2]	...
		0.337 [8.56]	14.98	[22.31]	XS	80	2800 [19.3]	...
		0.438 [11.13]	19.00	[28.30]	...	120	...	2800 [19.3]
		0.531 [13.49]	22.51	[33.53]	...	160	...	2800 [19.3]
		0.674 [17.12]	27.54	[41.02]	XXS	...	...	2800 [19.3]
5	125	0.258 [6.55]	14.62	[21.78]	std	40	1900 [13.1]	...
		0.375 [9.52]	20.78	[30.95]	XS	80	2800 [19.3]	...
		0.500 [12.70]	27.04	[40.28]	...	120	...	2800 [19.3]
		0.625 [15.88]	32.96	[49.09]	...	160	...	2800 [19.3]
		0.750 [19.05]	38.55	[57.42]	XXS	...	...	2800 [19.3]
6	150	0.280 [7.11]	18.97	[28.26]	std	40	1800 [12.4]	...
		0.432 [10.97]	28.57	[42.56]	XS	80	...	2300 [15.9]
		0.562 [14.27]	36.39	[54.20]	...	120	...	2800 [19.3]
		0.719 [18.26]	45.35	[67.55]	...	160	...	2800 [19.3]
		0.864 [21.95]	53.16	[79.68]	XXS	...	...	2800 [19.3]
8	200	0.250 [6.35]	22.36	[33.31]	...	20	1200 [8.3]	...
		0.277 [7.04]	24.70	[36.79]	...	30	1300 [9.0]	...
		0.322 [8.18]	28.55	[42.53]	std	40	1600 [11.0]	...
		0.406 [10.31]	35.64	[53.10]	...	60	...	1700 [11.7]
		0.500 [12.70]	43.39	[64.63]	XS	80	...	2100 [14.5]
		0.594 [15.09]	50.95	[75.92]	...	100	...	2500 [17.2]
		0.719 [18.26]	60.71	[90.43]	...	120	...	2800 [19.3]
		0.812 [20.62]	67.76	[100.96]	...	140	...	2800 [19.3]
		0.875 [22.22]	72.42	[107.87]	XXS	...	...	2800 [19.3]
		0.906 [23.01]	74.69	[111.29]	...	160	...	2800 [19.3]
10	250	0.250 [6.35]	28.04	[41.77]	...	20	1000 [6.9]	...
		0.279 [7.09]	31.20	[46.47]	...	...	1100 [7.6]	...
		0.307 [7.80]	34.24	[51.00]	...	30	1200 [8.3]	...
		0.365 [9.27]	40.48	[60.29]	std	40	1400 [9.7]	...
		0.500 [12.70]	54.74	[81.55]	XS	60	...	1700 [11.7]
		0.594 [15.09]	64.43	[96.00]	...	80	...	2000 [13.8]
		0.719 [18.26]	77.03	[114.74]	...	100	...	2400 [16.5]
		0.844 [21.44]	89.29	[133.04]	...	120	...	2800 [9.3]
		1.000 [25.40]	104.13	[155.15]	XXS	140	...	2800 [9.3]
		1.125 [28.58]	115.65	[172.32]	...	160	...	2800 [9.3]
12	300	0.250 [6.35]	33.38	[49.72]	...	20	800 [5.5]	...
		0.330 [8.38]	43.77	[65.20]	...	30	1100 [7.6]	...

		0.375 [9.52]	49.56	[73.82]	std	...	1200 [8.3]	...
		0.406 [10.31]	53.52	[79.74]	...	40	...	1100 [7.6]
		0.500 [12.70]	65.42	[97.44]	XS	...	...	1400 [9.7]
		0.562 [14.27]	73.15	[108.96]	...	60	...	1600 [11.0]
		0.688 [17.48]	88.63	[132.01]	...	80	...	1900 [13.1]
		0.844 [21.44]	107.32	[159.91]	...	100	...	2400 [16.5]
		1.000 [25.40]	125.49	[186.98]	XXS	120	...	2800 [19.3]
		1.125 [28.58]	139.68	[208.12]	...	140	...	2800 [19.3]
		1.312 [33.32]	160.27	[238.80]	...	160	...	2800 [19.3]
14	350	0.250 [6.35]	36.71	[54.68]	...	10	750 [5.2]	...
		0.312 [7.92]	45.61	[67.94]	...	20	950 [6.6]	...
		0.375 [9.52]	54.57	[81.28]	std	30	1100 [7.6]	...
		0.438 [11.13]	63.44	[94.49]	...	40	...	1100 [7.6]
		0.500 [12.70]	72.09	[107.38]	XS	...	...	1300 [9.0]
		0.594 [15.09]	85.05	[126.72]	...	60	...	1500 [10.3]
		0.750 [19.05]	106.13	[158.08]	...	80	...	1900 [13.1]
		0.938 [23.83]	130.85	[194.90]	...	100	...	2400 [16.5]
		1.094 [27.79]	150.79	[234.68]	...	120	...	2800 [19.3]
		1.250 [31.75]	170.22	[253.63]	...	140	...	2800 [19.3]
		1.406 [35.71]	189.11	[281.77]	...	160	...	2800 [19.3]
16	400	0.250 [6.35]	42.05	[62.63]	...	10	650 [4.5]	...
		0.312 [7.92]	52.27	[77.86]	...	20	800 [5.5]	...
		0.375 [9.52]	62.58	[93.21]	std	30	1000 [6.9]	...
		0.500 [12.70]	82.77	[123.29]	XS	40	...	1100 [7.6]
		0.656 [16.66]	107.50	[160.18]	...	60	...	1500 [10.3]
		0.844 [21.44]	136.62	[203.56]	...	80	...	1900 [13.1]
		1.031 [26.19]	164.82	[245.58]	...	100	...	2300 [15.9]
		1.219 [30.96]	192.43	[286.72]	...	120	...	2700 [18.6]
		1.438 [36.52]	223.64	[333.22]	...	140	...	2800 [19.3]
		1.594 [40.49]	245.25	[365.42]	...	160	...	2800 [19.3]
18	450	0.250 [6.35]	47.39	[70.59]	...	10	600 [4.1]	...
		0.312 [7.92]	58.94	[87.79]	...	20	750 [5.2]	...
		0.375 [9.52]	70.59	[105.14]	std	...	900 [6.2]	...
		0.438 [11.13]	82.15	[122.36]	...	30	...	900 [6.2]
		0.500 [12.70]	93.45	[139.19]	XS	...	...	1000 [6.9]
		0.562 [14.27]	104.67	[155.91]	...	40	...	1100 [7.6]
		0.750 [19.05]	138.17	[205.80]	...	60	...	1500 [10.3]
		0.938 [23.83]	170.92	[254.59]	...	80	...	1900 [13.1]
		1.156 [29.36]	207.96	[309.86]	...	100	...	2300 [15.9]
		1.375 [34.92]	244.14	[363.77]	...	120	...	2800 [19.3]
		1.562 [39.67]	274.22	[408.54]	...	140	...	2800 [19.3]
		1.781 [45.24]	308.50	[459.67]	...	160	...	2800 [19.3]
20	500	0.250 [6.35]	52.73	[78.54]	...	10	500 [3.4]	...
		0.375 [9.52]	78.60	[117.07]	std	20	800 [5.5]	...
		0.500 [12.70]	104.13	[155.10]	XS	30	...	900 [6.2]
		0.594 [15.09]	123.11	[183.43]	...	40	...	1100 [7.6]
		0.812 [20.62]	166.40	[247.85]	...	60	...	1500 [10.3]
		1.031 [26.19]	208.87	[311.22]	...	80	...	1900 [13.1]
		1.281 [32.54]	256.10	[381.59]	...	100	...	2300 [15.9]
		1.500 [38.10]	296.37	[441.59]	...	120	...	2700 [18.6]
		1.750 [44.45]	341.10	[508.24]	...	140	...	2800 [19.3]
		1.969 [50.01]	379.17	[564.96]	...	160	...	2800 [19.3]
24		0.250 [6.35]	63.41	[94.45]	...	10	450 [3.1]	...
		0.375 [9.52]	94.62	[140.94]	std	20	650 [4.5]	...
		0.500 [12.70]	125.49	[186.92]	XS	...	...	750 [5.2]
		0.562 [14.27]	140.68	[209.54]	...	30	...	850 [5.9]
		0.688 [17.48]	171.29	[255.14]	...	40	...	1000 [6.9]
		0.969 [24.61]	238.85	[355.89]	...	60	...	1500 [10.3]
		1.219 [30.96]	296.58	[441.90]	...	80	...	1800 [12.4]
		1.531 [38.89]	367.39	[547.41]	...	100	...	2300 [15.9]
		1.812 [46.02]	429.39	[639.79]	...	120	...	2700 [18.6]
		2.062 [52.37]	483.12	[719.85]	...	140	...	2800 [19.3]
		2.344 [59.64]	542.14	[807.79]	...	160	...	2800 [19.3]
26		0.250 [6.35]	68.75	[102.40]	...	...	400 [2.8]	...
		0.312 [7.92]	85.60	[127.50]	...	10	500 [3.4]	...
		0.375 [9.52]	102.63	[152.87]	std	...	610 [4.2]	...
		0.500 [12.70]	136.17	[202.83]	XS	20	...	690 [4.8]

SPECIFICATION FOR GENERAL REQUIREMENTS FOR SPECIALIZED CARBON AND ALLOY STEEL PIPE

SA-530/SA-530M

(23)

(Identical with ASTM Specification A530/A530M-18.)

Specification for
General Requirements for Specialized Carbon and Alloy Steel Pipe

1. Scope

1.1 This specification covers a group of requirements which, with the exceptions of Section 6.3, Section 14, Section 21, and Section 22, are mandatory requirements to the ASTM pipe product specifications noted below unless the product specification specifies different requirements, in which case the requirement of the product specification shall prevail.

1.2 Sections 6.3 or 21 are mandatory if the product specification has a requirement for product analysis or flattening tests.

1.3 Section 22 is mandatory if the product specification has a hydrostatic test requirement without defining the test parameters.

1.4 Section 14 is for information only.

1.5 In case of conflict between a requirement of the product specification and a requirement of this general requirement specification, only the requirement of the product specification need be satisfied.

Title of Specification	ASTM Designation[A]
Seamless Carbon Steel Pipe for High-Temperature Service	A106/A106M
Metal-Arc-Welded Steel Pipe for Use With High-Pressure Transmission Systems	A381
Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures	A524
Centrifugally Cast Carbon Steel Pipe for High-Temperature Service	A660/A660M
Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures	A671/A671M
Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures	A672/A672M
Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures	A691/A691M

[A] These designations refer to the latest issue of the respective specifications.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation (SI) of the product specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A106/A106M Specification for Seamless Carbon Steel Pipe for High-Temperature Service

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A381 Specification for Metal-Arc-Welded Carbon or High-Strength Low-Alloy Steel Pipe for Use With High-Pressure Transmission Systems

A450/A450M Specification for General Requirements for Carbon and Low Alloy Steel Tubes

A524 Specification for Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures

A660/A660M Specification for Centrifugally Cast Carbon Steel Pipe for High-Temperature Service
A671/A671M Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures
A672/A672M Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures
A691/A691M Specification for Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures
A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A1058 Test Methods for Mechanical Testing of Steel Products—Metric
D3951 Practice for Commercial Packaging
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *ASME Standards:*
B36.10 Welded and Seamless Wrought Steel Pipe
B36.19[4] Stainless Steel Pipe

2.3 *Military Standards:*
MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage
MIL-STD-271 Nondestructive Testing Requirements for Metals[5]
MIL-STD-792 Identification Marking Requirements for Special Purpose Components

2.4 *Federal Standards:*
Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.5 *Steel Structures Painting Council:*
SSPC-SP 6 Surface Preparation Specification No. 6 Commercial Blast Cleaning

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *remelted heat, n*—in secondary melting, all of the ingots remelted from a single primary heat.

3.1.2 *jointer, n*—a length of pipe created by welding two or more shorter lengths of pipe, end-to-end.

3.1.3 *thin-wall pipe, n*—a pipe having a wall thickness of 3 % or less of the outside diameter.

3.2 *Other defined terms*—The definitions in Test Methods and Definitions A370, Test Methods, Practices, and Terminology A751, and Terminology A941 are applicable to this specification and to those listed in 1.5.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements necessary for product under this specification. Such requirements to be considered include, but are not limited to, the following:

4.1.1 Quantity (feet, meters, or number of lengths),

4.1.2 Specification number with grade or class, or both, as applicable and year date,

4.1.3 Manufacture (hot-finished or cold drawn),

4.1.4 Size (NPS [DN] and weight class or schedule number, or both; outside diameter and nominal wall thickness; or inside diameter and nominal wall thickness),

4.1.5 Length (specific or random),

4.1.6 Choice of testing track from the options listed in Test Methods A1058 when material is ordered to an M suffix (SI units) product standard. If the choice of test track is not specified in the order, then the default ASTM test track shall be used as noted in Test Methods A1058,

4.1.7 Supplementary Requirements, and

4.1.8 Additional requirements.

5. Process

5.1 The steel shall be made from any process.

5.2 If a specific type of melting is required by the purchaser, it shall be stated on the purchase order.

5.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electroslag remelting or vacuum remelting.

5.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

6. Chemical Composition

6.1 *Chemical Analysis*—Samples for chemical analysis and method of analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

6.2 *Heat Analysis*—If the heat analysis reported by the steel producer is not sufficiently complete for conformance with the heat analysis requirements of the applicable product specification to be fully assessed, the manufacturer may complete the assessment of conformance with such heat analysis requirements by using a product analysis for the specified elements that were not reported by the steel producer, provided that product analysis tolerances are not applied and the heat analysis is not altered.

6.2.1 For steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification.

6.3 *Product Analysis*—Product analysis requirements and options, if any, are contained in the product specification.

7. Mechanical Requirements

7.1 *Method of Mechanical Tests*—The specimens and the mechanical tests required shall be made in accordance with Annex A2 of Test Methods and Definitions A370 if inch-pound units are specified, or to the requirements described in the applicable track of Test Methods A1058, if SI units are specified.

7.2 Specimens shall be tested at room temperature.

7.3 Small or subsize specimens as described in Test Methods and Definitions A370 or Test Methods A1058 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in the individual specifications.

8.2 The yield strength corresponding to a permanent offset of 0.2 % of the gage length or to a total extension of 0.5 % of the gage length under load shall be determined.

8.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

9. Permissible Variation in Weight

9.1 The weight of any length of pipe NPS 12 [DN 300] and under shall not vary more than 10 % over or 3.5 % under that specified. For sizes over NPS 12 [DN 300], the weight of any length of pipe shall not vary more than 10 % over or 5 % under that specified. Unless otherwise specified, pipe of NPS 4 [DN 100] and smaller may be weighed in convenient lots; pipe in sizes larger than NPS 4 [DN 100] shall be weighed separately.

10. Permissible Variations in Wall Thickness

10.1 *Seamless and Welded (no filler metal added)*—The minimum wall thickness at any point shall be within the tolerances specified in Table 1, except that for welded pipe the weld area shall not be limited by the over tolerance. The minimum wall thickness on inspection for – 12.5 % is shown in Table X1.1.

10.2 *Forged and Bored*—The wall thickness shall not vary over that specified by more than ⅛ in. [3.2 mm]. There shall be no variation under the specified wall thickness.

10.3 *Cast*—The wall thickness shall not vary over that specified by more than 1⁄16 in. [1.6 mm]. There shall be no variation under the specified wall thickness.

11. Permissible Variations in Inside Diameter

11.1 *Forged and Bored, and Cast*—The inside diameter shall not vary under that specified by more than 1⁄16 in. [1.6 mm]. There shall be no variation over the specified inside diameter.

12. Permissible Variations in Outside Diameter

12.1 Variations in outside diameter, unless otherwise specified, shall not exceed the limits prescribed in Table 2. The tolerances on outside diameter include ovality except as provided for in 12.2.

12.2 Thin-wall pipe usually develops significant ovality (out-of-roundness) during final annealing, straightening, or both. The diameter tolerances of Table 2 are not sufficient to provide for additional ovality expected in thin-wall pipe and are applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross-section. However, for thin-wall pipe the difference in extreme outside diameter readings (ovality) in any one cross-section shall not exceed 1.5 % of the specified outside diameter.

13. Permissible Variations in Length

13.1 *Seamless and Welded (no filler metal added)*—If definite cut lengths are ordered, no length of pipe shall be under the length specified and not more than ¼ in. [6 mm] over that specified.

13.2 *Forged and Bored, Cast, and Cast Cold-Wrought*—If definite cut lengths are ordered, no length of pipe shall be under the length specified and not more than ⅛ in. [3 mm] over that specified.

13.3 For pipe ordered to random lengths, the lengths and variations shall be agreed upon between the manufacturer and purchaser.

TABLE 1 Permissible Variations in Wall Thickness

NPS Designator	Tolerance, % from Nominal	
	Over	Under
⅛ to 2½, incl., all t / D [A,B] ratios	20.0	12.5
3 to 18 incl., t / D up to 5 % incl.	22.5	12.5
3 to 18 incl., t / D > 5 %	15.0	12.5
20 and larger, welded, all t / D ratios	17.5	12.5
20 and larger, seamless, t / D up to 5 % incl.	22.5	12.5
20 and larger, seamless, t / D > 5 %	15.0	12.5

[A] t = Nominal wall thickness.
[B] D = Ordered outside diameter.

TABLE 2 Permissible Variations in Outside Diameter

NPS Designator	Permissible Variations In Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
⅛ to 1½, incl	1⁄64 (0.015)	0.4	1⁄32 (0.031)	0.8
Over 1½ to 4, incl	1⁄32 (0.031)	0.8	1⁄32 (0.031)	0.8
Over 4 to 8, incl	1⁄16 (0.062)	1.6	1⁄32 (0.031)	0.8
Over 8 to 18, incl	3⁄32 (0.093)	2.4	1⁄32 (0.031)	0.8
Over 18 to 26, incl	⅛ (0.125)	3.2	1⁄32 (0.031)	0.8
Over 26 to 34, incl	5⁄32 (0.156)	4.0	1⁄32 (0.031)	0.8
Over 34	3⁄16 (0.187)	4.8	1⁄32 (0.031)	0.8

13.4 No jointers are permitted unless otherwise agreed upon.

14. Standard Weight

14.1 A system of standard pipe sizes has been approved by the American National Standards Institute as ASME B36.10 and B36.19. These standard sizes do not prohibit the production and use of other sizes of pipe produced to the various specifications referenced to this Specification.

14.2 For nonstandard sizes of pipe, the calculated weight per foot, shall be determined from the following equation:

$$W = C(D - t)t \quad (1)$$

where:

C = 10.69 [0.0246615],
W = weight, lb/ft [kg/m],
D = specified or calculated (from specified inside diameter and wall thickness) outside diameter, in. [mm], and
t = specified wall thickness, in. (to 3 decimal places) [mm to 2 decimal places].

NOTE 2—The weights given in the American National Standards and the calculated weights given by Eq 1 are based on the weights for carbon steel pipe. The weight of pipe made of ferritic stainless steels may be about 5 % less, and that made of austenitic stainless steel about 2 % greater than the values given.

15. Ends

15.1 Unless otherwise specified, the pipe shall be furnished with plain ends. All burrs at the ends of the pipe shall be removed.

16. Straightness

16.1 The finished pipe shall be reasonably straight.

16.2 For metal-arc welded pipe, the maximum deviation from a 10-ft [3.0-m] straightedge placed so that both ends are in contact with the pipe shall be ⅛ in. [3.2 mm]. For metal-arc welded pipe with lengths shorter than 10 ft [3.0 m], this maximum deviation shall be pro-rated with respect to the ratio of the actual length to 10 ft [3.0 m].

17. Repair by Welding

17.1 Repair by welding of defects in seamless pipe (including centrifugally cast and forged and bored) and of plate defects in welded pipe and, when specifically stated by the product specification weld seam defects in welded pipe, shall be permitted subject to the approval of the purchaser and with the further understanding that the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired pipe shall be tested hydrostatically as required by the product specification.

17.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

18. Retests

18.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional lengths of pipe of double the original number from the same group or lot, each of which shall conform to the requirements specified. Only one retest of any group or lot will be permitted. Nonconformance will be cause for the rejection of the group or lot.

18.2 Any individual length of pipe that meets the test requirements is acceptable. Individual lengths that do not conform to the test requirements may be resubmitted for test provided the reason for nonconformance is established and the nonconforming portion removed.

19. Retreatment

19.1 If individual lengths of pipe selected to represent any group or lot fail to conform to the test requirements, the group or lot represented may be reheat treated and resubmitted for test. The manufacturer may reheat treat the pipe, but not more than twice, except with the approval of the purchaser on the basis of satisfactory metallurgical evidence that the cause of failure of the test is curable and the quality of the material is satisfactory.

20. Test Specimens

20.1 Test specimens shall be taken from the ends of as-heat treated finished pipe prior to any forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws, except for specimens for the flattening test when made from crop ends.

20.2 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

20.3 If any test specimen shows flaws or defective machining, the specimen may be discarded and another substituted.

21. Flattening Test Requirements

21.1 *Seamless and Centrifugally Cast Pipe*—A section of pipe not less than 2½ in. [63 mm] in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside, or end surfaces, except as provided for in 21.3.4, shall occur until the distance between the plates is less than the value of H calculated as follows:

$$H = (1 + e)t/(e + t/D) \quad (2)$$

where:

H = distance between flattening plates, in. [mm],
t = specified wall thickness, in. [mm],
D = specified or calculated (from the specified inside diameter and wall thickness) outside diameter, in. [mm], and
e = deformation per unit length (constant for a given grade of steel; 0.07 for medium carbon steel (maximum specified carbon 0.19 % or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18 % or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet.

21.2 *Welded Pipe*—A section of welded pipe not less than 4 in. [100 mm] in length shall be flattened cold between parallel plates in two steps. The weld shall be placed 90° from the direction of the applied force (at the point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks on the inside or outside surfaces, except as provided for in 21.3.4, shall occur until the distance between the plates is less than the value of H calculated by Eq 2. During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet.

21.3 *Seamless, Centrifugally Cast, and Welded Pipe:*

21.3.1 Evidence of laminated or defective material or weld that is revealed during the entire flattening test shall be cause for rejection.

21.3.2 Surface imperfections not evident in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

21.3.3 Superficial ruptures resulting from surface imperfections shall not be a cause for rejection.

21.3.4 When low D-to-t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D to t ratio is less than 10.

22. Hydrostatic Test Requirements

22.1 Except as provided in 22.2 and 22.3, each length of pipe shall be tested by the manufacturer to a hydrostatic pressure which will produce in the pipe wall a stress not less than 60 % of the minimum specified yield strength for carbon and ferritic alloy steel pipe, or 50 % of the specified minimum yield strength for austenitic alloy steel pipe. The test pressure or stress shall be determined by the following equation:

$$P = 2St/D \text{ or } \quad S = PD/2t \tag{3}$$

where:

P = hydrostatic test pressure in psi or MPa,
S = pipe wall stress in psi or MPa,
t = specified nominal wall thickness, nominal wall thickness corresponding to specified ANSI schedule number, or 1.143 times the specified minimal wall thickness, in. [mm], and
D = specified outside diameter, outside diameter corresponding to specified ANSI pipe size, or outside diameter calculated by adding $2t$ (as defined above) to the specified inside diameter, in. [mm].

22.1.1 The hydrostatic test pressure determined by the equation shall be rounded to the nearest 50 psi [0.5 MPa] for pressures below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending, or other forming operations.

22.2 Regardless of pipe-wall stress-level determined by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed 2500 psi [17.0 MPa] for outside diameters (see D in 22.1) of 3.5 in. [88.9 mm] or less, nor 2800 psi [19.0 MPa] for outside diameters over 3.5 in. [88.9 mm]. This does not prohibit testing at higher pressures at the manufacturer's option or as provided in 22.3.

22.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 22.2 or 22.1, or both, may be stated on the order.

22.4 The test pressure shall be held for a minimum of 5 s, without resultant leakage through the pipe wall. For welded pipe, the test pressure shall be held for a time sufficient to permit the inspector to examine the entire length of the welded seam.

22.5 The hydrostatic test may not be capable of inspecting the end portion of the pipe. The length of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

23. Material Test Report

23.1 The producer or supplier shall furnish a material test report certifying that the material was manufactured, sampled, tested and inspected in accordance with the specification, including year date, the supplementary requirements, and any other requirements designated in the purchase order or contract, and that the results met the requirements of that specification, the supplementary requirements and the other requirements. A signature or notarization is not required on the material test report, but the document shall be dated and shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature or notarization, the organization submitting the report is responsible for the contents of the report.

23.2 In addition, the material test report shall include the following information and test results, when applicable:

23.2.1 Heat Number,
23.2.2 Heat Analysis,
23.2.3 Product Analysis, if specified or required,
23.2.4 Tensile Properties,
23.2.5 Width of the gage length, when longitudinal strip tension test specimens are used,
23.2.6 Bend Test acceptable,
23.2.7 Flattening Test acceptable,
23.2.8 Hydrostatic Test pressure
23.2.9 Non-destructive Electric Test method,
23.2.10 Impact Test results, and
23.2.11 Other test results or information required to be reported by the product specification.

23.3 Test results or information required to be reported by supplementary requirements, or other requirements designated in the purchase order or contract shall be reported, but may be reported in a separate document.

23.4 The material test report shall include a statement of explanation for the letter added to the specification number marked on the material (see 26.5) when all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before removal of the letter (that is, X, Y, or Z).

23.5 When certification is required for material that has not been hydrostatically tested, the certificate of test shall state "Not hydrostatically tested", and the letters "NH" shall be appended to the product specification number, material grade and class shown on the certificate.

23.6 A material test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the material test report.

24. Inspection

24.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with operation of the works.

25. Rejection

25.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

25.2 Pipe that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the suitability of the pipe. Disposition of such pipe shall be a matter for agreement.

26. Product Marking

26.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number (year of issue not required) and grade. Marking shall begin approximately 12 in. [300 mm] from the end of each length of pipe. For pipe less than NPS 2 [DN 50] and pipe under 3 ft [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the pipes are shipped.

26.2 When pipe marked as specified is rejected, the ASTM designation shall be cancelled.

26.3 For austenitic steel pipe, the marking paint or ink shall not contain any harmful metal, or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

26.4 Pipes which have been weld repaired in accordance with 17.1 shall be marked *WR*.

26.5 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as *X, Y,* or *Z*, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in 25.1.

26.6 *Bar Coding*—In addition to the requirements in 26.1, 26.2, 26.3, 26.4 and 26.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

27. Packaging, Marking, and Loading

27.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A700.

28. Government Procurement

28.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order for agencies of the U.S. Government where scale free pipe is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

28.1.1 Pipe shall be ordered to nominal pipe size (NPS) and schedule. Nominal pipe shall be as specified in ASME B36.10.

28.1.2 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

28.1.3 *Sampling for Flattening and Flaring Test and for Visual and Dimensional Examination*—Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (pieces per lot)	Sample Size
2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

28.1.4 *Sampling for Chemical Analysis*—One sample for chemical analysis shall be selected from each of two pipes chosen from each lot. A lot shall be all material poured from one heat.

28.1.5 *Sampling for Tension and Bend Test*—One sample shall be taken from each lot. A lot shall consist of all pipe of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

28.1.6 *Hydrostatic and Ultrasonic Tests*—Each pipe shall be tested by the ultrasonic (when specified) and hydrostatic tests.

28.1.7 Pipe shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel pipe shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

28.1.8 In addition to the marking in Specification A450/A450M, each length of pipe ¼ in. outside diameter and larger shall be marked with the following listed information. Marking shall be in accordance with FED-STD-183 and MIL-STD-792. (*a*) Nominal Pipe Size Schedule and Length (*b*) Heat or lot identification number.

28.1.9 Pipe shall be straight to within the tolerances specified in Table 3.

28.1.10 When specified, each pipe shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the calibration standard shall be 5 % of the wall thickness or 0.005 in., whichever is greater. Any pipe which produces an indication equal to or greater than 100 % of the indication from the calibration standard shall be rejected.

28.1.11 The pipe shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the pipe as determined by visual and ultrasonic examination, or alternate tests, as specified.

28.1.12 Pipe shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality pipe. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in., whichever is greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

28.1.13 No weld repair by the manufacturer is permitted.

28.1.14 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163 and commercial preservation and packing shall be in accordance with Practices A700 or Practice D3951.

29. Keywords

29.1 alloy steel pipe; carbon steel pipe; general delivery requirements; steel pipe

TABLE 3 Straightness Tolerances

Specified OD, in.	Specified wall thickness, in.	Maximum curvature in any 3 ft, in.	Maximum curvature in total length, in.
Up to 5.0, incl.	Over 3 % OD to 0.5, incl.	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl.	Over 4 % OD to 0.75, incl.	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl.	Over 4 % OD to 1.0, incl.	0.060	0.020 × length, ft

APPENDIX

(Nonmandatory Information)

X1. TABLE OF MINIMUM WALL THICKNESSES

Table X1.1 displays minimum wall thicknesses.

TABLE X1.1 Minimum Wall Thicknesses on Inspection for Nominal (Average) Pipe Wall Thicknesses

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:

t_n = nominal (average) wall thickness, in. [mm], and
t_m = minimum wall thickness, in. [mm].
The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with the Practice E29.

NOTE 2—This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.068	1.73	0.060	1.52	0.294	7.47	0.257	6.53	0.750	19.05	0.656	16.62
0.088	2.24	0.077	1.96	0.300	7.62	0.262	6.65	0.812	20.62	0.710	18.03
0.091	2.31	0.080	2.03	0.307	7.80	0.269	6.83	0.843	21.41	0.738	18.75
0.095	2.41	0.083	2.11	0.308	7.82	0.270	6.86	0.864	21.95	0.756	19.20
0.113	2.87	0.099	2.51	0.312	7.92	0.273	6.93	0.875	22.22	0.766	19.46
0.119	3.02	0.104	2.64	0.318	8.08	0.278	7.06	0.906	23.01	0.793	20.14
0.125	3.18	0.109	2.77	0.322	8.18	0.282	7.17	0.937	23.80	0.820	20.83
0.126	3.20	0.110	2.79	0.330	8.38	0.289	7.34	0.968	24.59	0.847	21.51
0.133	3.38	0.116	2.95	0.337	8.56	0.295	7.49	1.000	25.40	0.875	22.22
0.140	3.56	0.122	3.10	0.343	8.71	0.300	7.62	1.031	26.19	0.902	22.91
0.145	3.68	0.127	3.23	0.344	8.74	0.301	7.65	1.062	26.97	0.929	23.60
0.147	3.73	0.129	3.28	0.358	9.09	0.313	7.95	1.093	27.76	0.956	24.28
0.154	3.91	0.135	3.43	0.365	9.27	0.319	8.10	1.125	28.57	0.984	24.99
0.156	3.96	0.136	3.45	0.375	9.52	0.328	8.33	1.156	29.36	1.012	25.70
0.179	4.55	0.157	3.99	0.382	9.70	0.334	8.48	1.218	30.94	1.066	27.08
0.187	4.75	0.164	4.17	0.400	10.16	0.350	8.89	1.250	31.75	1.094	27.77
0.188	4.78	0.164	4.17	0.406	10.31	0.355	9.02	1.281	32.54	1.121	28.47
0.191	4.85	0.167	4.24	0.432	10.97	0.378	9.60	1.312	33.32	1.148	29.16
0.200	5.08	0.175	4.44	0.436	11.07	0.382	9.70	1.343	34.11	1.175	29.84
0.203	5.16	0.178	4.52	0.437	11.10	0.382	9.70	1.375	34.92	1.203	30.56
0.216	5.49	0.189	4.80	0.438	11.13	0.383	9.73	1.406	35.71	1.230	31.24
0.218	5.54	0.191	4.85	0.500	12.70	0.438	11.13	1.438	36.52	1.258	31.95
0.219	5.56	0.192	4.88	0.531	13.49	0.465	11.81	1.500	38.10	1.312	33.32
0.226	5.74	0.198	5.03	0.552	14.02	0.483	12.27	1.531	38.89	1.340	34.04
0.237	6.03	0.207	5.23	0.562	14.27	0.492	12.50	1.562	39.67	1.367	34.72
0.250	6.35	0.219	5.56	0.593	15.06	0.519	13.18	1.593	40.46	1.394	35.40
0.258	6.55	0.226	5.74	0.600	15.24	0.525	13.34	1.750	44.45	1.531	38.89
0.276	7.01	0.242	6.15	0.625	15.88	0.547	13.89	1.781	45.24	1.558	39.57
0.277	7.04	0.242	6.15	0.656	16.62	0.573	14.55	1.812	46.02	1.586	40.28
0.279	7.09	0.244	6.20	0.674	17.12	0.590	14.99	1.968	49.99	1.722	43.74
0.280	7.11	0.245	6.22	0.687	17.45	0.601	15.27	2.062	52.38	1.804	45.82
0.281	7.14	0.246	6.25	0.719	18.26	0.629	15.98	2.343	59.51	2.050	52.07

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SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, QUENCHED AND TEMPERED, MANGANESE-MOLYBDENUM AND MANGANESE-MOLYBDENUM-NICKEL

SA-533/SA-533M

(Identical with ASTM Specification A533/A533M-16.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel

1. Scope

1.1 This specification covers one type of manganese-molybdenum and four types of manganese-molybdenum-nickel alloy steel plates for use in the quenched and tempered condition for the construction of welded pressure vessels.

1.2 Material under this specification is available in five types, designated "A", "B", "C", "D", and "E". The material is also available in three classes having the following strength levels.

Class	Tensile Strength, ksi [MPa]
1	80–100 [550 to 690]
2	90–115 [620 to 795]
3	100–125 [690 to 860]

1.3 The maximum thickness of Class 1 and Class 2 plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness to 12 in. [300 mm] for Types A through D and to 7 in. [180 mm] for Type E.

1.4 The maximum thickness of Class 3 plates is 2½ in. [65 mm] for Types A through D and 2 in. [50 mm] for Type E.

1.5 The minimum nominal thickness of plates of all classes is 0.25 in. [6.5 mm].

1.6 These alloy steel plates in the as-rolled condition are sensitive to cracking during transit and handling, particularly in thicknesses over about 1 or 2 in. [25 or 50 mm]. They should be shipped in the as-rolled conditions only by mutual agreement of manufacturer and the purchaser.

1.7 Plates covered by this specification are often used in the beltline region of nuclear reactor vessels where the material properties may be affected by high levels of radiation. Appendix X1 provides some information pertinent to this usage.

1.8 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

TABLE 1 Chemical Requirements

NOTE 1—Where "..." appears there is no requirement.

	Composition, %				
	Type A	Type B	Type C	Type D	Type E
Carbon, max[A]	0.25	0.25	0.25	0.25	0.20
Manganese:[B]					
Heat analysis	1.15–1.50	1.15–1.50	1.15–1.50	1.15–1.50	1.15–1.70
Product analysis	1.07–1.62	1.07–1.62	1.07–1.62	1.07–1.62	1.04–1.84
Phosphorus, max[A]	0.025	0.025	0.025	0.025	0.020
Sulfur, max[A]	0.025	0.025	0.025	0.025	0.015
Silicon:					
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45
Molybdenum:					
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.60	0.45–0.60	0.25–0.60
Product analysis	0.41–0.64	0.41–0.64	0.41–0.64	0.41–0.64	0.21–0.64
Nickel:					
Heat analysis	. . .	0.40–0.70	0.70–1.00	0.20–0.40	0.60–1.00
Product analysis	. . .	0.37–0.73	0.67–1.03	0.17–0.43	0.57–1.03
Chromium, max:					
Heat analysis	. . .	. . .	. . .	. . .	0.60
Product analysis	. . .	. . .	. . .	. . .	0.64

[A] Applies to both heat and product analyses.
[B] For Types A, B, C, and D, the maximum manganese content may be increased to 1.60 % on heat analysis and 1.65 % on product analysis when Class 2 or Class 3 properties are specified and when Supplementary Requirement S3 (see Specification A20/A20M) is specified with a total holding time of more than 1 h/in. [2.4 min/mm] of thickness.

TABLE 2 Tensile Requirements

	Class 1	Class 2	Class 3
	ksi [MPa]	ksi [MPa]	ksi [MPa]
Tensile strength	80–100 [550–690]	90–115 [620–795]	100–125 [690–860]
Yield strength, min	50 [345]	70 [485]	83 [570]
Elongation in 2 in. [50 mm], min, %[A]	18	16	16

[A] See Specification A20/A20M for elongation adjustment.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain requirement of Specification A20/A20M.

5. Heat Treatment

5.1 All plates shall be heat treated by heating to a suitable temperature within the range from 1550 to 1800°F [845 to 980°C], holding for a sufficient time to obtain uniform temperature throughout the plate thickness and then quenching, in water. Subsequently the plates shall be tempered at a suitable temperature to produce the specified properties, but not less than 1100°F [595°C] with a minimum holding time of ½ h/in. [1.2 min/mm] of thickness, but not less than ½ h.

5.2 When the plates are heat treated by the fabricator, it shall be his responsibility to apply the proper heat treatment and to conduct tests he deems necessary to assure that the specified properties are attained. Plates thicker than 2 in. [50 mm] shall be stress-relieved by the manufacturer prior to shipment at a temperature no lower than 1100°F [595°C].

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements:*

7.1.1 The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½-in. [40 mm] wide rectangular specimen may be used, and the elongation may be determined in a 2-in. [50-mm] gage length that include the fracture and that shows the greatest elongation.

8. Keywords

8.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessels

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.2 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M,

S17. Vacuum Carbon-Deoxidized Steel, and

S19. Restricted Chemical Requirements.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below is additional optional Supplementary Requirements S53, which is suitable for this specification.

S53.

S53.1 When specified by the purchaser, the axis of the tensile and impact test specimens shall come from the mid-thickness of each plate tested, in lieu of midway between the center thickness and the top or bottom surface of the plate.

APPENDIX

(Nonmandatory Information)

X1. NUCLEAR REACTOR BELTLINE CONSIDERATIONS—RESIDUAL ELEMENTS

X1.1 Reactor design requires review and control of residual elements that affect the material properties. Copper and phosphorus are limited to levels determined by the total fluence to be encountered during plant life. Vanadium and sulfur can affect the upper energy shelf level. In the case of sulfur, control of this element or its morphology in the plate, or both, may offer alternative means of control. The limits required shall be specified in the ordering data. The following table itemizes currently available commercial limits for the referenced elements:

Element	Heat Analysis, %	Product Analysis, %
Copper	0.10	0.12
Phosphorus	0.012	0.015
Sulfur	0.010	0.013
Vanadium	0.03	0.04

SPECIFICATION FOR PRESSURE VESSEL PLATES, HEAT-TREATED, CARBON-MANGANESE-SILICON STEEL

SA-537/SA-537M

(Identical with ASTM Specification A537/A537M-20.)

Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel

1. Scope

1.1 This specification covers heat-treated carbon-manganese-silicon steel plates intended for fusion welded pressure vessels and structures.

1.2 Plates furnished under this specification are available in the following three classes:

Class	Heat Treatment	Thickness	Yield Strength, min, ksi [MPa]	Tensile Strength, min, ksi [MPa]
1	Normalized	2½ in. and under [65 mm and under]	50 [345]	70 [485]
		Over 2½ in. [Over 65 mm]	45 [310]	65 [450]
2	Quenched and tempered	2½ in. and under [65 mm and under]	60 [415]	80 [550]
		Over 2½ to 4 in. [Over 65 to 100 mm]	55 [380]	75 [515]
		Over 4 in. [Over 100 mm]	46 [315]	70 [485]
3	Quenched and tempered	2½ in. and under [65 mm and under]	55 [380]	80 [550]
		Over 2½ to 4 in. [Over 65 to 100 mm]	50 [345]	75 [515]
		Over 4 in. [Over 100 mm]	40 [275]	70 [485]

1.3 The maximum thickness of plates is limited only by the capacity of the material to meet the specified mechanical property requirements.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other without combining values in any way.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates furnished supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures; permissible variations in dimensions; and mass, quality, and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

TABLE 1 Chemical Requirements

Element	Composition, %
Carbon, max[A]	0.24
Manganese:	
1½ in. [40 mm] and under in thickness:[B]	
Heat analysis	0.70–1.35
Product analysis	0.64–1.46
Over 1½ in. [40 mm] in thickness:	
Heat analysis	1.00–1.60
Product analysis	0.92–1.72
Phosphorus, max[A]	0.025
Sulfur, max[A]	0.025
Silicon:	
Heat analysis	0.15–0.50
Product analysis	0.13–0.55
Copper, max:	
Heat analysis	0.35
Product analysis	0.38
Nickel, max:[B]	
Heat analysis	0.25
Product analysis	0.28
Chromium, max:	
Heat analysis	0.25
Product analysis	0.29
Molybdenum, max:	
Heat analysis	0.08
Product analysis	0.09

[A] Applies to both heat and product analyses.
[B] Manganese may exceed 1.35 % on heat analysis, up to a maximum of 1.60 %, and nickel may exceed 0.25 % on heat analysis, up to a maximum of 0.50 %, provided the heat analysis carbon equivalent does not exceed 0.57 % when based upon the following equation:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

When this option is exercised, the manganese and nickel contents on product analysis shall not exceed the heat analysis content by more than 0.12 % and 0.03 %, respectively.

TABLE 2 Tensile Requirements

	Class 1	Class 2	Class 3
	ksi [MPa]	ksi [MPa]	ksi [MPa]
Tensile strength:			
2½ in. and under	70–90	80–100	80–100
[65 mm and under]	[485–620]	[550–690]	[550–690]
Over 2½ to 4 in., incl	65–85	75–95	75–95
[Over 65 to 100 mm, incl]	[450–585]	[515–655]	[515–655]
Over 4 in.	65–85	70–90	70–90
[Over 100 mm]	[450–585]	[485–620]	[485–620]
Yield strength, min:			
2½ in. and under	50	60	55
[65 mm and under]	[345]	[415]	[380]
Over 2½ to 4 in., incl	45	55	50
[Over 65 to 100 mm, incl]	[310]	[380]	[345]
Over 4 in.	45	46	40
[Over 100 mm]	[310]	[315]	[275]
Elongation in 2 in. [50 mm], min, %:[A]			
4 in. [100 mm] and under	22	22	22
Over 4 in. [100 mm]	20	20	20
Elongation in 8 in. [200 mm], min, %[A]	18	[B]	[B]

[A] See Specification A20/A20M for elongation adjustments.
[B] There is no requirement for elongation in 8 in.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 All plates shall be thermally treated as follows:

5.1.1 Class 1 plates shall be normalized.

5.1.2 Class 2 and Class 3 plates shall be quenched and tempered. The tempering temperature for Class 2 plates shall not be less than 1100°F [595°C] and not less than 1150°F [620°C] for Class 3 plates.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Requirements

7.1 *Tension Tests:*

7.1.1 *Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 For Class 2 and Class 3 plates with a nominal thickness of ¾ in. [20 mm] and under, the 1½-in. [40-mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation.

8. Keywords

8.1 carbon steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessel application

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR ALLOY-STEEL BOLTING FOR SPECIAL APPLICATIONS

SA-540/SA-540M (23)

(Identical with ASTM Specification A540/A540M-15(2021).)

Specification for
Alloy-Steel Bolting for Special Applications

1. Scope

1.1 This specification covers regular and special-quality alloy steel bolting materials and bolting components that may be used for nuclear and other special applications. See Specification A962/A962M for the definition of bolting.

1.2 The following referenced common requirements are indispensable for application of this specification: Specification A962/A962M.

1.3 Supplementary requirements of an optional nature are provided for use at the option of the purchaser. These supplementary requirements only apply when specified individually by the purchaser in the purchase order or contract.

1.4 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable "*M*" specification designation (SI units), inch-pound units shall apply.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A962/A962M Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

E45 Test Methods for Determining the Inclusion Content of Steel

3. Ordering Information

3.1 The inquiry and orders for bolting material and bolting components under this specification shall include the following, as required, to describe the desired items adequately:

3.1.1 Grade and Class

3.1.2 Condition (Section 5),

3.1.3 Heat treatment (Section 6),

3.1.4 Supplementary Requirements (S1 to S9),

3.1.5 Reports required (Section 16),

3.1.6 End use, and

3.1.7 Any special requirements.

3.2 The purchaser is referred to the listed supplementary requirements.

4. Common Requirements

4.1 Bolting materials and bolting components supplied to this specification shall conform to the requirements of Specification A962/A962M. These requirements include test methods, finish, thread dimensions, macro etch, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A962/A962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A962/A962M, this specification shall prevail.

5. Manufacture

5.1 Bolting material shall be supplied hot-rolled or hot-forged or cold-finished at the option of the producer. However, if desired by the purchaser, cold finishing may be specified.

6. Heat Treatment

6.1 Bolting material ordered in the annealed condition shall have a structure suitable for machining. Such annealed material is not intended to be used without subsequent quenching and tempering as specified in 6.2.

6.2 Bolting material ordered in the liquid-quenched and tempered condition shall be uniformly reheated from a temperature below the cooling transformation range to the proper austenitizing temperature, quenched in a liquid medium under substantially uniform conditions, and then uniformly reheated for tempering. The minimum tempering temperature shall be 850 °F [455 °C].

6.3 Bolting material that has been straightened after quenching and tempering shall be stress relieved by reheating to a temperature not lower than 100 °F [55 °C] under the tempering temperature.

7. Chemical Composition

7.1 Steels used for bolting materials shall conform to the chemical requirements prescribed in Table 1.

8. Tensile Requirements

8.1 Bolting material furnished in the annealed condition shall be capable of meeting the specified tensile properties for the class as specified in Table 2 when heat treated in accordance with 6.2 and 6.3 (see Supplementary Requirement S4).

8.2 Bolting material in the quenched and tempered or quenched, tempered and stress-relieved condition shall conform to properties shown in Table 2 for the specified class.

9. Hardness Requirements

9.1 The hardness shall be determined on the surface of the material after removal of decarburization.

9.2 The hardness of bolting material in the annealed condition shall not be greater than 235 HBW.

9.3 The hardness of bolting material in the quenched and tempered or quenched, tempered and stress-relieved condition shall be within the limits in Table 2 for the specified class.

10. Impact Requirements

10.1 Annealed bolting material after proper heat treatment shall be capable of meeting the impact requirements in Table 2 or of Supplementary Requirement S8, if so specified (see Supplementary Requirement S4).

10.2 Bolting material in the quenched and tempered or quenched, tempered, and stress-relieved condition shall conform to the impact requirements in Table 2, or of Supplementary Requirement S8 if so specified.

10.3 The percent of shear (ductility or fibrous) fracture shall be computed. The computed value shall be recorded for all impact specimens.

10.4 The amount of lateral expansion shall be measured. The measured value shall be recorded for all impact specimens.

10.5 The percent shear and the amount of lateral expansion shall be reported for information purposes (see 16.1).

11. Workmanship, Finish, and Appearance

11.1 Bolting material shall be uniform in quality and free of defects that would be detrimental to the intended service. If magnetic particle inspection for such defects is desired, Supplementary Requirement S6 should be specified.

11.2 *Surface Quality*—Bolting material shall be free of seams, laps, cracks, or other defects that are not removable within the machining cleanup allowance specified in Table 3.

TABLE 1 Chemical Requirements^{A}

Grade Symbol	B21		B22		B23		B24		B24V	
	(Cr-Mo-V)		(4142-H)		(E-4340-H)		(4340 Mod.)		(4340V Mod.)	
	Chromium-Molybdenum-Vanadium		Chromium-Molybdenum		Chromium-Nickel-Molybdenum		Chromium-Nickel-Molybdenum		Chromium-Nickel-Molybdenum-Vanadium	
	Range, %	Product Variation, Over or Under,^{B} %	Range, %	Product Variation, Over or Under,^{B} %	Range, %	Product Variation, Over or Under,^{B} %	Range, %	Product Variation, Over or Under,^{B} %		Product Variation, Over or Under,^{B} %
Carbon	0.36–0.44	0.02	0.39–0.46	0.02	0.37–0.44	0.02	0.37–0.44	0.02	0.37–0.44	0.02
Manganese	0.45–0.70	0.03	0.65–1.10	0.04	0.60–0.95	0.04	0.70–0.90	0.04	0.60–0.95	0.04
Phosphorus, max	0.025^{C}	0.005	0.025^{C}	0.005	0.025^{C}	0.005	0.025^{C}	0.005	0.025^{C}	0.005
Sulfur, max	0.025^{C}	0.005	0.025^{C}	0.005	0.025^{C}	0.005	0.025^{C}	0.005	0.025^{C}	0.005
Silicon	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35^{D}	0.02
Chromium	0.80–1.15	0.05	0.75–1.20	0.05	0.65–0.95	0.05	0.70–0.95	0.05	0.60–0.95	0.05
Nickel	. . .	. . .	. . .	. . .	1.55–2.00	0.05	1.65–2.00	0.05	1.55–2.00	0.05
Molybdenum	0.50–0.65	0.03	0.15–0.25	0.02	0.20–0.30	0.02	0.30–0.40	0.02	0.40–0.60	0.03
Vanadium	0.25–0.35	0.03	. . .	. . .	. . .	. . .	. . .	. . .	0.04–0.10	0.01

^{A} The intentional addition of Bi, Se, Te, and Pb is not permitted.
^{B} Unless otherwise specified, separate determinations may vary from the specified ranges, except that elements in any heat must not vary both above and below the specified range.
^{C} Phosphorus and sulfur content is 0.04 % max when open-hearth steel is specified.
^{D} Silicon content is 0.35 % max if vacuum-carbon deoxidized.

TABLE 2 Mechanical Property Requirements

NOTE 1—The minimum average of 3 specimens shall not be less than 35 ft·lbf [47 J]. One specimen from a set of 3 may be less than 35 ft·lbf [47 J] but not less than 30 ft·lbf [41 J].

NOTE 2— The minimum average of 3 specimens shall not be less than 30 ft·lbf [41 J]. One specimen from a set of 3 may be less than 30 ft·lbf [41 J] but not less than 25 ft·lbf [34 J].

NOTE 3—The minimum average of 3 specimens shall not be less than 25 ft·lbf [34 J]. One specimen from a set of 3 may be less than 25 ft·lbf [34 J] but not less than 20 ft·lbf [27 J].

NOTE 4—No minimum values established. Tests shall be run for information only.

Grade	Class	Diameter	Tensile Strength, min	Yield Strength, 0.2 % offset, min	Elongation, min, %	Reduction of Area, min, %	Surface Brinell Hardness		Charpy V-Notch +10 °F [−12.2 °C]
							min	max	
Inch-Pound Units									
		in.	ksi	ksi	In 2 in.				
B21	5	to 2, incl	120	105	15	50	241	285	Note 4
(Cr-Mo-V)		over 2 to 6, incl	115	100	15	50	248	302	Note 4
		over 6 to 8, incl	115	100	15	50	255	311	Note 4
	4	to 3, incl	135	120	13	45	269	331	Note 4
		over 3 to 6, incl	135	120	13	45	277	352	Note 4
	3	to 3, incl	145	130	12	40	293	352	Note 4
		over 3 to 6, incl	145	130	12	40	302	375	Note 4
	2	to 4, incl	155	140	11	40	311	401	Note 4
	1	to 4, incl	165	150	10	35	321	429	Note 4
B22	5	to 2, incl	120	105	15	50	248	293	Note 1
(4142-H)		over 2 to 4, incl	115	100	15	50	255	302	Note 4
	4	to 1, incl	135	120	13	45	269	341	Note 1
		over 1 to 4, incl	135	120	13	45	277	363	Note 4
	3	to 2, incl	145	130	12	40	293	363	Note 4
		over 2 to 4, incl	145	130	12	40	302	375	Note 4
	2	to 3, incl	155	140	11	40	311	401	Note 4
	1	to 1½ , incl	165	150	10	35	321	401	Note 4
B23	5	to 6, incl	120	105	15	50	248	311	Note 1
(E-4340-H)		over 6 to 8, incl	115	100	15	50	255	321	Note 1
		over 8 to 9½, incl	115	100	15	50	262	321	Note 4
	4	to 3, incl	135	120	13	45	269	341	Note 1
		over 3 to 6, incl	135	120	13	45	277	352	Note 1
		over 6 to 9½, incl	135	120	13	45	285	363	Note 4
	3	to 3, incl	145	130	12	40	293	363	Note 2
		over 3 to 6, incl	145	130	12	40	302	375	Note 2
		over 6 to 9½, incl	145	130	12	40	311	388	Note 4
	2	to 3, incl	155	140	11	40	311	388	Note 4
		over 3 to 6, incl	155	140	11	40	311	401	Note 4
		over 6 to 9½, incl	155	140	11	40	321	415	Note 4
	1	to 3, incl	165	150	10	35	321	415	Note 4
		over 3 to 6, incl	165	150	10	35	331	429	Note 4
		over 6 to 8, incl	165	150	10	35	341	444	Note 4
B24	5	to 6, incl	120	105	15	50	248	311	Note 1
(4340 Mod.)		over 6 to 8, incl	115	100	15	50	255	321	Note 1
		over 8 to 9½, incl	115	100	15	50	262	321	Note 1
	4	to 3, incl	135	120	13	45	269	341	Note 1
		over 3 to 6, incl	135	120	13	45	277	352	Note 1
		over 6 to 8, incl	135	120	13	45	285	363	Note 1
		over 8 to 9½, incl	135	120	13	45	293	363	Note 4
	3	to 3, incl	145	130	12	40	293	363	Note 2
		over 3 to 8, incl	145	130	12	40	302	388	Note 2
		over 8 to 9½, incl	145	130	12	40	311	388	Note 4
	2	to 7, incl	155	140	11	40	311	401	Note 2
		over 7 to 9½, incl	155	140	11	40	321	415	Note 4
	1	to 6, incl	165	150	10	35	321	415	Note 3
		over 6 to 8, incl	165	150	10	35	331	429	Note 4
B24V	3	to 4, incl	145	130	12	40	293	363	Note 1
(4340V Mod.)		over 4 to 8, incl	145	130	12	40	302	375	Note 2
		over 8 to 11, incl	145	130	12	40	311	388	Note 3
	2	to 4, incl	155	140	11	40	311	388	Note 2
		over 4 to 8, incl	155	140	11	40	311	401	Note 3
		over 8 to 11, incl	155	140	11	40	321	415	Note 4
	1	to 4, incl	165	150	10	35	321	415	Note 3
		over 4 to 8, incl	165	150	10	35	331	429	Note 4
		over 8 to 11, incl	165	150	10	35	331	444	Note 4

TABLE 2 *Continued*

Grade	Class	Diameter	Tensile Strength, min	Yield Strength, 0.2 % offset, min	Elongation, min, %	Reduction of Area, min, %	Surface Brinell Hardness min	Surface Brinell Hardness max	Charpy V-Notch +10 °F [−12.2 °C]
Metric Units									
		mm	MPa	MPa	In 50 mm				
B21	5	to 50, incl	825	725	15	50	241	285	Note 4
(Cr-Mo-V)		over 50 to 150, incl	795	690	15	50	248	302	Note 4
		over 150 to 205, incl	795	690	15	50	255	311	Note 4
	4	to 75, incl	930	825	13	45	269	331	Note 4
		over 75 to 150, incl	930	825	13	45	277	352	Note 4
	3	to 75, incl	1000	895	12	40	293	352	Note 4
		over 75 to 150, incl	1000	895	12	40	302	375	Note 4
	2	to 100, incl	1070	965	11	40	311	401	Note 4
	1	to 100, incl	1140	1035	10	35	321	429	Note 4
B22	5	to 50, incl	825	725	15	50	248	293	Note 1
(4142-H)		over 50 to 100, incl	795	690	15	50	255	302	Note 4
	4	to 25, incl	930	825	13	45	269	341	Note 1
		over 25 to 100, incl	930	825	13	45	277	363	Note 4
	3	to 50, incl	1000	895	12	40	293	363	Note 4
		over 50 to 100, incl	1000	895	12	40	302	375	Note 4
	2	to 75, incl	1070	965	11	40	311	401	Note 4
	1	to 38, incl	1140	1035	10	35	321	401	Note 4
B23	5	to 150, incl	825	725	15	50	248	311	Note 1
(E-4340-H)		over 150 to 200 incl	795	690	15	50	255	321	Note 1
		over 200 to 240, incl	795	690	15	50	262	321	Note 4
	4	to 75, incl	930	825	13	45	269	341	Note 1
		over 75 to 150, incl	930	825	13	45	277	352	Note 1
		over 150 to 240, incl	930	825	13	45	285	363	Note 4
	3	to 75, incl	1000	895	12	40	293	363	Note 2
		over 75 to 150, incl	1000	895	12	40	302	375	Note 2
		over 150 to 240, incl	1000	895	12	40	311	388	Note 4
	2	to 75, incl	1070	965	11	40	311	388	Note 4
		over 75 to 150, incl	1070	965	11	40	311	401	Note 4
		over 150 to 240, incl	1070	965	11	40	321	415	Note 4
	1	to 75, incl	1140	1035	10	35	321	415	Note 4
		over 75 to 150, incl	1140	1035	10	35	331	429	Note 4
		over 150 to 200, incl	1140	1035	10	35	341	444	Note 4
B24	5	to 150, incl	825	725	15	50	248	311	Note 1
(4340 Mod.)		over 150 to 200, incl	795	690	15	50	255	321	Note 1
		over 200 to 240, incl	795	690	15	50	262	321	Note 1
	4	to 75, incl	930	825	13	45	269	341	Note 1
		over 75 to 150, incl	930	825	13	45	277	352	Note 1
		over 150 to 200, incl	930	825	13	45	285	363	Note 1
		over 200 to 240, incl	930	825	13	45	293	363	Note 4
	3	to 75, incl	1000	895	12	40	293	363	Note 2
		over 75 to 200, incl	1000	895	12	40	302	388	Note 2
		over 200 to 240, incl	1000	895	12	40	311	388	Note 4
	2	to 180, incl	1070	965	11	40	311	401	Note 2
		over 180 to 240, incl	1070	965	11	40	321	415	Note 4
	1	to 150, incl	1140	1035	10	35	321	415	Note 3
		over 150 to 200, incl	1140	1035	10	35	331	429	Note 4
B24V	3	to 100, incl	1000	895	12	40	293	363	Note 1
(4340V Mod.)		over 100 to 200, incl	1000	895	12	40	302	375	Note 2
		over 200 to 240, incl	1000	895	12	40	311	388	Note 3
	2	to 100, incl	1070	965	11	40	311	388	Note 2
		over 100 to 200, incl	1070	965	11	40	311	401	Note 3
		over 200 to 280, incl	1070	965	11	40	321	415	Note 4
	1	to 100, incl	1140	1035	10	35	321	415	Note 3
		over 100 to 200, incl	1140	1035	10	35	331	429	Note 4
		over 200 to 280, incl	1140	1035	10	35	331	444	Note 4

12. Surface Condition

12.1 Bolting material shall be cleaned and furnished in the scale-free condition.

13. Number of Tests

13.1 *Mechanical Tests on Quenched and Tempered Bolting Material:*

TABLE 3 Rolled Bars[A] —Permissible Grinding Depth for Removal of Surface Defects

Diameter, in. [mm]	Minimum Stock Removal Per Side	
	in.	mm
1 to 1⅛ [25 to 29], incl	0.025	0.64
Over 1⅛ to 1¼ [29 to 32], incl	0.028	0.71
Over 1¼ to 1⅜ [32 to 35], incl	0.030	0.76
Over 1⅜ to 1½ [35 to 38], incl	0.033	0.84
Over 1½ to 2 [38 to 50], incl	0.042	1.07
Over 2 to 2½ [50 to 65], incl	0.052	1.32
Over 2½ to 3½ [65 to 90], incl	0.072	1.83
Over 3½ to 4½ [90 to 115], incl	0.090	2.29
Over 4½ to 5½ [115 to 140], incl	0.110	2.79
Over 5½ to 6½ [140 to 165], incl	0.125	3.18
Over 6½ to 8¼ [165 to 210], incl	0.155	3.94
Over 8¼ to 9½ [210 to 240], incl	0.203	5.16

[A] Consult the manufacturer on forged bars, cold-finished bars, bored bars, seamless tubes, and forged hollows.

13.1.1 One test coupon shall be removed from each end of one bar, one seamless tube, or one bored bar or from each of two forged hollows from each size of each heat in each tempering charge, or each 10 000 lb [4540 kg], whichever is less. One tension test and one impact test consisting of three Charpy V-notch specimens shall be taken from each test coupon. For testing in accordance with 15.1.1, two tests shall be obtained from two representative production pieces from each size of each heat in each tempering charge or each 10 000 lb [4540 kg], whichever is less.

13.1.2 *Hardness Test:*

13.1.2.1 Bars 2 in. [50 mm] and over and all seamless tubes or bored bars shall be tested near each end of each mill-treated length. Each forged hollow with thickness 2 in. [50 mm] or over shall be tested on the surface.

13.1.2.2 Bars under 2 in. [50 mm] shall be tested near each end of not less than 10 % of the bars. Forged hollows less than 2 in. [50 mm] thick shall be tested on the surface of not less than 10 % of the forgings.

13.2 *Hardness Tests of Annealed Bolting Material:*

13.2.1 Hardness tests shall be made on the annealed bars to assure compliance with 10.2.

13.3 *Bolting Components:*

13.3.1 The number of bolting components tested shall be as specified in Specification A962/A962M.

14. Retests

14.1 If the results of the mechanical tests of any test lot do not conform to the specified requirements, the manufacturer shall reject the lot or the manufacturer may re-heat treat such a lot no more than twice. After the lot is re-heat treated, all of the tests specified in Section 13 shall be repeated, and all shall conform to the specified requirements.

15. Test Specimens and Methods of Testing

15.1 A discard equivalent to the diameter of the bar when heat treated as a solid or a discard equivalent to the wall thickness when heat treated as a seamless tube, bored bar, or hollow forging shall be taken prior to removal of test coupons.

15.1.1 When production pieces are not of sufficient length to permit removal of test coupons in accordance with 15.1, the mid-length of the specimens shall be at the mid-length of the production pieces selected for destruction to provide test coupons of the bolting material. The production pieces selected for test shall be identical with respect to the quenched contour and size except for length which shall equal or exceed the length of the represented production pieces.

15.2 Tension and impact specimens from bolting components with cross sections of 1½ in. [38 mm] or less shall be taken so that their longitudinal axis is on a line representing the center of the diameter or thickness.

15.3 Tension test specimens from bolting components with cross sections exceeding 1½ in. [38 mm] shall be taken so that their longitudinal axis is midway between mid-thickness and surface.

15.4 Impact specimens from bolting components with cross sections exceeding 1½ in. [38 mm] shall be taken so that their longitudinal axis is midway between mid-thickness and surface or 1 in. [25 mm] below the surface plus the machining allowance per side, whichever is less.

16. Certification

16.1 When requested in the purchaser's order, a test report shall be furnished to the purchaser. In addition to the requirements of Specification A962/A962M the report shall include any other tests which may be specified in writing by the purchaser.

17. Product Marking

17.1 Bars under 2 in. [50 mm] in diameter shall be bundled and tagged with the specification, grade symbol, and mill heat number. The specification number marked on the tag need not include specification year date and revision number.

17.2 Bars 2 in. [50 mm] and over in diameter and all seamless tubes and bored bars shall be die-stamped with the mill heat number and grade symbol on one surface.

17.3 Each hollow forging shall be die-stamped with the heat number or heat symbol code and grade symbol.

17.4 See Specification A962/A962M for marking bolting components. Use the grade symbol shown in Table 1.

18. Keywords

18.1 bolts—steel; chromium-molybdenum alloy steel; chromium-molybdenum-vanadium alloy steel; chromium-nickel-molybdenum-vanadium alloy steel; bolting components—steel; nickel-chromium-molybdenum alloy steel; nuclear applications; nuts—steel; steel bars—alloy; steel bolting material

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order, in which event the tests shall be made at the mill at the purchaser's expense unless otherwise agreed upon.

S1. Product Analysis

S1.1 Product analysis shall be made on each bar, seamless tube, bored bar, or the parent bar from which forged hollows are made. Individual pieces failing to conform to Table 1 shall be rejected.

S2. Macroetch Test

S2.1 The material shall be macroetch tested and shall meet the quality and cleanliness requirements as specified by the purchaser. The macroetch examination may be made on representative billets from which the material will be produced or it may be made on samples cut from the ends of the bars, seamless tubes, bored bars, or forged hollows. The samples shall be prepared in accordance with the procedure described in Method E381.

NOTE S2.1—The quality and cleanliness may be specified by the purchaser as equal to or better than that indicated by a designated letter and plate number of Military Standard—430 (latest revision).

S3. Ultrasonic Test

S3.1 Each length shall be ultrasonically inspected in a manner agreeable to the purchaser and supplier.

S4. Demonstration of Capability

S4.1 When annealed bolting material is ordered to 6.1, a sample piece in length at least 3 × diameter *D* of a representative bar shall be heat treated in accordance with 6.2 and 6.3. Mechanical test samples taken as required by Section 15 shall meet the requirements of 8.2 and 10.2.

S5. Fracture Transition Temperature

S5.1 The fracture transition temperature for a 50 % fibrous (ductile shear) fracture shall be determined. The procedure for determination of the fracture transition temperature shall be to prepare four sets (three to a set) of Charpy V-notch specimens in accordance with Section 15. One set of three specimens shall be tested at approximately 70 °F [20 °C]. The absorbed energy in foot-pounds shall be recorded and the percent of fibrous fracture determined from Table S5.1 and Fig. S5.1. The other three sets shall be tested at successively lower or higher temperatures to bracket the temperature where the bolting material will exhibit a 50 % fibrous fracture. The results of all test data are to be reported to the purchaser.

S6. Magnetic Particle Inspection

S6.1 Bolting material may be supplied to cleanliness requirements by agreement between the purchaser and supplier. The cleanliness shall be determined by the magnetic particle method described in the latest issue of Practice E45.

NOTE S6.1—The bolting material shall have the minimum stock removal specified in Table S6.1 prior to magnetic particle inspection.

S7. Elevated Temperature Test

S7.1 Three Charpy V-notch specimens shall be tested at 212 °F [100 °C] to determine the "upper shelf" fracture energy of the material. No specimen thus tested shall break at an energy less than 30 ft·lbf [41 J].

S8. Alternative Fracture Toughness Requirement

S8.1 The fracture toughness requirements (Charpy impact test) for bolting material of the ASME Boiler and Pressure Vessel Code, Section III, Subarticle NB 2300, shall be used instead of the Charpy impact test requirement specified in

TABLE S5.1 Percent Fibrous Fracture[A]
Dimension *A* Width, mm

	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
Dimension *B* Height, mm																		
1.0	98	98	97	96	96	95	94	94	93	93	92	91	91	90	89	89	88	87
1.5	97	96	95	94	93	93	92	91	90	89	88	87	86	85	85	83	82	81
2.0	96	95	94	93	91	90	89	88	86	85	84	82	81	80	79	78	76	75
2.5	95	94	92	91	89	87	86	84	83	81	80	79	76	75	73	72	70	69
3.0	94	93	91	90	87	85	83	81	79	78	76	74	72	70	68	66	64	63
3.5	93	91	89	87	85	83	80	78	75	74	72	69	67	65	63	61	58	56
4.0	93	90	87	85	83	80	78	75	72	70	68	65	62	60	57	55	52	50
4.5	92	89	86	83	80	78	75	72	69	66	63	61	58	55	52	49	46	43
5.0	91	88	84	81	78	75	72	69	66	63	59	56	53	50	48	44	40	38
5.5	90	86	83	79	75	72	69	66	63	59	55	52	48	45	42	38	35	31
6.0	89	85	81	78	74	70	66	63	59	55	51	47	44	40	36	33	29	25
6.5	88	84	80	76	72	68	63	59	55	51	47	43	40	35	31	27	23	19
7.0	87	82	79	74	69	65	61	56	52	47	43	39	34	30	26	21	16	12
7.5	86	81	76	72	67	62	58	53	48	44	40	34	30	25	23	16	11	6
8.0	85	80	75	70	65	70	55	50	45	40	35	30	25	20	15	10	5	0

[A] See Fig. S5.1.

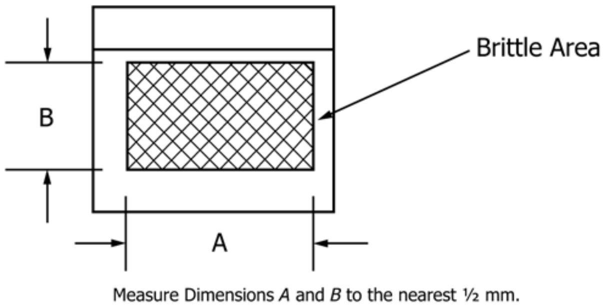

FIG. S5.1 Calculation of Percent Fibrous Area

TABLE S6.1 Rolled Bars[A] —Stock Removal for Magnetic Particle Inspection

Diameter, in. [mm]	Minimum Stock Removal Per Side	
	in.	mm
1 to 1½ [25 to 38], incl	0.075	1.90
Over 1½ to 2 [38 to 50], incl	0.090	2.29
Over 2 to 2½ [50 to 65], incl	0.125	3.18
Over 2½ to 3½ [65 to 90], incl	0.156	3.96
Over 3½ to 4½ [90 to 115], incl	0.187	4.75
Over 4½ to 6 [115 to 155], incl	0.250	6.35
Over 6 to 10 [155 to 255], incl	0.312	7.92

[A] Consult the manufacturer on forged bars, cold-finished bars, bored bars, seamless tubes, and forged hollows.

Table 2.

SPECIFICATION FOR QUENCHED AND TEMPERED CARBON AND ALLOY STEEL FORGINGS FOR PRESSURE VESSEL COMPONENTS

SA-541/SA-541M

(Identical with ASTM Specification A541/A541M-05(2015).)

SPECIFICATION FOR QUENCHED AND TEMPERED CARBON AND ALLOY STEEL FORGINGS FOR PRESSURE VESSEL COMPONENTS

SA-541/SA-541M

[Identical with ASTM Specification A 541/A 541M-05(2015).]

1. Scope

1.1 This specification covers requirements for quenched and tempered carbon and alloy steel forgings for pressure vessel components.

1.2 All grades are considered weldable under proper conditions. Welding technique is of fundamental importance, and it is presupposed that welding procedure and inspection will be in accordance with approved methods for the grade of material used.

NOTE 1 — Grades 1 and 1A have different chemistries but the same mechanical requirements.

NOTE 2 — Designations have been changed as follows:

Current	Formerly
Grade 1	Class 1
Grade 1A	Class 1A
Grade 1C	Class 4
Grade 2 Class 1	Class 2
Grade 2 Class 2	Class 2A
Grade 3 Class 1	Class 3
Grade 3 Class 2	Class 3A
Grade 4N Class 1	Class 7
Grade 4N Class 2	Class 7A
Grade 4N Class 3	Class 7B
Grade 5 Class 1	Class 8
Grade 5 Class 2	Class 8A
Grade 11 Class 4	Class 11C
Grade 22 Class 3	Class 22B
Grade 22 Class 4	Class 22C
Grade 22 Class 5	Class 22D
Grade 22V	Class 22V
Grade 3V	Class 3V

1.3 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 788 Specification for Steel Forgings, General Requirements

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing that locates areas of significant loading in the forging (when required); the method of selecting test locations (see 6.2); purchase option (if any) in accordance with 9.1, and any supplementary requirements desired.

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

4. Chemical Composition

4.1 *Heat Analysis* — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1 except that the additional features of Supplementary Requirements S8, S9, S10, S12, and S15 shall also apply as individually specified in the ordering information.

4.2 *Product Analysis* — The manufacturer shall use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat. The permissible variations of Table 1 of Specification A 788 do not apply to carbon, phosphorus, silicon, and sulphur for all classes, vanadium for Grade 1C, and columbium and calcium for Grades 22V and 3VCb. Boron is not subject to product analysis. The purchaser may also make this determination in accordance with Specification A 788.

5. Heat Treatment for Mechanical Properties

5.1 After complete austenitization, the forgings shall be quenched in a suitable liquid medium by spraying or immersion. For Grade 22V forgings, the minimum austenitizing temperature shall be 1650°F [900°C]. Quenching shall be followed by tempering at a subcritical temperature and holding at this temperature for a minimum time of ½ h/in. [25 mm] of maximum section thickness. Minimum tempering temperatures shall be:

Grade	°F [°C]
1, 1A, 2 Class 2, 3 Class 2	1150 [620]
2, 3 Class 1, 22 Class 3	1200 [650]
1C, 11 Class 4, 22 Class 4, 4N Class 1, 4N Class 2, 5 Class 1, 5 Class 2	1100 [595]
22 Class 15	1050 [565]
4N Class 3	1125 [605]
3V, 3VCb	1250 [675]
22V	1250 [675]

5.2 For Classes 1, 1A, 2, 2A, 3, or 3A, a multiple stage austenitizing procedure may be used whereby the forging is first fully austenitized and liquid quenched, followed by reheating within the intercritical temperature range to partially reaustenitize, and again liquid quenched. On completion of the austenitizing/quenching cycles, the forgings shall be tempered at a subcritical temperature as described in 5.1.

6. Mechanical Properties

6.1 *General Requirements* — The forgings shall conform to the requirements of Table 2. The forgings shall also conform to the requirements of Table 3 unless either Supplementary Requirement S6 or S13 is specified, in which case the requirements of those sections shall apply. The largest obtainable tension test specimen as specified in Fig. 4 of Test Methods and Definitions A 370 shall be used. Impact specimens shall be Charpy V-notch, as shown in Fig. 10 of Test Methods and Definitions A 370. The usage of subsize impact specimens due to material limitations must have prior purchaser approval.

6.2 *Sampling* — The longitudinal axis and mid-length of tension and impact test specimens shall be positioned in accordance with one of the following methods as specified by the purchaser:

6.2.1 *Method 1* — This method shall always be used when the maximum quenched thickness does not exceed 2 in. [50 mm]. Specimens shall be located in the production forging or test forging (as described in Method 4) at mid-thickness and at least 2 in. from other quenched surfaces.

6.2.2 *Method 2* — t by $2t$, where t is the distance from the area of significant loading (see 3.1) to the nearest quenched surface. However, the specimens shall not be nearer to one quenched surface than ¾ in. [20 mm] and to the second quenched surface than 1½ in. [40 mm]. When this method of testing is employed, forgings are usually manufactured in accordance with a purchaser-approved drawing showing pre-quenched dimensions and the location of mechanical test specimens.

6.2.3 *Method 3* — ¼ T by T, where T is the maximum thickness of the forging as heat treated. Where this method of testing is employed, the following limitations for as-treated thickness shall apply, unless otherwise agreed upon:

Grade	in. [mm], max
1 and 1A	3 [75]
2 Class 2 and 3 Class 2	6 [150]
2 Class 1 and 3 Class 1	8 [200]
1C	4 [100]
11 Class 4	5 [125]
22 Class 4, 4N Class 2, 5 Class 2	6 [150]
22 Class 5	8 [200]
4N Class 1, 5 Class 1, 4N Class 3, 3V, 3VCb, 22V, and 22 Class 3	10 [250]

6.2.4 *Method 4* — Test specimens shall be taken from a representative separate test forging or bar made from the same heat of steel, which shall receive substantially the same reduction and type of hot working as the production forgings that it represents, except that a longitudinally forged bar may be used to represent a rolled ring of similar cross section. It shall be of the same nominal thickness as the as-quenched production forgings and shall be heat treated in the same furnace charge and under the same conditions as the production forgings. Test specimens shall be removed using the $\frac{1}{4}$ *T* by *T* procedure referenced in Method 3 with the same limitation on forging thickness as in 6.2.3. This method shall be limited to forgings with a rough machined weight of not more than 1 000 lb [450 kg].

6.3 *Metal Buffers* — The required distances from quenched surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at least $\frac{1}{2}$ in. [13 mm] from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to ensure freedom from cracks unless the welded areas are completely removed by subsequent machining.

6.4 Samples shall be removed from forgings after the quenching and tempering heat treatments. This sample material shall be subjected to a simulated post-weld heat treatment if Supplementary Requirement S1 is specified.

6.5 *Orientation* — For upset disk forgings, the longitudinal axis of all test specimens shall be oriented in the tangential direction. For all other forgings, the longitudinal axis of the specimens shall be oriented in the direction of maximum working of the forging unless Supplementary Requirements S11 or S14 are imposed.

6.6 *Number of Tests:*

6.6.1 *Forgings under 500 lb* [230 kg] *As Treated* — For duplicate forgings weighing less than 500 lb [230 kg] as treated, one tension test and one impact test (three specimens) shall be made to represent each heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature control and equipped with recording pyrometers so that complete heat-treatment records are available, a heat-treatment charge shall be considered as any continuous run not exceeding an 8 h duration.

6.6.2 *Forgings weighing 500 to 10 000 lb* [*230 to 4500 kg*] *As-Heat Treated* — One tension and one impact test (3 specimens) shall be made for each forging.

6.6.3 Each forging weighing over 10 000 lb [4500 kg] shall require two tension tests and two impact tests, located at opposite ends if the length is $1\frac{1}{2}$ times the diameter or more, or 180° apart otherwise.

7. Repair Welding

7.1 Repair welding of forgings may be permitted, but only at the option of the purchaser.

7.2 If repair welding is performed, welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

8. Workmanship and Quality Level Requirements

8.1 Dimensional and visual inspections shall be conducted by the manufacturer. Forgings shall be free of cracks, thermal ruptures, or other imperfections.

9. Certification and Reports

9.1 In addition to items required to be reported by Specification A 788, the following items shall also be reported:

9.1.1 Product chemical analysis.

9.1.2 The method used for locating test specimens.

9.1.3 Sketches included in the report of non-destructive examinations.

9.1.4 Details of the heat treatment cycle, as listed in Specification A 788.

10. Product Marking

10.1 The purchaser may specify additional identification marking and the location of the marking. If stamps are used, they shall be round-nosed or "interrupted-dot" die stamps having a minimum radius of $\frac{1}{32}$ in. [0.8 mm].

11. Keywords

11.1 chromium-molybdenum steel; nickel-chromium-molybdenum alloy steel; pressure vessel service; quenched and tempered steel; steel forgings—alloy; steel forgings—carbon

TABLE 1
CHEMICAL REQUIREMENTS COMPOSITION, %

	Grade 1	Grade 1A	Grade 2	Grade 3	Grade 1C	Grade 11 Class 4	Grade 22 Classes 4 and 5	Grade 4N	Grade 5	Grade 3V	Grade 22 Class 3	Grade 22V	Grade 3VCb
Carbon	0.35 max	0.30 max	0.27 max	0.25 max	0.18 max	0.10–0.20	0.05–0.15	0.23 max	0.23 max	0.10–0.15	0.11–0.15	0.11–0.15	0.10–0.15
Manganese	0.40–0.90	0.70–1.35	0.50–0.90	1.20–1.50	1.30 max	0.30–0.80	0.30–0.60	0.20–0.40	0.20–0.40	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Phosphorus	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.015 max	0.015 max	0.020 max
Sulfur	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.015 max	0.010 max	0.010 max
Silicon[1]	0.35 max	0.40 max	0.35 max	0.35 max	0.35 max	0.50–1.00	0.50 max	0.30 max	0.30 max	0.10 max	0.50 max	0.10 max	0.10 max
Nickel	0.40 max	0.40 max	0.50–1.00	0.40–1.00	0.25 max	0.50 max	0.50 max	2.8–3.9	2.8–3.9	. . .	0.25 max	0.25 max	0.25 max
Chromium	0.25 max	0.25 max	0.25–0.45	0.25 max	0.15 max	1.00–1.50	2.00–2.50	1.25–2.00	1.25–2.00	2.8–3.3	2.00–2.50	2.00–2.50	2.7–3.3
Molybdenum	0.10 max	0.10 max	0.55–0.70	0.45–0.60	0.05 max	0.45–0.65	0.90–1.10	0.40–0.60	0.40–0.60	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10
Vanadium	0.05 max	0.05 max	0.05 max	0.05 max	0.02–0.12	0.05 max	0.05 max	0.03 max	0.08 max	0.20–0.30	0.02 max	0.25–0.35	0.20–0.30
Titanium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.015–0.035	. . .	0.030 max	0.015 max
Boron	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.001–0.003	. . .	0.0020 max	. . .
Copper	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.20 max	0.25 max
Columbium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.07 max	0.015–0.070
Calcium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.015 max[2]	0.0005-0.0150

NOTES:

(1) When vacuum carbon-deoxidation is required for the classes included in Supplementary Requirements S10, the silicon content shall be 0.10% max.

(2) For Grade 22V, rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.

TABLE 2
TENSILE REQUIREMENTS

	Grades 1 and 1A	Grades 2 Class 1, 3 Class 1, 1C and 11 Class 4	Grade 2 Class 2 and Grade 3 Class 2	Grade 22 Class 4	Grade 22 Class 5	Grade 4N Class 1 and Grade 5 Class 1	Grades 4N Class 2 and 5 Class 2	Grade 4N Class 3	Grades 3V and 22V	Grade 22 Class 3	Grade 3VCb
Tensile strength, ksi [MPa]	70 to 95 [485–655]	80 to 105 [550–725]	90 to 115 [620–795]	105–130 [725–895]	115–140 [795–965]	105 to 130 [725–895]	115–140 [795–965]	90 to 115 [620–795]	85–110 [585–760]	85–110 [585–760]	85–110 [585–760]
Yield strength (0.2% offset), min, ksi [MPa]	36 [250]	50 [345]	65 [450]	85 [585]	100 [690]	85 [585]	100 [690]	70 [485]	60 [415]	55 [380]	60 [415]
Elongation in 2 in. or 50 mm, min, %	20	18	16	16	15	18	16	20	18	18	18
Reduction of area, min, %	38	38	35	45	40	48	45	48	45	45	45

TABLE 3
CHARPY V-NOTCH IMPACT REQUIREMENTS AT 40°F (4°C) (EXCEPT FOR 2A)[1, 2]

	Grades 1, 1A, and 11 Class 4	Grade 2 Class 2 and 3 Class 2	Grade 2 Class 1, 3 Class 1 and 1C	Grade 22 Class 5	Grades 22 CL 4 4N Classes 1, 2, 3, 5 Classes 1,2	Grades 3V and 3VCb, Grade 22, Class 3 and Grade 22V
Minimum average value of set of three specimens, ft·lbf (J)[3]	15 [20]	35 [47][4]	30 [41]	25 [34]	35 [47]	40 [54][5]
Minimum value of one specimen, ft·lbf (J)	10 [14]	30 [41][4]	25 [34]	20 [27]	30 [41]	35 [47][5]

NOTES:

(1) These Charpy values are for tests made on standard 10 mm square specimens. If sub-size impact specimens are used, the required minimum ft·lbf values shall be determined by multiplying the ft·lbf values in Table 3 by $\frac{5}{6}$ for 7.5 by 10 mm specimens, and by $\frac{2}{3}$ for 5 by 10 mm specimens.

(2) These values apply for tests at lower temperatures if Supplementary Requirement S6 is specified in the order.

(3) Not more than one specimen from a set may be below this value.

(4) Tested at 70°F [21°C].

(5) Tested at 0°F [−18°C].

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S1.1 All test coupons shall be subjected to single or multiple heat treatments at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, times, and cooling rates.

S2. Ultrasonic Inspection

S2.1 Forgings shall be ultrasonically examined in accordance with the procedures of Practice A 388/A 388M.

S2.1.1 *Longitudinal Wave Test:*

S2.1.1.1 Unless otherwise specified, the back reflection method of tuning shall be used in accordance with the Procedure Section (the paragraph regarding Back-Reflection Technique) of Practice A 388/A 388M.

S2.1.1.2 In addition to the reportable conditions of the Recording Section of Practice A 388/A 388M, indications exceeding the resultant back reflection shall be recorded.

S2.1.1.3 The following conditions are subject to rejection:

(a) Complete loss of back reflection accompanied by an indication of a discontinuity. For this purpose, a back reflection less than 5% of full screen height shall be considered complete loss of back reflection.

(b) An indication equal in amplitude to that of the back reflection established in an indication-free portion of the forging.

S2.1.2 *Angle Beam Test:*

S2.1.2.1 Calibration notches, calibration reference, and method of scanning shall be in accordance with the Procedure Section (the paragraph regarding AngleBeam Examination) of Practice A 388/A 388M.

S2.1.2.2 A forging that contains a discontinuity that results in an indication exceeding the amplitude of the reference line is subject to rejection.

S2.1.3 The report of the ultrasonic examination shall be in compliance with the Report Section of Practice A 388/A 388M.

S2.1.4 Additional nondestructive examination or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious conditions that will not be removed in final machining.

S3. Magnetic Particle Examination

S3.1 Each forging shall be inspected by magnetic particle methods described in Test Method A 275/A 275M. Acceptance and rejection standards shall be mutually agreed upon by the purchaser and manufacturer.

S4. Charpy V-Notch Impact Transition Curve

S4.1 Sufficient impact tests shall be made from the forging test material to establish a temperature-absorbed energy curve. The test temperature range shall be wide enough to establish the upper and lower shelf foot pound energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S5. Additional Charpy Data

S5.1 The percent shear fracture and mils or millimetres of lateral expansion, defined in Test Methods and Definitions A 370, shall be reported for each Charpy specimen tested.

S6. Charpy Impact Tests

S6.1 Charpy impact tests shall be made in accordance with the provisions of Section 6 of this specification except that the test temperature shall be lower than that specified in Table 3.

S7. Drop-Weight Test

S7.1 Drop-weight tests shall be conducted in accordance with the requirements of Test Method E 208. The fracture plane of the specimens shall coincide with the location required for other mechanical test specimens as specified by the purchaser in accordance with 6.2. However, since the drop-weight specimen can be taken in any orientation, the fracture plane of the specimen when tested to Method 2 (6.2.2) shall be a minimum distance of $^7/_{16}$ in. [11 mm] from the nearest quenched surface, and $1\frac{1}{2}$ in. [40 mm] from any second surface. The purchaser may specify either duplicate no-break performance when tested 10° warmer than a specified temperature or request a determination of the nil-ductility temperature.

S8. Restrictive Chemistry for Grades 4N and 5

S8.1 Phosphorus and sulfur limits for Grades 4N and 5 may be specified 0.020%, max.

S9. Additional Vanadium

S9.1 For Grade 5 forgings, 0.05 to 0.15% vanadium may be specified.

S10. Special Steels

S10.1 Vacuum treated steel shall be specified.

S10.2 When Grades 2, 3, 4N, and 5 are vacuum carbon deoxidized, the silicon content shall be 0.10% maximum.

S10.3 The test report shall indicate that the steel was vacuum carbon deoxidized.

S11. Rings and Hollow Cylindrically Shaped Parts

S11.1 Tests shall be removed in the tangential (circumferential) direction regardless of direction of maximum working.

S12. Restrictive Chemistry

S12.1 The following restricted phosphorus and copper limits may be specified as follows:

P 0.012% max heat, 0.015% max product; Cu 0.10% max

P 0.015% max heat, 0.018% max product; Cu 0.15% max

S13. Alternative Fracture Toughness Requirements

S13.1 The fracture toughness requirements (drop-weight or Charpy impact tests, or both) for materials of the ASME Boiler and Pressure Vessel Code, Section III, Article NB-2300, NC-2300, ND-2300, NE-2300, NF-2300 or NG-2300, as specified, shall be used instead of the Charpy impact test requirements of this specification.

S14. Alternative Test Specimen Orientation

S14.1 The longitudinal axis of all test specimens shall be oriented in a direction transverse to the direction of maximum working of the forging.

S15. Restricted Sulfur Content

S15.1 The sulfur content shall be limited to 0.015% maximum heat and 0.018% maximum product.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, QUENCHED-AND-TEMPERED, CHROMIUM-MOLYBDENUM, AND CHROMIUM-MOLYBDENUM-VANADIUM

SA-542/SA-542M (23)

(Identical with ASTM Specification A542/A542M-19.)

Specification for Pressure Vessel Plates, Alloy Steel, Quenched-and-Tempered, Chromium-Molybdenum, and Chromium-Molybdenum-Vanadium

1. Scope

1.1 This specification covers two types of 2¼ Cr-1 Mo and three types of Cr-Mo-V alloy steel plates for use in the quenched-and-tempered condition, intended for the fabrication of welded pressure vessels and components.

1.2 Material under this specification is available in five types, designated "A," "B," "C," "D," and "E." Type B is identical to Type A except for restrictive limits for carbon, phosphorus, sulfur, and nickel. The material is also available in five classes having the following strength levels. Type E is available only as Class 4 and 4a.

Class	Minimum Tensile Strength, ksi [MPa]
1	105 [725]
2	115 [795]
3	95 [655]
4 and 4a	85 [585]

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements.

1.4 The minimum thickness of plates is limited to 3⁄16 in. [5 mm].

1.5 The material is intended to be suitable for fusion welding. Welding technique is of fundamental importance and it is presupposed that welding procedures will be in accordance with approved methods.

1.6 These alloy steel plates in the as-rolled condition are sensitive to cracking during flame cutting, transit, and handling. They should be shipped in the as-rolled condition only with the mutual agreement of the manufacturer and the purchaser or fabricator.

1.7 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A387/A387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available

TABLE 1 Chemical Requirements

Note 1—Where "..." appears there is no requirement. Values are maximum unless minimum or a range is indicated.

Element	Composition, %				
	Type A	Type B	Type C	Type D	Type E
Carbon:					
Heat analysis	0.15	0.11–0.15	0.10–0.15	0.11–0.15	0.10–0.15
Product analysis	0.18	0.09–0.18	0.08–0.18	0.09–0.18	0.08–0.18
Manganese:					
Heat analysis	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Product analysis	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66
Phosphorus:					
Heat analysis	0.025	0.015	0.025	0.015	0.025
Product analysis	0.025	0.015	0.025	0.020	0.025
Sulfur:					
Heat analysis	0.025	0.015	0.025	0.010	0.010
Product analysis	0.025	0.015	0.025	0.015	0.010
Silicon:					
Heat analysis	0.50	0.50	0.13	0.10	0.15
Product analysis	0.50	0.50	0.13	0.13	0.15
Chromium:					
Heat analysis	2.00–2.50	2.00–2.50	2.75–3.25	2.00–2.50	2.75–3.25
Product analysis	1.88–2.62	1.88–2.62	2.63–3.37	1.88–2.62	2.63–3.37
Molybdenum:					
Heat analysis	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10
Product analysis	0.85–1.15	0.85–1.15	0.85–1.15	0.85–1.15	0.85–1.15
Copper:					
Heat analysis	0.40	0.25	0.25	0.20	0.25
Product analysis	0.43	0.28	0.28	0.23	0.28
Nickel:					
Heat analysis	0.40	0.25	0.25	0.25	0.25
Product analysis	0.43	0.28	0.28	0.28	0.28
Vanadium:					
Heat analysis	0.03	0.02	0.20–0.30	0.25–0.35	0.20–0.30
Product analysis	0.04	0.03	0.18–0.33	0.23–0.37	0.18–0.33
Titanium:					
Heat analysis	. . .	. . .	0.015–0.035	0.030	. . .
Product analysis	. . .	. . .	0.005–0.045	0.035	. . .
Boron:					
Heat analysis	. . .	. . .	0.001–0.003	0.0020	. . .
Product analysis	. . .	. . .	. . .	. . .	. . .
Columbium (niobium):[A]					
Heat analysis	. . .	. . .	. . .	0.07	0.015–0.070
Product analysis	. . .	. . .	. . .	0.08	0.010–0.075

[A] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.

when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 All plates shall be heat treated by heating to a suitable austenitizing temperature, holding for a sufficient period of time to attain uniform temperature throughout the thickness, and quenching in a suitable liquid medium by spraying or immersion. For Type D material, the minimum austenitizing temperature shall be 1650°F [900°C]. For Type E material, the minimum austenitizing temperature shall be 1850°F [1010°C].

5.2 After quenching, the plates shall be tempered to produce the specified tensile requirements by heating to a suitable temperature and holding for a period of time of not less that 30 min/in. [1.2 min/mm] of thickness but not less than ½ h. The minimum tempering temperature shall be as follows:

Type	Class	Temperature, °F [°C]
A, B, C	1, 2, 3	1050 [565]
A, B, C	4	1200 [650]
A, B, C, D	4a	1250 [675]

5.3 Plates over 4 in. [100 mm] in thickness shall receive a prior heat treatment of normalizing at, or water quenching from, a temperature within the range from 1650 to 1850°F [900 to 1010°C] for Types A, B, C, and D and 1850 to 2050°F [1010 to 1120°C] for Type E before the heat treatment specified in 5.1.

5.4 Plates ordered without the heat treatment required by 5.1 – 5.3 shall be furnished in either the stress-relieved or the

TABLE 2 Tensile Requirements

	Class 1	Class 2	Class 3	Class 4	Class 4a
Tensile strength, ksi [MPa]	105–125 [725–860]	115–135 [795–930]	95–115 [655–795]	85–110 [585–760]	85–110 [585–760]
Yield strength, min, ksi [MPa]	85 [585]	100 [690]	75 [515]	55 [380]	60 [415]
Elongation in 2 in. [50 mm], min, %[A]	14	13	20	20	18

[A] See Specification A20/A20M for elongation adjustment.

annealed condition. Minimum stress relieving temperature shall be 1050°F [565°C] except for Type E which shall be 1200°F [650°C].

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements shown in Table 1.

7. Mechanical Properties

7.1 *Tension Test Requirements:*

7.1.1 The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½-in. [40-mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation.

7.2 *Notch Toughness Requirements—Classes 4 and 4a:*

7.2.1 A transverse Charpy V-notch test from each plate-as-heat-treated shall have a minimum energy absorption value of 40 ft·lbf [54 J] average of three specimens and 35 ft·lbf [48 J] for one specimen only in the set.

7.2.2 For Class 4, the impact test temperature shall be as specified on the order.

7.2.3 For Class 4a, the impact test temperature shall be 0°F [−18°C].

8. Keywords

8.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessels

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed in this section by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.2 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M,

S17. Vacuum Carbon-Deoxidized Steel.

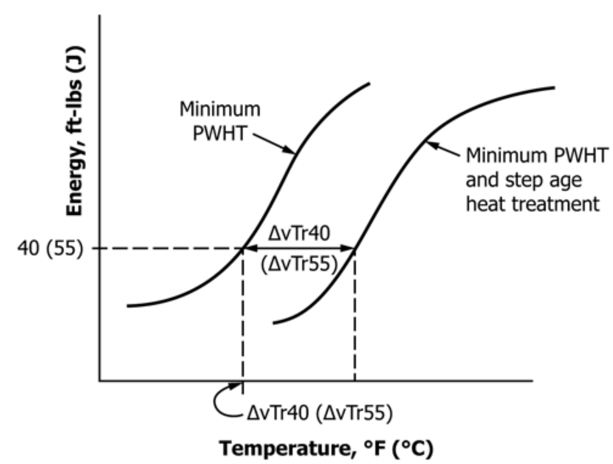

FIG. S1.1 Transition Temperature Curves Before and After Step Cool Heat Treatment

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirements are suitable for this application.

S53. Alternative Location for Mechanical Testing

S53.1 When specified by the purchaser, the axis of the tensile and impact test specimens shall come from the mid-thickness of each plate tested, in lieu of midway between the center thickness and the top or bottom surface of the plate.

S62. Temper Embrittlement Factor

S62.1 The composition of the steel, based on heat analysis, shall be restricted in accordance with the following equations:

$$J = (\mathrm{Si+Mn}) \times (\mathrm{P+Sn}) \times 10^4 \leq 150 \qquad (\mathrm{Si, Mn, P, and\ Sn\ in\ wt\,\%})$$
$$\mathrm{Cu} \leq 0.20\,\%$$
$$\mathrm{Ni} \leq 0.30\,\%$$

S62.1.1 Lower values of J, Cu, and Ni can be specified by agreement between purchaser and the supplier.

S62.1.2 When so specified by the purchaser, the maximum value of J shall not exceed 100.

S62.1.3 The values of J shall be reported.

S62.1.4 If the plates are repaired by welding, the composition of the weld deposit shall be restricted in accordance with the following equations:

$$X = (10\mathrm{P} + 5\mathrm{Sb} + 4\mathrm{Sn} + \mathrm{As})/100 \leq 15 \qquad (\mathrm{P, Sb, Sn, and\ As\ in\ ppm})$$
$$\mathrm{Cu} \leq 0.20\,\%$$
$$\mathrm{Ni} \leq 0.30\,\%$$

S62.1.5 The values of *X* shall be reported.

S63. Impact Properties After Step Cooling

S63.1 The Charpy V-notch impact properties shall be determined as follows:

S63.1.1 A sufficient amount of Charpy V-notch test specimens shall be taken from the same location from a plate from each heat of steel to construct two transition temperature curves.

S63.1.2 The test specimens for one transition temperature curve shall be given the minimum post-weld heat treatment (PWHT) cycle specified by the purchaser.

S63.2 The test specimens for the other transition temperature curve shall be given the PWHT cycle specified in S63.1.2 plus the following step cooling heat treatment:

Hold at 1100°F (593°C) for 1 h, then cool at 10°F (5.6°C)/h to 1000°F (538°C).

Hold at 1000°F (538°C) for 15 h, then cool at 10°F (5.6°C)/h to 975°F (524°C).

Hold at 975°F (524°C) for 24 h, then cool at 10°F (5.6°C)/h to 925°F (496°C).

Hold at 925°F (496°C) for 60 h, then cool at 5°F (2.8°C)/h to 875°F (468°C).

Hold at 875°F (468°C) for 100 h, then cool at 50°F (27.8°C)/h to 600°F (315°C).

Cool in still air.

S63.3 Test the Charpy V-notch test specimens in accordance with Test Methods and Definitions A370 to determine the 40 ft-lbs (55 J) transition temperature from each transition temperature curve using a set of three test specimens at each test temperature. The test temperatures shall include tests on the upper and lower shelves and a minimum of four intermediate temperatures.

S63.4 The following requirements shall be met.

$$\mathrm{vTr40} + 2.5\Delta\mathrm{vTr40} \leq 50°\mathrm{F}$$
$$\mathrm{vTr55} + 2.5\Delta\mathrm{vTr55} \leq 10°\mathrm{C}$$

where:

vTr40 (vTr55) = the 40 ft-lbs (55 J) transition temperature of the material subjected to the minimum PWHT specified by the purchaser.

ΔvTr40 (ΔvTr55) = the shift of the 40 ft-lbs (55 J) transition temperature the of the step cooled material. (The 40 ft-lbs (55 J) transition temperature the of the step cooled material minus that of the material subjected to the minimum PWHT only).

S63.5 The 40 ft-lbs (55 J) transition temperatures for the two material conditions shall be reported.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, QUENCHED AND TEMPERED, NICKEL-CHROMIUM-MOLYBDENUM

SA-543/SA-543M

(Identical with ASTM Specification A543/A543M-09(2014).)

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, QUENCHED AND TEMPERED, NICKEL-CHROMIUM-MOLYBDENUM

SA-543/SA-543M

[Identical with ASTM Specification A 543/A 543M-09(2014).]

1. Scope

1.1 This specification covers nickel-chromium-molybdenum alloy steel plates for use in the quenched and tempered condition, intended for the fabrication of welded pressure vessels and other pressure equipment. These alloy compositions are normally considered for construction involving plate thicknesses of 2 in. [50 mm] or greater.

1.2 Material under this specification is available in two types, B and C. The material is also available in three classes as follows:

Class	Minimum Tensile Strength, ksi [MPa]
1	105 [725]
2	115 [795]
3	90 [620]

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements.

1.4 The minimum plate thickness is $^{3}/_{16}$ in. [5 mm].

1.5 These alloy steel plates in the as-rolled condition are sensitive to cracking during flame cutting, transit, and handling. They should be shipped in the as-rolled condition only with the mutual agreement of the manufacturer and the purchaser or fabricator.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be heat treated by heating to a suitable austenitizing temperature, holding for a sufficient time period to attain uniform temperature through the thickness and quenching in a suitable liquid medium by spraying or immersion. The plates shall then be tempered to produce the required properties by heating to a suitable temperature not lower than 1100°F [595°C] with a holding time of not less than ½ h/in. [1.2 min/mm] of thickness but not less than ½ h.

5.2 Plates over 4 in. [100 mm] in thickness shall receive a prior treatment of normalizing at, or water quenching from a temperature within the range from 1650 to 1850°F [900 to 1010°C] before the heat treatment specified in 5.1.

5.3 When the fabricator elects to perform the heat treatment in 5.1 and 5.2, the manufacturer shall normalize the plates at an appropriate temperature prior to shipment unless otherwise agreed to.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements:*

7.1.1 The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½ in. [40 mm] wide rectangular specimen may be used for the tension test and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and shows the greatest elongation.

8. Keywords

8.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessels

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Type B	Type C
Carbon, max[A]	0.20	0.18
Manganese, max[A]	0.40	0.40
Phosphorus, max[A]	0.020	0.020
Sulfur, max[A]	0.020	0.020
Silicon:		
Heat analysis	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45
Nickel:		
Heat analysis	2.25–4.00	2.00–3.50
Product analysis	2.18–4.07	1.93–3.57
Chromium:		
Heat analysis	1.00–1.90	1.00–1.90
Product analysis	0.94–1.96	0.94–1.96
Molybdenum:		
Heat analysis	0.20–0.65	0.20–0.65
Product analysis	0.16–0.69	0.16–0.69

[A] Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Class 1	Class 2	Class 3
Tensile strength, ksi [MPa]	105–125 [725–860]	115–135 [795–930]	90–115 [620–795]
Yield strength, min, ksi [MPa]	85 [585]	100 [690]	70 [485]
Elongation, 2 in. [50 mm], min, %[A, B]	14	14	16

[A] See 7.1.2.
[B] See Specification A 20/A 20M for elongation adjustment.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.2 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, QUENCHED AND TEMPERED 7, 8, AND 9% NICKEL

SA-553/SA-553M

(Identical with ASTM Specification A553/A553M-17.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 7, 8, and 9 % Nickel

1. Scope

1.1 This specification covers 7, 8, and 9 % nickel alloy steel plates for use in the water quenched and tempered condition intended for the fabrication of welded pressure vessels.

1.2 Material under this specification is available in three types having different chemical composition as follows:

Type	Nominal Nickel Content, %
I	9
II	8
III	7

1.3 Plates produced under this specification are subject to impact testing at −320°F [−195°C] for Type I or Type III, and −275°F [−170°C] for Type II; or at such other temperatures as are agreed upon.

1.4 The maximum thickness of plates is limited only by the capacity of the material to meet the specified mechanical property requirements; however, current mill practice normally limits this material to 2 in. [50 mm] max.

1.5 This material is susceptible to magnetization. Use of magnets in handling after heat treatment should be avoided if residual magnetism would be detrimental to subsequent fabrication or service.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

TABLE 1 Chemical Requirements

Element	Composition, %		
	Type I	Type II	Type III
Carbon, max[A]	0.13	0.13	0.13
Manganese, max:			
Heat analysis	0.90	0.90	0.90
Product analysis	0.98	0.98	0.98
Phosphorus, max[A]	0.015	0.015	0.010
Sulfur, max[A]	0.015	0.015	0.010
Silicon:			
Heat analysis	0.15–0.40[B]	0.15–0.40[B]	0.05–0.30[A]
Product analysis	0.13–0.45[C]	0.13–0.45[C]	
Nickel:			
Heat analysis	8.50–9.50	7.50–8.50	6.50–7.50[A]
Product analysis	8.40–9.60	7.40–8.60	
Molybdenum[A]	...	...	0.10–0.30
Columbium (Niobium),[D] max[A]	...	...	0.03

[A] Applies to both heat and product analyses.
[B] Silicon may be less than 0.15 %, provided total aluminum is 0.030 % or over, or provided acid soluble aluminum is 0.025 % or over.
[C] Silicon may be less than 0.13 %, provided total aluminum is 0.030 % or over, or provided acid soluble aluminum is 0.025 % or over.
[D] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.

TABLE 2 Tensile Requirements

Tensile strength, ksi [MPa]	100 to 120 [690–825]
Yield strength (0.2 % offset), min, ksi [MPa]	85 [585]
Elongation in 2 in. [50 mm], min, %[A]	20.0

[A] See Specification A20/A20M for elongation adjustment.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 All plates shall be heat treated in accordance with 5.2. Shell plates and other parts, including heads and reinforcing pads, which are heated for forming, shall be heat treated after forming in accordance with 5.2.

5.2 *Heat Treatment Procedure*—Heat treat all plates by heating to a suitable temperature within the range from 1475 to 1700°F [800 to 925°C], holding for a sufficient time to obtain uniform temperature throughout the plate thickness and then quenching in water. Subsequently, temper the plates within the range from 1050 to 1175°F [565 to 635°C] for Type I and Type II, or from 1000 to 1125°F [540 to 615°C] for Type III, holding at this temperature for a minimum of 30 min/in. [1.2 min/mm] of thickness but not less than 15 min, and cool in air or water quench at a rate not less than 300°F/h [165°C/h].

5.2.1 *Hardening*—The plates shall be heated to a temperature within the range from 1475 to 1700°F [800 to 925°C], held at that temperature for a sufficient time to obtain uniform temperature throughout the plate thickness, and then quenched in a liquid media.

5.2.2 *Tempering*—The plates shall be tempered at a temperature within the range from 1050 to 1175°F [565 to 635°C] for Type I and Type II, or from 1000 to 1125°F [540 to 615°C] for Type III; being held at that temperature for a minimum of 30 min/in. [1.2 min/mm] of thickness, but in no case less than 15 min, and then cooled in air or liquid-quenched at a rate not less than 300°F/h [165°C/h].

5.2.2.1 Prior to the tempering treatment, the plates may be subjected to an intermediate heat treatment consisting of heating to a temperature in the range from 1165 to 1290°F [630 to 700°C] for Type I, or 1185 to 1310°F [640 to 710°C] for Type II, or 1205 to 1330°F [650 to 720°C] for Type III; holding at that temperature for a suitable time, but in no case less than 15 min, and then water-quenching to below 300°F [150°C] in the case of plate thicknesses of more than ⅝ in. [16 mm] or cooling in air or water-quenching to below 300°F [150°C] in the case of plate thicknesses of ⅝ in. [16 mm] and under.

NOTE 1—The intermediate heat treatment is for the purpose of enhancing elongation and notch-toughness and for reducing susceptibility to strain-aging embrittlement and temper embrittlement. It may be performed at the option of the material manufacturer or may be specified by the purchaser.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by tension-test specimens shall conform to the requirements specified in Table 2.

7.1.1 Upon agreement between the purchaser and the manufacturer, yield strength may be determined by the extension under load method, using 0.005 in./in. [mm/mm] total extension.

7.1.2 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½ in. [40 mm] wide rectangular specimen may be used for the tension test and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and shows the greatest elongation.

7.2 *Impact Test Requirements:*

7.2.1 Charpy V-notch impact tests shall be made in accordance with Specification A20/A20M.

7.2.2 The longitudinal axis of the test specimens shall be transverse to the final rolling direction of the plate.

7.2.3 Unless otherwise agreed, tests shall be conducted at −320°F [−195°C] for Type I or Type III, and at −275°F [−170°C] for Type II.

7.2.4 Each test specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.381 mm].

8. Finish

8.1 Because retained scale may mask surface imperfections, as well as mar the plate surface, plates shall be descaled by the producer after heat treatment. In the case of material to be heat-treated by the purchaser, the plates shall be descaled by the producer prior to shipment.

9. Marking

9.1 In addition to the marking required in Specification A20/A20M, each plate shall be legibly stamped or stenciled, depending upon the ordered thickness, with the letters *QT*, except as otherwise specified in 9.1.1.

9.1.1 When the optional heat treatment in 5.2.2.1 is performed, the plates shall be marked with the letters *QTT* instead of *QT*.

10. Keywords

10.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standard supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below are additional optional Supplementary Requirements S55 and S56, which are suitable for this specification.

S55. Longitudinal Charpy Impact Energy Absorption Requirement

S55.1 The longitudinal Charpy V-notch impact properties shall not be less than 25 ft·lbf [34 J] at the specified temperature.

S55.2 Each impact test value shall constitute the average value of three specimens, with not more than one value below the specified minimum value of 25 ft·lbf [34 J] but in no case below 20 ft·lbf [27 J] for full size specimens.

S56. Transverse Charpy Impact Energy Absorption Requirement

S56.1 The transverse Charpy V-notch impact properties shall not be less than 20 ft·lbf [27 J] at the specified temperature.

S56.2 Each impact test value shall constitute the average value of three specimens, with not more than one value below the specified minimum value of 20 ft·lbf [27 J] but in no case below 15 ft·lbf [20 J] for full size specimens.

SPECIFICATION FOR SEAMLESS COLD-DRAWN CARBON STEEL FEEDWATER HEATER TUBES

SA-556/SA-556M

(Identical with ASTM Specification A556/A556M-90(1995)$^{\varepsilon 1}$.)

SPECIFICATION FOR SEAMLESS COLD-DRAWN CARBON STEEL FEEDWATER HEATER TUBES

SA-556/SA-556M

[Identical with ASTM Specification A 556/A 556M-90a (1995)$^{\epsilon 1}$.]

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless cold-drawn carbon steel tubes including bending into the form of U-tubes, if specified, for use in tubular feedwater heaters.

1.2 The tubing sizes covered shall be $\frac{5}{8}$ to $1\frac{1}{4}$ in. [15.9 to 31.8 mm] outside diameter, inclusive, with minimum wall thicknesses equal to or greater than 0.045 in. [1.1 mm].

1.3 Optional supplementary requirements are provided, and when desired, shall be stated in the order.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron

3. General Requirements

3.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of the Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following as required to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of pieces).

4.1.2 Name of material (seamless steel tubing).

4.1.3 Dimensions (outside diameter and minimum wall thickness).

4.1.4 Length (specific or random).

4.1.5 Manufacture (cold drawn).

4.1.6 Grade (chemical composition).

4.1.7 Optional requirements.

4.1.8 *Bending Requirements* — If order specifies tubes to be bent, the design of the U-tubes shall accompany the order. Purchaser must specify if stress-relief anneal of the U-bends is required.

4.1.9 Test report required (see Certification Section of Specification A 450/A 450M).

4.1.10 Specification number.

4.1.11 Special requirements and any supplementary requirements selected.

5. Manufacture

5.1 *Manufacture* — Tubes shall be made by the seamless process and shall be cold drawn.

5.2 *Heat Treatment:*

5.2.1 Cold-drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200°F [640°C] or higher to ensure ductility satisfactory for rolling into tube sheets and to meet mechanical properties as specified.

5.2.2 If stress-relief anneal of the U-bends is specified, the anneal shall consist of heating the bent portion within a range of 1100 to 1200°F [585 to 640°C].

6. Chemical Composition

6.1 The steel shall conform to one of the requirements as to chemical composition as prescribed in Table 1.

6.2 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted.

7. Product Analysis

7.1 When requested in the purchase order, a product analysis shall be made by the manufacturer or supplier from one tube or billet per heat.

7.2 If the original test for product analysis fails, retests of two additional tubes or billets shall be made. Both retests for the elements in question shall meet the requirements of this specification; otherwise, all remaining material in the heat or lot (Note) shall be rejected or, at the option of the producer, each tube may be individually tested for acceptance. Tubes that do not meet the requirements of this specification shall be rejected.

NOTE — For tension and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat and furnace speed.

7.3 For referee purposes, Test Methods E 30 shall be used.

8. Mechanical Properties

8.1 *Tensile Properties* — The material shall conform to the requirements as to tensile properties prescribed in Table 2, when pulled in full section.

8.2 *Hardness Requirements* — The tubes shall not exceed the Rockwell Hardness shown in Table 3.

9. Permissible Variations in Dimensions (Fig. 1)

9.1 Permissible variations from the specified outside diameter shall not exceed ±0.004 in. [0.10 mm] for tubing under 1.0 in. [25.4 mm] outside diameter nor ±0.006 in. [0.15 mm] for tubing 1.0 in. [25.4 mm] to 1.25 in. [31.7 mm] inclusive. These tolerances do not apply to the bent portion of the U-tubes. At the bent portion of a U-tube for $R = 2 \times D$ or greater neither the major nor minor diameter of tube shall deviate from nominal by more than 10%. If $1\frac{1}{2}$ D is specified, tolerances could be greater.

9.2 Permissible variations from the specified minimum wall thickness shall not exceed +20% or −0. The wall thickness of the tube in U-bent section shall be not less than value determined by:

$$t_f = T(2R)/(2R + D)$$

where:

t_f = wall thickness after bending, in. [mm],
T = specified minimum tube wall thickness, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

9.3 In the case of U-tubes, the length of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg shall not be less than specified, but may exceed the specified values by the amount given in Table 4. The difference in lengths of the tube legs shall not be greater than $\frac{1}{8}$ in. [3 mm] unless otherwise specified.

9.4 The end of any tube may depart from square by not more than the amount given in Table 5.

9.5 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value (2R — specified tube OD) by more than $\frac{1}{16}$ in. [1.5 mm] where R is the centerline bend radius.

9.6 The bent portion of the U-tube shall be substantially uniform in curvature and not exceed $\pm\frac{1}{16}$ in. [±1.5 mm] of the normal centerline radius.

10. Workmanship, Finish, and Appearance

10.1 Finished tubes shall be free from scale but may have a superficial oxide film on the surfaces. A light oxide scale on the outside and inside surfaces of U-bend shall be allowed for tubes which have been heat treated.

10.2 Finished tubes shall be reasonably straight and have smooth ends free from burrs. Tubes shall have a workmanlike finish and shall be free of surface imperfections that cannot be removed within the allowable wall tolerances. Removal of surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be required provided they are within the allowable wall tolerances.

10.3 Finished tubes shall be coated both on the outside and the inside diameter to prevent corrosion in transit. The type of coating applied should be mutually agreed upon and specified in the order.

11. Mechanical Tests Required

11.1 *Tension Test* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note).

11.2 *Flattening Test* — One flattening test shall be made on specimens taken from each end of one finished tube, not the one used for the flaring test, from each lot of not more than 125 tubes or fraction thereof.

11.3 *Flaring Test* — One flaring test shall be made on specimens taken from each end of one finished tube, not the one used for flattening test, from each lot of not more than 125 tubes or fraction thereof.

11.4 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note).

11.5 *Hydrostatic Test* — Each U-tube shall be subjected to a hydrostatic test, using a noncorrosive fluid, or when agreed upon between the purchaser and manufacturer, they may be tested at $1\frac{1}{2}$ times the specified design working pressure.

12. Nondestructive Test (Electric Test)

12.1 Each tube shall be tested after the finish heat treatment following the final cold-drawn pass by passing through a nondestructive tester capable of detecting defects on the entire cross section of the tube, in accordance with Specification A 450/A 450M.

13. Packaging and Package Marking

13.1 The tubing shall be packaged or bundled in such a manner as to prevent damage in ordinary handling and transportation and identified by a tag with the name of the manufacturer, purchase order number, specification number and grade, and size.

13.2 In the case of U-tubes, each box shall be palletized and legibly marked showing the manufacturer's name, purchase order number, specification number and grade, size, and identification of items contained.

14. Keywords

14.1 feedwater heater tubes; seamless steel tube; steel tube, carbon

FIG. 1 BENT PORTION OF U-TUBE

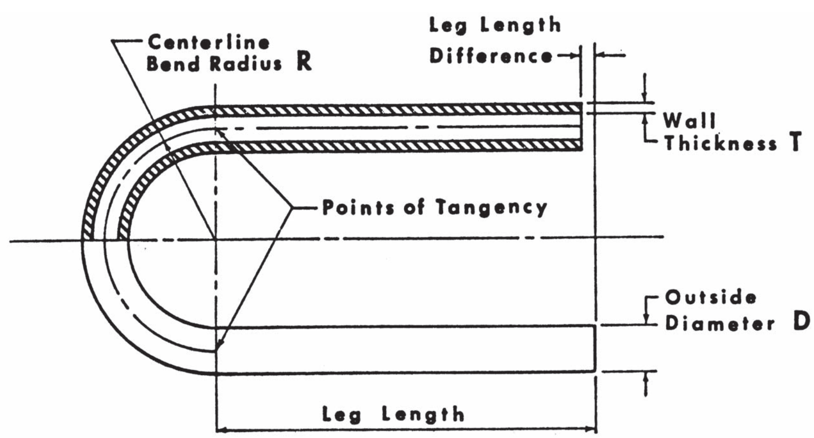

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A2	Grade B2	Grade C2
Carbon, max	0.18	0.27	0.30
Manganese	0.27–0.63	0.29–0.93	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	. . .	0.10	0.10

TABLE 2
TENSILE REQUIREMENTS

	Grade A2	Grade B2	Grade C2
Tensile strength, min, ksi [MPa]	47 [320]	60 [410]	70 [480]
Yield strength, min, ksi [MPa]	26 [180]	37 [260]	40 [280]
Elongation in 2 in. or 50 mm, min, % (longitudinal)	35	30	30

TABLE 3
HARDNESS REQUIREMENTS

Grade A2	HR B72
Grade B2	HR B79
Grade C2	HR B89

TABLE 4
TUBE LEG LENGTH TOLERANCE

Leg Length, ft [m]	Plus Tolerance in. [mm]
Up to 20 [6], incl	$\frac{1}{8}$ [3.2]
Over 20 to 30 [6 to 9], incl	$\frac{5}{32}$ [4.0]
Over 30 to 40 [9 to 12.2], incl	$\frac{3}{16}$ [4.8]

TABLE 5
SQUARENESS OF ENDS TOLERANCE

Tube OD, in. [mm]	Tolerance, in. [mm]
$\frac{5}{8}$ [15.9]	0.010 [0.25]
Over $\frac{5}{8}$ to $1\frac{1}{4}$ [15.9 to 31.7], incl	0.016 [0.4]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement or requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which event the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

S1. Nondestructive Ultrasonic Test — Round Tubing (Commercial Grade)

S1.1 The manufacturer shall test the tubing by an ultrasonic nondestructive test for detection of harmful faults and soundness.

S1.1.1 Ultrasonic testing shall be performed using pulse-echo shear wave techniques to locate longitudinal or circumferential defects, or both.

S1.1.2 Tubes being tested shall be reasonably straight for proper rotation. The outside and inside diameter surfaces of the tubes shall be free of dirt, grit, grease, oil, loose scale, or other materials which tend to attenuate, scatter, or reflect ultrasonic signals.

S1.1.3 Tubing shall be inspected by feeding spirally past a suitable transducer with rotation of material to be toward the transducer.

S1.1.4 Suitable ultrasonic instrumentation shall be used to clearly distinguish the artificial defects (hereafter called reference notches) described later. Automatic electronic monitoring of the reflected ultrasonic signals shall be provided in such manner that any naturally occurring defects which present an ultrasonic reflection equal to or greater than the reference standard(s) shall trigger audible and visible alarms.

S1.1.5 Instrument calibration as described herein shall be accomplished with the reference standard being rotated and fed past the transducer at the same approximate rate at which the tubing under test will be tested.

S1.1.6 The following factors will be adjusted so as to achieve optimum instrument distinction between the reference notch(es) and plain portion of tubing when calibrating equipment to the reference standard.

S1.1.6.1 Search unit position shall be such that shear waves are propagated within the tube being tested. If both outside and inside diameter reference notches are used, the optimum angle shall be used which will indicate both notches as close to equal size as possible.

S1.1.6.2 The test frequency to be used shall be chosen to yield the best distinction between reference notches and plain areas of tubing. In general, 2.25 or 5.0 MHz will be used.

S1.1.6.3 Instrument sensitivity shall be adjusted to allow reference notch or notches to present a pip or pips on the scope screen at 50% to 70% of instrument saturation level. The Automatic Defect Monitoring System shall be adjusted to monitor by means of electronic gates, the portion of the screen where the reference notch is presented. The sensitivity of the alarm system shall be adjusted to indicate audibly and visibly when the reference notch is fed past the search unit.

S1.1.6.4 The recording equipment, if agreed upon, shall be adjusted to clearly indicate the reference notch or notches and also whether or not any reflected signals actuate the alarm system.

S1.1.7 A reference standard of an appropriate length (sufficient to allow in-line feeding) shall be prepared from a randomly selected tube of the same size, grade, and physical condition as the material to be tested.

S1.1.8 The reference standard shall contain machined notches as follows:

Notch to be 10% of wall thickness in depth but not less than 0.004 in. [0.10 mm]. Tolerance on depth +0.0000 in. or −0.001 in. [0.03 mm].

S1.1.8.1 *Notch Locations and Orientation* — Notches shall be located on outside or inside diameter, or both, and shall be oriented to lie in a longitudinal direction for radial inspection or circumferentially, or both, for transverse inspection. The notch or notches shall be located in the reference tube in such a manner that no physical or acoustical interference exists between notches or end of reference tube. These various locations and orientations will be classified as follows:

Type A — Longitudinal outside diameter for radial inspection,

Type B — Longitudinal inside diameter for radial inspection,

Type C — Circumferential outside diameter for transverse inspection, and

Type D — Circumferential inside diameter for transverse inspection.

S1.1.8.2 *Standard Nomenclature* — The size, location and orientation of the reference notches which become a part of a particular order covered under this specification shall be specified.

S1.1.9 The basic procedure will be to rotary feed all the tubes in the order past the search unit (transducer) with the feed helix less than the scanning width of the search unit. As the tubes are fed past the transducer, the alarm system shall be observed for indications of defects equal to or greater than the reference standard. Tubes which show such indications shall be rejected.

S1.1.10 Standard procedure will be to test the material in one direction of helical feed only. Testing in both directions may be done if so specified by customer.

S1.1.11 Any tubes that do not show indications above the level determined by the reference standard shall be held in a lot until the reference standard is run and instrument calibration is proved by triggering alarm system on the reference notch or notches. After calibration is proved to have been correct, this lot of tubes shall be considered tested and accepted as to maximum defect size corresponding to the reference standard used.

S1.1.12 Rejected tubing may be salvaged by polishing or other suitable means when practical and retested after the elimination of the cause of rejection. Such material that meets the dimensional requirements and does not cause triggering of ultrasonic alarm system upon retesting shall be considered as having met the requirements of this supplement.

S2. Nondestructive Ultrasonic Test — Round Tubing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch depth, which shall be 5% of wall thickness in depth but not less than 0.004 in. [0.10 mm]. Tolerance on depth shall be +0.000 in. or −0.0005 in. [0.01 mm].

S3. Nondestructive Eddy-Current Test

S3.1 Each tube shall be tested after the finish heat treatment following the final cold-draw pass by passing through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation shall be used to clearly distinguish artificial defects or reference notches. Tubes to be tested shall be reasonably straight and the outside and inside diameter surfaces shall be free of loose scale, metallic particles, or other material which would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding longitudinally through an inspection coil or coils of a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from an appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed at which the inspection of the tubing is performed. The following factors shall be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portion of the tube. These as well as other factors involved shall not be used in such a manner that they detract from the instrument's overall ability to detect injurious defects:

S3.1.1 Test frequency.

S3.1.2 Direct-current saturation level.

S3.1.3 Filter networks.

S3.1.4 Phase analysis circuits.

S3.1.5 Coil diameter.

S3.1.6 Instrument gain.

S3.2 The reference standard shall contain longitudinal and circumferential notches in the outside diameter and shall be used to establish the rejection level for the tubing to be tested. Inside diameter notches, both longitudinal and circumferential, shall also be a part of the reference standard. These notches may be larger than outside diameter notches and are intended for use only to assure instrument phase settings capable of yielding optimum inside diameter surface sensitivity. The outside diameter reference notches shall have a depth equal to 10% of the wall thickness. The tolerance of the notch shall be ±8% or 0.0005 in. [0.01 mm], whichever is the greater. Width of notch shall not exceed twice the depth. The length of the reference notches shall not exceed 0.375 in. [9.5 mm]. All tubing including that which may be reconditioned, provided the dimensional or other properties of the tubing are not adversely affected and provided the tubing does not show indications above the level determined by the outside diameter references, shall meet this specification provided the instrument calibration is verified by indicating the standard outside diameter reference notches of a given lot. Tubes generating a signal above the calibration standard sensitivity level shall be rejected. Tubes may be reconditioned if not adversely affecting the dimensional or other properties of the tube and so tested as to assure a satisfactory tube within the limits of this specification. All tubing shall be demagnetized after inspection has been completed.

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SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON STEEL FEEDWATER HEATER TUBES

SA-557/SA-557M (23)

(Identical with ASTM Specification A557/A557M-90a.)

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SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, MANGANESE-TITANIUM FOR GLASS OR DIFFUSED METALLIC COATINGS

SA-562/SA-562M

(Identical with ASTM Specification A562/A562M-10.)

Standard Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings

1. Scope

1.1 This specification covers titanium-bearing carbon steel plates intended for welded glass lined pressure vessels or other applications where the presence of free-iron carbide would be deleterious to the coating. A minimum specific ratio of titanium to carbon is specified.

1.2 The maximum thickness of plates is limited to 2 in. [50 mm].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

5. Heat Treatment

5.1 Plates shall be thermally treated to produce grain refinement, either by normalizing or heating uniformly for hot forming at a minimum temperature of 1600°F [870°C] or some higher agreed temperature, and held at this temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

TABLE 1 Chemical Requirements

Element	Composition, %
Carbon, max[A]	0.12
Manganese, max	
Heat analysis	1.20
Product analysis	1.30
Phosphorus, max[A]	0.025
Sulfur, max[A]	0.025
Silicon[A]	0.15–0.50
Copper, max[A]	0.15
Titanium, min	4 × C

[A] Applies to both heat and product analyses.

TABLE 2 Tensile Requirements

	ksi [MPa]
Tensile strength	55–75 [380–515]
Yield strength, min	30 [205]
Elongation in 8 in. [200 mm] min, %[A]	22
Elongation in 2 in. [50 mm] min, %[A]	26

[A] See Specification A20/A20M for elongation adjustments.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4. Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and

S17. Vacuum Carbon-Deoxidized Steel.

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SPECIFICATION FOR CARBON AND ALLOY STEEL NUTS

SA-563

(Identical with ASTM Specification A563-07a(2014) except for deletion of the term “private label distributor” in para. 14.7 and 14.9 and editorially correct title.)

SPECIFICATION FOR CARBON AND ALLOY STEEL NUTS

SA-563

[Identical with ASTM Specification A 563-07a(2014) except for deletion of the term "private label distributor" in para. 14.7 and 14.9 and editorially correct title.]

1. Scope

1.1 This specification covers chemical and mechanical requirements for eight grades of carbon and alloy steel nuts for general structural and mechanical uses on bolts, studs, and other externally threaded parts.

NOTE 1 — See Appendix X1 for guidance on suitable application of nut grades.

1.2 The requirements for any grade of nut may, at the supplier's option, and with notice to the purchaser, be fulfilled by furnishing nuts of one of the stronger grades specified herein unless such substitution is barred in the inquiry and purchase order.

1.3 Grades C3 and DH3 nuts have atmospheric corrosion resistance and weathering characteristics comparable to that of the steels covered in Specifications A 242/A 242M, A 588/A 588M, and A 709/A 709M. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition (see 5.2). When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

NOTE 2 — A complete metric companion to Specification A 563 has been developed–A 563M; therefore, no metric equivalents are presented in this specification.

1.4 Terms used in this specification are defined in Terminology F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 *ASTM Standards:*

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A 242/A 242M Specification for High-Strength Low-Alloy Structural Steel

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength

A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A 394 Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare

A 449 Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use

A 490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance

A 687 Specification for High-Strength Nonheaded Steel Bolts and Studs

A 709/A 709M Specification for Structural Steel for Bridges

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets

F 812/F 812M Specification for Surface Discontinuities of Nuts, Inch and Metric Series

F 1789 Terminology for F16 Mechanical Fasteners

F 2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

2.2 *ANSI Standards:*
ANSI B1.1 Unified Screw Threads
ANSI B18.2.2 Square and Hex Nuts

3. Ordering Information

3.1 Orders for nuts under this specification shall include the following:

3.1.1 Quantity (number of nuts),

3.1.2 Nominal size and thread series of nuts,

3.1.3 Style of nut (for example, heavy hex),

3.1.4 Grade of nut,

3.1.5 *Zinc Coating* — Specify the zinc-coating process required, for example, hot-dip, mechanically deposited, or no preference (see 4.7),

3.1.6 *Other Finishes* — Specify other protective finish if required,

3.1.7 ASTM designation and year of issue, and

3.1.8 Supplementary or special requirements.

NOTE 3 — An example of an ordering description follows: 1000 $\frac{7}{8}$-9 heavy hex nuts, Grade DH, hot-dip zinc-coated, and lubricated, ASTM A 563-XX.

4. Materials and Manufacture

4.1 Steel for nuts shall be made by the open-hearth, basic-oxygen, or electric-furnace process except that steel for Grades O, A, and B nuts may be made by the acid-bessemer process.

4.2 Nuts may be made cold or hot by forming, pressing, or punching or may be machined from bar stock.

4.3 Grades DH and DH3 nuts shall be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and tempering at a temperature of at least 800°F.

4.4 Grades C and D nuts made of steel having carbon content not exceeding 0.20%, phosphorus not exceeding 0.04%, and sulfur not exceeding 0.05% by heat analysis may be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and need not be tempered. When this heat treatment is used, there shall be particular attention to the requirements in 6.1.1.

4.5 Grades C, C3, and D nuts made of any steel permitted for these grades may be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and tempering at a temperature of at least 800°F.

4.6 Threads shall be formed by tapping or machining.

4.7 *Zinc Coatings, Hot-Dip and Mechanically Deposited:*

4.7.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.

4.7.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process in accordance with the requirements of Specification F 2329.

4.7.3 When mechanically deposited is specified, the fasteners shall be zinc coated by the mechanical deposition process in accordance with the requirements of Class 55 of Specification B 695.

4.7.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification F 2329, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 55. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier's option is limited to one process per item with no mixed processes in a lot.

4.7.5 Hot-dip zinc-coated nuts shall be tapped after zinc coating.

4.7.6 Mechanically deposited zinc-coated nuts for assembly with mechanically deposited zinc-coated bolts shall be tapped oversize prior to zinc coating and need not be retapped afterwards.

4.8 *Lubricant:*

4.8.1 Hot-dip and mechanically deposited zinc-coated Grade DH nuts shall be provided with an additional lubricant which shall be clean and dry to the touch (see Supplementary Requirement S1 to specify lubrication requirements for plain finish nuts).

4.8.2 See Supplementary Requirement S2 for option to specify a dye in the lubricant.

5. Chemical Composition

5.1 Grades O, A, B, C, D, and DH shall conform to the chemical composition specified in Table 1.

5.2 Grades C3 and DH3 shall conform to the chemical composition specified in Table 2. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.

5.3 Resulfurized or rephosphorized steel, or both, are not subject to rejection based on product analysis for sulfur or phosphorus.

5.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for Grades D, DH, and DH3.

5.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 *Hardness:*

6.1.1 The hardness of nuts of each grade shall not exceed the maximum hardness specified for the grade in Table 3.

6.1.2 Jam nuts, slotted nuts, nuts smaller in width across flats or thickness than standard hex nuts (7.1), and nuts that would require a proof load in excess of 160 000 lbf may be furnished on the basis of minimum hardness requirements specified for the grade in Table 3, unless proof load testing is specified in the inquiry and purchase order.

6.2 *Proof Load:*

6.2.1 Nuts of each grade, except those listed in 6.1.2, shall withstand the proof load stress specified for the grade, size, style, thread series, and surface finish of the nut in Table 3 and Table 4.

6.2.2 Nuts hot dip or mechanically zinc coated in accordance with 4.7.2 or 4.7.3 shall be proof load tested after zinc coating and overtapping.

7. Dimensions

7.1 Unless otherwise specified, nuts shall be plain (uncoated) and shall conform to the dimensions prescribed in ANSI B18.2.2.

7.2 Hex and hex-slotted nuts over $1\frac{1}{2}$ to 2 in. inclusive shall have dimensions conforming to ANSI B18.2.2 calculated using the formulas for the $1\frac{1}{4}$ through $1\frac{1}{2}$ in. size range in Appendix III (Formulas for Nut Dimensions) of ANSI B18.2.2.

7.3 *Threads: Plain (Uncoated) Nuts*

7.3.1 Unless otherwise specified, the threads shall conform to the dimensions for coarse threads with Class 2B tolerances prescribed in ANSI B1.1.

7.4 *Threads: Nuts Hot Dip Zinc Coated* Specification F 2329 (4.7.2)

7.4.1 Nuts to be used on bolts with Class 2A threads before hot-dip zinc coating, and then hot-dip zinc coated in accordance with Specification F 2329, shall be tapped oversize after coating, to the minimum and maximum thread dimensions in Table 5. The major and minor diameters shall also be increased by the allowance to provide the corresponding minimum and maximum major and minor diameters.

7.5 *Threads: Nuts With Other Coatings*

7.5.1 Nuts to be used on bolts mechanically zinc coated or on bolts hot-dip zinc-coated to a specification other than Specification F 2329, or otherwise hot-dip coated, shall be tapped oversize by a diametral amount sufficient to permit assembly on the coated bolt thread, unless other requirements are specified in the inquiry or purchase order.

7.5.2 When specifically permitted by the purchaser, nuts for bolts with electrodeposited coating, such as cadmium, zinc, and so forth, or with chemically applied coating may be tapped oversize by a diametral amount sufficient to permit assembly on the coated bolt thread.

7.5.3 The allowable oversize tapping shall not exceed that specified in Table 5.

8. Workmanship

8.1 Surface discontinuity limits shall be in accordance with Specification F 812/F 812M.

9. Number of Tests

9.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

9.2 When additional tests are specified in the inquiry and purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time that has the following common characteristics:

9.2.1 Grade,

9.2.2 Nominal size,

9.2.3 Style of nut,

9.2.4 Thread series and class, and

9.2.5 Surface finish.

9.3 Unless otherwise specified in the inquiry and purchase order, the number of tests for each lot of required property shall be as follows:

Number of Nuts in Lot	Number of Specimens
800 and under	1
801 to 8 000	2
8 001 to 22 000	3
Over 22 000	5

9.4 If any test specimen shows flaws, it may be discarded and another specimen substituted.

9.5 Should any specimen fail to meet the requirements of any specified test, double the number of specimens from the same lot shall be tested for this property, in which case all of the additional specimens shall meet the specifications.

10. Test Methods

10.1 Tests shall be conducted in accordance with Test Methods F 606.

11. Report

11.1 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Product Marking

14.1 Nuts made to the requirements of Grades O, A, and B are not required to be marked unless individual marking is specified in the inquiry and order. When individual marking is required, the mark shall be the grade letter symbol on one face of the nut.

14.2 Heavy hex nuts made to the requirements of Grade C (Note 4) shall be marked on one face with three circumferential marks 120° apart.

14.3 Heavy hex nuts made to the requirements of Grade C3 shall be marked on one face with three circumferential marks 120° apart and the numeral 3. In addition, the manufacturer may add other distinguishing marks indicating that the nut is atmospheric corrosion resistant and of a weathering type.

14.4 Nuts made to the requirements of Grade D shall be marked with the grade symbol, D (Note 4) on one face.

14.5 Nuts made to the requirements of Grade DH shall be marked with the grade symbol, DH (Note 4) on one face.

14.6 Heavy hex nuts made to the requirements of Grade DH3 shall be marked with the grade symbol DH3 on one face. Hex nuts made to the requirements of DH3 shall be marked with the symbol HX3 on one face. In addition, the manufacturer may add other distinguishing marks indicating that the nut is atmospheric corrosion resistant and of a weathering type.

14.7 In addition, nuts of Grades C, C3, D, DH, and DH3 and hex nuts made to the requirements of DH3, shall be marked with a symbol to identify the manufacturer.

14.8 Marks may be raised or depressed at the option of the manufacturer. However, if markings are located on the bearing surface, they shall be depressed.

14.9 Grade and manufacturer's identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

NOTE 4 — See Table 3 for marking of equivalent nuts made in accordance with requirements of Specification A 194/A 194M.

15. Packaging and Package Marking

15.1 *Packaging:*

15.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

15.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

15.2 *Package Marking:*

15.2.1 Each shipping unit shall include or be plainly marked with the following information:

15.2.1.1 ASTM designation and grade,

15.2.1.2 Size,

15.2.1.3 Name and brand or trademark of the manufacturer,

15.2.1.4 Number of pieces,

15.2.1.5 Purchase order number, and

15.2.1.6 Country of origin.

16. Responsibility

16.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

17. Keywords

17.1 alloy steel; carbon steel; nuts; steel; weathering steel

TABLE 1
CHEMICAL REQUIREMENTS FOR GRADES O, A, B, C, D, AND DH NUTS

Grade of Nut	Analysis	Composition, % Carbon	Manganese, min	Phosphorus, max	Sulfur, max
O, A, B, C	heat	0.55 max	. . .	0.12	0.15(A)
	product	0.58 max	. . .	0.13 (B)	. . .
D (C)	heat	0.55 max	0.30	0.04	0.05
	product	0.58 max	0.27	0.048	0.058
	heat	0.20–0.55	0.60	0.04	0.05
DH (C)	product	0.18–0.58	0.57	0.048	0.058

NOTES:

(A) For Grades O, A, and B a sulfur content of 0.23% max is acceptable with the purchasers approval.

(B) Acid bessemer steel only.

(C) For Grades D and DH a sulfur content of 0.05 – 0.15% is acceptable provided the manganese is 1.35% min.

TABLE 2
CHEMICAL REQUIREMENTS FOR GRADES C3 AND DH3 NUTS

Element	Composition, %							
	Classes for Grade C3 Nuts (A)							Grade DH3 Nuts
	N	A	B	C	D	E	F	
Carbon:								
Heat analysis	. . .	0.33–0.40	0.38–0.48	0.15–0.25	0.15–0.25	0.20–0.25	0.20–0.25	0.20–0.53
Product analysis	. . .	0.31–0.42	0.36–0.50	0.14–0.26	0.14–0.26	0.18–0.27	0.19–0.26	0.19–0.55
Manganese:								
Heat analysis	. . .	0.90–1.20	0.70–0.90	0.80–1.35	0.40–1.20	0.60–1.00	0.90–1.20	0.40 min
Product analysis	. . .	0.86–1.24	0.67–0.93	0.76–1.39	0.36–1.24	0.56–1.04	0.86–1.24	0.37 min
Phosphorus:								
Heat analysis	0.07–0.15	0.040 max	0.06–0.12	0.035 max	0.040 max	0.040 max	0.040 max	0.046 max
Product analysis	0.07–0.155	0.045 max	0.06–0.125	0.040 max	0.045 max	0.045 max	0.045 max	0.052 max
Sulfur:								
Heat analysis	0.050 max	0.050 max	0.050 max	0.040 max	0.050 max	0.040 max	0.040 max	0.050 max
Product analysis	0.055 max	0.055 max	0.055 max	0.045 max	0.055 max	0.045 max	0.045 max	0.055 max
Silicon:								
Heat analysis	0.20–0.90	0.15–0.35	0.30–0.50	0.15–0.35	0.25–0.50	0.15–0.35	0.15–0.35	. . .
Product analysis	0.15–0.95	0.13–0.37	0.25–0.55	0.13–0.37	0.20–0.55	0.13–0.37	0.13–0.37	. . .
Copper:								
Heat analysis	0.25–0.55	0.25–0.45	0.20–0.40	0.20–0.50	0.30–0.50	0.30–0.60	0.20–0.40	0.20 min
Product analysis	0.22–0.58	0.22–0.48	0.17–0.43	0.17–0.53	0.27–0.53	0.27–0.63	0.17–0.43	0.17 min
Nickel:								
Heat analysis	1.00 max	0.25–0.45	0.50–0.80	0.25–0.50	0.50–0.80	0.30–0.60	0.20–0.40	0.20 min (B)
Product analysis	1.03 max	0.22–0.48	0.47–0.83	0.22–0.53	0.47–0.83	0.27–0.63	0.17–0.43	0.17 min
Chromium:								
Heat analysis	0.30–1.25	0.45–0.65	0.50–0.75	0.30–0.50	0.50–1.00	0.60–0.90	0.45–0.65	0.45 min
Product analysis	0.25–1.30	0.42–0.68	0.47–0.83	0.27–0.53	0.45–1.05	0.55–0.95	0.42–0.68	0.42 min
Vanadium:								
Heat analysis	. . .	. . .	. . .	0.020 min	. . .	. . .	. . .	. . .
Product analysis	. . .	. . .	. . .	0.010 min	. . .	. . .	. . .	. . .
Molybdenum:								
Heat analysis	. . .	. . .	0.06 max	. . .	0.10 max	. . .	. . .	0.15 min (B)
Product analysis	. . .	. . .	0.07 max	. . .	0.11 max	. . .	. . .	0.14 min
Titanium:								
Heat analysis	. . .	. . .	. . .	. . .	0.05 max	. . .	. . .	. . .
Product analysis	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

NOTES:
(A) C3 nuts may be made of any of the above listed material classes. Selection of the class shall be at the option of the manufacturer.
(B) Nickel or molybdenum may be used.

TABLE 3
MECHANICAL REQUIREMENTS
Nuts With UNC, 8 UN, 6 UN and Coarser Pitch Threads

			Proof Load Stress, ksi (A)		Hardness			
					Brinell		Rockwell	
Grade of Nut	Nominal Nut Size, in.	Style of Nut	Non-Zinc-Coated Nuts (B)	Zinc-Coated Nuts (B)	min	max	min	max
0	$\frac{1}{4}$ to $1\frac{1}{2}$	square	69	52	103	302	B55	C32
A	$\frac{1}{4}$ to $1\frac{1}{2}$	square	90	68	116	302	B68	C32
0	$\frac{1}{4}$ to $1\frac{1}{2}$	hex	69	52	103	302	B55	C32
A	$\frac{1}{4}$ to $1\frac{1}{2}$	hex	90	68	116	302	B68	C32
B	$\frac{1}{4}$ to 1	hex	120	90	121	302	B69	C32
B	$1\frac{1}{8}$ to $1\frac{1}{2}$	hex	105	79	121	302	B69	C32
D (C)	$\frac{1}{4}$ to $1\frac{1}{2}$	hex	135	135	159	352	B84	C38
DH (D)	$\frac{1}{4}$ to $1\frac{1}{2}$	hex	150	150	248	352	C24	C38
DH3	$\frac{1}{2}$ to 1	hex	150	150	248	352	C24	C38
A	$\frac{1}{4}$ to 4	heavy hex	100	75	116	302	B68	C32
B	$\frac{1}{4}$ to 1	heavy hex	133	100	121	302	B69	C32
B	$1\frac{1}{8}$ to $1\frac{1}{2}$	heavy hex	116	87	121	302	B69	C32
C (C)	$\frac{1}{4}$ to 4	heavy hex	144	144	143	352	B78	C38
C3	$\frac{1}{4}$ to 4	heavy hex	144	144	143	352	B78	C38
D (C)	$\frac{1}{4}$ to 4	heavy hex	150	150	159	352	B84	C38
DH (D)	$\frac{1}{4}$ to 4	heavy hex	175	150	248	352	C24	C38
DH3	$\frac{1}{4}$ to 4	heavy hex	175	150	248	352	C24	C38
A	$\frac{1}{4}$ to $1\frac{1}{2}$	hex thick	100	75	116	302	B68	C32
B	$1\frac{1}{4}$ to 1	hex thick	133	100	121	302	B69	C32
B	$1\frac{1}{8}$ to $1\frac{1}{2}$	hex thick	116	87	121	302	B69	C32
D (C)	$\frac{1}{4}$ to $1\frac{1}{2}$	hex thick	150	150	159	352	B84	C38
DH (D)	$\frac{1}{4}$ to $1\frac{1}{2}$	hex thick	175	175	248	352	C24	C38
Nuts with UNF, 12 UN, and Finer Pitch Threads								
0	$\frac{1}{4}$ to $1\frac{1}{2}$	hex	65	49	103	302	B55	C32
A	$\frac{1}{4}$ to $1\frac{1}{2}$	hex	80	60	116	302	B68	C32
B	$\frac{1}{4}$ to 1	hex	109	82	121	302	B69	C32
B	$1\frac{1}{8}$ to $1\frac{1}{2}$	hex	94	70	121	302	B69	C32
D (C)	$\frac{1}{4}$ to $1\frac{1}{2}$	hex	135	135	159	352	B84	C38
DH (D)	$\frac{1}{4}$ to $1\frac{1}{2}$	hex	150	150	248	352	C24	C38
A	$\frac{1}{4}$ to 4	heavy hex	90	68	116	302	B68	C32
B	$\frac{1}{4}$ to 1	heavy hex	120	90	121	302	B69	C32
B	$1\frac{1}{8}$ to $1\frac{1}{2}$	heavy hex	105	79	121	302	B69	C32
D (C)	$\frac{1}{4}$ to 4	heavy hex	150	150	159	352	B84	C38
DH (D)	$\frac{1}{4}$ to 4	heavy hex	175	150	248	352	C24	C38
A	$\frac{1}{4}$ to $1\frac{1}{2}$	hex thick	90	68	116	302	B68	C32
B	$\frac{1}{4}$ to 1	hex thick	120	90	121	302	B69	C32
B	$1\frac{1}{8}$ to $1\frac{1}{2}$	hex thick	105	79	121	302	B69	C32
D (C)	$\frac{1}{4}$ to $1\frac{1}{2}$	hex thick	150	150	159	352	B84	C38
DH (D)	$\frac{1}{4}$ to $1\frac{1}{2}$	hex thick	175	175	248	352	C24	C38

NOTES:

(A) To determine nut proof load in pounds, multiply the appropriate nut proof load stress by the tensile stress area of the thread. Stress areas for UNC, UNF, and 8 UN thread series are given in Table 4.

(B) Non-zinc-coated nuts are nuts intended for use with externally threaded fasteners which have a plain (nonplated or noncoated) finish or have a plating or coating of insufficient thickness to necessitate overtapping the nut thread to provide assemblability. Zinc-coated nuts are nuts intended for use with externally threaded fasteners which are hot-dip zinc-coated, mechanically zinc-coated, or have a plating or coating of sufficient thickness to necessitate overtapping the nut thread to provide assemblability.

(C) Nuts made in accordance to the requirements of Specification A 194/A 194M, Grade 2 or Grade 2H, and marked with their grade symbol are acceptable equivalents for Grades C and D nuts. When A 194 zinc-coated inch series nuts are supplied, the zinc coating, overtapping, lubrication and rotational capacity testing shall be in accordance with Specification A 563.

(D) Nuts made in accordance with the requirements of Specification A 194/A 194M, Grade 2H, and marked with its grade symbol are an acceptable equivalent for Grade DH nuts. When A 194 zinc-coated inch series nuts are supplied, the zinc coating, overtapping, lubrication and rotational capacity testing shall be in accordance with Specification A 563.

TABLE 4
TENSILE STRESS AREAS

Nominal Size–Threads per Inch	UNC Tensile Stress Area, A_s in.^{2}	Nominal Size-Threads per Inch	UNF Tensile Stress Area A_s in.^{2}	Nominal Size–Threads per Inch	8 UN Tensile Stress Area, A_s in.^{2}
1⁄4–20	0.0318	1⁄4–28	0.0364	. . .	. . .
5⁄16–18	0.0524	5⁄16–24	0.0580	. . .	. . .
3⁄8–16	0.0775	3⁄8–24	0.0878	. . .	. . .
7⁄16–14	0.1063	7⁄16–20	0.1187	. . .	. . .
1⁄2–13	0.1419	1⁄2–20	0.1599	. . .	. . .
9⁄16–12	0.182	9⁄16–18	0.203	. . .	. . .
5⁄8–11	0.226	5⁄8–18	0.256	. . .	. . .
3⁄4–10	0.334	3⁄4–16	0.373	. . .	. . .
7⁄8–9	0.462	7⁄8–14	0.509	. . .	. . .
1–8	0.606	1–12	0.663	1–8	0.606
1 1⁄8–7	0.763	1 1⁄8–12	0.856	1 1⁄8–8	0.790
1 1⁄4–7	0.969	1 1⁄4–12	1.073	1 1⁄4–8	1.000
1 3⁄8–6	1.155	1 3⁄8–12	1.315	1 3⁄8–8	1.233
1 1⁄2–6	1.405	1 1⁄2–12	1.581	1 1⁄2–8	1.492
1 3⁄4–5	1.90	. . .	. . .	1 3⁄4–8	2.08
2–4 1⁄2	2.50	. . .	. . .	2–8	2.77
2 1⁄4–4 1⁄2	3.25	. . .	. . .	2 1⁄4–8	3.56
2 1⁄2–4	4.00	. . .	. . .	2 1⁄2–8	4.44
2 3⁄4–4	4.93	. . .	. . .	2 3⁄4–8	5.43
3–4	5.97	. . .	. . .	3–8	6.51
3 1⁄4–4	7.10	. . .	. . .	3 1⁄4–8	7.69
3 1⁄2–4	8.33	. . .	. . .	3 1⁄2–8	8.96
3 3⁄4–4	9.66	. . .	. . .	3 3⁄4–8	10.34
4–4	11.08	. . .	. . .	4–8	11.81

GENERAL NOTE: A_s The stress area is calculated as follows:

$$A_s = 0.7854 \left[D - \frac{0.9743}{n} \right]^2$$

where:

A_s = stress area, in.^{2},
D = nominal size, in., and
n = threads per inch.

TABLE 5
THREAD DIMENSIONS AND OVERTAPPING ALLOWANCES FOR NUTS HOT DIP ZINC COATED PER SPECIFICATION F 2329

Nominal Nut Size, in. and Pitch	Diametral Allowance, in. (A)	Pitch Diameter, in.	
		min	max
0.250-20	0.016	0.2335	0.2384
0.312-18	0.017	0.2934	0.2987
0.375-16	0.017	0.3514	0.3571
0.437-14	0.018	0.4091	0.4152
0.500-13	0.018	0.4680	0.4745
0.562-12	0.020	0.5284	0.5352
0.625-11	0.020	0.5860	0.5932
0.750-10	0.020	0.7050	0.7127
0.875-9	0.022	0.8248	0.8330
1.000-8	0.024	0.9428	0.9516
1.125-8	0.024	1.0678	1.0768
1.125-7	0.024	1.0562	1.0656
1.250-8	0.024	1.1928	1.2020
1.250-7	0.024	1.1812	1.1908
1.375-8	0.027	1.3208	1.3301
1.375-6	0.027	1.2937	1.3041
1.500-8	0.027	1.4458	1.4553
1.500-6	0.027	1.4187	1.4292
1.750-5	0.050	1.6701	1.6817
2.000-4.5	0.050	1.9057	1.9181
2.250-4.5	0.050	2.1557	2.1683
2.500-4	0.050	2.3876	2.4011
2.750-4	0.050	2.6376	2.6513
3.000-4	0.050	2.8876	2.9015
3.250-4	0.050	3.1376	3.1517
3.500-4	0.050	3.3876	3.4019
3.750-4	0.050	3.6376	3.6521
3.750-4	0.050	3.6376	3.6521
4.000-4	0.050	3.8876	3.9023

NOTE:
(A) These allowances also apply to the minimum and maximum major and minor diameters.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall be applied only when specified by the purchaser on the contract or order. Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser. This supplementary requirement shall in no way negate any requirement of the specification itself.

S1. Supplementary Lubricant Requirements for Nuts

S1.1 Nuts, regardless of specified finish, shall be provided with an additional lubricant that shall be clean and dry to the touch.

S2. Lubricant Dye

S2.1 In addition to the requirements of Supplementary Requirement S1, the lubricant shall have a contrasting color so that it's presence is visually obvious.

S3. Lubricant Placement

The lubricant shall be applied to specified surfaces on the nuts, such as *(1)* principally only those portions which are threaded, or *(2)* on threaded portions and either only one bearing face or both bearing faces, as required, or *(3)* such other specific lubricant placement criteria as are agreed to between the purchaser and the user.

APPENDIX

(Nonmandatory Information)

X1. INTENDED APPLICATION

X1.1 Table X1.1 gives additional information for the intended application of nuts.

TABLE X1.1
NUT AND BOLT SUITABILITY GUIDE

Grade of Bolt (D)	Surface Finish (E)	Nominal Size in.	A563 Grade and ANSI Nut Style (A)					
			Recommended (B)		Suitable (C)			
			Hex	Heavy Hex	Square	Hex	Heavy Hex	Hex Thick
A 307 Grade A	non-zinc-coated and zinc-coated	$\frac{1}{4}$ to $1\frac{1}{2}$	A	. . .	A	B,D,DH	A,B,C,D,DH,DH3	A,B,D,DH
		>$1\frac{1}{2}$ to 2	. . .	A	. . .	A(F)	C,D,DH,DH3	. . .
		>2 to 4	. . .	A	. . .	. . .	C,D,DH,DH3	. . .
A 307 Grade B	non-zinc-coated and zinc-coated	$\frac{1}{4}$ to $1\frac{1}{2}$	. . .	A	A	B,D,DH	B,C,D,DH,DH3	A,B,D,DH
		>$1\frac{1}{2}$ to 2	. . .	A	. . .	A (F)	C,D,DH,DH3	. . .
		>2 to 4	. . .	A	. . .	. . .	C,D,DH,DH3	. . .
A 325 Type 1	non-zinc-coated	$\frac{1}{2}$ to $1\frac{1}{2}$	. . .	C	. . .	. . .	C3,D,DH,DH3	. . .
	zinc-coated	$\frac{1}{2}$ to $1\frac{1}{2}$	. . .	DH	. . .	. . .	. . .	. . .
A 325 Type 3	non-zinc-coated	$\frac{1}{2}$ to $1\frac{1}{2}$	. . .	C3	. . .	. . .	DH3	. . .
A 354 Grade BC	non-zinc-coated	$\frac{1}{4}$ to $1\frac{1}{2}$	. . .	C	. . .	D,DH	C3,D,DH,DH3	D,DH
		>$1\frac{1}{2}$ to 4	. . .	C	. . .	. . .	C3,D,DH,DH3	. . .
	zinc-coated	$\frac{1}{4}$ to $1\frac{1}{2}$	. . .	DH	. . .	. . .	. . .	DH
		>$1\frac{1}{2}$ to 4	. . .	DH	. . .	. . .	. . .	. . .
A 354 Grade BD	non-zinc-coated	$\frac{1}{4}$ to $1\frac{1}{2}$	. . .	DH	. . .	DH	D,DH,DH3	D,DH
		>$1\frac{1}{2}$ to 4	. . .	DH	. . .	. . .	DH3	. . .
A 394 Type 0	zinc-coated	$\frac{1}{2}$ to 1	A	. . .	. . .	B,D	. . .	. . .
A 394 Types 1 and 2	zinc-coated	$\frac{1}{2}$ to 1	DH	. . .	. . .	D	. . .	. . .
A 394 Type 3	non-zinc-coated	$\frac{1}{2}$ to 1	DH3	. . .	. . .	. . .	C3	. . .
A 449 Types 1 and 2	non-zinc-coated	$\frac{1}{4}$ to $1\frac{1}{2}$	B	. . .	. . .	D,DH	B,C,C3,D,DH,DH3	B,D,DH
		>$1\frac{1}{2}$ to 3	. . .	A	. . .	. . .	C,C3,D,DH,DH3	. . .
	zinc-coated	$\frac{1}{4}$ to $1\frac{1}{2}$	. . .	DH	. . .	D,DH	D	D,DH
		>$1\frac{1}{2}$ to 3	. . .	DH	. . .	. . .	D	. . .
A 490 Types 1 and 2	non-zinc-coated	$\frac{1}{2}$ to $1\frac{1}{2}$	. . .	DH	. . .	. . .	DH3	. . .
A 490 Type 3	non-zinc-coated	$\frac{1}{2}$ to $1\frac{1}{2}$	. . .	DH3	. . .	. . .	. . .	. . .
A 687	non-zinc-coated	$1\frac{1}{4}$ to 3	. . .	D	. . .	. . .	DH,DH3	. . .
	zinc-coated	$1\frac{1}{4}$ to 3	. . .	DH	. . .	. . .	. . .	. . .

NOTES:

(A) The availability of DH nuts in nominal sizes $\frac{3}{4}$ in. and larger is very limited and generally available only on special orders for 50 000 pieces or more. For smaller quantities A 194 Gr. 2H nuts should be considered.

(B) "Recommended" denotes a commercially available nut having the most suitable mechanical properties and dimensional configuration (style) that will make it possible to torque the bolt to the required load when used in combination with the nut.

(C) "Suitable" denotes nuts having mechanical properties that will make it possible to torque the bolt to the required load when used in combination with the nut; but, which require consideration of dimensional configuration (style) suitability and availability. Others are not suitable.

(D) The term "bolt" includes all externally threaded types of fasteners.

(E) Non-zinc-coated nuts are nuts intended for use with externally threaded fasteners which have a plain (nonplated or noncoated) finish or have a plating or coating of insufficient thickness to necessitate overlapping the nut thread to provide assemblability. Zinc-coated nuts are nuts intended for use with externally threaded fasteners which are hot-dip zinc-coated, mechanically zinc-coated, or have a plating or coating of sufficient thickness to necessitate overlapping the nut thread to provide assemblability.

(F) Hex nuts in nominal sizes over $1\frac{1}{2}$ to 2 in. inclusive are not covered in the tables of tabulated sizes in ANSI B18.2.2 but are commercially available. Such nuts are suitable. See 7.2 for dimensions.

SPECIFICATION FOR HOT-ROLLED AND COLD-FINISHED AGE-HARDENING STAINLESS STEEL BARS AND SHAPES

SA-564/SA-564M

(Identical with ASTM Specification A564/A564M-04(2009).)

SPECIFICATION FOR HOT-ROLLED AND COLD-FINISHED AGE-HARDENING STAINLESS STEEL BARS AND SHAPES

SA-564/SA-564M

[Identical with ASTM Specification A 564/A 564M-04(2009).]

1. Scope

1.1 This specification covers bars and shapes of age-hardening stainless steels. Hot-finished or cold-finished rounds, squares, hexagons, bar shapes, angles, tees, and channels are included; these shapes may be produced by hot rolling, extruding, or forging. Billets or bars for reforging may be purchased to this specification.

1.2 These steels are generally used for parts requiring corrosion resistance and high strength at room temperature, or at temperatures up to 600°F [315°C]; 700°F [370°C] for Type 632; 840°F [450°C] for Type UNS S46910. They are suitable for machining in the solution-annealed condition after which they may be age-hardened to the mechanical properties specified in Section 7 without danger of cracking or distortion. Type XM-25 is machinable in the as-received fully heat treated condition. Type UNS S46910 is suitable for machining in the solution-annealed, cold-worked, and aged-hardened condition.

1.3 Types 631 and 632 contain a large amount of ferrite in the microstructure and can have low ductility in forgings and larger diameter bars. Applications should be limited to small diameter bar.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 Unless the order specifies an "M" designation, the material shall be furnished to inch-pound units.

NOTE 1 — For forgings, see Specification A 705/A 705M.

NOTE 2 — For billets and bars for forging see Specification A 314.

2. Referenced Documents

2.1 *ASTM Standards:*

A 314 Specification for Stainless Steel Billets and Bars for Forging

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

A 705/A 705M Specification for Age-Hardening, Stainless Steel Forgings

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *Other Documents:*

SAE J1086 Recommended Practice for Numbering Metals and Alloys (UNS)

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include but are not limited to the following:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Type or UNS designation (Table 1),

3.1.3 Specific melt type when required,

3.1.4 Heat treated condition (5.1),

3.1.5 Transverse properties when required (7.6),

3.1.6 Finish (Specification A 484/A 484M),

3.1.7 Surface preparation of shapes (5.2.1),

3.1.8 Size, or applicable dimension including diameter, thickness, width, length, etc.,

3.1.9 Preparation for delivery (Specification A 484/A 484M),

3.1.10 Special requirements (refer to 7.4 and 8.3),

3.1.11 Marking requirements (Specification A 484/A 484M), and

3.1.12 ASTM designation and date of issue if other than that currently published.

3.2 If possible, the intended use of the item should be given on the purchase order especially when the item is ordered for a specific end use or uses.

NOTE 3 — A typical ordering description is as follows: 5000 lb [2270 kg] Type 630, Solution-Annealed Cold Finished Centerless Ground, $1\frac{1}{2}$ in. [38.0 mm] round bar, 10 to 12 ft [3.0 to 3.6 m] in length, ASTM A 564 dated ________ . End use: valve shafts.

4. General Requirements

4.1 In addition to the requirements of this specification, all requirements of the current edition of Specifications A 484/A 484M shall apply. Failure to comply with the general requirements of Specification A 484/A 484M constitutes nonconformance with this specification.

5. Materials and Manufacture

5.1 *Heat Treatment and Condition:*

5.1.1 Material of types other than XM-16, XM-25, and Type 630 shall be furnished in the solution-annealed condition, or in the equalized and oven-tempered condition, as noted in Table 2, unless otherwise specified by the purchaser.

5.1.1.1 Types 630, XM-16, and XM-25 may be furnished in the solution-annealed or age-hardened condition.

5.1.2 Type UNS S46910 shall be funished in solution-annealed condition per Table 2, or solution-annealed and cold-worked condition per Table 3, or aged-hardened condition per Table 4.

5.1.3 Reforging stock shall be supplied in a condition of heat treatment to be selected by the forging manufacturer.

5.2 Shapes may be subjected to either Class A or Class C preparation as specified on the purchase order.

5.2.1 Class A consists of preparation by grinding for the removal of imperfections of a hazardous nature such as fins, tears, and jagged edges provided the underweight tolerance is not exceeded and the maximum depth of grinding at any one point does not exceed 10% of the thickness of the section.

5.2.2 Class C consists of preparation by grinding for the removal of all visible surface imperfections provided the underweight tolerance is not exceeded and the maximum depth of grinding at any one point does not exceed 10% of the thickness of the section.

6. Chemical Composition

6.1 Each alloy covered by this specification shall conform to the chemical requirements specified in Table 1.

6.2 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties Requirements

7.1 The material, as represented by mechanical test specimens, shall conform to the mechanical property requirements specified in Table 2 or Table 3 and shall be capable of developing the properties in Table 4 when heat treated as specified in 5.1.

7.2 Samples cut from bars for forging stock shall conform to the mechanical properties of Table 2 and Table 4 when heat treated as specified in Table 2 and Table 4.

7.3 The yield strength shall be determined by the offset method as described in the current edition of Test Methods and Definitions A 370. The limiting permanent offset shall be 0.2% of the gage length of the specimen.

7.4 The impact requirement shall apply only when specified in the purchase order. When specified, the material, as represented by impact test specimens, shall be capable of developing the impact property requirements specified in Table 4 when heat treated in accordance with 5.1.

7.5 Longitudinal impact requirements are not applicable to bars less than $\frac{5}{8}$ in. (16.9 mm) diameter or size or flats less than $\frac{5}{8}$ in. (16.9 mm) thick.

7.6 Tensile and impact requirements in the transverse (through thickness) direction are not applicable to bars less than 3 in. [75 mm] diameter in size or flats less than 3 in. [75 mm] thick.

7.7 Material tensile tested and, when specified, impact tested in the transverse (through thickness) direction and meeting the requirements shown in Table 4 need not be tested in the longitudinal direction.

8. Number of Tests

8.1 At least one room temperature tension test and one or more hardness tests shall be made on each lot.

8.2 One or more hardness tests and at least one tension test shall be made from each lot on test samples heat treated as required in 5.1. Unless otherwise specified in the purchase order, the condition of hardening heat treatment shall be at the option of the producer. The tests shall meet the requirements of Table 4.

8.3 When specified in the purchase order, the impact test shall consist of testing three Charpy V-notch Type A specimens in accordance with Methods and Definitions A 370. The specimens shall be heat treated in accordance with 5.1. Unless otherwise specified in the purchase order, the condition of hardening heat treatment shall be at the option of the producer and testing shall be done at 70 to 80°F [20 to 25°C]. The tests shall meet the requirements of Table 4. When tested at temperatures other than 70 to 80°F, [20 to 25°C] the impact test requirements will be as agreed upon by purchaser and producer.

9. Keywords

9.1 age-hardening stainless steel; precipitation hardening stainless steel; stainless steel bars; stainless steel shapes

TABLE 1
CHEMICAL REQUIREMENTS[A]

Composition, %													
UNS Designation[B]	Type	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Aluminum	Molybdenum	Titanium	Copper	Other Elements
S17400	630	0.07	1.00	0.040	0.030	1.00	15.00–17.50	3.00–5.00	. . .	. . .	. . .	3.00–5.00	[C]
S17700	631	0.09	1.00	0.040	0.030	1.00	16.00–18.00	6.50–7.75	0.75–1.50	. . .	. . .	. . .	. . .
S15700	632	0.09	1.00	0.040	0.030	1.00	14.00–16.00	6.50–7.75	0.75–1.50	2.00–3.00	. . .	. . .	. . .
S35500	634	0.10–0.15	0.50–1.25	0.040	0.030	0.50	15.00–16.00	4.00–5.00	. . .	2.50–3.25	. . .	. . .	[D]
S17600	635	0.08	1.00	0.040	0.030	1.00	16.00–17.50	6.00–7.50	0.40	. . .	0.40–1.20	. . .	. . .
S15500	XM-12	0.07	1.00	0.040	0.030	1.00	14.00–15.50	3.50–5.50	. . .	. . .	. . .	2.50–4.50	[C]
S13800	XM-13	0.05	0.20	0.010	0.008	0.10	12.25–13.25	7.50–8.50	0.90–1.35	2.00–2.50	. . .	. . .	[E]
S45500	XM-16	0.03	0.50	0.015	0.015	0.50	11.00–12.50	7.50–9.50	. . .	0.50	0.90–1.40	1.50–2.50	[F]
S45503	. . .	0.010	0.50	0.010	0.010	0.20	11.00–12.50	7.50–9.50	. . .	0.50	1.00–1.35	1.50–2.50	[F]
S45000	XM-25	0.05	1.00	0.030	0.030	1.00	14.00–16.00	5.00–7.00	. . .	0.50–1.00	. . .	1.25–1.75	[G]
S46500	. . .	0.02	0.25	0.015	0.010	0.25	11.00–12.50	10.75–11.25	. . .	0.75–1.25	1.50–1.80	. . .	[E]
S46910	. . .	0.030	1.00	0.030	0.015	0.70	11.0–13.0	8.0–10.0	0.15–0.50	3.0–5.0	0.50–1.20	1.5–3.5	. . .

[A] Limits are in percent maximum unless shown as a range or stated otherwise.
[B] New designation established in accordance with Practice E 527 and SAE J1086.
[C] Columbium plus tantalum 0.15–0.45.
[D] Nitrogen 0.07–0.13.
[E] Nitrogen 0.01.
[F] Columbium plus tantalum 0.10–0.50.
[G] Columbium 8 times carbon minimum.

TABLE 2
SOLUTION TREATMENT

UNS Designation	Type	Condition	Solution Treatment	Mechanical Test Requirements in Solution Treated Condition[A]: Tensile Strength, min		Yield Strength, min[B]		Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Hardness[C]	
				ksi	[MPa]	ksi	[MPa]			Rockwell C, max	Brinell, max
S17400	630	A	1900 ± 25°F [1040 ± 15°C] (cool as required to below 90°F (32°C))	. . .	. . .	. . .	. . .	. . .	. . .	38	363
S17700	631	A	1900 ± 25°F [1040 ± 15°C] (water quench)	. . .	. . .	. . .	. . .	. . .	. . .	HRB98	229
S15700	632	A	1900 ± 25°F [1040 ± 15°C] (water quench)	. . .	. . .	. . .	. . .	. . .	. . .	HRB100	269[D]
S35500	634[E]	A	1900 ± 25°F [1040 ± 15°C] quench, hold not less than 3 h at minus 100°F or lower	. . .	. . .	. . .	. . .	. . .	. . .	. . .	363[E]
S17600	635	A	1900 ± 25°F [1040 ± 15°C] (air cool)	120	[825]	75	[515]	10	45	32	302
S15500	XM-12	A	1900 ± 25°F [1040 ± 15°C] (cool as required to below 90°F (32°C))	. . .	. . .	. . .	. . .	. . .	. . .	38	363
S13800	XM-13	A	1700 ± 25°F [925 ± 15°C] Cool as required to below 60°F [16°C]	. . .	. . .	. . .	. . .	. . .	. . .	38	363
S45500	XM-16	A	1525 ± 25°F [830 ± 15°C] (cool rapidly)	. . .	. . .	. . .	. . .	. . .	. . .	36	331
S45000	XM-25	A	1900 ± 25°F [1040 ± 15°C] (cool rapidly)	125[F]	[860]	95	[655]	10	40	32	321
S45503	. . .	A	1525 ± 25°F [830 ± 15°C] (cool rapidly)	. . .	. . .	. . .	. . .	. . .	. . .	36	331
S46500	. . .	A	1800 ± 25°F [980 ± 15°C] (oil or water quench), hold for min. 8 h at minus 100°F (73°C), air warm	. . .	. . .	. . .	. . .	. . .	. . .	36	331
S46910	. . .	A	1830 − 2050°F [1000 − 1120°C] (cool rapidly)	87	[600]	58	[400]	10	. . .	33	315

[A] See 7.1.
[B] See 7.3.
[C] Either Rockwell C hardness or Brinell is permissible. On sizes ½ in. (12.70 mm) and smaller, Rockwell C is preferred.
[D] 321 BH for rounds cold drawn after solution treating.
[E] Equalization and over-tempering treatment 1425 ± 50°F (775 ± 30°C] for not less than 3 h, cool to room temperature, heat to 1075 ± 25°F [580 ± 15°C] for not less than 3 h.
[F] Maximum 165 ksi [1140 MPa] tensile strength only for sizes up to ½ in. (13 mm).

TABLE 3
SOLUTION-ANNEALED AND COLD-WORKED CONDITION

UNS Designation	Type	Condition	Mechanical Test Requirements in Solution Annealed and Cold-Worked Condition: Tensile Strength, min, ksi	Tensile Strength, min, [MPa]	Yield Strength, min, ksi	Yield Strength, min, [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Hardness: Rockwell C, max	Hardness: Brinell, max
S46910	. . .	CW ½ hard	131	[900]	109	[750]	8	. . .	40	380
	. . .	CW full hard	189	[1300]	175	[1200]	3	. . .	55	580

TABLE 4
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A]

Type	Condition	Suggested Hardening or Aging Treatment, or Both[B,C,D]			Applicable Thickness, in. and Test Direction[E]	Tensile Strength, min		Yield Strength, min[F]		Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of area, min, %	Hardness[G]		Impact Charpy-V, min	
		Temperature, °F [°C]	Time, h	Quench[H]		ksi	[MPa]	ksi	[MPa]			Rockwell C, min	Brinell, min	ft·lbf	J
630	H900	900 [480]	1.0	air cool	Up to 3 in. incl [75 mm] (L)	190	[1310]	170	[1170]	10	40	40	388	...	...
					Over 3 in. [75 mm] to 8 in. incl [200 mm] (T)						35				
	H925	925 [495]	4.0	air cool	Up to 3 in. incl [75 mm] (L)	170	[1170]	155	[1070]	10	44	38	375	5	6.8
					Over 3 in. [75 mm] to 8 in. incl [200 mm] (T)						38				
	H1025	1025 [550]	4.0	air cool	Up to 8 in. incl [200 mm] (L)	155	[1070]	145	[1000]	12	45	35	331	15	20
	H1075	1075 [580]	4.0	air cool		145	[1000]	125	[860]	13	45	32	311	20	27
	H1100	1100 [595]	4.0	air cool		140	[965]	115	[795]	14	45	31	302	25	34
	H1150	1150 [620]	4.0	air cool		135	[930]	105	[725]	16	50	28	277	30	41
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool				115	[795]	75	[520]	18	55	24	255	55	75
	H1150D	1150 [620] for 4 h, air cool plus 1150 [620] for 4 h, air cool				125	[860]	105	[725]	16	50	24 33 max	255 311 max	30	41
631	RH950	1750°F [955°C] for not less than 10 min, but not more than 1 h, cool rapidly to room temperature. Cool within 24 h to minus 100 ± 10°F [75°C], hold not less than 8 h. Warm in air to room temperature. Heat to 950°F [510°C], hold 1 h, air cool.			Up to 4 in. incl. [100 mm] (L)	185	[1280]	150	[1030]	6	10	41	388	...	...
	TH1050	Alternative treatment: 1400°F [760°C] hold 90 min, cool to 55 ± 5°F [15 ± 3°C] within 1 h. Hold not less than 30 min, heat to 1050°F [565°C] hold for 90 min, air cool.			Up to 6 in. incl [150 mm] (L)	170	[1170]	140	[965]	6	25	38	352	...	...
632	RH950	Same as Type 631			Up to 4 in. incl [100 mm] (L)	200	[1380]	175	[1210]	7	25	...	415	...	...
	TH1050				Up to 6 in. incl [150 mm] (L)	180	[1240]	160	[1100]	8	25	...	375	...	...
634[I]	H1000	1750 [955] for not less than 10 min, but not more than 1 h. Water quench. Cool to not higher than minus 100°F [75°C]. Hold for not less than 3 h. Temper at 1000°F [540°C], holding for not less than 3 h.				170	[1170]	155	[1070]	12	25	37	341	...	...
635	H950	950 [510]	0.5	air cool		190	[1310]	170	[1170]	8	25	39	363	...	...
	H1000	1000 [540]	0.5	air cool		180	[1240]	160	[1100]	8	30	37	352	...	...
	H1050	1050 [565]	0.5	air cool		170	[1170]	150	[1035]	10	40	35	331	...	...
XM-12	H900	900 [480]	1.0	air cool	Up to 12 in. incl [300 mm] (L)	190	[1310]	170	[1170]	10	35	40	388	...	...
					Up to 12 in. incl [300 mm] (T)					6	15				
	H925	925 [495]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	170	[1170]	155	[1070]	10	38	38	375	5	6.8
					Up to 12 in. incl [300 mm] (T)					7	20			...	...

TABLE 4
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A] (CONT'D)

Type	Condition	Suggested Hardening or Aging Treatment, or Both[B,C,D] Temperature, °F [°C]	Time, h	Quench[H]	Applicable Thickness, in. and Test Direction[E]	Tensile Strength, min ksi	Tensile Strength, min [MPa]	Yield Strength, min[F] ksi	Yield Strength, min[F] [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of area, min, %	Hardness[G] Rockwell C, min	Hardness[G] Brinell, min	Impact Charpy-V, min ft·lbf	Impact Charpy-V, min J
XM-12	H1025	1025 [550]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	155	[1070]	145	[1000]	12	45	35	331	15	20
					Up to 12 in. incl [300 mm] (T)					8	27			10	14
	H1075	1075 [580]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	145	[1000]	125	[860]	13	45	32	311	20	27
					Up to 12 in. incl [300 mm] (T)					9	28			15	20
	H1100	1100 [595]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	140	[965]	115	[795]	14	45	31	302	25	34
					Up to 12 in. incl [300 mm] (T)					10	29			15	20
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	135	[930]	105	[725]	16	50	28	277	30	41
					Up to 12 in. incl [300 mm] (T)					11	30			20	27
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool			Up to 12 in. incl [300 mm] (L)	115	[795]	75	[515]	18	55	24	255	55	75
					Up to 12 in. incl [300 mm] (T)					14	35			35	47
XM-13	H950	950 [510]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	220	[1515]	205	[1415]	10	45	45	430	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						35				
	H1000	1000 [540]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	205	[1415]	190	[1310]	10	50	43	400	. . .	. . .
					Up to 12 in. incl [300 mm] (T)					10	40				
	H1025	1025 [550]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	185	[1280]	175	[1210]	11	50	41	380	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						45				
	H1050	1050 [565]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	175	[1210]	165	[1140]	12	50	40	372	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						45				
	H1100	1100 [595]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	150	[1035]	135	[930]	14	50	34	313	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						50				
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	135	[930]	90	[620]	14	50	30	283	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						50				
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool			Up to 12 in. incl [300 mm] (L)	125	[860]	85	[585]	16	55	26	259	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						55				

TABLE 4
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A] (CONT'D)

Type	Condition	Suggested Hardening or Aging Treatment, or Both[B,C,D] Temperature, °F [°C]	Time, h	Quench[H]	Applicable Thickness, in. and Test Direction[E]	Tensile Strength, min ksi	Tensile Strength, min [MPa]	Yield Strength, min[F] ksi	Yield Strength, min[F] [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of area, min, %	Hardness[G] Rockwell C, min	Hardness[G] Brinell, min	Impact Charpy-V, min ft·lbf	Impact Charpy-V, min J
XM-16	H900	900 [480]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	235	[1620]	220	[1515]	8	30	47	444	...	...
	H950	950 [510]	4.0	air cool		220	[1515]	205	[1415]	10	40	44	415	...	...
	H1000	1000 [540]	4.0	air cool		205	[1415]	185	[1275]	10	40	40	363	...	...
S45503	H900	900 [480]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	235	[1620]	220	[1520]	8	30	47	444	...	...
					Up to 6 in. incl [150 mm] (T)					4	15				
	H950	950 [510]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	220	[1515]	205	[1410]	10	40	44	415	...	...
					Up to 6 in. incl [150 mm] (T)					5	20				
	H1000	1000 [540]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	205	[1410]	185	[1275]	10	40	40	363	...	...
					Up to 6 in. incl [150 mm] (T)					6	25				
XM-25	H900	900 [480]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	180	[1240]	170	[1170]	10	40	39	363	...	...
					Up to 12 in. incl. [300 mm] (T)					6	20				
	H950	950 [510]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	170	[1170]	160	[1100]	10	40	37	341	...	...
					Up to 12 in. incl [300 mm] (T)					7	22				
	H1000	1000 [540]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	160	[1100]	150	[1035]	12	45	36	331	...	...
					Up to 12 in. incl [300 mm] (T)					8	27				
	H1025	1025 [550]	4.0	air cool	Up to 8 in. incl [200 mm] (L)	150	[1035]	140	[965]	12	45	34	321	...	...
	H1050	1050 [565]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	145	[1000]	135	[930]	12	45	34	321	...	...
					Up to 12 in. incl [300 mm] (T)					9	30				
	H1100	1100 [595]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	130	[895]	105	[725]	16	50	30	285	...	...
					Up to 12 in. incl [300 mm] (T)					11	30				
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	125	[860]	75	[515]	10	55	26	262	...	...
					Up to 12 in. incl [300 mm] (T)					12	35				

TABLE 4
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A] (CONT'D)

Type	Condition	Suggested Hardening or Aging Treatment, or Both[B,C,D]			Applicable Thickness, in. and Test Direction[E]	Tensile Strength, min		Yield Strength, min[F]		Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of area, min, %	Hardness[G]		Impact Charpy-V, min	
		Temperature, °F [°C]	Time, h	Quench[H]		ksi	[MPa]	ksi	[MPa]			Rockwell C, min	Brinell, min	ft·lbf	J
S46500	H950	950 [510]	4.0	air or oil	Up to 12 in. incl [300 mm] (L)	240	[1655]	220	[1515]	10	45	47	444	. . .	. . .
					Up to 12 in. incl. [300 mm] (T)					8	35				
	H1000	1000 [540]	4.0	air or oil	Up to 12 in. incl [300 mm] (L)	220	[1515]	200	[1380]	10	50	45	430	. . .	. . .
					Up to 12 in. incl. [300 mm] (T)					10	40				
	H1025	1025 [560]	4.0	air or oil	Up to 12 in. incl [300 mm] (L)	210	[1450]	195	[1345]	12	50	44	415	. . .	. . .
					Up to 12 in. incl [300 mm] (T)					11	45				
	H1050	1050 [565]	430	air or oil	Up to 12 in. incl [300 mm] (L)	200	[1380]	185	[1280]	13	50	43	400	. . .	. . .
					Up to 12 in. incl [300 mm] (T)					12	45				
UNS S46910	CW ½ hard + aging	890 [475]	1.0	air cool	. . .	245	[1690]	218	[1500]	6	. . .	48	456	. . .	. . .
	CW full hard + aging	890 [475]	1.0	air cool	. . .	320	[2205]	290	[2005]	2	. . .	55	561	. . .	. . .

[A] See 7.1.
[B] Time refers to minimum time material is at temperature and may be extended to obtain required ductility properties.
[C] Unless otherwise noted, temperatures shown are suggested temperatures and may be varied to obtain required tensile properties.
[D] Intermediate temperatures must meet the ductility requirements of the next highest suggested hardening or aging temperature, or both. Example: Type 630 at 1050°F [565°C] must have 13% elongation and 45% reduction, same as for age hardening at 1075°F [580°C].
[E] (L) — Longitudinal axis of specimen parallel to direction of grain flow during rolling or forging. (T) — Transverse axis of specimen perpendicular to direction of grain flow during rolling or forging.
[F] See 7.3.
[G] Either Rockwell C hardness or Brinell is permissible. On sizes ½ in. (12.70 mm) and smaller, Rockwell C is preferred.
[H] When air cooling is specified, gases other than air may be used.
[I] Refer to Table 2 for details on equalize and over temper heat treatment.

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SPECIFICATION FOR STEEL, SHEET, CARBON, STRUCTURAL, AND HIGH-STRENGTH, LOW-ALLOY, HOT-ROLLED AND COLD-ROLLED, GENERAL REQUIREMENTS FOR

SA-568/SA-568M

(Identical with ASTM Specification A568/A568M-07a.)

SPECIFICATION FOR STEEL, SHEET, CARBON, STRUCTURAL, AND HIGH-STRENGTH, LOW-ALLOY, HOT-ROLLED AND COLD-ROLLED, GENERAL REQUIREMENTS FOR

SA-568/SA-568M

(Identical with ASTM Specification A 568/A 568M-07a.)

1. Scope

1.1 This specification covers the general requirements for steel sheet in coils and cut lengths. It applies to the following specifications that describe carbon steel, structural steel, and high-strength, low-alloy steel (HSLA) furnished as hot-rolled sheet and cold-rolled sheet: Specifications A 414/A 414M, A 424, A 606, A 659/A 659M, A 794, A 1008/A 1008M, A 1011/A 1011M, and A 1039/A 1039M.

1.2 This specification is not applicable to hot-rolled heavythickness carbon sheet coils (Specification A 635/A 635M).

1.3 In case of any conflict in requirements, the requirements of the individual material specification shall prevail over those of this general specification.

1.4 For the purposes of determining conformance with this and the appropriate product specification referenced in 1.1, values shall be rounded to the nearest unit in the right hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

1.5 Annex A1 lists permissible variations in dimensions and mass (see Note 1) in SI [metric] units. The values listed are not exact conversions of the values listed in the inch-pound tables, but instead are rounded or rationalized values. Conformance to Annex A1 is mandatory when the "M" specification is used.

NOTE 1 — The term *weight* is used when inch-pound units are the standard. However, under SI the preferred term is *mass*.

1.6 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.7 This specification and the applicable material specifications are expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 414/A 414M Specification for Steel, Sheet, Carbon, for Pressure Vessels

A 424 Specification for Steel, Sheet, for Porcelain Enameling

A 606 Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance

A 635/A 635M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for

A 659/A 659M Specification for Commercial Steel (CS), Sheet and Strip, Carbon (0.16 Maximum to 0.25 Maximum Percent), Hot-Rolled

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 794 Specification for Commercial Steel (CS), Sheet, Carbon (0.16% Maximum to 0.25% Maximum), Cold-Rolled
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 1008/A 1008M Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable
A 1011/A 1011M Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
A 1030/A 1030M Practice for Measuring Flatness Characteristics of Steel Sheet Products
A 1039/A 1039M Specification for Steel, Sheet, Hot Rolled, Carbon, Commercial and Structural, Produced by the Twin-Roll Casting Process
E 11 Specification for Wire Cloth and Sieves for Testing Purposes
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition
E 290 Test Methods for Bend Testing of Material for Ductility

2.2 *Military Standards:*
MIL-STD-129 Marking for Shipment and Storage

2.3 *Federal Standards:*
Fed. Std. No. 123 Marking for Shipments (Civil Agencies)
Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *Steel Types:*

3.1.2 *carbon steel* — designation for steel when no minimum content is specified or required for aluminum, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any element added to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40%; or when the maximum content specified for any of the following elements does not exceed the percentages noted: manganese 1.65, silicon 0.60, or copper 0.60.

3.1.2.1 *Discussion* — In all carbon steels small quantities of certain residual elements unavoidably retained from raw materials are sometimes found which are not specified or required, such as copper, nickel, molybdenum, chromium, etc. These elements are considered as incidental and are not normally determined or reported.

3.1.3 *high-strength, low-alloy steel* — specific group of steels in which higher strength, and in some cases additional resistance to atmospheric corrosion or improved formability, are obtained by moderate amounts of one or more alloying elements.

3.1.4 *Product Types:*

3.1.5 *hot-rolled sheet* — manufactured by hot rolling slabs in a continuous mill to the required thickness and can be supplied in coils or cut lengths as specified.

(1) Hot-rolled carbon and high-strength low-alloy (HSLA) steel sheet is commonly classified by size as follows:

Coils and Cut Lengths

Width, in.	Thickness, in.
Over 12	0.031 to 0.230, excl

Coils and Cut Lengths

Width, mm	Thickness, mm
Over 300	0.7 to 6.0, excl

NOTE 2 — The changes in width limits with the publication of A 568/A 568M-06a result in a change in tensile testing direction for material from 0.180 in. [4.5 mm] to 0.230 in. exclusive [6.0 mm exclusive] over 48 in. [1200 mm] wide. Material formerly tested in the transverse direction will be tested in the longitudinal direction. This is expected to result in some changes in reported properties. The purchaser is advised to discuss this change with the supplier.

3.1.6 *cold-rolled sheet* — manufactured from hot-rolled descaled coils by cold reducing to the desired thickness, generally followed by annealing to recrystallize the grain structure. If the sheet is not annealed after cold reduction it is known as full hard with a hardness of 84 HRB minimum and can be used for certain applications where ductility and flatness are not required.

(1) Cold-rolled carbon sheet is commonly classified by size as follows:

Width, in.	Thickness, in.
All Width[A,B]	Through 0.142

Width, mm	Thickness, mm
All Width[A, B]	Through 4.0

[A] Cold-rolled sheet coils and cut lengths, slit from wider coils with cut edge (only) and in thicknesses through 0.142 in. [4.0 mm] carbon 0.25% maximum by cast analysis.
[B] When no special edge or finish (other than matte, commercial bright, or luster finish) or single strand rolling of widths, or both under 24 in. [600 mm] is not specified or required.

(2) Cold-rolled high-strength low-alloy sheet is commonly classified by size as follows:

Width, in.	Thickness, in.
Through 12[A]	0.019 through 0.082
Over 12[B]	0.020 and over

Width, mm	Thickness, mm
To 300, incl[A]	0.5 to 2.0, incl
Over 300[B]	0.5 and over

[A] Cold-rolled sheet coils and cut lengths, slit from wider coils with cut edge (only) and in thicknesses 0.019 in. [0.5 mm] through 0.82 in. [2.0 mm] carbon 0.25% maximum by cast analysis.
[B] When no special edge or finish (other than matte, commercial bright, or luster finish) or single strand rolling of widths, or both under 24 in. [600 mm] is not specified or required.

3.1.6.1 *Discussion* — Steel products are available in various thickness, width, and length combinations depending upon equipment and processing capabilities of various manufacturers and processors. Historic limitations of a product based upon dimensions (thickness, width, and length) do not take into account current production and processing capabilities. To qualify any product for a particular product specification requires all appropriate and necessary tests be performed and that the results meet the limits prescribed in that product specification. If the necessary tests required by a product specification cannot be conducted, the product cannot be qualified to that specification. This general requirements specification contains permitted variations for the commonly available sizes. Permitted variations for other sizes are subject to agreement between the customer and the manufacturer or processor, whichever is applicable.

3.1.7 *retests, n* — additional test, or tests, made from the original material when the original test did not meet the appropriate acceptance criteria required by a product specification and the failure was mechanical in natures as described in Section 11.

3.1.8 *resample, n* — additional test or tests made when the test on the original sample did not meet the appropriate acceptance criteria required by the product specification, but possibly requiring that the material in question have an appropriate amount discarded prior to securing the new sample or samples.

3.1.9 *steel manufacturer, n* — the organization that directly controls or is responsible for the melting and refining of steel and the conversion of that steel into semifinished steel products known as slabs either through continuous casting, conventional or compact methods, or ingot casting and subsequent conversion of the ingots to slabs, and for one or more additional operations such as testing, marking, loading for shipment, and certification.

3.1.10 *coil processor* — the organization that directly controls or is responsible for operations involved in processing the coil such as leveling, cutting to length, testing, inspection, blanking, slitting, pickling, cold rolling (cold reduction), heat treating, temper rolling, coating, packaging, marking, loading for shipment, and certification.

3.1.10.1 *Discussion* — The processing operations need not be controlled by the organization that hot rolls the slab into a coil. If only one organization controls or is responsible for (or both) the hot rolling and processing operations, that organization is termed the manufacturer. If more than one organization controls or is responsible for (or both) hot rolling and processing operations, the organization that controls and is responsible for the hot rolling is termed the hot roll manufacturer and the organization or organizations controlling and responsible for the processing operations is/are termed the processor or processors. Likewise, one organization may be the manufacturer of the hot roll coil and another the manufacturer of the cold roll coil. In such case, the organization responsible for the conversion of the hot roll coil to a cold roll coil and other processing operations will also be termed the cold roll manufacturer and organizations performing additional processing operations to the cold roll coil will be termed the coil processor or coil processors.

3.1.11 *hot roll manufacturer, n* — the organization that directly controls or is responsible for the conversion of steel slabs, by hot rolling into coils, and for one or more additional operations such as leveling, cutting to length, testing, inspection, blanking, slitting, pickling, cold rolling, heat treating, coating, packaging, marking, loading for shipment, and certification.

3.1.12 *cold roll manufacturer, n* — the organization that directly controls or is responsible for the conversion of hot roll coils into cold roll coils, and for one or more additional operations such as pickling, annealing, temper rolling, slitting, cutting to length, testing, inspection, blanking, coating, packaging, marking, loading for shipment, and certification.

3.2 Refer to Terminology A 941 for additional definitions of terms used in this standard.

4. Materials and Manufacture

4.1 Unless otherwise specified, hot-rolled material shall be furnished hot-rolled, not annealed, not pickled.

4.2 Coil breaks, stretcher strains, and fluting can occur during the user's processing of hot-rolled or hot-rolled pickled sheet. When any of these features are detrimental to the application, the manufacturer shall be notified at time of ordering in order to properly process the sheet.

4.3 Cold-rolled carbon steel sheet is available as discussed in 10.2, 10.3, and in Table 1.

4.4 Unless specified as a full-hard product, cold-rolled sheet is annealed after being cold reduced to thickness.

The annealed, cold-rolled sheet can be used as annealed last (dead soft) for unexposed end-use applications. When cold-rolled sheet is used for unexposed applications and coil breaks are a hazard in uncoiling, it may be necessary to further process the material. In this case the manufacturer should be consulted. After annealing, cold-rolled sheet is generally given a light skin pass to impart shape or may be given a heavier skin pass or temper pass to prevent the phenomenon known as stretcher straining or fluting, when formed. Temper passing also provides a required surface texture.

4.5 *Temper Rolling:*

4.5.1 Unless otherwise specified, cold-rolled sheet for exposed applications shall be temper rolled and is usually specified and furnished in the strain free condition as shipped. See Appendix X1, Effect of Aging of Cold-Rolled Carbon Steel Sheet on Drawing and Forming.

4.5.2 Cold-rolled sheet for unexposed applications may be specified and furnished "annealed last" or "temper rolled." "Annealed last" is normally produced without temper rolling but may be lightly temper rolled during oiling or rewinding. Unexposed temper-rolled material may be specified strain-free or nonfluting. Where specific hardness range or limit or a specified surface texture is required, the application is considered as exposed.

NOTE 3 — Skin-passed sheet is subject to an aging phenomenon (see Appendix X1). Unless special killed (nonaging) steel is specified, it is to the user's interest to fabricate the sheet as soon as possible, for optimum performance.

5. Chemical Composition

5.1 *Limits:*

5.1.1 The chemical composition shall be in accordance with the applicable product specification. However, if other compositions are required for carbon steel, they shall be prepared in accordance with Appendix X2.

5.1.2 Where the material is used for fabrication by welding, care must be exercised in selection of chemical composition or mechanical properties to assure compatibility with the welding process and its effect on altering the properties.

5.2 *Cast or Heat Analysis:*

5.2.1 An analysis of each cast or heat of steel shall be made by the steel manufacturer to determine the percentage of elements specified or restricted by the applicable specification.

5.2.2 When requested, cast or heat analysis for elements listed or required shall be reported to the purchaser or to his representative. The steel manufacturer, or the hot roll manufacturer, cold roll manufacturer, or processor, if different from the steel manufacturer, is responsible for providing this information to the purchaser or his representative as requested.

5.3 *Product, Check, or Verification Analysis:*

5.3.1 Non-killed steels such as capped or rimmed steels are not technologically suited to product analysis due to the nonuniform character of their chemical composition and therefore, the tolerances in Table 2 do not apply. Product analysis is appropriate on these types of steel only when misapplication is apparent or for copper when copper steel is specified.

5.3.2 For steels other than non-killed (capped or rimmed), product analysis may be made by the purchaser. The chemical analysis shall not vary from the limits specified by more than the amounts in Table 2. The several determinations of any element in a cast shall not vary both above and below the specified range.

5.4 *Sampling for Product Analysis:*

5.4.1 To indicate adequately the representative composition of a cast by product analysis, it is general practice to select samples to represent the steel, as fairly as possible, from a minimum number of pieces as follows: 3 pieces for lots up to 15 tons incl, and 6 pieces for lots over 15 tons (see Practice E 59).

5.4.2 When the steel is subject to tension test requirements, samples for product analysis may be taken either by drilling entirely through the used tension test specimens themselves, or as covered in 5.4.3.

5.4.3 When the steel is not subject to tension test requirements, the samples for analysis must be taken by milling or drilling entirely through the sheet in a sufficient number of places so that the samples are representative of the entire sheet or strip. The sampling may be facilitated by folding the sheet both ways, so that several samples may be taken at one drilling. Steel subjected to certain heating operations by the purchaser may not give chemical analysis results that properly represent its original composition. Therefore, users must analyze chips taken from the steel in the condition in which it is received from the steel manufacturer.

5.5 *Specimen Preparation* — Drillings or chips must be taken without the application of water, oil, or other lubricant, and must be free of scale, grease, dirt, or other foreign substances. They must not be overheated during cutting to the extent of causing decarburization. Chips must be well mixed and those too coarse to pass a No. 10 sieve or too fine to remain on a No. 30 sieve are not suitable for proper analysis. Sieve size numbers are in accordance with Specification E 11.

5.6 *Test Methods* — In case a referee analysis is required and agreed upon to resolve a dispute concerning the results of a chemical analysis, the procedure of performing the referee analysis must be in accordance with the latest issue of Test Methods, Practices, and Terminology A 751, unless otherwise agreed upon between the manufacturer and the purchaser.

6. Mechanical Properties

6.1 The mechanical property requirements, number of specimens, and test locations and specimen orientation shall be in accordance with the applicable product specification.

6.2 Unless otherwise specified in the applicable product specification, test specimens must be prepared in accordance with Test Methods and Definitions A 370.

6.3 Mechanical tests shall be conducted in accordance with Test Methods and Definitions A 370.

6.4 Bend tests where required shall be conducted in compliance with Test Method E 290.

6.5 To determine conformance with the product specification, a calculated value should be rounded to the nearest 1 ksi tensile strength and yield point or yield strength, and to the nearest unit in the right hand place of figures used in expressing the limiting value for other values in accordance with the rounding off method given in Practice E 29.

6.6 Structural sheet steels are commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a given steel to cold form over a given radius under shop conditions. These factors include thickness, strength level, degree of restraint, relationship to rolling direction, chemistry and microstructure. Each of the appropriate product specifications lists in the appendix the suggested minimum inside radius for cold bending. These radii should be used as minima for 90° bends. They presuppose "hard way" bending (bend axis parallel to rolling direction) and reasonably good shop forming practices. Where possible, the use of larger radii or "easy way" bends are recommended for improved performance.

6.7 Fabricators should be aware that cracks may initiate upon bending a sheared or burned edge. This is not considered to be a fault of the steel but is rather a function of the induced cold-work or heat-affected zone.

7. General Requirements for Delivery

7.1 The products covered by this specification are produced to inch-pound or metric decimal thickness only and the appropriate thickness tolerances apply.

7.2 Steel may be produced as ingot-cast or strand-cast. When different grades of strand-cast steel are sequentially cast, identification and separation of the transition material is required.

8. Dimensions, Tolerances, and Allowances

8.1 Dimensions, tolerances, and allowances applicable to products covered by this specification are contained in Tables 3-23 [Annex A1, Tables A1.1–A1.20]. The appropriate tolerance tables shall be identified in each individual specification.

8.2 *Flatness Tolerances:*

8.2.1 Standard flatness tolerances are contained in Table 15 and Table 16 for hot-rolled sheet and Table 23 for cold-rolled sheet.

8.2.2 Measurement techniques for flatness characteristics are described in Practice A 1030/A 1030M.

8.2.3 Two alternative methods for flatness determination are the use of I-units and percent steepness. A description of these two alternative methods is contained in Practice A 1030/A 1030M, as well as Appendix X5.

8.2.3.1 The use of I-units or percent steepness as a flatness standard is subject to negotiation between the purchaser and the producer.

8.2.3.2 Measurement techniques for I-units and percent steepness and rejection limits are subject to negotiation between the purchaser and the producer.

9. Finish and Condition

9.1 Hot-rolled sheet has a surface with an oxide or scale resulting from the hot-rolling operation. The oxide or scale can be removed by pickling or blast cleaning when required for press-work operations or welding. Hot-rolled and hot-rolled descaled sheet is not generally used for exposed parts where surface is of prime importance.

9.1.1 Hot-rolled sheet can be supplied with mill edges or cut edges as specified. Mill edges are the natural edges resulting from the hot-rolling operation. They do not conform to any particular contour. They may also contain some edge imperfections, the more common types of which are cracked edges, thin edges (feather), and damaged edges due to handling or processing and which should not extend in beyond the ordered width. These edge conditions are detrimental where joining of the mill edges by welding is practiced. When the purchaser intends to shear or to blank, a sufficient width allowance should be made when purchasing to ensure obtaining the desired contour and size of the pattern sheet. The manufacturer may be consulted for guidance. Cut edges are the normal edges which result from the shearing, slitting, or trimming of mill-edge sheet.

9.1.1.1 The ends of plain hot-rolled mill-edge coils are irregular in shape and are referred to as uncropped ends. Where such ends are not acceptable, the purchaser's order should so specify. Processed coils such as pickled or blast cleaned are supplied with square-cut ends.

9.2 Cold-rolled carbon sheet (exposed) is intended for those applications where surface appearance is of primary importance. This class will meet requirements for controlled surface texture, surface quality, and flatness. It is normally processed by the manufacturer to be free of stretcher strain and fluting. Subsequent user roller leveling immediately before fabrication will minimize strain resulting from aging.

9.2.1 Cold-rolled carbon sheet, when ordered for exposed applications, can be supplied in the following finishes:

9.2.1.1 Matte finish is a dull finish, without luster, produced by rolling on rolls that have been roughened by mechanical or chemical means to various degrees of surface texture depending upon application. With some surface preparation matte finish is suitable for decorative painting. It is not generally recommended for bright plating.

9.2.1.2 Commercial bright finish is a relatively bright finish having a surface texture intermediate between that of matte and luster finish. With some surface preparation commercial bright finish is suitable for decorative painting or certain plating applications. If sheet is deformed in fabrication the surface may roughen to some degree and areas so affected will require surface preparation to restore surface texture to that of the undeformed areas.

9.2.1.3 Luster finish is a smooth bright finish produced by rolling on ground rolls and is suitable for decorative painting or plating with additional special surface preparation by the user. The luster may not be retained after fabrication; therefore, the formed parts will require surface preparation to make them suitable for bright plating.

9.3 Cold-rolled carbon sheet, when intended for unexposed applications, is not subject to limitations on degree and frequency of surface imperfections, and restrictions on texture and mechanical properties are not applicable. When ordered as "annealed last," the product will have coil breaks and a tendency toward fluting and stretcher straining. Unexposed cold-rolled sheet may contain more surface imperfections than exposed cold-rolled sheet because steel applications, processing procedures, and inspection standards are less stringent.

9.4 Cold-rolled high-strength low-alloy sheet is supplied with a matte finish, unless otherwise specified.

9.5 The cold-rolled products covered by this specification are furnished with cut edges and square cut ends, unless otherwise specified.

9.6 *Oiling:*

9.6.1 Plain hot-rolled sheet is customarily furnished not oiled. Oiling must be specified, when required.

9.6.2 Hot-rolled pickled or descaled sheet is customarily furnished oiled. If the product is not to be oiled, it must be so specified since the cleaned surface is prone to rusting.

9.6.3 Cold-rolled products covered by this specification can be furnished oiled or not oiled as specified.

9.7 Sheet steel in coils or cut lengths may contain surface imperfections that can be removed with a reasonable amount of metal finishing by the purchaser.

10. Workmanship

10.1 Cut lengths shall have a workmanlike appearance and shall not have imperfections of a nature or degree for the product, the grade, class, and the quality ordered that will be detrimental to the fabrication of the finished part.

10.2 Coils may contain some abnormal imperfections that render a portion of the coil unusable since the inspection of coils does not afford the producer the same opportunity to remove portions containing imperfections as in the case with cut lengths.

10.3 *Surface Conditions:*

10.3.1 Exposed cold-rolled sheet is intended for applications where surface appearance is of primary importance, that is, exposed applications. Unexposed or annealed cold-rolled sheet is intended for applications where surface appearance is not of primary importance, that is, unexposed applications.

10.3.2 Cut lengths for exposed applications shall not include individual sheets having major surface imperfections (holes, loose slivers, and pipe) and repetitive minor surface imperfections. Cut lengths may contain random minor surface imperfections that can be removed with a reasonable amount of metal finishing by the purchaser. These imperfections shall be acceptable to the purchaser within the manufacturer's published standards.

10.3.3 For coils for exposed applications, it is not possible to remove the surface imperfections listed in 10.3.2. Coils will contain such imperfections which shall be acceptable to the purchaser within the manufacturer's published standards. Coils contain more surface imperfections than cut lengths because the producer does not have the same opportunity to sort portions containing such imperfections as is possible with cut lengths.

10.3.4 Cut lengths for unexposed applications shall not include individual sheets having major surface imperfections such as holes, loose slivers, and pipe. In addition, unexposed cut lengths can be expected to contain more minor imperfections such as pits, scratches, sticker breaks, edge breaks, pinchers, cross breaks, roll marks, and other surface imperfections than exposed. These imperfections shall be acceptable to the purchaser without limitation.

10.3.5 For coils for unexposed applications, it is not possible to remove the surface imperfections listed in 10.3.4. Coils will contain surface imperfections that are normally not repairable. Minor imperfections shall be acceptable to the purchaser within the manufacturer's published standards. Unexposed coils contain more surface imperfections than exposed coils.

11. Retests and Disposition of Non-Conforming Material

11.1 *Retests:*

11.1.1 Unless otherwise prohibited by the product specification, retests are permitted under the following circumstances:

11.1.1.1 If any tension test specimen shows defective machining or develops flaws, it must be discarded and another specimen substituted.

11.1.1.2 If the percent elongation of any tension test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [20 mm] from the center of the gauge length of a 2 in. [50 mm] specimen or is outside the middle half of the gauge length of an 8 in. [200 mm] specimen, as indicated by scribe scratches marked on the specimen before testing, a retest is allowed.

11.1.1.3 If the test result of any tension test specimen fails to meet the specification requirements and the failure is the result of improper adherence to tension test procedures, a retest is permitted.

11.1.1.4 If the test result of an original tension test specimen fails to meet the specification requirements and the failure is not related to the conditions described in 11.1.1.1, 11.1.1.2, and 11.1.1.3, but the results are within 2 ksi [14 MPa] of the required yield strength, within 2 ksi [14 MPa] of the required tensile strength, or within 2 percentage points of the required elongation, one retest shall be permitted to replace the failing test.

11.1.2 The retest specimen shall be taken either adjacent to the first failed specimen, or selected at random from the material to be certified to the specification.

11.1.3 If the results of a retest satisfy the specified tension test requirements and all other requirements of the applicable specification are satisfied, the material shall be accepted.

11.2 *Disposition of Non-Conforming Material:*

11.2.1 In those cases where the lot is found to be non-conforming, and resampling of non-conforming material is not prohibited by the specification, resampling is permitted under the following circumstances and using the following practices:

11.2.1.1 If the results of an original tension test or retest specimen fail to satisfy the specification requirements and the failed test results are not related to the conditions described in 11.1, the lot shall be quarantined and resampled for certification of the non-conforming material to the specification requirements.

11.2.1.2 Resampling for certification of the non-conforming material shall include the discarding of out-of-specification material and the resampling of the lot. The resampling shall be appropriate to the specific out-of-specification condition and the processing history of the lot.

11.2.1.3 A maximum of two resampling efforts shall be permitted. If after conducting two resampling efforts, the material does not satisfy the specification requirements, the lot shall be rejected.

12. Inspection

12.1 When purchaser's order stipulates that inspection and tests (except product analyses) for acceptance on the steel be made prior to shipment from the mill, the manufacturer shall afford the purchaser's inspector all reasonable facilities to satisfy him that the steel is being produced and furnished in accordance with the specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operation.

13. Rejection and Rehearing

13.1 Unless otherwise specified, any rejection shall be reported to the manufacturer within a reasonable time after receipt of material by the purchaser.

13.2 Material that is reported to be defective subsequent to the acceptance at the purchaser's works shall be set aside, adequately protected, and correctly identified. The manufacturer shall be notified as soon as possible so that an investigation may be initiated.

13.3 Samples that are representative of the rejected material shall be made available to the manufacturer. In the event that the manufacturer is dissatisfied with the rejection, he may request a rehearing.

14. Test Reports and Certification

14.1 When test reports are required by the purchase order or the material specification, the supplier shall report the results of all test required by the material specification and the order.

14.2 When certification is required by the purchase order, the supplier shall furnish a certification that the material has been manufactured and tested in accordance with the requirements of the material specification.

14.3 A signature is not required on test reports or certifications. However, the document shall clearly identify the organization submitting the document. Notwithstanding the absence of a signature, the organization submitting the document is responsible for the content of the document.

14.4 When test reports are required, copies of the original material manufacturer's test report shall be included with any subsequent test report.

14.5 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

NOTE 4 — The industry definition as invoked here is: EDI is the computer to computer exchange of business information in an agreed upon standard format such as ANSI ASC X12.

15. Product Marking

15.1 As a minimum requirement, the material shall be identified by having the manufacturer's name, ASTM designation, weight, purchaser's order number, and material identification legibly stenciled on top of each lift or shown on a tag attached to each coil or shipping unit.

15.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

15.3 Bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the primary metals subcommittee of the AIAG bar code project team.

16. Packing and Package Marking

16.1 Unless otherwise specified, the sheet shall be packaged and loaded in accordance with Practices A 700.

16.2 When coils are ordered, it is customary to specify a minimum or range of inside diameter, maximum outside diameter, and a maximum coil weight, if required. The ability of manufacturers to meet the maximum coil weights depends upon individual mill equipment. When required, minimum coil weights are subject to negotiation.

17. Keywords

17.1 carbon steel sheet; cold rolled steel sheet; general delivery requirements; high strength low alloy steel; hot rolled steel sheet; steel sheet; structural steel sheet

TABLE 1
COLD-ROLLED SHEET STEEL CLASS COMPARISON

	Exposed	Unexposed
Major imperfections:		
Cut lengths	Mill rejects	Mill rejects
Coils	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts within the manufacturer's published standards (policy)
Minor imperfections:		
Cut lengths	Mill rejections repetitive imperfections. May contain random imperfections which the purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts all minor imperfections
Coils	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts all minor imperfections
Finish	Matte unless otherwise specified	Purchaser accepts all finishes
Special oils	May be specified	May not be specified
Thickness, width and length tolerance:		
Standard	Will be met	Will be met
Restricted	May be specified	May not be specified
Flatness tolerance:		
Standard	Will be met	Will be met (temper rolled) Not guaranteed — normally within twice standard (annealed last)
Restricted Squareness	May be specified	May not be specified
Coil wraps	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts all
Coil welds	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts within the manufacturer's published standards (policy)
Outside inspection	May be specified	May not be specified
Special testing	May be specified	May not be specified

TABLE 2
TOLERANCES FOR PRODUCT ANALYSIS

Element	Limit, or Maximum of Specified Element, %	Tolerance: Under Minimum Limit	Tolerance: Over Maximum Limit
Carbon	to 0.15, incl	0.02	0.03
	over 0.15 to 0.40, incl	0.03	0.04
	over 0.40 to 0.80, incl	0.03	0.05
	over 0.80	0.03	0.06
Manganese	to 0.60, incl	0.03	0.03
	over 0.60 to 1.15, incl	0.04	0.04
	over 1.15 to 1.65, incl	0.05	0.05
Phosphorus	...	...[A]	0.01
Sulfur	...	...[A]	0.01
Silicon	to 0.30, incl	0.02	0.03
	over 0.30 to 0.60, incl	0.05	0.05
Copper	...	0.02	...[A]
Nickel	to 1.00, incl	...[A]	0.03
Chromium	to 0.90, incl	...[A]	0.04
Molybdenum	to 0.20, incl	...[A]	0.01
Vanadium	to 0.10, incl	0.01[B]	0.01[B]
Columbium (Niobium)	to 0.10, incl	0.01[B]	0.01[B]
Titanium	to 0.15, incl	0.01[A]	0.01[B]
Aluminum	to 0.10, incl	0.03[C]	...[A]
Nitrogen	to 0.030, incl	0.005	0.005

[A] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.
[B] If the minimum of the range is 0.01%, the under tolerance is 0.005%.
[C] If the minimum of the range is 0.01%, the under tolerance is 0.005%, and if the minimum of the range is 0.02%, the under tolerance is 0.01%.

TABLE 3
LIST OF TABLES FOR DIMENSIONS, TOLERANCES, AND ALLOWANCES

Carbon[A] and High-Strength Low-Alloy Steel				
	Table No.			
	Hot-Rolled Sheet		Cold-Rolled Sheet	
Dimensions	Inch-Pound Units	SI Units	Inch-Pound Units	SI Units
Camber tolerances	12	A1.9	12, 22	A1.9, A1.19
Diameter tolerances of sheared circles	11	A1.8	11	A1.8
Flatness tolerances	15, 16	A1.12, A1.13	23	A1.20
Length tolerances	10	A1.7	19, 20	A1.16, A1.17
Out-of-square tolerances	13	A1.10	13	A1.10
Restricted squareness tolerances	14	A1.11	14	A1.11
Thickness tolerances	4, 5, 6, 7	A1.1, A1.2, A1.3, A1.4	17, 18	A1.14, A1.15
Width tolerances of cut edge	9	A1.6	9, 21	A1.6, A1.18
Width tolerances of mill edge	8	A1.5	...	

[A] Tolerances for hot-rolled carbon sheet steel with 0.25% maximum carbon, cast or heat analysis.

TABLE 4
STANDARD THICKNESS TOLERANCES FOR HOT-ROLLED SHEET (CARBON AND STRUCTURAL STEEL ONLY) — $\frac{3}{8}$ in. (CUT EDGE) AND $\frac{3}{4}$ in. (MILL EDGE) MINIMUM EDGE DISTANCE (Coils and Cut Lengths, Including Pickled)

Specified Width, in.	Specified Ordered Thickness, in.[A] Thickness Tolerances Over, in., No Tolerance Under[B] 0.027 to 0.051, incl	Over 0.051 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
Over 12 to 20, incl	0.010	0.010	0.012	0.012	0.014	0.014
Over 20 to 40, incl	0.010	0.010	0.012	0.014	0.014	0.016
Over 40 to 48, incl	0.010	0.012	0.012	0.014	0.016	0.018
Over 48 to 60, incl	. . .[C]	0.012	0.014	0.014	0.016	0.020
Over 60 to 72, incl	. . .[C]	0.014	0.014	0.016	0.016	0.022
Over 72	. . .[C]	. . .[C]	. . .[C]	0.016	0.016	0.024

NOTE 1 — Thickness is measured at any point across the width not less than $\frac{3}{8}$ in. from a cut edge and not less than $\frac{3}{4}$ in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.

[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 5
RESTRICTED THICKNESS TOLERANCES FOR HOT-ROLLED SHEET (CARBON AND STRUCTURAL STEEL ONLY) — $\frac{5}{8}$ in. (CUT EDGE) AND 1 in. (MILL EDGE) MINIMUM EDGE DISTANCE (Coils and Cut Lengths, Including Pickled)

Specified Width, in.	Specified Ordered Thickness, in.[A] Thickness Tolerances Over, in., No Tolerance Under[B] 0.027 to 0.051, incl	Over 0.051 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
Over 12 to 20, incl	0.008	0.008	0.009	0.009	0.010	0.010
Over 20 to 40, incl	0.008	0.008	0.009	0.010	0.010	0.012
Over 40 to 48, incl	0.008	0.009	0.009	0.010	0.012	0.014
Over 48 to 60, incl	. . .[C]	0.009	0.010	0.010	0.012	0.015
Over 60 to 72, incl	. . .[C]	0.010	0.010	0.012	0.012	0.016
Over 72	. . .[C]	. . .[C]	. . .[C]	0.012	0.012	0.018

NOTE 1 — Thickness is measured at any point across the width not less than $\frac{5}{8}$ in. from a cut edge and not less than 1 in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3 — This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 3 decimal places using standard ASTM practice.

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as nominal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.

[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 6
STANDARD THICKNESS TOLERANCES FOR HOT-ROLLED SHEET (HIGH-STRENGTH, LOW-ALLOY STEEL) — 3⁄8 in. (CUT EDGE) AND 3⁄4 in. (MILL EDGE) MINIMUM EDGE DISTANCE (Coils and Cut Lengths, Including Pickled)

	Specified Ordered Thickness, in.[A]						
	Thickness Tolerances, Over, in., No Tolerance Under[B]						
Specified Width, in.	0.031 to 0.051, incl	Over 0.051 to 0.059, incl	Over 0.059 to 0.070, incl	Over 0.070 to 0.082, incl	Over 0.082 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
Over 12 to 15, incl	0.010	0.012	0.012	0.012	0.012	0.014	0.014
Over 15 to 20, incl	0.010	0.012	0.014	0.014	0.014	0.016	0.016
Over 20 to 32, incl	0.012	0.012	0.014	0.014	0.014	0.016	0.018
Over 32 to 40, incl	0.012	0.012	0.014	0.014	0.016	0.016	0.018
Over 40 to 48, incl	0.012	0.014	0.014	0.014	0.016	0.020	0.020
Over 48 to 60, incl	. . .[C]	0.014	0.014	0.014	0.016	0.020	0.020
Over 60 to 72, incl	. . .[C]	. . .[C]	0.016	0.016	0.018	0.022	0.022
Over 72 to 80, incl	. . .[C]	. . .[C]	. . .[C]	0.016	0.018	0.024	0.024
Over 80	. . .[C]	. . .[C]	. . .[C]	. . .[C]	0.020	0.024	0.024[C]

NOTE 1 — Thickness is measured at any point across the width not less than 3⁄8 in. from a cut edge and not less than 3⁄4 in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nomimal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is didvided equally over and under.

[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 7
RESTRICTED THICKNESS TOLERANCES FOR HOT-ROLLED SHEET (HIGH-STRENGTH, LOW-ALLOY STEEL) — 5⁄8 in. (CUT EDGE) AND 1 in. (MILL EDGE) MINIMUM EDGE DISTANCE (Coils and Cut Lengths, Including Pickled)

	Specified Ordered Thickness, in.[A]						
	Thickness Tolerances All Over, in., No Tolerance Under[B]						
Specified Width, in.	0.031 to 0.051, incl	Over 0.051 to 0.059, incl	Over 0.059 to 0.070, incl	Over 0.070 to 0.082, incl	Over 0.082 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
Over 12 to 15, incl	0.008	0.009	0.009	0.009	0.009	0.010	0.010
Over 15 to 20, incl	0.008	0.009	0.010	0.010	0.010	0.012	0.012
Over 20 to 32, incl	0.009	0.009	0.010	0.010	0.010	0.012	0.014
Over 32 to 40, incl	0.009	0.009	0.010	0.010	0.012	0.012	0.014
Over 40 to 48, incl	0.009	0.010	0.010	0.010	0.012	0.015	0.015
Over 48 to 60, incl	. . .[C]	0.010	0.010	0.010	0.012	0.015	0.015
Over 60 to 72, incl	. . .[C]	. . .[C]	0.012	0.012	0.014	0.016	0.016
Over 72 to 80, incl	. . .[C]	. . .[C]	. . .[C]	0.012	0.014	0.018	0.018
Over 80	. . .[C]	. . .[C]	. . .[C]	. . .[C]	0.015	0.018	0.018[C]

NOTE 1 — Thickness is measured at any point across the width not less than 5⁄8 in. from a cut edge and not less than 1 in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3 — This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 3 places using standard ASTM practice.

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nomimal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness the tolerance is divided equally over and under.

[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 8
WIDTH TOLERANCES[A] OF HOT-ROLLED MILL EDGE SHEET (ALL DESIGNATIONS)
(Coils and Cut Lengths, Including Pickled)

Specified Width, in.	Tolerances Over Specified Width, in., No Tolerance Under
Carbon	
Over 12 to 14, incl	7/16
Over 14 to 17, incl	1/2
Over 17 to 19, incl	9/16
Over 19 to 21, incl	5/8
Over 21 to 24, incl	11/16
Over 24 to 26, incl	13/16
Over 26 to 30, incl	15/16
Over 30 to 50, incl	1 1/8
Over 50 to 78, incl	1 1/2
Over 78	1 7/8
High-Strength Low-Alloy	
Over 12 to 14, incl	7/16
Over 14 to 17, incl	1/2
Over 17 to 19, incl	9/16
Over 19 to 21, incl	5/8
Over 21 to 24, incl	11/16
Over 24 to 26, incl	13/16
Over 26 to 28, incl	15/16
Over 28 to 35, incl	1 1/8
Over 35 to 50, incl	1 1/4
Over 50 to 60, incl	1 1/2
Over 60 to 65, incl	1 5/8
Over 65 to 70, incl	1 3/4
Over 70 to 80, incl	1 7/8
Over 80	2

[A] The above tolerances do not apply to the uncropped ends of mill edge coils (10.1.1.1).

TABLE 9
WIDTH TOLERANCES OF HOT-ROLLED CUT EDGE SHEET AND COLD-ROLLED SHEET (OVER 12 in. WIDTH) (ALL DESIGNATIONS)
(Not Resquared, Coils and Cut Lengths, Including Pickled)

Specified Width, in.	Tolerances Over Specified Width, in., No Tolerance Under
Over 12 to 30, incl	1/8
Over 30 to 48, incl	3/16
Over 48 to 60, incl	1/4
Over 60 to 80, incl	5/16
Over 80	3/8

TABLE 10
LENGTH TOLERANCES OF HOT-ROLLED SHEET (ALL DESIGNATIONS)
(Cut Lengths not Resquared, Including Pickled)

Specified Length, in.	Tolerances Over Specified Length, in., No Tolerance Under
To 15, incl	1/8
Over 15 to 30, incl	1/4
Over 30 to 60, incl	1/2
Over 60 to 120, incl	3/4
Over 120 to 156, incl	1
Over 156 to 192, incl	1 1/4
Over 192 to 240, incl	1 1/2
Over 240	1 3/4

TABLE 11
DIAMETER TOLERANCES OF CIRCLES SHEARED FROM HOT-ROLLED (INCLUDING PICKLED) AND COLD-ROLLED SHEET (OVER 12 in. WIDTH) (ALL DESIGNATIONS)

	Tolerances Over Specified Diameter, in. (No Tolerances Under)		
Specified Thickness,[A] in.	Under 30	Over 30 to 48, incl	Over 48
0.044 to 0.057, incl	1/16	1/8	3/16
Over 0.057 to 0.098, incl	3/32	5/32	7/32
Over 0.098	1/8	3/16	1/4

[A] 0.071 in. minimum thickness for hot-rolled high-strength low-alloy steel sheet.

TABLE 12
CAMBER TOLERANCES[A] FOR HOT-ROLLED (INCLUDING PICKLED) AND COLD-ROLLED SHEET (OVER 12 in. WIDTH) (ALL DESIGNATIONS)
(Cut Lengths, not Resquared)

Cut Length, ft	Camber Tolerances, in.
To 4, incl	1/8
Over 4 to 6, incl	3/16
Over 6 to 8, incl	1/4
Over 8 to 10, incl	5/16
Over 10 to 12, incl	3/8
Over 12 to 14, incl	1/2
Over 14 to 16, incl	5/8
Over 16 to 18, incl	3/4
Over 18 to 20, incl	7/8
Over 20 to 30, incl	1 1/4
Over 30 to 40, incl	1 1/2

NOTE 1 — Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.

[A] The camber tolerance for coils is 1 in. in any 20 ft.

TABLE 13
OUT-OF-SQUARE TOLERANCES OF HOT-ROLLED CUT-EDGE (INCLUDING PICKLED) AND COLD-ROLLED SHEET (OVER 12 in. WIDTH)
(ALL DESIGNATIONS)
(Cut Lengths not Resquared)

Out-of-square is the greatest deviation of an end edge from a straight line at right angle to a side and touching one corner. It is also obtained by measuring the difference between the diagonals of the cut length. The out-of-square deviation is one half of that difference. The tolerance for all thicknesses and all sizes is 1/16 in./6 in. of width or fraction thereof.

TABLE 14
RESTRICTED SQUARENESS TOLERANCES OF HOT-ROLLED (INCLUDING PICKLED) AND COLD-ROLLED SHEET (OVER 12 in. WIDTH) (ALL DESIGNATIONS)
(Cut Lengths)

When cut lengths are specified resquared, the width and the length are not less than the dimensions specified. The individual tolerance for over-width, overlength, camber, or out-of-square should not exceed 1/16 in. up to and including 48 in. in width and up to and including 120 in. in length. For cut lengths wider or longer, the applicable tolerance is 1/8 in.

TABLE 15
FLATNESS TOLERANCES[A] OF TEMPER ROLLED OR PICKLED HOT-ROLLED SHEET CUT LENGTHS[B]
(ALL DESIGNATIONS)

Specified Minimum Thickness, in.	Specified Width, in.	Flatness Tolerances,[C] in. — Specified Yield Strength, min, ksi: Under 45	45 to 50[D, E]
0.027 to 0.057, incl	over 12 to 36, incl	1/2	3/4
	over 36 to 60, incl	3/4	1 1/8
	over 60	1	. . .
0.057 to 0.180, excl	over 12 to 60, incl	1/2	3/4
	over 60 to 72, incl	3/4	1 1/8
	over 72	1	1 1/2
0.180 to 0.230, excl	over 12 to 60, incl	1/2	3/4
	over 60 to 72, incl	3/4	1 1/8
	over 72	1	1 1/2

[A] The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
[B] Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
[C] Maximum deviation from a horizontal flat surface.
[D] Tolerances for steels with specified minimum yield strength in excess of 50 ksi are subject to negotiation.
[E] 0.071 minimum thickness of HSLA.

TABLE 16
FLATNESS TOLERANCES[A] OF NON-PROCESSED HOT ROLLED SHEET CUT LENGTHS[B]
(ALL DESIGNATIONS)

Specified Minimum Thickness, in.	Specified Width, in.	Flatness Tolerances,[C] in. — Specified Yield Strength, min, ksi: Under 45	45 to 50[D, E]
0.027 to 0.057, incl	over 12 to 36, incl	1 1/2	2 1/4
	over 36 to 60, incl	2 1/4	3 3/8
	over 60	3	. . .
over 0.057 to 0.180, excl	over 12 to 60, incl	1 1/2	2 1/4
	over 60 to 72, incl	2 1/4	3 3/8
	over 72	3	4 1/2
0.180 to 0.230, excl	over 12 to 60, incl	1 1/2	2 1/4
	over 60 to 72, incl	2 1/4	3 3/8
	over 72	3	4 1/2

[A] The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
[B] Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
[C] Maximum deviation from a horizontal flat surface.
[D] Tolerances for steels with specified minimum yield strength in excess of 50 ksi are subject to negotiation.
[E] 0.071 minimum thickness of HSLA.

TABLE 17
STANDARD THICKNESS TOLERANCES FOR COLD-ROLLED SHEET (ALL DESIGNATIONS)[A] — 3/8 in. MINIMUM EDGE DISTANCE (Coils and Cut Lengths)

	Specified Ordered Thickness, in.[B]						
	Thickness Tolerances, Over, in., No Tolerance Under[C]						
Specified Width, in.	To 0.014, excl	0.014 to 0.019, incl	Over 0.019[A] to 0.039, incl	Over 0.039 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.142, incl
To 15, incl	0.002	0.004	0.006	0.008	0.010	0.010	0.010
Over 15 to 72, incl	0.002	0.004	0.006	0.008	0.010	0.010	0.012
Over 72	. . .[D]	. . .[D]	0.006	0.008	0.010	0.012	0.014

NOTE 1 — Thickness is measured at any point across the width not less than 3/8 in. from a side edge.
NOTE 2 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.
NOTE 3 — The thickness of material <1 in. wide shall be measured at mid-width.

[A] Minimum thickness, 0.021 in. for high-strength, low-alloy.
[B] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.
[C] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.
[D] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 18
RESTRICTED THICKNESS TOLERANCES FOR COLD-ROLLED SHEET (ALL DESIGNATIONS)[A] — 1 in. MINIMUM EDGE DISTANCE (Coils and Cut Lengths)

	Specified Ordered Thickness, in.[B]						
	Thickness Tolerances, Over, in., No Tolerance Under[C]						
Specified Width, in.	To 0.014, excl	0.014 to 0.019, incl	Over 0.019[A] to 0.039, incl	Over 0.039 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.142, incl
To 15, incl	0.001	0.002	0.003	0.004	0.005	0.005	0.005
Over 15 to 72, incl	0.001	0.002	0.003	0.004	0.005	0.005	0.006
Over 72	. . .[D]	. . .[D]	0.003	0.004	0.005	0.006	0.007

NOTE 1 — Thickness is measured at any point across the width not less than 1 in. from a side edge.
NOTE 2 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.
NOTE 3 — This table was constructed by multiplying the values in the standard table by 0.50 and rounding to 3 places using standard ASTM practice.
NOTE 4 — The thickness of material < 2 in. wide shall be measured at mid-width.

[A] Minimum thickness, 0.021 in. for high-strength, low-alloy.
[B] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.
[C] The tolerance provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.
[D] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 19
LENGTH TOLERANCES OF COLD-ROLLED SHEET (ALL DESIGNATIONS)
(Cut Lengths Over 12 in. in Width, Not Resquared)

Specified Length, in.	Tolerances Over Specified Length, in., No Tolerances Under
Over 12 to 30, incl	1/8
Over 30 to 60, incl	1/4
Over 60 to 96, incl	1/2
Over 96 to 120, incl	3/4
Over 120 to 156, incl	1
Over 156 to 192, incl	1 1/4
Over 192 to 240, incl	1 1/2
Over 240	1 3/4

TABLE 20
LENGTH TOLERANCES OF COLD-ROLLED SHEET (ALL DESIGNATIONS)
(Cut Length Sheets, to 12 in. in Width, Not Resquared)

Specified Length, in.	Tolerances Over Specified Length, in., No Tolerance Under
24 to 60, incl	1/2
Over 60 to 120, incl	3/4
Over 120 to 240, incl	1

NOTE 1 — This table applies to widths produced by slitting from wider sheet.

TABLE 21
WIDTH TOLERANCES FOR COLD-ROLLED SHEET (ALL DESIGNATIONS)[A]
(Coils and Cut Lengths to 12 in. Width, Not Resquared)

Specified Width, in.	Width Tolerance Plus and Minus, in.
To 6, incl	0.012
Over 6 to 9, incl	0.016
Over 9 to 12, incl	0.032

[A] 0.020 in. minimum thickness for high-strength, low-alloy.

TABLE 22
CAMBER TOLERANCES OF COLD-ROLLED SHEET IN COILS (ALL DESIGNATIONS)[A] (Coils to 12 in. Width)

Width, in.	Camber Tolerance
To 12, incl	1/4 in. any 8 ft

NOTE 1 — Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.
NOTE 2 — This table applies to widths produced by slitting from wider sheet.

[A] 0.020 in. minimum thickness for high-strength, low-alloy.

TABLE 23
FLATNESS TOLERANCES OF COLD-ROLLED SHEET (ALL DESIGNATIONS)

		Flatness Tolerance,[A] in.	
		Specified Yield Point, min, ksi	
Specified Thickness, in.	Specified Width, in.	Under 45	45 to 50[B] incl
To 0.044, incl	to 36, incl	3/8	3/4
	over 36 to 60, incl	5/8	1 1/8
	over 60	7/8	1 1/2
Over 0.044	to 36, incl	1/4	3/4
	over 36 to 60, incl	3/8	3/4
	over 60 to 72, incl	5/8	1 1/8
	over 72	7/8	1 1/2

NOTE 1 — This table does not apply when product is ordered full hard, to a hardness range, or "annealed last" (dead soft).
NOTE 2 — This table also applies to lengths cut from coils by the consumer when adequate flattening measures are performed.

[A] Maximum deviation from a horizontal flat surface.
[B] Tolerances for high-strength, low-alloy steel with specified minimum yield point in excess of 50 ksi are subject to negotiation.

ANNEX

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS AND MASS IN SI UNITS

A1.1 Listed in Tables A1.1–A1.20 are permissible variations in dimensions and mass expressed in the International System of Units (SI) terminology.

TABLE A1.1
STANDARD THICKNESS TOLERANCES [METRIC] FOR HOT-ROLLED SHEET (CARBON AND STRUCTURAL STEEL ONLY) — 10 mm (CUT EDGE) AND 20 mm (MILL EDGE) MINIMUM EDGE DISTANCE
(Coils and Cut Lengths, Including Pickled)

	Specified Ordered Thickness, mm[A]			
	Thickness Tolerances, Over, mm, No Tolerance Under[B]			
Specified Width, mm	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
Over 300 to 600, incl	0.30	0.30	0.35	0.40
Over 600 to 1200, incl	0.30	0.35	0.40	0.45
Over 1200 to 1500, incl	0.35	0.35	0.40	0.50
Over 1500 to 1800, incl	0.35	0.40	0.40	0.56
Over 1800	0.35	0.40	0.40	0.60

NOTE 1 — Thickness is measured at any point across the width not less than 10 mm from a cut edge and not less than 20 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[B] The tolerance provided in the table are based on minimum thickness (tolerance over, not tolerance under). For nominal thickness, the tolerance is divided equally over and under.

TABLE A1.2
RESTRICTED THICKNESS TOLERANCES [METRIC] FOR HOT-ROLLED SHEET (CARBON AND STRUCTURAL STEEL ONLY) — 15 mm (CUT EDGE) AND 25 mm (MILL EDGE) MINIMUM EDGE DISTANCE (Coils and Cut Lengths, Including Pickled)

	Specified Ordered Thickness, mm[A]			
	Thickness Tolerances Over, mm, No Tolerance Under[B]			
Specified Width, mm	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
Over 300 to 600	0.22	0.22	0.26	0.30
Over 600 to 1200, incl	0.22	0.26	0.30	0.34
Over 1200 to 1500, incl	0.26	0.26	0.30	0.38
Over 1500 to 1800, incl	0.26	0.30	0.30	0.42
Over 1800	0.26	0.30	0.30	0.45

NOTE 1 — Thickness is measured at any point across the width not less than 15 mm from a cut edge and not less than 25 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3 — This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 2 decimal places using standard ASTM practice.

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, not tolerance under). For nominal thickness, the tolerance is divided equally over and under.

TABLE A1.3
STANDARD THICKNESS TOLERANCES [METRIC] FOR HOT-ROLLED SHEET (HIGH-STRENGTH, LOW-ALLOY STEEL) — 10 mm (CUT EDGE) AND 20 mm (MILL EDGE) MINIMUM EDGE DISTANCE
(Coils and Cut Lengths, Including Pickled)

	Specified Ordered Thickness, mm[A]			
	Thickness Tolerances Over, mm, No Tolerance Under[B]			
Specified Width, mm	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
Over 300 to 600, incl	0.30	0.35	0.40	0.40
Over 600 to 1200, incl	0.35	0.40	0.45	0.50
Over 1200 to 1500, incl	0.35	0.40	0.50	0.50
Over 1500 to 1800, incl	0.40	0.45	0.55	0.56
Over 1800 to 2000, incl	0.40	0.45	0.60	0.60
Over 2000	. . .[C]	0.50	0.60	0.60[C]

NOTE 1 — Thickness is measured at any point across the width not less than 10 mm from a cut edge and not less than 20 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[B] The tolerance provided in the table are based on minimum thickness (tolerance over, not tolerance under). For nominal thickness, the tolerance is divided equally over and under.

[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.4
RESTRICTED THICKNESS TOLERANCES OF HOT-ROLLED SHEET (HIGH-STRENGTH, LOW-ALLOY STEEL) — 15 mm (CUT EDGE) AND 25 mm (MILL EDGE) MINIMUM EDGE DISTANCE (Coils and Cut Lengths, Including Pickled)

	Specified Ordered Thickness, mm[A]			
	Thickness Tolerances Over, mm, No Tolerance Under[B]			
Specified Width, mm	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
Over 300 to 600, incl	0.22	0.26	0.30	0.30
Over 600 to 1200, incl	0.26	0.30	0.34	0.38
Over 1200 to 1500, incl	0.26	0.30	0.38	0.38
Over 1500 to 1800, incl	0.30	0.34	0.41	0.42
Over 1800 to 2000, incl	0.30	0.34	0.45	0.45
Over 2000	. . .[C]	0.38	0.45	0.45[C]

NOTE 1 — Thickness is measured at any point across the width not less than 15 mm from a cut edge and not less than 25 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.
NOTE 2 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.
NOTE 3 — This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 2 decimal places using standard ASTM practice.

[A] The specified thickness captions apply independent of whether the ordered thickness is stated as a nominal or minimum.
[B] The tolerances provided in the table are based on minimum thickness (tolerance over, not tolerance under). For nominal thickness, the tolerance is divided equally over and under.
[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.5
WIDTH TOLERANCES[A] OF HOT-ROLLED MILL EDGE SHEET (ALL DESIGNATIONS) (Coils and Cut Lengths, Including Pickled)

Specified Width, mm		Width Tolerance, Over Only, mm	
Over	Through	Carbon	HSLA
300	600	16	16
600	1200	26	28
1200	1500	32	38
1500	1800	35	45
1800	. . .	48	50

[A] The above tolerances do not apply to the uncropped ends of mill edge coils (9.1.1.1).

TABLE A1.6
WIDTH TOLERANCES OF HOT-ROLLED CUT EDGE SHEET AND COLD-ROLLED SHEET (ALL DESIGNATIONS)
(Not Resquared Coils and Cut Lengths, Including Pickled)

Specified Width, mm		Width Tolerance, Over Only, mm
Over	Through	
300	600	3
600	1200	5
1200	1500	6
1500	1800	8
1800	. . .	10

TABLE A1.7
LENGTH TOLERANCES OF HOT-ROLLED SHEET (ALL DESIGNATIONS)
(Cut Lengths not Resquared, Including Pickled)

Specified Length, mm		Length Tolerance, Over Only, mm
Over	Through	
300	600	6
600	900	8
900	1500	12
1500	3000	20
3000	4000	25
4000	5000	35
5000	6000	40
6000	. . .	45

TABLE A1.8
DIAMETER TOLERANCES OF CIRCLES FROM HOT-ROLLED (INCLUDING PICKLED) AND COLD-ROLLED SHEET (OVER 300 mm WIDTH) (ALL DESIGNATIONS)

Specified Thickness[A], mm		Tolerances Over Specified Diameter, mm, (No Tolerances Under)		
		Diameters, mm		
Over	Through	Through 600	Over 600 to 1200, incl	Over 1200
. . .	1.5	1.5	3.0	5.0
1.5	2.5	2.5	4.0	5.5
2.5	. . .	3.0	5.0	6.5

[A] 1.8 mm minimum thickness for hot-rolled high-strength low-alloy steel sheet.

TABLE A1.9
CAMBER TOLERANCES[A] FOR HOT-ROLLED (INCLUDING PICKLED) AND COLD-ROLLED SHEET (OVER 300 mm WIDTH) (ALL DESIGNATIONS)
(Cut Lengths, not Resquared)

Cut Length, mm		Camber Tolerances[A], mm
Over	Through	
. . .	1200	4
1200	1800	5
1800	2400	6
2400	3000	8
3000	3700	10
3700	4300	13
4300	4900	16
4900	5500	19
5500	6000	22
6000	9000	32
9000	12 200	38

NOTE 1 — Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.

[A] The camber tolerance for coils is 25.0 mm in any 6000 mm.

TABLE A1.10
OUT-OF-SQUARE TOLERANCES OF HOT-ROLLED CUT-EDGE (INCLUDING PICKLED) AND COLD-ROLLED SHEET (OVER 300 mm WIDTH) (ALL DESIGNATIONS)
(Cut Lengths not Resquared)

Out-of-square is the greatest deviation of an end edge from a straight line at right angle to a side and touching one corner. It is also obtained by measuring the difference between the diagonals of the cut length. The out-of-square deviation is one half of that difference. The tolerance for all thicknesses and all sizes is 1.0 mm/100 mm of width or fraction thereof.

TABLE A1.11
RESTRICTED SQUARENESS TOLERANCES OF HOT-ROLLED (INCLUDING PICKLED) AND COLD-ROLLED SHEET (OVER 300 mm WIDTH) (ALL DESIGNATIONS)
(Cut Lengths)

When cut lengths are specified resquared, the width and the length are not less than the dimensions specified. The individual tolerance for overwidth, overlength, camber, or out-of-square should not exceed 1.6 mm up to and including 1200 mm in width and up to and including 3000 mm in length. For cut lengths wider or longer, the applicable tolerance is 3.2 mm.

TABLE A1.12
FLATNESS TOLERANCES[A] OF TEMPER ROLLED OR PICKLED HOT-ROLLED SHEET CUT LENGTHS[B] (ALL DESIGNATIONS)

Specified Thickness, mm			Flatness Tolerance[C], mm Specified Yield Strength, min, MPa[D]	
Over	Through	Specified Width, mm	Under 310	310 to 340 MPa Yield Point, min, MPa
1.2	1.5	to 900, incl	15	20
		over 900 to 1500, incl	20	30
		over 1500	25	. . .
1.5	4.5	to 1500, incl	15	20
		over 1500 to 1800, incl	20	30
		over 1800	25	40
4.5	6.0 excl	to 1500, incl	15	20
		over 1500 to 1800, incl	20	30
		over 1800	25	40

[A] The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
[B] Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
[C] Maximum deviation from a horizontal surface.
[D] Tolerances for high-strength, low-alloy steels with specified minimum yield strength in excess of 340 MPa are subject to negotiation.

TABLE A1.13
FLATNESS TOLERANCES[A] OF NON-PROCESSED HOT-ROLLED SHEET CUT LENGTHS[B] (ALL DESIGNATIONS)

Specified Thickness, mm			Flatness Tolerance[C], mm Specified Yield Strength, min, MPa[D]	
Over	Through	Specified Width, mm	Under 310	310 to 340 MPa Yield Point, min, MPa
1.2	1.5	to 900, incl	45	60
		over 900 to 1500, incl	60	90
		over 1500	75	. . .
1.5	4.5	to 1500, incl	45	60
		over 1500 to 1800, incl	60	90
		over 1800	75	120
4.5	6.0 excl	to 1500, incl	45	60
		over 1500 to 1800, incl	60	90
		over 1800	75	120

[A] The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
[B] Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
[C] Maximum deviation from a horizontal surface.
[D] Tolerances for high-strength, low-alloy steels with specified minimum yield strength in excess of 340 MPa are subject to negotiation.

TABLE A1.14
STANDARD THICKNESS TOLERANCES [METRIC] FOR COLD-ROLLED SHEET (ALL DESIGNATIONS)[A] — 10 mm MINIMUM EDGE DISTANCE

Specified Width, mm		Specified Ordered Thickness, mm[B]				
		Thickness Tolerances Over, mm, No Tolerance Under[C]				
Over	Through	Through 0.4	Over 0.4 to 1.0, incl	Over 1.0 to 1.2, incl	Over 1.2 to 2.5, incl	Over 2.5 to 4.0, incl
...	1800	0.10	0.15	0.20	0.25	0.30
1800	2000	...[D]	0.15	0.20	0.30	0.35
2000	...[D]	...[D]	0.30	0.30	0.35	0.40

NOTE 1 — Thickness is measured at any point across the width not less than 10 mm from a side edge.

NOTE 2 — Widths up to and including 300 mm in this table apply to widths produced by slitting from wider sheet.

NOTE 3 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 4 — The thickness of material <25 mm wide shall be measured at mid-width.

[A] 0.55 mm minimum thickness for high-strength, low-alloy.

[B] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[C] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.

[D] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.15
RESTRICTED THICKNESS TOLERANCES OF COLD-ROLLED SHEET (ALL DESIGNATIONS)[A] — 25 mm MINIMUM EDGE DISTANCE

Specified Width, mm		Specified Ordered Thickness, mm[B]				
		Thickness Tolerances Over, mm, No Tolerance Under[C]				
Over	Through	Through 0.4	Over 0.4 to 1.0, incl	Over 1.0 to 1.2, incl	Over 1.2 to 2.5, incl	Over 2.5 to 4.0, incl
...	1800	0.05	0.08	0.10	0.12	0.15
1800	2000	...[D]	0.08	0.10	0.15	0.18
2000	...[D]	...[D]	0.15	0.15	0.15	0.20

NOTE 1 — Thickness is measured at any point across the width not less than 25 mm from a side edge.

NOTE 2 — Widths up to and including 300 mm in this table apply to widths produced by slitting from wider sheet.

NOTE 3 — Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 4 — This table was constructed by multiplying the values in the standard table by 0.50 and rounding to 2 decimal places using standard ASTM practice.

NOTE 5 — The thickness of material <50 mm wide shall be measured at mid-width.

[A] 0.55 mm minimum thickness for high-strength, low-alloy.

[B] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[C] Th tolerance provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.

[D] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.16
LENGTH TOLERANCES OF COLD-ROLLED SHEET (ALL DESIGNATIONS)
(Cut Lengths Over 300 mm in Width, not Resquared)

Specified Length, mm		Tolerance Over Specified Length (No Tolerance Under), mm
Over	Through	
300	1500	6
1500	3000	20
3000	6000	35
6000	. . .	45

TABLE A1.17
LENGTH TOLERANCES OF COLD-ROLLED SHEET (ALL DESIGNATIONS) (Cut Length Sheets, to 300 mm in Width, not Resquared)

Specified Length, mm		Tolerances Over Specified Length (No Tolerance Under), mm
Over	Through	
600	1500	15
1500	3000	20
3000	6000	25

NOTE 1 — This table applies to widths produced by slitting from wider sheet.

TABLE A1.18
WIDTH TOLERANCES FOR COLD-ROLLED SHEET (ALL DESIGNATIONS)^A
(Coils and Cut Lengths to 300 mm in Width, not Resquared)

Specified Width, mm		Width Tolerance, Over and Under, mm
Over	Through	
50	100	0.3
100	200	0.4
200	300	0.8

NOTE 1 — This table applies to widths produced by slitting from wider sheet.

^{A} 0.50 mm thickness for high-strength, low-alloy.

TABLE A1.19
CAMBER TOLERANCES OF COLD-ROLLED SHEET IN COILS (ALL DESIGNATIONS)
(Coils to 300 mm in Width, Not Resquared)

Width, mm	Camber Tolerances
Through 300, incl	5.0 mm in any 2000 mm

NOTE 1 — Camber is the greatest deviation of a side edge from a straight line, the measurements being taken on the concave side with a straightedge.

NOTE 2 — This table applies to widths produced by slitting from wider sheet.

TABLE A1.20
FLATNESS TOLERANCES OF COLD-ROLLED SHEET (ALL DESIGNATIONS)^A

	Specified Width, mm		Flatness Tolerance, mm Specified Yield Point, min, MPa	
Specified Thickness, mm	Over	Through	Under 310 MPa	310 to 340 MPa^B
Through 1.0	. . .	900	10	20
	900	1500	15	30
	1500	. . .	20	40
Over 1.0	. . .	900	8	20
	900	1500	10	20
	1500	1800	15	30
	1800	. . .	20	40

NOTE 1 — This table does not apply when product is ordered full hard, to a hardness range or "annealed last" (dead soft).

NOTE 2 — This table also applies to lengths cut from coils by the consumer when adequate flattening measures are performed.

NOTE 3 — Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.

^{A} Maximum deviation from a horizontal flat surface.

^{B} Tolerances for high-strength, low-alloy steel with specified minimum yield point in excess of 340 MPa are subject to negotiation.

APPENDICES

(Nonmandatory Information)

X1. AGING EFFECTS ON FORMABILITY OF COLD-ROLLED CARBON-STEEL SHEET PRODUCTS

X1.1 Cold-rolled carbon-steel sheet products exhibit maximum formability in the annealed last, or dead-soft, condition. However, many sheet products are not suitable for exposed applications in the dead-soft condition because Luder's lines (sometimes referred to as "stretcher strains" or "fluting") may develop during subsequent forming. This problem is avoided in most cases by temper rolling the sheet after annealing. After temper rolling, however, some sheet products are susceptible to aging. Aging refers to a gradual increase in yield strength and corresponding decrease in ductility during storage after temper rolling. Aging always has a negative effect on formability and, when aging leads to the redevelopment of an upper yield point, can result in renewed susceptibility to fluting.

X1.2 Aging can occur when interstitial solute atoms, carbon or nitrogen, are present in the steel. Solute carbon or nitrogen atoms are those not chemically combined with other elements in the steel (as carbides or nitrides, for example). Over time, these carbon or nitrogen interstitial solute atoms diffuse to crystalline imperfections within the steel and, in so doing, give rise to aging. The extent to which aging occurs depends on the interstitial solute level and the combination of temperature and time to which the steel is exposed after temper rolling. In general, higher interstitial solute levels result in larger strength increases during storage; the rate of aging increases with increasing temperature. As described as follows, the final interstitial solute level and aging characteristics depend on the chemical composition of the steel as well as specific sheet-processing methods used by the steel producer.

X1.3 *Low-Carbon Steels* — In conventional aluminum-killed low-carbon steels, the level of interstitial solute is affected mainly through the formation of aluminum nitride and iron carbides within the steel during processing, which is influenced by the manner in which annealing is performed.

X1.3.1 Many sheet products are annealed in batches of large, tightly wound coils. During heating, any solute nitrogen present in the full-hard sheet combines with aluminum to form aluminum nitride. Subsequent cooling is very slow and allows essentially all of the carbon to precipitate as iron carbide. Final interstitial solute levels are very low and, as a result, batch-annealed low-carbon steels have excellent resistance to aging.

X1.3.1.1 Deep drawing steel (DDS) sheet typically is batch-annealed and has excellent aging resistance. With temper rolling, DDS sheet is suitable for use in many exposed applications with severe forming requirements.

X1.3.2 Cold-rolled low-carbon steels are sometimes processed in a continuous annealing line, in which the full-hard sheet is uncoiled, passed through an annealing furnace, and then rewound in a continuous manner. Heating and cooling rates are much higher than those found in batch annealing. The faster cooling, in particular, results in higher levels of interstitial solute in the product as compared with batch annealing. The manner in which the sheet is cooled can be controlled to minimize the solute carbon level, and temper rolling is effective for reducing fluting tendencies. However, continuous-annealed low-carbon steels are more prone to subsequent aging than batch-annealed steels.

X1.3.2.1 Low-carbon commercial steel (CS) and drawing steel (DS) sheet are available as either batch- or continuous-annealed products, depending on the facilities of a given producer. To minimize aging effects in continuous-annealed products, rotation of stock by fabricating the oldest material first is recommended.

X1.4 *Interstitial-Free Steels* — Interstitial-free steels have essentially no interstitial solutes and, as a result, are nonaging. Processing involves vacuum degassing during refining of the liquid steel, as well as additions of elements that form very stable carbides and nitrides, such as titanium or columbium (niobium). These steps ensure that total interstitial levels are very low, and that the interstitials are all chemically combined (or stabilized) in the form of alloy carbides or nitrides. Interstitial-free steels are nonaging regardless of whether annealing is conducted in a continuous or batch manner.

X1.4.1 Extra-deep drawing steel (EDDS) must be vacuum degassed and stabilized. This nonaging, interstitial-free product is suitable for exposed applications with the most severe forming requirements.

X1.5 *Bake-Hardenable Steels* — Bake-hardenable steels are a special product class with controlled interstitial solute levels and aging behavior. These steels are processed to have moderate aging resistance, to permit forming while the steel is in its most ductile condition. Aging occurs largely during a subsequent thermal treatment (for example, paint-curing), which results in desirable hardening of the final part for better durability.

X1.5.1 Continuous-annealed low-carbon steels can exhibit significant bake-hardening, as well as certain vacuum-degassed and batch-annealed steels.

X2. STANDARD CHEMICAL RANGES AND LIMITS

X2.1 Standard chemical ranges and limits are prescribed for carbon steels in Table X2.1 and Table X2.2.

X3. PROCEDURE FOR DETERMINING BREAKAGE ALLOWANCE LEVELS (APPLICABLE TO CARBON STEEL SHEET ONLY)

X3.1 In spite of the many extra precautions exercised in making sheet for drawing purposes, certain manufacturing variables may be encountered, all beyond the manufacturer's reasonable control, which may contribute to breakage in fabrication and must be considered as part of the normal hazard of the purchaser's use. The manufacturer will undertake to establish with the purchaser's concurrence a breakage allowance level.

X3.2 Breakage, for the purpose of this proposal, is defined as unrepairable parts, broken during drawing and classed as scrap. Parts showing laminations, resulting from pipe, may be excluded provided they are separately identified. Broken parts that can be salvaged are not covered in this procedure.

X3.3 This procedure is intended to establish a breakage allowance without the need for reinspection of each broken stamping. It will apply to overall breakage on a given part (as calculated by the method outlined below) in excess of 1% up to and including 8%. Inherent variations in steel and normal variables in the stamping operation preclude 100% satisfactory performance. Therefore, it is accepted that practical perfection is attained when 99% of the stampings are produced without breakage. When the overall breakage is in excess of 8%, it is considered to be the result of abnormal stamping conditions, and this method does not apply.

X3.4 When there are two or more suppliers, the recommended procedure for determining a breakage allowance for an identified part is based on the average percentage of breakage of at least 75% of the blanks run on that part, on one set of dies, during at least one month (3000 piece minimum). The total production of all suppliers used to obtain this 75% minimum is to be included in the calculation starting with the best performance. The average breakage thus determined shall be considered the allowance for the part.

X3.4.1 Example:

Vendor	Parts Produced	Parts Scrap	% Scrap
A	32 466	630	1.94
B	27 856	579	2.08
C	67 120	1477	2.20
D	56 200	1349	2.40
E	40 900	1125	2.75
F	850	60	7.05
11	225 392 total	5220 total	2.32 avg

X3.4.2 Seventy-five percent of 225 392 equals to 169 044; therefore, it is necessary to include the total production of vendors A, B, C, and D (A + B + C + D = total production of 183 642 parts) since the total of A, B, and C is only 127 442, which is less than 75% of the total. Total production of 183 642 parts (A + B + C + D) with 4035 parts being rejected, results in a percentage allowance of 2.20%. On this basis, vendors D, E, and F exceed the allowance.

X4. PROCEDURES FOR DETERMINING THE EXTENT OF PLASTIC DEFORMATION ENCOUNTERED IN FORMING OR DRAWING

X4.1 Introduction

X4.1.1 The preferred method for determining plastic strain is the circle grid and forming limit curve. The scribed square and change in thickness methods may also be used to evaluate deformation during the forming of a flat sheet into the desired shape.

X4.2 Circle Grid Method

X4.2.1 The test system employs photographic or electro-chemically etched circle patterns on the surface of a sheet metal blank of known "quality" and a forming limit curve for the evaluation of strains developed by forming in press operations. It is useful in the laboratory and in the press room. Selection from the various steels that are commercially available can be done effectively by employing this technique. In addition, corrective action in die or part design to improve performance is indicated.

X4.2.2 The forming limit curve in Fig. X4.1 has been developed from actual measurements of the major (e_1) and associated minor (e_2) strains found in critical areas of production type stampings. Strain combinations that locate below this curve are safe, while those that fail above the curve are critical. For analysis of metal strain on production stampings, one must recognize that day-to-day variations of material, lubrication, and die settings will affect the strain level. To ensure trouble-free press performance a zone below the forming limit curve bounded by the dashed and solid lines is designated as the "safety band." Therefore, strain combinations falling below the dashed lines should not exceed the forming limit curve in normal production operations. The left of zero portion of the curve defines the limiting biaxial tension-compression strain combination while the right side defines the forming limit curve. Because the production stampings used to develop for forming limit curve represented all qualities of low-carbon light-gauge sheet steel, this single forming limit curve can be used successfully for these products.

X4.2.3 The circle grid method can also be used for other low-carbon sheet categories if the following adjustments to the forming limit curve are made:

X4.2.3.1 *Material Thickness* — As the metal thickness increases the forming limit curve shifts upwards in a parallel manner, 0.2% (e_1) strain for each 0.025 mm increase in metal thickness above 0.75 mm.

X4.2.3.2 *Material Properties* — When material properties are considerably different from that of conventional low-carbon sheet steel (for example, higher strength-low ductility), the forming limit curve is lower. The magnitude of the downgrade displacement is specific to each material; therefore, current material information should be consulted to determine placement of the forming limit curve.

X4.3 Procedure

X4.3.1 Obtain a sheet sample of "known quality," the sheet quality being established by either supplier designation, consumer purchase order, or most preferred tensile data obtained from a companion sheet sample.

X4.3.2 Obtain or prepare a negative on stencil with selected circles in a uniform pattern. The circles may be 2.5 to 25.0 mm in diameter; the most convenient diameter is 5.0 mm because it is easy to read and the gauge spacing is short enough to show the maximum strain in a specific location on the part.

X4.3.3 The sheet metal blanks should be cleaned to remove excess oil and dirt; however, some precoated sheets can be etched without removing the coating. The area(s) to be etched should be determined from observation of panels previously formed; generally, the area that has a split problem is selected for etching. Normally, the convex side of the radius is gridded. If sufficient time is available, the entire blank may be etched, since valuable information can be obtained about the movement of metal in stamping a part when strains can be evaluated in what may appear to be noncritical areas. Additionally, for complex shapes it may be desirable to etch both surfaces of blanks so that the strains that occur in reverse draws can be determined.

X4.3.4 The sheet metal blanks may be etched by a photographic or electrochemical method. In the former method of photosensitive solution, for example, 50% Kodak Photo Resist (KPR) emulsion and 50% KPR-thinner, is sprayed onto the sheet. The emulsion is dried by baking the sheet at 65°C for 15 min or by just standing it for several hours at room temperature in a dark room. The latter should be employed in materials that age and, hence, become stronger when baked at 65°C. The negative is placed on the emulsion, held intimately in contact with the sheet, and exposed to a strong ultraviolet light source for 1 to 1½ min. The sheet is developed for 30 to 45 s in KPR developer, rinsed with water, and sprayed with alcohol to set the resist. It is again rinsed with water and then sprayed with KPR black dye to reveal the etched circles.

X4.3.5 In the electrochemical method, the etch pad is saturated with an appropriate electrolyte. Various electrolytes are available from suppliers of the etching equipment. Some electrolytes are more effective than others for etching certain surfaces, such as terne plate and other metallic coated steels. A rust-inhibiting solution is preferred for steel sheets.

X4.3.6 A ground clamp for the transformer of suitable amperage (10 to 50 A is usually used) is fastened to the blank and the second lead is attached to the etch pad. Although the current may be turned on at this time, caution should be taken not to lay the pad on the sheet blank as it will arc. It is advisable to refrain from touching the metal of the etch pad and the grounded sheet blank.

X4.3.7 The stencil is placed with the plastic coating against the sheet surface in the area to be etched. Wetting the stencil with a minimum amount of electrolyte will assist in smoothing out the wrinkles and gives a more uniform etch. The etch pad is now positioned on the stencil and the current turned on, if it is not already on. Apply suitable pressure to the pad. Only the minimum time necessary to produce a clear etched pattern should be used. The etching time will vary with the amperage available from the power source and the stencil area, as well as the pad area in contact with the stencil. Rocker-type etch pads give good prints and require less amperage than flat-surfaced pads. Excessive current causes stencil damage.

X4.3.8 The etching solution activates the surface of the metal and may cause rusting unless it is inhibited. After the desired area has been etched, the blank should be wiped or rinsed, dried, and neutralized.

X4.3.9 The etched blank is now ready for forming. The lubricants and press conditions should simulate production situations. If a sequence of operations is used in forming a part, it is desirable to etch sufficient blanks so that each operation can be studied.

X4.4 Measurement of Strain After Forming

X4.4.1 After forming, the circles are generally distorted into elliptical shapes (Fig. X4.2). These ellipses have major and minor strain axes. The major strain (e_1) is always defined to be the direction in which the greatest positive strain has occurred without regard to original blank edges or the sheet rolling direction. The minor strain (e_2) is defined to be 90° to the major strain direction.

X4.4.2 There are several methods for determining the major and minor strains of the formed panel. Typical tools are a pair of dividers and a scale ruled in 0.5 mm. For sharp radii, a thin plastic scale that can follow the contour of the stamping can be used to determine the dimensions of the ellipses. (Scales are available to read the percent strain directly.)

X4.5 Evaluation of Strain Measurements

X4.5.1 The e_1 strain is always positive while the e_2 strain may be zero, positive, or negative, as indicated on the forming limit curve chart (Fig. X4.1). The maximum e_1 and associated e_2 values measured in critical areas on the formed part are plotted on the graph paper containing the forming limit curve by locating the point of intersections of the e_1, e_2 strains.

X4.5.2 If this point is on or below the "safety band" of the forming limit curve, the strain should not cause breakage. Points further below the curve indicate that a less ductile material of a lower grade may be applied. Points above the "safety band" show that fabrication has induced strains that could result in breakage. Therefore, in evaluation on stampings exhibiting these strains, efforts should be made to provide an e_1, e_2 strain combination that would lie on or below the "safety band" of the forming limit curve. A different e_1, e_2 strain combination can be obtained through changes of one or more of the forming variables such as die conditions, lubricants, blank size, thickness, or material grade. It should be noted at this time that these conclusions are derived from a reference base being the steel "quality" used to fabricate the grid stamping.

X4.5.3 When attempting to change the relationship of e_1 and e_2 strains, it should be noted that on the forming limit curve the most severe condition for a given e_1 strain is at 0% e_2 strain. This means the metal works best when it is allowed to deform in two dimensions, e_1 and e_2, rather than being restricted in one dimension. A change in e_2 to decrease the severity can be made by changing one of the previously mentioned forming variables of the die design, for example, improving lubrication on the tension-tension side will increase e_2 and decrease the severity.

X4.5.4 In addition to the forming limit curve, the e_1e_2 strain measurements may be used to evaluate the material requirements on the basis of strain gradients, as illustrated in Fig. X4.3, or by plotting contours of equivalent strain levels on the surface of the formed part. Even when the level of strain is relatively low, parts in which the e_1 strain is changing rapidly either in magnitude or direction over a short span on the surface may require more ductile grades of sheet metal, change in lubrication, or change in part design.

X4.6 Example of Major and Minor Strain Distribution

X4.6.1 A formed panel (Fig. X4.4) with a cross section as shown in Fig. X4.3 is used to illustrate major and minor strain combinations. A plot of the major strain distribution should be made by finding the ellipse with the largest major strain (circle 7) and measuring both the major and minor strains in the row of ellipses running in the direction of the major strain. The solid dots (Fig. X4.3) are the measured major strains for each ellipse. The Xs are the critical major strains as determined from the forming limit curve at the corresponding minor strain (intersection of the measured minor strain and the severity curve).

X4.6.2 Usually a single row of ellipses will suffice to determine the most severe strain distribution. The resulting strain distribution plot (Fig. X4.3) illustrates both severity of the strain compared to the critical strain limits and the concentration of strain in the stamping. Steep strain gradients should be avoided because they are inherent to fracture sites.

X4.7 Example for Reducing Splitting Tendency

X4.7.1 In an area such as that represented in Fig. X4.3, the splitting tendency can be reduced as follows:

X4.7.1.1 If the radius of the part in the region of circle 1 is increased, some strain can be induced to take place in this area which will allow the major strain in circle 7 to be reduced sufficiently to bring the strain combination below the critical limit. This course of action requires no binding nor reshaping of the punch, only grinding in the radius.

X4.7.1.2 The total average major strain required to make this formation is only 17.5%; yet in a 5.0 mm circle the strain is as high as 40%. The strain distribution curve puts forth graphically the need to distribute the strain over the length of the time by some means as described above.

X4.7.1.3 Change in lubrication can also improve the strain distribution of a stamping. If the strain over the punch is critical, the amount of stretch (strain) required to make the shape can be reduced by allowing metal to flow in over the punch by decreasing the friction through the use of a more effective lubricant in the hold-down era.

X4.7.1.4 If the part is critical, a change in material may help. That is, a material having a better uniform elongation will distribute the strain more uniformly or a material having a higher "r" value will make it possible to "draw" in more metal from the hold-down area so that less stretch is necessary to form the part.

X4.8 Scribed Square Method

X4.8.1 The basic technique is to draw a panel from a blank that has been scribed both longitudinally and transversely with a series of parallel lines spaced at 25.0 mm intervals. The lines on the panel are measured after drawing and the stretch or draw calculated as the percent increase in area of a 25.0 mm square. This is a fairly simple procedure for panels having generous radii and fairly even stretch or draw. Many major panels fall in this category, and in these instances it is quite easy to pick out the square area exhibiting the greatest increase.

X4.8.2 If the square or line to be measured is no longer a flat surface, place a narrow strip of masking (or other suitable tape) on the formed surface and mark the points which are to be measured. Remove the tape, place on a plane surface, and determine the distance between the points with a steel scale.

X4.8.3 There will be cases of minor increase in area with major elongation in the one direction. In these instances, the percent elongation should be recorded.

X4.9 Thickness Method

X4.9.1 There are instances when the maximum stretch is continued to an area smaller than 645 mm^2 or the shape of the square has been distorted irregularly, making measurements difficult and calculation inaccurate. When either of these conditions exists, an electronic thickness gauge may be used at the area in question or this area may be sectioned and the decrease in metal thickness measured with a ball-point micrometer. The increase in unit area can be calculated by dividing the original thickness by the final thickness.

X4.9.2 Example: Assuming the blank thickness to be 0.80 mm and the final thickness to be 0.60 mm, the increase in unit area would be a [(0.80 − 0.60)/0.80] × 100 = 25% increase.

X5.1 Introduction and Definitions

X5.1.1 In addition to the conventional expression of flatness, the "maximum deviation from a horizontal flat surface," at least two other flatness parameters have been developed and are in use for characterizing sheet with longitudinal waves or buckles. These are *steepness index* and *flatness index* (or "I-unit"), that are illustrated using the example in Fig. X5.1.

X5.1.2 *Steepness Index* — Fig. X5.1(a) shows a representation of a sheet sample exhibiting edge waves of height, H, and interval, L. The steepness index value for this sample is define as:

$$steepness\ index = H/L$$

Often, the steepness value is expressed as a percentage:

$$\%\ steepness = S = (H/L) \times 100$$

X5.1.3 *I-Units* — Making a series of lengthwise cuts to the sample in Fig. X5.1(a) relaxes elastic stresses present in the sheet and results in narrow strips of differing lengths, as shown in Fig. X5.1(b). Using the length of one of these strips as a reference (L_{ref}), the I-unit value (I) for an individual strip is defined as:

$$I = (DL/L_{ref}) \times 10^5$$

where:

ΔL = is the difference between the length of a given strip and the reference strip

X5.1.4 For the special case of waves/buckles that are perfectly sinusoidal in character, the following relationship applies:

$$I = \left[\left(\frac{\pi}{2}\right)\left(\frac{H}{L}\right)\right]^2 \times 10^5$$

or:

$$I = 24.7S^2$$

Table X5.1 provides I-unit values based on the sinusoidal approximation for wave heights up to ½ in. (increments of $\frac{1}{32}$ in.) and intervals between 10 and 40 in. (increments of 1 in.). Mathematical relationships between the three representations of flatness described here are given in Table X5.2; these relationships can be used to convert between I-unit, % steepness, and wave height values (see examples in Table X5.2).

X5.2 Flatness Evaluation Example and Determination of I-Unit or % Steepness Value

X5.2.1 While the strip is on an inspection table, find the locations on the strip that are not lying flat on the table. If no flatness deviation can be found, that portion of the coil (head/middle/tail) can be described as flat (that is, zero I-unit or zero % steepness).

X5.2.2 If the coil is not totally flat, the height of the deviation must be determined and recorded. If the coil has edge waves, a step gauge (incremented in intervals of $\frac{1}{16}$ or $\frac{1}{32}$ in.) can be inserted under a wave to determine the height. If the coil exhibits flatness deviation in the center of the strip, a lightweight straight edge can be placed on the highest portion of the buckle and on the highest portion of the next repeating buckle. The height can then be determined by inserting a step gauge between the straight edge and the strip.

X5.2.3 Along with the height, the wave period or wave interval must also be determined. The wave interval can be obtained by using a standard tape measure or straight edge to measure the distance between the highest point of one flatness deviation to the highest point of the next repeating flatness deviation.

X5.2.4 After determining height and wave interval, either the I-unit or % steepness value can be obtained. To determine the I-unit flatness, locate the appropriate height and wave interval in Table X5.1 and read the I-unit value at the intersection of the two measurements. To determine % steepness, divide the height by the wave interval and multiply the result by 100.

FIG. X4.1 FORMING LIMIT CURVE

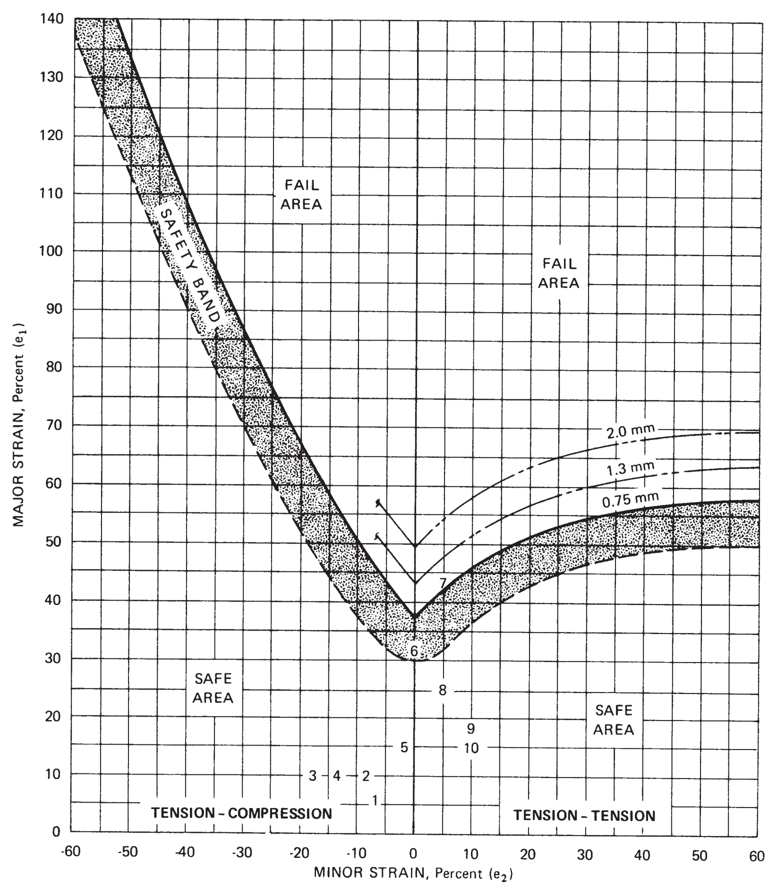

FIG. X4.2 MAJOR AND MINOR STRAIN AXES

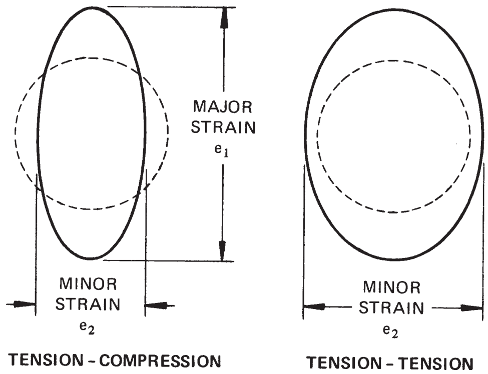

FIG. X4.3 GRAPH OF MAJOR STRAINS AND CRITICAL MAJOR STRAINS AND CROSS SECTION OF ETCHED PANEL

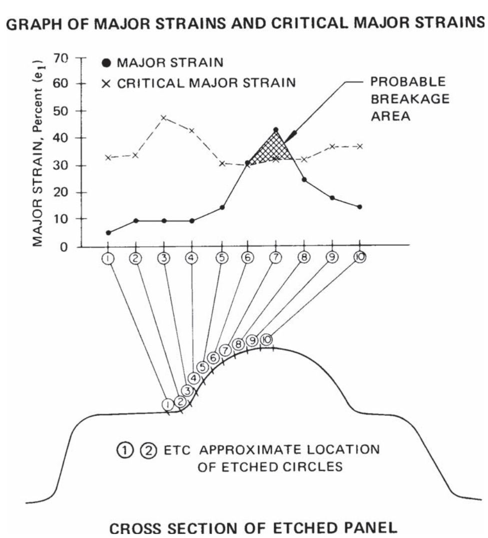

FIG. X4.4 FORMED PANEL AND CROSS SECTION

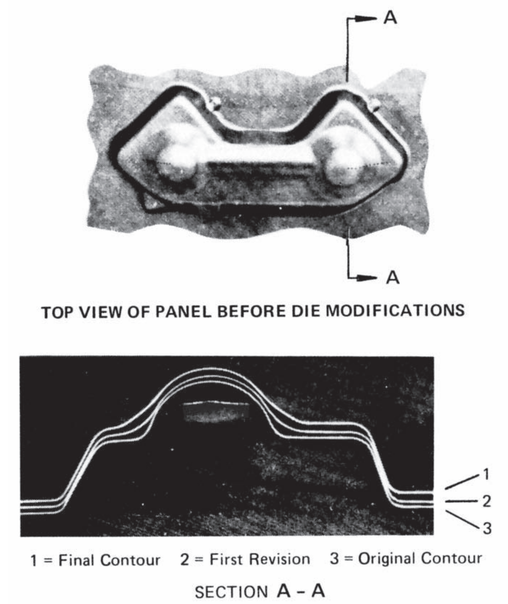

FIG. X5.1 REPRESENTATION OF SHEET SAMPLE WITH EDGE WAVES (a) AND STRIPS OF DIFFERING LENGTH THAT RESULT FROM MAKING LONGITUDINAL CUTS ALONG THE SAMPLE (b)

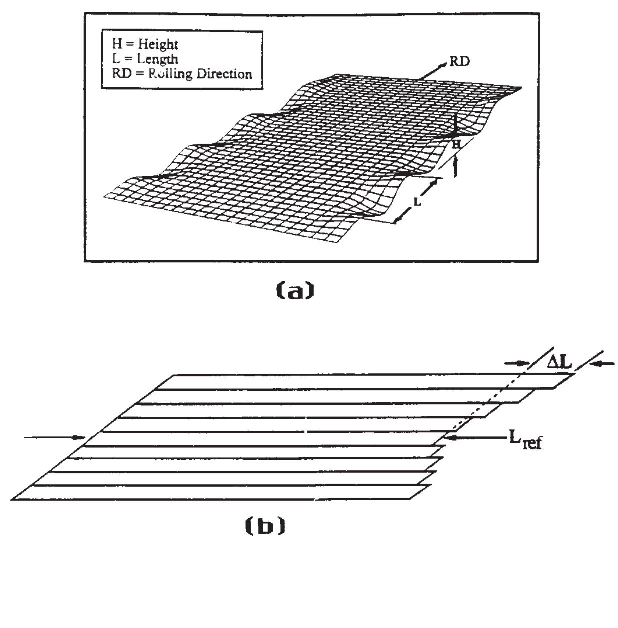

TABLE X2.1
STANDARD STEELS — CARBON SHEET STEEL COMPOSITIONS

Steel Designation No.	Chemical Composition Limits, %			
	C	Mn	P max	S max
1001	0.01 max	0.35 max	0.030	0.035
1002	0.02 max	0.35 max	0.030	0.035
1003	0.04 max	0.35 max	0.030	0.035
1004	0.02/0.06	0.35 max	0.030	0.035
1005	0.06 max	0.35 max	0.030	0.035
1006A	0.02/0.08	0.45 max	0.030	0.035
1006	0.08 max	0.45 max	0.030	0.035
1007	0.02/0.10	0.50 max	0.030	0.035
1008	0.10 max	0.50 max	0.030	0.035
1009	0.15 max	0.60 max	0.030	0.035
1010	0.08–0.13	0.30–0.60	0.030	0.035
1012	0.10–0.15	0.30–0.60	0.030	0.035
1015	0.13–0.18	0.30–0.60	0.030	0.035
1016	0.13–0.18	0.60–0.90	0.030	0.035
1017	0.15–0.20	0.30–0.60	0.030	0.035
1018	0.15–0.20	0.60–0.90	0.030	0.035
1019	0.15–0.20	0.70–1.00	0.030	0.035
1020	0.18–0.23	0.30–0.60	0.030	0.035
1021	0.18–0.23	0.60–0.90	0.030	0.035
1022	0.18–0.23	0.70–1.00	0.030	0.035
1023	0.20–0.25	0.30–0.60	0.030	0.035
1025	0.22–0.28	0.30–0.60	0.030	0.035
1026	0.22–0.28	0.60–0.90	0.030	0.035
1030	0.28–0.34	0.60–0.90	0.030	0.035
1033	0.30–0.36	0.70–1.00	0.030	0.035
1035	0.32–0.38	0.60–0.90	0.030	0.035
1037	0.32–0.38	0.70–1.00	0.030	0.035
1038	0.35–0.42	0.60–0.90	0.030	0.035
1039	0.37–0.44	0.70–1.00	0.030	0.035
1040	0.37–0.44	0.60–0.90	0.030	0.035
1042	0.40–0.47	0.60–0.90	0.030	0.035
1043	0.40–0.47	0.70–1.00	0.030	0.035
1045	0.43–0.50	0.60–0.90	0.030	0.035
1046	0.43–0.50	0.70–1.00	0.030	0.035
1049	0.46–0.53	0.60–0.90	0.030	0.035
1050	0.48–0.55	0.60-0.90	0.030	0.035
1055	0.50–0.60	0.60–0.90	0.030	0.035
1060	0.55–0.65	0.60–0.90	0.030	0.035
1064	0.59–0.70	0.50–0.80	0.030	0.035
1065	0.60–0.70	0.60–0.90	0.030	0.035
1070	0.65–0.75	0.60–0.90	0.030	0.035
1074	0.70–0.80	0.50–0.80	0.030	0.035
1078	0.72–0.85	0.30–0.60	0.030	0.035
1080	0.75–0.88	0.60–0.90	0.030	0.035
1084	0.80–0.93	0.60–0.90	0.030	0.035
1085	0.80–0.93	0.70–1.00	0.030	0.035
1086	0.80–0.93	0.30–0.50	0.030	0.035
1090	0.85–0.98	0.69–0.90	0.030	0.035
1095	0.90–1.03	0.30–0.50	0.030	0.035
1524	0.19–0.25	1.35–1.65	0.030	0.035
1527	0.22–0.29	1.20–1.50	0.030	0.035
1536	0.30–0.37	1.20–1.50	0.030	0.035
1541	0.36–0.44	1.35–1.65	0.030	0.035
1548	0.44–0.52	1.10–1.40	0.030	0.035
1552	0.47–0.55	1.20–1.50	0.030	0.035

NOTE — When silicon is required, the following ranges and limits are commonly used.

To 1015, excl	0.10 max
1015 to 1025, incl	0.10 max, 0.10–0.25, or 0.15–0.30
Over 1025	0.10–0.25 or 0.15–0.30

TABLE X2.2
STANDARD CHEMICAL RANGES AND LIMITS

Element	Carbon Steels Only, Cast or Heat Analysis		
	Maximum Specified Element, %	Range	Lowest max
Carbon (see Note)	to 0.15, incl	0.05	0.08
	over 0.15 to 0.30, incl	0.06	
	over 0.30 to 0.40, incl	0.07	
	over 0.40 to 0.60, incl	0.08	
	over 0.60 to 0.80, incl	0.11	
	over 0.80 to 1.35, incl	0.14	
Manganese	to 0.50, incl	0.20	0.40
	over 0.50 to 1.15, incl	0.30	
	over 1.15 to 1.65, incl	0.35	
Phosphorus	to 0.08, incl	0.03	0.030[A]
	over 0.08 to 0.015, incl	0.05	
Sulfur	to 0.08, incl	0.03	0.035[A]
	over 0.08 to 0.15, incl	0.05	
	over 0.15 to 0.23, incl	0.07	
	over 0.23 to 0.33, incl	0.10	
Silicon	to 0.15, incl	0.08	0.10
	over 0.15 to 0.30, incl	0.15	
	over 0.30 to 0.60, incl	0.30	
Copper	When copper is required 0.20 min is commonly specified.		

NOTE 1 — The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.00%. When the maximum manganese limit exceeds 1.00%, add 0.01 to the carbon ranges shown below.

[A] Certain individual specifications provide for lower standard limits for phosphorus and sulfur.

TABLE X5.1
I-UNIT CONVERSION CHART

Wave Height in.	Wavelength (in.) 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1/32	2	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1/16	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3/32	22	18	15	13	11	10	8	8	7	6	5	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	1	1
1/8	39	32	27	23	20	17	15	13	12	11	10	9	8	7	7	6	6	5	5	5	4	4	4	4	3	3	3	3	3	3	2
5/32	60	50	42	36	31	27	24	21	19	17	15	14	12	11	10	10	9	8	8	7	7	6	6	6	5	5	5	4	4	4	4
3/16	87	72	60	51	44	39	34	30	27	24	22	20	18	16	15	14	13	12	11	10	10	9	8	8	8	7	7	6	6	6	5
7/32	118	98	82	70	60	53	46	41	36	33	30	27	24	22	21	19	17	16	15	14	13	12	12	11	10	10	9	9	8	8	7
1/4	154	128	107	91	79	69	60	53	48	43	39	35	32	29	27	25	23	21	20	18	17	16	15	14	13	13	12	11	11	10	10
9/32	195	161	136	116	100	87	76	68	60	54	49	44	40	37	34	31	29	27	25	23	22	20	19	18	17	16	15	14	14	13	12
5/16	241	199	168	143	123	107	94	83	74	67	60	55	50	46	42	39	36	33	31	29	27	25	24	22	21	20	19	18	17	16	15
11/32	292	241	203	173	149	130	114	101	90	81	73	66	60	55	51	47	43	40	37	35	32	30	29	27	25	24	23	21	20	19	18
3/8	347	287	241	206	177	154	136	120	107	96	87	79	72	66	60	56	51	48	44	41	39	36	34	32	30	28	27	25	24	23	22
13/32	408	337	283	241	208	181	159	141	126	113	102	92	84	77	71	65	60	56	52	48	45	42	40	37	35	33	31	30	28	27	25
7/16	473	391	328	280	241	210	185	164	146	131	118	107	98	89	82	76	70	65	60	56	53	49	46	43	41	39	36	35	33	31	30
15/32	543	449	377	321	277	241	212	188	168	150	136	123	112	103	94	87	80	74	69	65	60	56	53	50	47	44	42	40	38	36	34
1/2	618	510	429	365	315	274	241	214	191	171	154	140	128	117	107	99	91	85	79	73	69	64	60	57	53	50	48	45	43	41	39

Wave Height (mm)	Wavelength (mm) 250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750	775	800	825	850	875	900	925	950	975	1000
0.5	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0	4	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1.5	9	7	6	5	5	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2.0	16	13	11	9	8	7	6	5	5	4	4	4	3	3	3	3	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1
2.5	25	20	17	15	13	11	10	9	8	7	6	6	5	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2
3.0	36	29	25	21	18	16	14	12	11	10	9	8	7	7	6	6	5	5	5	4	4	4	3	3	3	3	3	3	2	2	2
3.5	48	40	34	29	25	22	19	17	15	13	12	11	10	9	8	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3
4.0	63	52	44	37	32	28	25	22	20	18	16	14	13	12	11	10	9	9	8	8	7	7	6	6	5	5	5	5	4	4	4
4.5	80	66	56	47	41	36	31	28	25	22	20	18	17	15	14	13	12	11	10	10	9	8	8	7	7	7	6	6	6	5	5
5.0	99	82	69	58	50	44	39	34	30	27	25	22	20	19	17	16	15	14	13	12	11	10	10	9	9	8	8	7	7	6	6
5.5	120	99	83	71	61	53	47	41	37	33	30	27	25	23	21	19	18	16	15	14	13	12	12	11	10	10	9	9	8	8	7
6.0	142	118	99	84	73	63	56	49	44	39	36	32	29	27	25	23	21	20	18	17	16	15	14	13	12	12	11	10	10	9	9
6.5	167	138	116	99	85	74	65	58	52	46	42	38	34	32	29	27	25	23	21	20	19	17	16	15	14	14	13	12	12	11	10
7.0	194	160	134	115	99	86	76	67	60	54	48	44	40	37	34	31	29	27	25	23	22	20	19	18	17	16	15	14	13	13	12
7.5	222	184	154	132	113	99	87	77	69	62	56	50	46	42	39	36	33	30	28	26	25	23	22	20	19	18	17	16	15	15	14
8.0	253	209	176	150	129	112	99	88	78	70	63	57	52	48	44	40	37	35	32	30	28	26	25	23	22	21	20	18	18	17	16
8.5	286	236	198	169	146	127	112	99	88	79	71	65	59	54	50	46	42	39	36	34	32	30	28	26	25	23	22	21	20	19	18
9.0	320	265	222	189	163	142	125	111	99	89	80	73	66	61	56	51	47	44	41	38	36	33	31	29	28	26	25	23	22	21	20
9.5	357	295	248	211	182	159	139	123	110	99	89	81	74	67	62	57	53	49	45	42	40	37	35	33	31	29	28	26	25	23	22
10.0	395	327	274	234	202	176	154	137	122	109	99	90	82	75	69	63	58	54	50	47	44	41	39	36	34	32	30	29	27	26	25

TABLE X5.2
FLATNESS CONVERSION FACTORS[A]

	I Unit	Height	% Steepness
I Unit (I)	1	$\frac{2L}{\pi}\sqrt{I\,10^{-5}}$	$\frac{2}{\pi}\sqrt{I\,10^{-1}}$
Height (H) (peak to peak)	$\left(\frac{H\pi}{2L}\right)^2 10^5$	1	$\frac{(100H)}{L}$
% Steepness (S)	$2.5\,(\pi\,S)^2$	$\frac{(LS)}{100}$	1

[A] Examples — *(1)* Assume % steepness is given as 1.5 and the corresponding I-unit value is desired. From Table X5.2, $I = 2.5(\pi S)^2 = 2.5[(3.14)(1.5)]^2 = 55.5$.
(2) Assume an I-unit value of 25 is given and the corresponding % steepness is desired. From Table X5.2, $S = 2/\pi(I \times 10^{-1})^{1/2} = 2/3.14\,(25 \times 10^{-1})^{1/2} = 1.0$.

NOTE 1 — "L" is the wave interval as defined in Fig. X5.1(a).

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SPECIFICATION FOR HIGH-STRENGTH LOW-ALLOY COLUMBIUM-VANADIUM STRUCTURAL STEEL

SA-572/SA-572M

(**23**)

(Identical with ASTM Specification A572/A572M-21$^{\varepsilon 1}$.)

Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel

1. Scope

1.1 This specification covers five grades of high-strength low-alloy structural steel shapes, plates, sheet piling, and bars. Grades 42 [290], 50 [345], and 55 [380] are intended for riveted, bolted, or welded structures. Grades 60 [415] and 65 [450] are intended for riveted or bolted construction of bridges, or for riveted, bolted, or welded construction in other applications.

1.2 For applications, such as welded bridge construction, where notch toughness is important, notch toughness requirements are to be negotiated between the purchaser and the producer.

1.3 Specification A588/A588M shall not be substituted for Specification A572/A572M without agreement between the purchaser and the supplier.

1.4 The use of columbium (niobium), vanadium, titanium, nitrogen, or combinations thereof, within the limitations noted in Section 5, is required; the selection of type (1, 2, 3, or 5) is at the option of the producer, unless otherwise specified by the purchaser. (See Supplementary Requirement S90.)

1.5 The maximum thicknesses available in the grades and products covered by this specification are shown in Table 1.

1.6 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A6/A6M for information on weldability.

1.7 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

1.8 The text of this specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

1.9 For structural products produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional tests, of Specification A6/A6M apply.

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
A36/A36M Specification for Carbon Structural Steel
A514/A514M Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding
A588/A588M Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance

TABLE 1 Maximum Product Thickness or Size

Grade	Yield Point, min		Maximum Thickness or Size					
	ksi	[MPa]	Plates and Bars		Structural Shape Flange or Leg Thickness		Sheet Piling	Zees and Rolled Tees
			in.	[mm]	in.	[mm]		
42 [290][A]	42	[290]	6	[150]	all	all	all	all
50 [345][A]	50	[345]	4[B]	[100][B]	all	all	all	all
55 [380]	55	[380]	2½	[64]	all	all	all	all
60 [415][A]	60	[415]	2½[C]	[64][C]	2	[50]	all	all
65 [450]	65	[450]	2	[50]	2	[50]	all	all

[A] In the above tabulation, Grades 42, 50, and 60 [290, 345, and 415], are the yield point levels most closely approximating a geometric progression pattern between 36 ksi [250 MPa], min, yield point steels covered by Specification A36/A36M and 100 ksi [690 MPa], min, yield strength steels covered by Specification A514/A514M.
[B] Round bars up to and including 11 in. [275 mm] in diameter are permitted.
[C] Round bars up to and including 3½ in. [90 mm] in diameter are permitted.

TABLE 2 Chemical Requirements[A]
(Heat Analysis)

Diameter, Thickness, or Distance Between Parallel Faces, in. [mm] Plates and Bars	Structural Shape Flange or Leg Thickness, in. [mm]	Grade	Carbon, max, %	Manganese,[B] max, %	Phosphorus,[I] max, %	Sulfur,[I] max, %	Silicon: Plates to 1½ in. [40 mm] Thick, Shapes with Flange or Leg Thickness to 3 in. [75 mm] inclusive, Sheet Piling, Bars, Zees, and Rolled Tees[C]	Silicon: Plates Over 1½ in. [40 mm] Thick and Shapes with Flange Thickness Over 3 in. [75 mm]
							max, %	range, %
6 [150]	all	42 [290]	0.21	1.35[D]	0.030	0.030	0.40	0.15–0.40
4 [100][E]	all	50 [345]	0.23	1.35[D]	0.030	0.030	0.40	0.15–0.40
2½ [64][F]	all	55 [380]	0.25	1.35[D]	0.030	0.030	0.40	0.15–0.40
2½ [64][F]	≤2 [50]	60 [415]	0.26	1.35[D]	0.030	0.030	0.40	0.15–0.40
>½ – 2 [13–50]	>1–2 [25–50]	65 [450]	0.23	1.65	0.030	0.030	0.40	0.15–0.40
≤½ [13][H]	≤1	65 [450]	0.26	1.35[D]	0.030	0.030	0.40	[G]

[A] Copper when specified shall have a minimum content of 0.20 % by heat analysis (0.18 % by product analysis).
[B] Manganese, minimum, by heat analysis of 0.80 % (0.75 % by product analysis) shall be required for all plates over ⅜ in. [10 mm] in thickness; a minimum of 0.50 % (0.45 % by product analysis) shall be required for plates ⅜ in. [10 mm] and less in thickness, and for all other products. The manganese to carbon ratio shall not be less than 2 to 1.
[C] Bars over 1½ in. [40 mm] in diameter, thickness, or distance between parallel faces shall be made by a killed steel practice.
[D] For each reduction of 0.01 percentage point below the specified carbon maximum, an increase of 0.06 percentage point manganese above the specified maximum is permitted, up to a maximum of 1.60 %.
[E] Round bars up to and including 11 in. [275 mm] in diameter are permitted.
[F] Round bars up to and including 3½ in. [90 mm] in diameter are permitted.
[G] The size and grade is not described in this specification.
[H] An alternative chemical requirement with a maximum carbon of 0.21 % and a maximum manganese of 1.65 % is permitted, with the balance of the elements as shown in Table 2.
[I] A maximum phosphorus content of 0.04 % and a maximum sulfur content of 0.05 % are permitted for the following materials:
· Structural shapes
· Sheet piling
· Bars
· Plates with widths up to and including 15 in. [380 mm]

3. General Requirements for Delivery

3.1 Structural products furnished under this specification shall conform to the requirements of the current edition of Specification A6/A6M, for the specific structural product ordered, unless a conflict exists in which case this specification shall prevail.

3.2 Coils are excluded from qualification to this specification until they are processed into a finished structural product. Structural products produced from coil means structural products that have been cut to individual lengths from a coil. The processor directly controls, or is responsible for, the operations involved in the processing of a coil into a finished structural product. Such operations include decoiling, leveling or straightening, hot-forming or cold-forming (if applicable), cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For structural products produced from coil and furnished without heat treatment or with stress relieving only, two test results are to be reported for each qualifying coil. Additional requirements regarding structural products produced from coil are described in Specification A6/A6M.

4. Materials and Manufacture

4.1 The steel shall be killed.

TABLE 3 Alloy Content

Type[A]	Elements	Heat Analysis, %
1	Columbium/niobium[E]	0.005–0.05[B]
2	Vanadium	0.01–0.15[C]
3	Columbium/niobium[E]	0.005-0.05[B]
	Vanadium	0.01–0.15[C]
	Columbium/niobium[E] plus vanadium	0.02–0.15[D]
5	Titanium	0.006-0.04
	Nitrogen	0.003–0.015
	Vanadium	0.06 max

[A] Alloy content shall be in accordance with Type 1, 2, 3, or 5 and the contents of the applicable elements shall be reported on the test report.
[B] Product analysis limits = 0.004 to 0.06 %.
[C] Product analysis limits = 0.005 to 0.17 %.
[D] Product analysis limits = 0.01 to 0.16 %.
[E] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in Committee A01 specifications.

TABLE 4 Tensile Requirements[A]

Grade	Yield Point, min		Tensile Strength, min		Minimum Elongation, % [B, C, D]	
	ksi	[MPa]	ksi	[MPa]	in 8 in. [200 mm]	in 2 in. [50 mm]
42 [290]	42	[290]	60	[415]	20	24
50 [345]	50	[345]	65	[450]	18	21
55 [380]	55	[380]	70	[485]	17	20
60 [415]	60	[415]	75	[520]	16	18
65 [450]	65	[450]	80	[550]	15	17

[A] See specimen orientation under the Tension Tests section of Specification A6/A6M.
[B] Elongation not required to be determined for floor plate.
[C] For wide flange shapes over 426 lb/ft [634 kg/m], elongation in 2 in. [50 mm] of 19 % minimum applies.
[D] For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points for Grades 42, 50, and 55 [290, 345, and 380], and three percentage points for Grades 60 and 65 [415 and 450]. See elongation requirement adjustments in the Tension Tests section of Specification A6/A6M.

5. Chemical Composition

5.1 The heat analysis shall conform to the requirements prescribed in Table 2 and Table 3.

5.2 The steel shall conform on product analysis to the requirements prescribed in Table 2 and Table 3, subject to the product analysis tolerances in Specification A6/A6M.

6. Mechanical Properties

6.1 *Tensile Properties:*

6.1.1 The material as represented by the test specimens shall conform to the tensile properties given in Table 4.

7. Test Reports

7.1 In addition to the Test Reports requirements in Specification A6/A6M, when Specification A588/A588M is substituted for Specification A572/A572M, the test report shall include the statement "Specification A588/A588M substituted."

8. Keywords

8.1 bars; bolted construction; bridges; buildings; columbium/niobium-vanadium; high-strength; low-alloy; plates; riveted construction; shapes; sheet piling; steel; structural steel; welded construction

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order or contract. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A6/A6M. Those that are considered suitable for use with this specification are listed by title:

S5. Charpy V-Notch Impact Test.

S18. Maximum Tensile Strength

S30. Charpy V-Notch Impact Test for Structural Shapes: Alternate Core Location

S32. Single Heat Bundles.

In addition, the following supplementary requirements are suitable for use:

S81. Tensile Strength

S81.1 For Grade 50 [345] steel of thicknesses ¾ in. [20 mm] and less, the tensile strength shall be a minimum of 70 ksi [485 MPa].

S90. Type

S90.1 The specific type of steel shall be as specified by the purchaser in the order or contract.

S99. Interlock Strength

S99.1 The minimum strength of the interlocked joint required for certain services may be specified for straight web (PS type) and arched web (PSA type) sheet piling sections subject to specific agreement between the material purchaser and the manufacturer.

SPECIFICATION FOR ALLOY STEEL SOCKET-HEAD CAP SCREWS

SA-574

(Identical with ASTM Specification A574-04$^{\varepsilon 1}$ except that Table 1 on chemical requirements has been deleted and Supplementary Requirement S1 is now mandatory. Paragraphs 6.1 and 6.2 have been revised to refer to Table S1.1 and para. 6.3 has been deleted.)

SPECIFICATION FOR ALLOY STEEL SOCKET-HEAD CAP SCREWS

SA-574

(Identical with ASTM Specification A 574-04$^{\epsilon 1}$ except that Table 1 on chemical requirements has been deleted and Supplementary Requirement S1 is now mandatory. Paragraphs 6.1 and 6.2 have been revised to refer to Table S1.1 and para. 6.3 has been deleted.)

1. Scope

1.1 This specification covers the requirements for quenched and tempered alloy steel hexagon socket-head cap screws, 0.060 through 4 in. in diameter where high strength is required.

NOTE 1 — A complete metric companion to Specification A 574 has been developed—A 574M; therefore no metric equivalents are presented in this specification.

1.2 The following hazard caveat pertains only to the test method portion, Section 12, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

D 3951 Practice for Commercial Packaging

E 3 Guide for Preparation of Metallographic Specimens

E 112 Test Methods for Determining Average Grain Size

E 384 Test Method for Microindentation Hardness of Materials

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets

F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

2.2 *ASME Standards:*

B1.1 Unified Screw Threads

B18.3 Socket Cap, Shoulder, and Set Screws

B18.24 Part Identifying Number (PIN) Code System Standard for B18 Fastener Products

2.3 *Federal Standard:*

H-28 Handbook of Thread Dimensions

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of discontinuities covered by 10.2 follow:

3.1.2 *crack* — clean crystalline break passing through the grain or grain boundary without inclusion of foreign elements.

3.1.3 *inclusions* — particles of nonmetallic impurities, usually oxides, sulfides, silicates, and such, which are mechanically held in the steel during solidification.

3.1.4 *nicks or pits* — depressions or indentations in the surface of the metal.

3.1.5 *seam or lap* — noncrystalline break through the metal which is inherently in the raw material.

4. Ordering Information

4.1 Orders for socket head cap screws under this specification shall include the following:

4.1.1 ASTM designation and year of issue.

4.1.2 Quantities (number of pieces by size).

4.1.3 Size and length.

4.2 Orders for socket head cap screws may include the following optional requirements:

4.2.1 Inspection at point of manufacture.

4.2.2 Coating, if a protective finish other than black oxide (thermal or chemical) is required, it must be specified.

4.2.3 Certified test reports (see 11.2).

4.2.4 Additional testing (see 11.3).

4.2.5 Special packaging (see 16.1.2).

4.2.6 Supplementary requirements (see S1).

4.2.7 Special requirements.

4.2.8 For establishment of a part identifying system, see ASME B18.24

5. Materials and Manufacture

5.1 The screws shall be fabricated from a steel which has been made by the open-hearth, basic-oxygen, or electric-furnace process.

5.2 The screws shall be fabricated from alloy steel made to a fine grain practice. In the event of controversy over grain size, referee tests on finished screws conducted in accordance with Test Methods E 112 shall prevail.

5.3 Unless otherwise specified, the heads of screws through 1.500 in. diameter shall be fabricated by hot or cold forging. Over 1.500 in. diameter, the heads may be fabricated by hot or cold forging or by machining. Sockets may be forged or machined.

5.4 Unless otherwise specified, threads of screws shall be rolled for diameters through 0.625 in. and for screw lengths through 4 in. For diameters and lengths other than this, threads may be rolled, cut, or ground.

5.5 The screws shall be heat treated by oil quenching from above the transformation temperature and then tempering at a temperature not lower than 650°F.

5.6 *Standard Finishes* — Unless otherwise specified, the screws shall be furnished with one of the following "standard surfaces as manufactured" at the option of the manufacturer: *(1)* bright uncoated, *(2)* thermal black oxide, or *(3)* chemical black oxide. Hydrogen embrittlement tests shall not be required for screws furnished in these conditions.

5.7 *Protective Coatings:*

5.7.1 When a protective finish other than as specified in 5.6 is required, it shall be specified on the purchase order with the applicable finish specification.

5.7.2 When protective or decorative coatings are applied to the screws, precautions specified by the coating requirements to minimize embrittlement shall be exercised.

6. Chemical Composition

6.1 The analysis of the screw material shall conform to the chemical composition specified in Table S1.1.

6.2 Product analyses may be made by the purchaser from finished material representing each lot. The chemical composition, thus determined, shall conform to the requirements prescribed for product analysis in Table S1.1.

6.3 DELETED

6.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

6.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties

7.1 The hardness of finished screws shall be 39 to 45 HRC for 0.500 in. and smaller and 37 to 45 HRC for 0.625 in. and larger. This shall be only the mechanical requirements for screws that are shorter than three times the diameter or that have insufficient threads for tension testing.

7.2 Screws, other than those exempted in 7.1 and 7.3, shall meet the proof load and tensile requirements in Table 2 and Table 3. The screws shall be tension tested with a wedge of the angle specified in Table 4 under the head. To meet the requirements of the wedge test, there must be a tensile failure in the body or thread section. For the purpose of this test, failure means separation into two pieces. Screws threaded to the head shall pass the requirements for this test if the fracture that caused failure originated in the thread area, even though it may have propagated into the fillet area or the head before separation.

7.3 Screws having a diameter larger than 1.500 in. shall be preferably tested in full size and shall meet the requirements of Table 2 and Table 3. When equipment of sufficient capacity is not readily available, screws shall meet 170 ksi, min, tensile strength, 153 ksi, min, yield strength at 0.2% offset, and 10% elongation on specimens machined in accordance with Test Methods F 606.

8. Metallurgical Requirement

8.1 *Carburization or Decarburization:*

8.1.1 There shall be no evidence of carburization or total decarburization on the surfaces of the heat-treated screws when measured in accordance with 12.3.

8.1.2 The depth of partial decarburization shall be limited to the values in Table 5 when measured as shown in Fig. 1 and in accordance with 12.3.

9. Dimensions

9.1 Unless otherwise specified, the product shall conform to the requirements of B18.3.

9.2 Unless otherwise specified, threads shall be Unified standard: Class 3A, UNRC and UNRF series for screw sizes 0.060 through 1 in. inclusive; Class 2A, UNRC and UNRF series for sizes over 1 in. to 1.500 in. inclusive; and Class 2A UNRC series for sizes larger than 1.500 in. in accordance with B1.1.

10. Workmanship, Finish, and Appearance

10.1 *Discontinuities* — The surface discontinuities for these products shall conform to Specification F 788/F 788M and the additional limitations specified herein.

10.2 *Socket Discontinuities:*

10.2.1 Depth of discontinuities in the socket area will be permissible within the limits of Condition 1 provided they do not affect the usability and performance of the screw. Discontinuities exceeding these limits are not acceptable.

10.2.2 Longitudinal discontinuities must not exceed $0.25T$ in length. Permissible and nonpermissible discontinuities are shown in Fig. 2.

NOTE 2 — T = actual key engagement.

10.3 *Permissible Head and Body Discontinuities* — Discontinuities as defined above are permitted in the locations illustrated in Fig. 3 to the depths shown in 10.4. These discontinuities are permitted, provided they do not affect the usability and performance of the screw. All discontinuities are to be measured perpendicular to indicated surfaces.

10.4 *Conditions for Permissible Discontinuity Depths:*

10.4.1 *Condition 1* — For bearing area, fillet, and other surfaces, max depth = $0.03D$ or 0.005 in. (whichever is greater).

NOTE 3 — D = nominal diameter of screw.

10.4.2 *Condition 2* — For peripheral discontinuities, max depth = $0.06D$, but not to exceed 0.064.

10.5 *Thread Discontinuities* — Threads shall have no laps at the root or on the flanks located below the pitch line. Laps are permissible at the thread crest to a depth of 25% of the basic thread height and on the thread flanks beyond the pitch diameter. Longitudinal seams in the threads are acceptable within the limits of Condition 1 (10.4.1).

11. Number of Tests and Retests

11.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. A record of individual heats of steel in each test lot shall be maintained. The container shall be coded to permit identification of the lot.

11.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last complete set of mechanical tests for each stock size in each shipment.

11.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all screws offered for inspection at one time of one diameter and length. From each lot, the number of samples for each requirement shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and less	1
Over 800 to 8 000, incl.	2
Over 8 000 to 22 000, incl.	3
Over 22 000	5

11.4 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be retested for the requirement(s) in which it failed. All of the additional samples shall conform to the specification or the lot shall be rejected.

12. Test Methods

12.1 Test the finished screws and specimens, as applicable, for mechanical properties and hardness requirements of Section 7. Testing shall be in accordance with Test Methods F 606 at room temperature. The minimum required length for tension testing shall be $3D$. The angle used in wedge tests shall be as specified in Table 4.

12.2 The speed of testing, as determined with a free running crosshead, shall be a maximum of 1 in./min for the tension tests of screws.

12.3 Decarburization and carburization tests shall be conducted as follows:

12.3.1 Section the thread area of the bolt longitudinally through the axis, mount, and polish it in accordance with Practice E 3. Take measurements *(1)* at the minor diameter in the center of the thread ridge, and *(2)* $0.75h$ toward the thread crest on the perpendicular bisector of the thread ridge. Take a measurement *(3)* on the thread flank approximately at the pitch line at a depth of 0.003 in. Use one of the two methods for carburization/decarburization evaluation either optical or microhardness measurements. The microhardness measurement shall constitute a referee method in case of dispute.

12.3.2 For optical measurement, etch the section in 2 to 4% nital. Examine the surface of the etched samples under a microscope at 100× using a measuring eyepiece graduated in 0.001-in. increments. The width of any light etching band normally defines the decarburization depth. A dark etching band indicates the possibility of carburization.

12.3.3 Measure microhardness in accordance with Test Method E 384 on unetched specimens using a DPH 136° indenter or a Knoop indenter using the following load application:

Number of Threads per Inch	Load
Less than 40	500 gf
40, 44, and 48	200 gf
Over 48	Use optical evaluation in 12.3.2

12.3.3.1 Take measurements at minor diameter (Reading No. 1) on the thread crest bisector to determine base metal hardness. Take measurements (Reading No. 2) on the bisector 0.75*h* from the minor measurement toward the thread crest. Also take measurements (Reading No. 3) on the thread flank at the pitch line at a depth within 0.003 from the surface. Reading No. 3 may be taken on the same or an adjacent thread.

12.3.4 Interpret microhardness readings as follows:

12.3.4.1 A decrease of more than 30 hardness points from Reading No. 1 to Reading No. 2 shall be regarded as decarburization and indicates the screw does not conform to specification requirements.

12.3.4.2 An increase of more than 30 hardness points from Reading No. 1 to Reading No. 3 shall be regarded as carburization and indicates that the screw does not conform to specification requirements.

13. Inspection

13.1 If the additional tests described in 11.3 are required by the purchaser it shall be specified in the inquiry, order, or contract.

13.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

14. Responsibility

14.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

15. Rejection and Rehearing

15.1 Rejections based on requirements herein shall be reported to the manufacturer within 30 days after receipt of material by the purchaser.

16. Packaging and Package Marking

16.1 *Packaging:*

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 *Package Marking:*

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation,

16.2.1.2 Size,

16.2.1.3 Name and brand or trademark of the manufacturer,

16.2.1.4 Number of pieces,

16.2.1.5 Purchase order number, and

16.2.1.6 Country of origin.

17. Keywords

17.1 alloy steel; cap screws; socket head

FIG. 1 DEFINITION OF PARTIAL DECARBURIZATION LIMITS

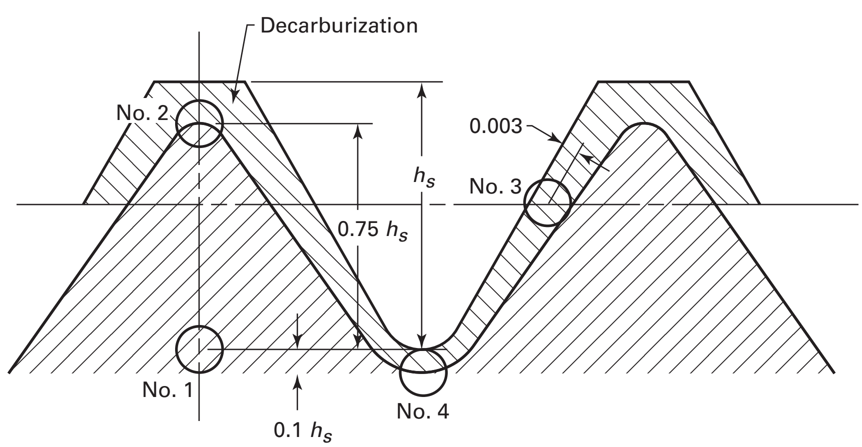

FIG. 2 SOCKET DISCONTINUITY LOCATION AND LIMITS

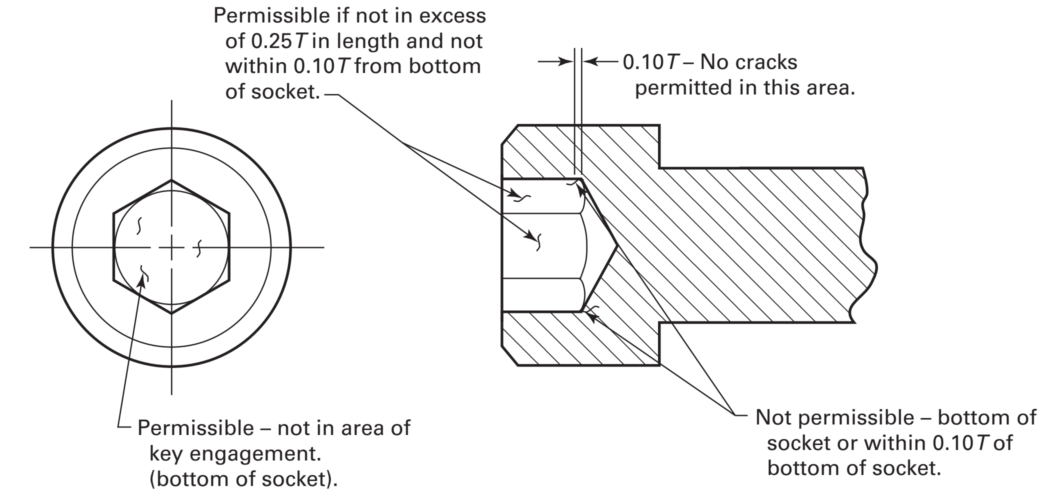

FIG. 3 HEAD AND BODY DISCONTINUITY LOCATION AND LIMITS

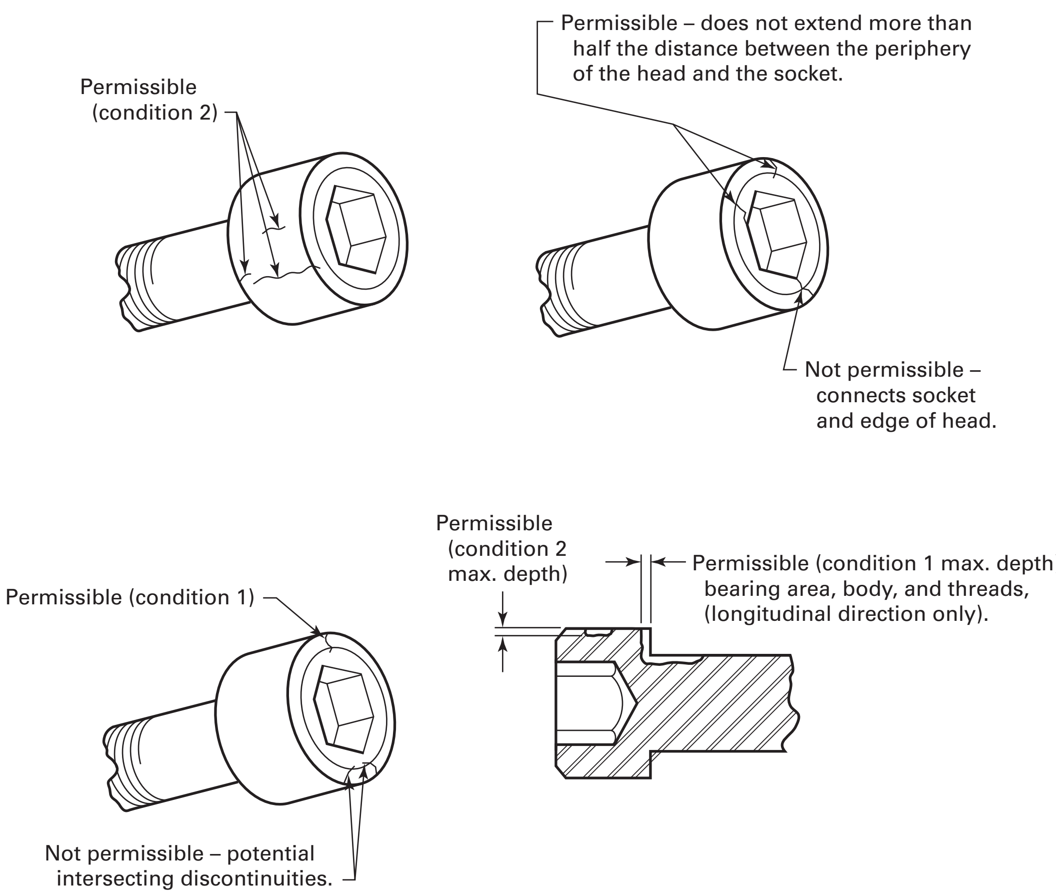

TABLE 1 DELETED

TABLE 2
TENSILE REQUIREMENTS
FOR COARSE THREAD SCREWS

Screw Dia (D), in.	Threads/ in.	Tensile Load, Min., lbf[A]	Stress Area, in.[2B]	Proof Load (Length Measurement Method), Min., lbf[C]
0.073	64	473	0.00263	368
0.086	56	666	0.00370	518
0.099	48	877	0.00487	682
0.112	40	1,090	0.00604	846
0.125	40	1,430	0.00796	1,110
0.138	32	1,640	0.00909	1,270
0.164	32	2,520	0.0140	1,960
0.190	24	3,150	0.0175	2,450
0.250	20	5,730	0.0318	4,450
0.3125	18	9,440	0.0524	7,340
0.375	16	13,900	0.0775	10,800
0.4375	14	19,100	0.1063	14,900
0.500	13	25,500	0.1419	19,900
0.625	11	38,400	0.226	30,500
0.750	10	56,800	0.334	45,100
0.875	9	78,500	0.462	62,400
1.000	8	103,000	0.606	81,800
1.125	7	129,000	0.763	103,000
1.250	7	165,000	0.969	131,000
1.375	6	196,000	1.155	156,000
1.500	6	239,000	1.405	190,000
1.750	5	323,000	1.90	256,000
2.000	$4\frac{1}{2}$	425,000	2.50	338,000
2.250	$4\frac{1}{2}$	552,000	3.25	439,000
2.500	4	680,000	4.00	540,000
2.750	4	838,000	4.93	666,000
3.000	4	1,010,000	5.97	806,000
3.250	4	1,210,000	7.10	958,000
3.500	4	1,420,000	8.33	1,120,000
3.750	4	1,640,000	9.66	1,300,000
4.000	4	1,880,000	11.08	1,500,000

NOTES:
[A] Values based on 180 ksi for 0.500 and smaller and 170 ksi for sizes larger than 0.500 in. and stress area in accordance with Footnote *B*.
[B] Stress areas based on Handbook H-28 (U.S. Department of Commerce) as follows:

$$A_s = 0.7854\,[D - (0.9743/n)]^2$$

where:

A_s = stress area,
D = nominal screw size, and
n = threads/in.

[C] Values based on 140 ksi for 0.500 and smaller and 135 ksi for sizes larger than 0.500 in. and stress area in accordance with Footnote *B*.

TABLE 3
TENSILE REQUIREMENTS
FOR FINE THREAD SCREWS

Screw Dia (D), in.	Threads/ in.	Tensile Load, min, Min., lbf[A]	Stress Area, in.[2B]	Proof Load (Length Measurement Method), Min., lbf[C]
0.060	80	324	0.00180	252
0.073	72	500	0.00278	389
0.086	64	709	0.00394	552
0.099	56	941	0.00523	732
0.112	48	1,190	0.00661	925
0.125	44	1,490	0.00830	1,160
0.138	40	1,830	0.01015	1,420
0.164	36	2,650	0.01474	2,060
0.190	32	3,600	0.0200	2,800
0.250	28	6,500	0.0364	5,100
0.3125	24	10,400	0.0580	8,120
0.375	24	15,800	0.0878	12,300
0.4375	20	21,400	0.1187	16,600
0.500	20	28,800	0.1599	22,400
0.625	18	43,500	0.256	34,600
0.750	16	63,400	0.373	50,400
0.875	14	86,500	0.509	68,700
1.000	12	113,000	0.663	89,500
1.125	12	146,000	0.856	116,000
1.250	12	182,000	1.073	145,000
1.375	12	224,000	1.315	178,000
1.500	12	269,000	1.581	213,000

NOTES:
[A] Values based on 180 ksi for 0.500 and smaller and 170 ksi for sizes larger than 0.500 in. and stress area in accordance with Footnote *B*.
[B] Stress areas based on H-28 as follows:

$$A_s = 0.7854\,[D - (0.9743/n)]^2$$

where:

A_s = stress area,
D = nominal screw size, and
n = threads/in.

[C] Values based on 140 ksi for 0.500 and smaller and 135 ksi for sizes larger than 0.500 in. and stress area in accordance with Footnote *B*.

TABLE 4
WEDGE TEST ANGLES

Screw Size, D, in.	Wedge Angle, Deg: Body Lengths 2D or Less or Threaded to the Head	Wedge Angle, Deg: Body Lengths Greater Than 2D
0.112 to 0.500, incl.	6	10
0.625 to 0.750, incl.	6	8
0.875 to 1.500, incl.	4	6

TABLE 5
DECARBURIZATION LIMITS

Threads/in.	Thread Height, h_s	0.75 h_s from Root to Crest, Min.	0.1 h_s at Root, Max.
48	0.013	0.010	0.001
44	0.014	0.011	0.001
40	0.015	0.011	0.002
36	0.017	0.013	0.002
32	0.019	0.014	0.002
28	0.022	0.017	0.002
24	0.026	0.020	0.003
20	0.031	0.023	0.003
18	0.034	0.026	0.003
16	0.038	0.029	0.004
14	0.044	0.033	0.004
13	0.047	0.035	0.005
12	0.051	0.038	0.005
11	0.056	0.042	0.006
10	0.061	0.046	0.006
9	0.068	0.051	0.007
8	0.077	0.058	0.008
7	0.088	0.066	0.009
6	0.102	0.077	0.010
5	0.123	0.092	0.012
4.5	0.136	0.102	0.014
4	0.153	0.115	0.015

SUPPLEMENTARY REQUIREMENTS

The following Supplementary Requirement shall apply only when specified by the purchaser in the contract or purchase order. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Specific Grade Chemical Compositions

S1.1 When Supplementary Requirement S1 is specified on the order, the chemical composition shall conform to one of the compositions in Table S1.1 at the option of the supplier, unless a specific composition (Grade) has been specified on the purchase order.

TABLE S1.1
CHEMICAL COMPOSITION

Grade Designation	4037	4042	4137	4140	4142	4145	4340	8740	5137M	51B37M
UNS Number	G40370	G40420	G41370	G41400	G41420	G41450	G43400	G87400	. . .	. . .
Carbon:										
Heat analysis	0.35–0.40	0.40–0.45	0.35–0.40	0.38–0.43	0.40–0.45	0.43–0.48	0.38–0.43	0.38–0.43	0.35–0.40	0.33–0.40
Product analysis	0.33–0.42	0.38–0.47	0.33–0.42	0.36–0.45	0.38–0.47	0.41–0.50	0.36–0.45	0.36–0.45	0.33–0.42	0.31–0.42
Manganese:										
Heat analysis	0.70–0.90	0.70–0.90	0.70–0.90	0.75–1.00	0.75–1.00	0.75–1.00	0.60–0.80	0.75–1.00	0.30–0.50	0.30–0.50
Product analysis	0.67–0.93	0.67–0.93	0.67–0.93	0.71–1.04	0.71–1.04	0.71–1.04	0.57–0.83	0.71–1.04	0.27–0.53	0.27–0.53
Phosphorus, max.:										
Heat analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Product analysis	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Sulfur, max.:										
Heat analysis	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Product analysis	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Silicon:										
Heat analysis	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35
Product analysis	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37
Nickel:										
Heat analysis	[A]	[A]	[A]	[A]	[A]	[A]	1.65–2.00	0.40–0.70	[A]	[A]
Product analysis	. . .	. . .	. . .	. . .	. . .	. . .	1.60–2.05	0.37–0.73	. . .	. . .
Chromium:										
Heat analysis	[A]	[A]	0.80–1.10	0.80–1.10	0.80–1.10	0.80–1.10	0.70–0.90	0.40–0.60	0.90–1.20	0.95–1.25
Product analysis	. . .	. . .	0.75–1.15	0.75–1.15	0.75–1.15	0.75–1.15	0.67–0.93	0.37–0.63	0.85–1.25	0.90–1.30
Molybdenum:										
Heat analysis	0.20–0.30	0.20–0.30	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25	0.20–0.30	0.20–0.30	[A]	[A]
Product analysis	0.18–0.32	0.18–0.32	0.13–0.27	0.13–0.27	0.13–0.27	0.13–0.27	0.18–0.32	0.18–0.32	. . .	. . .
Boron:										
Heat analysis	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	0.0005–0.003
Product analysis	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	[B]

NOTES:

[A] Elements shown with an "A" are not applicable to that grade designation.

[B] Boron is not subject to product analysis.

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SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED LOW-CARBON STEEL PIPE FOR THE CHEMICAL INDUSTRY

SA-587

(Identical with ASTM Specification A587-96(2005) except for the deletion of 1.5.)

Standard Specification for Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry

1. Scope

1.1 This specification covers electric-resistance-welded low-carbon steel pipe intended for use as process lines.

1.2 Pipe ordered under this specification shall be suitable for severe forming operations involving flanging in all sizes and bending to close radii up to and including NPS 4.

1.3 This specification covers NPS ½ through 10, plus additional sizes. The corresponding outside diameters and wall thicknesses for NPS ½ through 10 are listed in Table 1, as are the dimensions for the additional sizes.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 DELETED

2. Referenced Documents

2.1 *ASTM Standards:*

A53/A53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing

E309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

3. Ordering Information

3.1 Orders for material under this specification should include the following as required to describe the desired material adequately:

3.1.1 Quantity (feet or number of pieces),

3.1.2 Name of material (electric-resistance-welded steel pipe),

3.1.3 Size (NPS or outside diameter and wall thickness),

3.1.4 Length (definite cut length or random),

3.1.5 Test report required (see 14.2),

3.1.6 Specification number, and

3.1.7 Special requirements.

4. Materials and Manufacture

4.1 *Process*—The steel shall be aluminum killed steel made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 *Manufacture*—The pipe shall be made by electric resistance welding.

4.4 *Heat Treatment*—Pipe furnished in the as-welded condition shall be normalized at a temperature above the upper

TABLE 1 Tolerance for Outside Diameter and Wall Thickness

NPS Designator	Outside Diameter	Wall Thickness					
		Min	Nom	Max	Min	Nom	Max
				Inches			
—	0.8125 ± 0.004	0.095	0.103	0.111	0.129	0.140	0.151
½	0.840 ± 0.006	0.095	0.103	0.111	0.125	0.140	0.151
¾	1.050 ±0.006	0.099	0.108	0.117	0.135	0.147	0.159
—	1.0625 ± 0.006	0.099	0.108	0.117	0.135	0.147	0.159
—	1.3125 ± 0.006	0.116	0.126	0.136	0.157	0.171	0.185
1	1.315 ± 0.006	0.116	0.126	0.136	0.157	0.171	0.185
1¼	1.660 ± 0.007	0.121	0.132	0.143	0.167	0.182	0.197
—	1.875 ± 0.008	0.127	0.138	0.149	0.175	0.190	0.205
1½	1.900 ± 0.008	0.127	0.158	0.149	0.175	0.190	0.205
2	2.375 ± 0.010	0.135	0.147	0.159	0.191	0.208	0.225
3	3.500 ± 0.015	0.189	0.206	0.223	0.262	0.286	0.310
4	4.500 ± 0.017	0.207	0.226	0.245	0.295	0.322	0.349
6	6.625 ± .030	0.245	0.267	0.289	0.378	0.412	0.446
8	8.625 ± .040	0.282	0.308	0.334	0.438	0.478	0.518
10	10.750 ± .050	0.319	0.348	0.377	0.520	0.567	0.614
				Millimetres			
—	20.64 ± 0.10	2.41	2.62	2.82	3.28	3.56	3.84
½	21.30 ± 0.15	2.41	2.62	2.82	3.28	3.56	3.84
¾	26.70 ± 0.15	2.51	2.74	2.97	3.43	3.73	4.04
—	26.99 ± 0.15	2.51	2.74	2.97	3.43	3.73	4.04
—	33.34 ± 0.15	2.95	3.20	3.45	3.99	4.34	4.70
1	33.40 ± 0.15	2.95	3.20	3.45	3.99	4.34	4.70
1¼	42.16 ± 0.18	3.07	3.35	3.63	4.24	4.62	5.00
—	47.63 ± 0.20	3.22	3.51	3.78	4.45	4.83	5.21
1½	48.30 ± 0.020	3.22	3.51	3.78	4.45	4.83	5.21
2	60.33 ± 0.25	3.43	3.73	4.04	4.85	5.28	5.72
3	88.90 ± 0.38	4.80	5.23	5.66	6.66	7.26	7.87
4	114.30 ± 0.43	5.26	5.74	6.22	7.49	8.18	8.87
6	168.28 ± 0.76	6.22	9.32	7.34	9.60	10.47	11.33
8	219.08 ± 1.02	7.16	7.82	8.48	11.13	12.14	13.16
10	273.05 ± 1.27	8.10	8.84	9.58	13.21	14.40	15.60

critical temperature. Cold-drawn pipe shall be normalized after the final cold-draw pass.

5. Chemical Composition

5.1 *Heat Analysis*—An analysis of each heat of steel shall be made to determine the percentages of the elements specified. The chemical composition thus determined shall conform to the requirements specified in Table 2 and the chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

5.2 *Product Analysis*—When requested on the purchase order, a product analysis shall be made by the supplier from one pipe or coil of steel per heat. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Table 2.

5.3 *Retests*—If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or pipe shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise, all remaining material in the heat shall be rejected or, at the option of the producer, each length of flat-rolled stock or pipe may be individually tested for acceptance. Lengths of flat-rolled stock or pipe which do not meet the requirements of the specification shall be rejected.

5.4 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in Table 2 is not permitted.

TABLE 2 Chemical Composition Requirements

Element	Composition, %
Carbon, max	0.15
Manganese	0.27–0.63
Phosphorus, max	0.035
Sulfur, max	0.035
Aluminum	0.02–0.100

6. Mechanical Requirements

6.1 *Tensile Properties:*

6.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

6.1.2 The yield strength shall be determined by the drop of the beam, by the halt in the gauge of the testing machine, by the use of dividers, or by other approved methods. When a definite yield point is not exhibited, the yield strength corresponding to a permanent offset of 0.2 % of the gauge length of the specimen, or to a total extension of 0.5 % of the gauge length under load, shall be determined.

6.1.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. (19 mm) from the center of the gauge length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

TABLE 3 Tensile Requirements

Tensile strength, min, psi (MPa)	48 000 (331)
Yield strength, min, psi (MPa)	30 000 (207)
Elongation in 2 in. or 50 mm, min, %	40

6.2 *Flattening Test:*

6.2.1 A section of pipe not less than 4 in. (102 mm) in length shall be flattened cold between parallel plates in two steps. The weld shall be placed 90° from the direction of the applied force. During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 6.2.5, shall occur on the inside or outside surfaces until the distance between the plates is less than the value of H, calculated by the following equation:

$$H = \left[(1+e)t\right]/\left[e+t/D\right] \quad (1)$$

where:

H = distance between flattening plates, in.,
t = specified wall thickness of the pipe, in.,
D = specified outside diameter of the pipe, in., and
e = deformation per unit length (0.09 for low-carbon steel).

6.2.2 During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

6.2.3 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

6.2.4 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

6.2.5 When low D-to- t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

6.3 *Reverse Flattening Test*—A section 4 in. (102 mm) in length of pipe in sizes down to and including 13⁄16 in. (20.6 mm) in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

6.4 *Flange Test*—A section of pipe not less than 4 in. (102 mm) in length shall be capable of having a flange turned over at a right angle to the body of the pipe without cracking or showing flaws. This flange, as measured from the outside of the pipe, shall be not less than 1⁄8 in. (3.2 mm) nor more than 1⁄2 in. (12.7 mm). Within these limits, the width of the flange shall be not less than the percentages specified in Table 4.

7. Dimensions and Permissible Variations

7.1 *Permissible Variations in Outside Diameter and Wall Thickness*—The outside diameter and wall thickness variations shall not exceed the limits prescribed in Table 1.

TABLE 4 Flange Requirements

Outside Diameter of Pipe, in.	Width of Flange, % of OD
Over 3⁄4 to 21⁄2, incl	15
Over 21⁄2 to 33⁄4, incl	121⁄2
Over 33⁄4 to 41⁄2, incl	10
Over 41⁄2 to 65⁄8, incl	71⁄2
Over 65⁄8	5

7.2 *Permissible Variations in Straightness*—Each pipe shall be straight within 0.030 in. (0.76 mm) maximum deflection in any 3 ft (0.91 m) length to 8 NPS. For 8 NPS and above, pipe shall be straight within 0.060 in. (1.52 mm) maximum deflection in any 3 ft (0.91 m) length. Galvanized pipe shall be reasonably straight.

7.3 *Lengths:*

7.3.1 Pipe may be ordered in definite cut lengths or in random lengths as provided herein.

7.3.2 When ordered in definite cut lengths, the variation in length shall not exceed the amounts prescribed in Table 5.

7.3.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (4.9 to 6.7 m) with 5 % 12 to 16 ft (3.7 to 4.9 m), or in double random lengths with a minimum average of 35 ft (10.7 m) and a minimum length of 22 ft (6.7 m) with 5 % 16 to 22 ft (4.9 to 6.7 m).

8. Workmanship, Finish, and Appearance

8.1 The finished pipe shall be free of injurious defects and shall have a workman-like finish. Minor defects may be removed by grinding, provided the wall thickness is not reduced to less than the minimum thickness permitted for the ordered nominal wall thickness.

8.2 The pipe shall have smooth ends free of burrs and free of scale except that the pipe may have a superficial "blue" oxide film on the surfaces.

8.3 For NPS 1⁄2 to 11⁄2 inclusive, the inside diameter welding flash shall be removed so that the remaining flash does not exceed 0.006 in. (0.15 mm). For NPS over 11⁄2, the remaining inside diameter welding flash shall not exceed 0.010 in. (0.25 mm).

8.4 For all nominal sizes, the outside diameter welding flash shall be removed flush with the outside diameter contour.

8.5 Undercut flash must be smoothly blended into the pipe wall.

8.6 The intent of the flash conditions as prescribed in 8.3, 8.4, and 8.5 is to obtain a surface contour suitable for flanging.

9. Number of Tests

9.1 Two tensile tests as specified in 6.1 shall be made from each heat.

9.2 The flattening test as specified in 6.2 shall be made on two lengths of pipe from each lot of 250 lengths or fraction thereof.

TABLE 5 Permissible Variations in Length[A]

Outside Diameter, in.	Cut Length, in. (mm)	
	Over	Under
Under 2	1⁄8 (3.2)	0
2 and over	3⁄16 (4.8)	0

[A] These permissible variations in length apply to pipe before bending. They apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft, an additional over-tolerance of 1⁄8 in. for each 10 ft (3.0 m) or fraction thereof shall be permissible, up to a maximum of 1⁄2 in. (12.7 mm).

9.3 The reverse flattening test specified in 6.3 shall be made on 1 length of pipe from each lot of 250 lengths or fraction thereof.

9.4 The flange test as specified in 6.4 shall be made on specimens from 2 lengths of pipe from each lot of 250 lengths or fraction thereof.

10. Retests

10.1 If the results of the mechanical tests of any heat or lot do not conform to the requirements specified, retests may be made on additional pipe of double the original number from the same heat or lot, each of which shall conform to the requirements specified.

11. Retreatment

11.1 If a heat or lot fails to conform to the test requirements, that heat or lot may be reheat treated and resubmitted for tests. Not more than one reheat treatment shall be permitted.

12. Test Specimens and Methods of Testing

12.1 The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A370.

12.2 Test specimens shall be taken from the ends of finished pipe prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws.

12.3 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

13. Nondestructive Test

13.1 The nondestructive test shall be made instead of the hydrostatic test.

13.1.1 The test shall provide a 360° inspection for sizes up to and including 3½ in. (88.9 mm) outside diameter.

13.1.2 For pipe larger than 3½ in. (88.9 mm) outside diameter, nondestructive inspection of the weld and heat affected zone is required.

13.2 Each pipe shall be tested with a nondestructive test in accordance with Practices E213, E273, E309, or E570. Except as provided in 13.6.2, it is the intent of this test to reject pipe with imperfections that produce test signals equal to or greater than that of the calibration standard. In order to accommodate the various types of nondestructive testing equipment and techniques in use, and manufacturing practices employed, any one of the following calibration standards may be used, at the option of the producer, to establish a minimum sensitivity level for rejection:

13.3 For eddy-current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection. For welded pipe, they shall be placed in the weld if visible.

13.3.1 *Drilled Hole*—A hole not larger than 0.031 in. (0.79 mm) in diameter shall be drilled radially and completely through the pipe wall, taking care to avoid distortion of the pipe while drilling.

13.3.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. 6.4 mm diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe, preferably in the weld area. Said notch shall have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.10 mm), whichever is greater.

13.3.3 *Longitudinal Notch*—A notch 0.031 in. (0.79 mm) or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe, to a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

13.4 For ultrasonic testing, the longitudinal calibration reference notches shall be at the option of the producer, any one of the three common notch shapes shown in Practices E213 or E273. The depth of the notch shall not exceed 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater. For welded pipe, the notch shall be placed in the weld, if visible.

13.5 For flux leakage testing, each of the longitudinal calibration notches shall be a straight-sided notch not over 12½ % of the wall thickness in depth and not over 1.0 in. (25 mm) in length. Both outside diameter and inside diameter notches shall be placed in the tube located sufficiently apart to enable separation and identification of the signals.

13.6 Pipe producing a signal equal to or greater than the calibration defect shall be subject to rejection. The area producing the signal may be examined.

13.6.1 Test signals produced by imperfections that cannot be identified, or produced by cracks or crack-like defects shall result in rejection of the pipe subject to rework and retest.

13.6.2 Test signals produced by imperfections such as those listed below may be judged as injurious or noninjurious depending on visual observation or their severity or the type of signal they produce on the testing equipment used, or both:

13.6.2.1 Dinges,

13.6.2.2 Straightener marks,

13.6.2.3 Loose inside diameter bead and cutting chips,

13.6.2.4 Scratches,

13.6.2.5 Steel die stamps,

13.6.2.6 Chattered flash trim,

13.6.2.7 Stop marks, or

13.6.2.8 Tube reducer ripple.

13.6.3 Any imperfection of the above type exceeding 0.004 in. (0.102 mm) or 12½ % of the specified wall thickness (whichever is greater) in depth shall be considered injurious.

13.6.3.1 If the imperfection is judged as injurious, the pipe shall be rejected but may be reconditioned and retested providing the dimensional requirements are met.

13.6.3.2 If the imperfection is explored to the extent that it can be identified as noninjurious, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

14. Inspection

14.1 The inspector shall have entry at all times while work on an order is being done to all parts of the manufacturer's works that concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests and inspection shall be made prior to shipment.

14.2 When inspection at the place of manufacture has been waived by customer, the manufacturer shall furnish a statement that the material has been tested and has met all the requirements of this specification. A certificate or report shall be made available to customer when all the requirements of this specification have been met. When Supplementary Requirement S1 is furnished, certificates or reports furnished shall bear the notation "S-1."

15. Rejection

15.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

15.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

16. Product Marking

16.1 Each length of pipe NPS 1½ and larger shall be legibly marked by either stenciling or stenciling and light die marking. The die marking shall include the manufacturer's logo or symbol and the stenciling shall include the name or brand of the manufacturer, size, heat number, and the specification number. Such marking shall be applied starting within 8 in. (203 mm) of the end of each length.

16.2 For NPS under 1½ the markings prescribed in 16.1 may be applied to tags and securely attached to the bundle, bale, or other unit, prepared for shipment.

16.3 A tag shall be securely attached to each bundle of pipe shipped indicating the name of the manufacturer, size, wall thickness, length, and specification.

16.4 *Bar Coding*—In addition to the requirements in 16.1, 16.2, and 16.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

17. Packaging

17.1 The manufacturer, at his option, will box, crate, carton, or package in secured lifts, or bundle to ensure safe delivery. Special packaging requiring extra operations other than those normally used by the manufacturer must be specified on the order.

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below may be included in the purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirements details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Hydrostatic Testing

S1.1 Hydrostatic testing shall be in accordance with Specification A530/A530M. When this supplement is furnished the pipe shall be marked "S-1."

S2. Galvanizing

S2.1 Galvanizing shall be in accordance with Specification A53/A53M, except that the rate of application shall be 1.3 minimum to 1.7 maximum oz per f^2.

S3. Surface Coatings

S3.1 All surfaces shall be coated, the exterior with a hard drying lacquer, and the interior with a suitable rust inhibitor.

SPECIFICATION FOR HIGH-STRENGTH QUENCHED AND TEMPERED LOW-ALLOY STEEL FORGED FITTINGS AND PARTS FOR PRESSURE VESSELS

SA-592/SA-592M

(Identical with ASTM Specification A592/A592M-04(2009).)

SPECIFICATION FOR HIGH-STRENGTH QUENCHED AND TEMPERED LOW-ALLOY STEEL FORGED FITTINGS AND PARTS FOR PRESSURE VESSELS

SA-592/SA-592M

[Identical with ASTM Specification A 592/A 592M-04(2009).]

1. Scope

1.1 This specification covers high-strength quenched and tempered low-alloy steel forged fittings and parts for pressure vessels. The maximum thickness of forgings under this specification shall be $1\frac{1}{2}$ in. [38 mm] for Grade A, and 4 in. [100 mm] for Grades E and F.

NOTE 1— These grades are similar to corresponding grades in Specification A 517/A 517M.

1.2 Although no provision is made for supplementary requirements in this standard, the supplementary requirements in Specification A 788 may be considered by the purchaser.

1.3 Welding technique is of fundamental importance and it is presupposed that welding procedures will be in accordance with approved methods for the class of material used.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the standard; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 517/A 517M Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered

A 788 Specification for Steel Forgings, General Requirements

E 112 Test Methods for Determining the Average Grain Size

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order the following information:

3.1.1 A detailed drawing, a sketch, or written description of the forging.

3.1.2 The charpy impact test temperature if a test temperature lower than 32°F [0°C] is required.

3.1.3 Additional heat treatment cycles to be applied to the mechanical test specimens following removal from the heat-treated forging or special forged test block.

3.1.4 Required supplementary requirement(s) from specification A 788.

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements. Failure to comply with the requirements of Specification A 788 constitutes non-conformance with this specification.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Melting Process* — The steel shall be made in accordance with the Melting Process Section of Specification A 788.

4.2 *Grain Size* — The steel shall be fully killed, fine grained (ASTM No. 5 or finer), as determined in accordance with Test Methods E 112, Plate IV.

4.3 *Discard* — Sufficient discard shall be made from each ingot to ensure freedom from piping and excessive segregation.

4.4 The finished product shall be a hot-worked forging as defined by Specification A 788, and shall be forged as close as practicable to the finished shape and size.

5. Heat Treatment

5.1 After forging and before reheating, the forgings shall be cooled to provide substantially complete transformation of austenite. Heat treatment for properties shall consist of heating the forgings to not less than 1650°F [900°C], quenching in a liquid medium, and tempering at 1150°F [620°C] minimum, with a holding time of 1 h/in. [1 h/25 mm] minimum, but in no case less than $\frac{1}{2}$ h.

6. Chemical Requirements

6.1 *Heat Analysis* — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1.

6.2 *Product Analysis* — The purchaser may use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

7. Mechanical Requirements

7.1 The forgings as represented by tension tests shall conform to the requirements prescribed in Table 2, and to Table 3 for lateral expansion opposite the notch in Charpy V-notch impact tests. In addition, for the Charpy impact test, the values of energy absorption in foot-pounds [or joules] and the fracture appearance in percent shear shall be recorded and reported for information.

7.2 *Sampling:*

7.2.1 Samples for mechanical test specimens shall be removed after the quenching and tempering heat treatment. The purchaser shall specify any additional thermal treatments that shall be given to the heat treated test specimens. (This is intended to simulate subsequent thermal treatments which may be performed by the fabricator.)

7.2.2 Samples shall be removed so that the test specimens will have their major axes parallel to the direction of major working of the forging.

7.2.3 Test specimens may be machined from a production forging, or prolongation thereof, or from special forged blocks suitably worked and heat treated with the production forgings. Such special blocks shall be obtained from an ingot, slab, or billet from the same heat as the forgings they represent and shall be reduced by forging in a manner similar to that for the products to be represented. The forging reduction for a special test block shall not exceed the minimum forging reduction of the forgings represented, and its thickness shall not be less than the maximum thickness of the forgings represented. If a forging is tested, the tests must represent the maximum section thickness in the lot. All test specimens shall be located at the mid-plane of the thickness and, the mid length position of the gauge length ffoor tension test specimens, or the notch of the Charpy V-notch impact test specimens shall be at least *T* from any second surface of the production forging or test block, where T equals the maximum heat treated thickness of the forging.

7.3 *Number of Tests and Retests:*

7.3.1 *Number of Tests, and Test Temperature:*

7.3.1.1 One room-temperature tension test and one set of three Charpy V-notch specimens shall be made to represent the maximum section from each heat in each heat-treatment charge. Impact tests shall be conducted at the temperature specified on the order, but no higher than 32°F [0°C].

7.3.1.2 One grain size test shall be made from each heat.

7.3.2 *Retests of Tension Specimens* — If the results of tension tests do not conform to the requirements specified, retests are permitted, as outlined in Test Method A 370 and Specification A 788.

7.3.3 *Retests of Impact Specimens:*

7.3.3.1 If the lateral expansion value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm] and the average equals or exceeds 0.015 in. [0.38 mm], a retest of three additional specimens may be made. Each of the three retest specimens must equal or exceed the specified minimum value of 0.015 in. [0.38 mm].

7.4 *Test Methods* — Tension and impact tests shall be made in accordance with the latest issue of Test Methods and Definitions A 370.

8. Repair Welding

8.1 Repair welding of forgings may be permitted but onlyat the option of the purchaser. Such repair welds shall be made in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

9. Test Reports

9.1 The certification requirements of Specification A 788 shall apply.

10. Product Marking

10.1 Each forging shall be identified in accordance with the Marking Section of Specification A 788.

11. Keywords

11.1 high-strength low-alloy steel; fittings—steel; pressure vessel service; quenched and tempered steel; steel forgings—alloy

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A[A]	Grade E[A]	Grade F[A]
Carbon	0.15–0.21	0.12–0.20	0.10–0.20
Manganese	0.80–1.10	0.40–0.70	0.60–1.00
Phosphorus, max	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025
Silicon	0.40–0.80	0.20–0.35	0.15–0.35
Nickel	. . .	. . .	0.70–1.00
Chromium	0.50–0.80	1.40–2.00	0.40–0.65
Molybdenum	0.18–0.28	0.40–0.60	0.40–0.60
Vanadium	. . .	[B]	0.03–0.08
Titanium	. . .	0.04–0.10	. . .
Zirconium	0.05–0.15	. . .	. . .
Copper	. . .	0.20–0.40	0.15–0.50
Boron	0.0025 max	0.0015–0.005	0.002–0.006

[A] Similar to Specification A 517/A 517M Grades A, E, and F, respectively.
[B] May be substituted for part or all of titanium content on a one-for-one basis.

TABLE 2
TENSILE REQUIREMENTS

	Up to $2\frac{1}{2}$ in. [65 mm], incl	Over $2\frac{1}{2}$ in. to 4 in. [65 to 100 mm], incl
Tensile strength, psi (MPa)	115 000 to 135 000 [795 to 930]	105 000 to 135 000 [725 to 930]
Yield strength (0.2% offset), min, psi [MPa]	100 000 [690]	90 000 [620]
Elongation in 2 in. [50 mm], min, %	18	17
Reduction of area, min, %	45	40

TABLE 3
CHARPY IMPACT TEST REQUIREMENTS

All Grades and Thicknesses	15 mils (0.015 in.) [0.38 mm][A]

[A] Minimum value for each of three specimens. See 7.3.3.

SPECIFICATION FOR CASTINGS, CARBON, LOW-ALLOY, AND MARTENSITIC STAINLESS STEEL, ULTRASONIC EXAMINATION THEREOF

SA-609/SA-609M

(Identical with ASTM Specification A609/A609M-91(2007).)

SPECIFICATION FOR CASTINGS, CARBON, LOW-ALLOY, AND MARTENSITIC STAINLESS STEEL, ULTRASONIC EXAMINATION THEREOF

SA-609/SA-609M

[Identical with ASTM Specification A 609/A 609M-91(2007).]

1. Scope

1.1 This practice covers the standards and procedures for the pulse-echo ultrasonic examination of heat-treated carbon, low-alloy, and martensitic stainless steel castings by the longitudinal-beam technique.

1.2 This practice is to be used whenever the inquiry, contract, order, or specification states that castings are to be subjected to ultrasonic examination in accordance with Practice A 609/A 609M.

1.3 This practice contains two procedures for ultrasonic inspection of carbon, low-alloy, and martensitic stainless steel castings, that is, Procedure A and Procedure B. Procedure A is the original A 609/A 609M practice and requires calibration using a series of test blocks containing flat bottomed holes. It also provides supplementary requirements for angle beam testing. Procedure B requires calibration using a back wall reflection from a series of solid calibration blocks.

NOTE 1 — Ultrasonic examination and radiography are not directly comparable. This examination technique is intended to complement Guide E 94 in the detection of discontinuities.

1.4 The values stated in either inch–pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this practice.

1.5 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

E 94 Guide for Radiographic Testing

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments

2.2 *Other Document:*

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Ordering Information

3.1 The inquiry and order should specify which procedure is to be used. If a procedure is not specified, Procedure A shall be used.

3.2 *Procedure A — Flat-Bottomed Hole Calibration Procedure:*

3.2.1 When this practice is to be applied to an inquiry, contract, or order, the purchaser shall furnish the following information:

3.2.1.1 Quality levels for the entire casting or portions thereof.

3.2.1.2 Sections of castings requiring longitudinal-beam examination.

3.2.1.3 Sections of castings requiring dual element examination.

3.2.1.4 Sections of castings requiring supplementary examination, using the angle-beam procedure described in Supplementary Requirement S1 in order to achieve more complete examination.

3.2.1.5 Any requirements additional to the provisions of this practice.

3.3 *Procedure B: Back-Wall Reflection Calibration Procedure* — When this procedure is to be applied to an inquiry, contract, or order, the purchaser shall designate the quality levels for the entire casting or applicable portions.

PROCEDURE A — FLAT-BOTTOMED HOLE CALIBRATION PROCEDURE

4. Apparatus

4.1 *Electronic Apparatus:*

4.1.1 An ultrasonic, pulsed, reflection type of instrument that is capable of generating, receiving, and amplifying frequencies of at least 1 to 5 MHz.

4.1.2 The ultrasonic instrument shall provide linear presentation (within ±5%) for at least 75% of the screen height (sweep line to top of screen). Linearity shall be determined in accordance with Practice E 317 or equivalent electronic means.

4.1.3 The electronic apparatus shall contain a signal attenuator or calibrated gain control that shall be accurate over its useful range to ±10% of the nominal attenuation or gain ratio to allow measurement of signals beyond the linear range of the instrument.

4.2 *Search Units:*

4.2.1 *Longitudinal Wave,* internally grounded, having a $\frac{1}{2}$ to $1\frac{1}{8}$ in. [13 to 28 mm] diameter or 1 in. [25 mm] square piezo-electric elements. Based on the signals-to-noise ratio of the response pattern of the casting, a frequency in the range from 1 to 5 MHz shall be used. The background noise shall not exceed 25% of the distance amplitude correction curve (DAC). Transducers shall be utilized at their rated frequencies.

4.2.2 *Dual-Element,* 5 MHz, $\frac{1}{2}$ by 1 in. [13 by 25 mm], 12° included angle search units are recommended for sections 1 in. [25 mm] and under.

4.2.3 Other frequencies and sizes of search units may be used for evaluating and pinpointing indications.

4.3 *Reference Blocks:*

4.3.1 Reference blocks containing flat-bottom holes shall be used to establish test sensitivity in accordance with 8.2.

4.3.2 Reference blocks shall be made from cast steels that give an acoustic response similar to the castings being examined.

4.3.3 The design of reference blocks shall be in accordance with Fig. 1, and the basic set shall consist of those blocks listed in Table 1. When section thicknesses over 15 in. [380 mm] are to be inspected, an additional block of the maximum test thickness shall be made to supplement the basic set.

4.3.4 Machined blocks with $\frac{3}{32}$ in. [2.4 mm] diameter flat-bottom holes at depths from the entry surface of $\frac{1}{8}$ in. [3 mm], $\frac{1}{2}$ in. [13 mm], or $\frac{1}{2}t$ and $\frac{3}{4}$ in. [19 mm], or $\frac{3}{4}t$ (where t = thickness of the block) shall be used to establish the DAC for the dual-element search units (see Fig. 2).

4.3.5 Each reference block shall be permanently identified along the side of the block indicating the material and the block identification.

4.4 *Couplant* — A suitable couplant having good wetting characteristics shall be used between the search unit and examination surface. The same couplant shall be used for calibrations and examinations.

5. Personnel Requirements

5.1 The manufacturer shall be responsible for assigning qualified personnel to perform ultrasonic examination in conformance with the requirements of this practice.

5.2 Personnel performing ultrasonic examinations in accordance with this practice shall be familiar with the following:

5.2.1 Ultrasonic terminology.

5.2.2 Instrument calibration.

5.2.3 Effect of transducer material, size, frequency, and mode on test results.

5.2.4 Effect of material structure (grain size, cleanliness, etc.) on test results.

5.2.5 Effect of test distance on test results.

5.2.6 Effect of nonlinearity on test results.

5.2.7 Effect of thickness and orientation of discontinuities on test results.

5.2.8 Effect of surface roughness on test results.

5.3 A qualification record (see Note 2) of personnel considered suitable by the manufacturer to perform examinations in accordance with this practice shall be available upon request.

NOTE 2 — SNT-TC-1A, Ultrasonic Testing Method, provides a recommended procedure for qualifying personnel. Other personnel qualification requirement documents may be used when agreed upon between the purchaser and the supplier.

6. Casting Conditions

6.1 Castings shall receive at least an austenitizing heat treatment before being ultrasonically examined.

6.2 Test surfaces of castings shall be free of material that will interfere with the ultrasonic examination. They may be as cast, blasted, ground, or machined.

6.3 The ultrasonic examination shall be conducted prior to machining that prevents an effective examination of the casting.

7. Test Conditions

7.1 To assure complete coverage of the specified casting section, each pass of the search unit shall overlap by at least 10% of the width of the transducer.

7.2 The rate of scanning shall not exceed 6 in./s (150 mm/s).

7.3 The ultrasonic beam shall be introduced perpendicular to the examination surface.

8. Procedure

8.1 Adjust the instrument controls to position the first back reflection for the thickness to be tested at least one half of the distance across the cathode ray tube.

8.2 Using the set of reference blocks spanning the thickness of the casting being inspected, mark the flat-bottom hole indication height for each of the applicable blocks on the cathode ray tube shield. Draw a curve through these marks on the screen or on suitable graph paper. The maximum signal amplitude for the test blocks used shall peak at approximately three-fourths of the screen height above the sweep by use of the attenuator. This curve shall be referred to as the 100% distance amplitude correction (DAC) curve. If the attenuation of ultrasound in the casting thickness being examined is such that the system's dynamic range is exceeded, segmented DAC curves are permitted.

8.3 The casting examination surface will normally be rougher than that of the test blocks; consequently, employ a transfer mechanism to provide approximate compensation. In order to accomplish this, first select a region of the casting that has parallel walls and a surface condition representative of the rest of the casting as a transfer point. Next, select the test block whose overall length, *C* (Fig. 1), most closely matches the reflection amplitude through the block length. Place the search unit on the casting at the transfer point and adjust the instrument gain until the back reflection amplitude through the casting matches that through the test block. Using this transfer technique, the examination sensitivity in the casting may be expected to be within ±30% or less of that given by the test blocks.

8.4 Do not change those instrument controls and the test frequency set during calibration, except the attenuator, or calibrated gain control, during acceptance examination of a given thickness of the casting. Make a periodic calibration during the inspection by checking the amplitude of response from the $\frac{1}{4}$ in. (6.4 mm) diameter flat-bottom hole in the test block utilized for the transfer.

NOTE 3 — The attenuator or calibrated gain control may be used to change the signal amplitude during examination to permit small amplitude signals to be more readily detected. Signal evaluation is made by returning the attenuator or calibrated gain control to its original setting.

8.5 During examination of areas of the casting having parallel walls, recheck areas showing 75% or greater loss of back reflection to determine whether loss of back reflection is due to poor contact, insufficient couplant, misoriented discontinuity, etc. If the reason for loss of back reflection is not evident, consider the area questionable and further investigate.

9. Report

9.1 The manufacturer's report of final ultrasonic examination shall contain the following data and shall be furnished to the purchaser:

9.1.1 The total number, location, amplitude, and area when possible to delineate boundaries by monitoring the movement of the center of the search unit of all indications equal to or greater than 100% of the DAC.

9.1.2 Questionable areas from 8.5 that, upon further investigation, are determined to be caused by discontinuities.

9.1.3 The examination frequency, type of instrument, types of search units employed, couplant, manufacturer's identifying numbers, purchaser's order number, and data and authorized signature.

9.1.4 A sketch showing the physical outline of the casting, including dimensions of all areas not inspected due to geometric configuration, with the location and sizes of all indications in accordance with 9.1.1 and 9.1.2.

10. Acceptance Standards

10.1 This practice is intended for application to castings with a wide variety of sizes, shapes, compositions, melting processes, foundry practices, and applications. Therefore, it is impractical to specify an ultrasonic quality level that would be universally applicable to such a diversity of products. Ultrasonic acceptance or rejection criteria for individual castings should be based on a realistic appraisal of service requirements and the quality that can normally be obtained in production of the particular type of casting.

10.2 Acceptance quality levels shall be established between the purchaser and the manufacturer on the basis of one or more of the following criteria:

10.2.1 No indication equal to or greater than the DAC over an area specified for the applicable quality level of Table 2.

10.2.2 No reduction of back reflection of 75% or greater that has been determined to be caused by a discontinuity over an area specified for the applicable quality level of Table 2.

10.2.3 Indications producing a continuous response equal to or greater than the DAC with a dimension exceeding the maximum length shown for the applicable quality level shall be unacceptable.

10.2.4 Other criteria agreed upon between the purchaser and the manufacturer.

10.3 Other means may be used to establish the validity of a rejection based on ultrasonic inspection.

NOTE 4 — The areas for the ultrasonic quality levels in Table 2 of Practice A 609/A 609M refer to the surface area on the casting over which a continuous indication exceeding the DAC is maintained.

NOTE 5 — Areas are to be measured from dimensions of the movement of the search unit by outlining locations where the amplitude of the indication is 100% of the DAC or where the back reflection is reduced by 75%, using the center of the search unit as a reference point to establish the outline of the indication area.

NOTE 6 — In certain castings, because of very long metal path distances or curvature of the examination surfaces, the surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting; in such cases, other criteria that incorporate a consideration of beam angles or beam spread must be used for realistic evaluation of the discontinuity.

PROCEDURE B — BACK-WALL REFLECTION CALIBRATION PROCEDURE

11. Apparatus

11.1 Apparatus shall be kept on a regular six month maintenance cycle during which, as a minimum requirement, the vertical and horizontal linearities, sensitivity, and resolution shall be established in accordance with the requirements of Practice E 317.

11.2 *Search Units* — Ceramic element transducers not exceeding 1.25 in. [82 mm] diameter or 1 in.^{2} [25 mm^2] shall be used.

11.3 *Search Units Facing* — A soft urethane membrane or neoprene sheet, approximately 0.025 in. [0.64 mm] thick, may be used to improve coupling and minimize transducer wear caused by casting surface roughness.

11.4 *Calibration/Testing* — The same system, including the urethane membrane, used for calibration shall be used to inspect the casting.

11.5 *Other Inspections* — Other frequencies and type search units may be used for obtaining additional information and pinpointing of individual indications.

11.6 *Couplant* — A suitable liquid couplant, such as clean SAE 30 motor oil or similar commercial ultrasonic couplant, shall be used to couple the search unit to the test surface. Other couplants may be used when agreed upon between the purchaser and supplier.

11.7 *Reference Standards* — Reference standards in accordance with Fig. 3 shall be used to calibrate the instrument for inspecting machined and cast surfaces. Reference standards shall be flaw free and machined within tolerances indicated.

12. Ultrasonic Instrument

12.1 *Type* — Pulsed ultrasonic reflection instrument capable of generating, receiving, and amplifying frequencies of 1 MHz to 5 MHz shall be used for testing.

12.2 *Voltage* — Line voltage shall be suitably regulated by constant voltage equipment and metal housing must be grounded to prevent electric shock.

12.3 *Linearity* — The instrument must provide a linear presentation (within ±5%) of at least 1.5 in. [40 mm] sweep to peak (S/P).

12.4 *Calibrated Gain Control of Attenuator* — The instrument shall contain a calibrated gain control or signal attenuator (accurate within ±10%) which will allow indications beyond the linear range of the instrument to be measured.

12.5 *Time-Corrected Gain* — The instrument shall be equipped to compensate for signal decay with distance. A method should be available to equalize signal response at different depths.

13. Qualification

13.1 The requirements for pre-production qualification are as follows:

13.1.1 *Personnel* — The personnel qualification requirements of SNT-TC-1A are applicable. Other personnel qualification requirement documents may be used when agreed upon between the purchaser and the supplier. Records of all personnel shall be available to customers upon request.

13.1.2 *Equipment* — The equipment shall be capable of meeting the requirements in Section 12.

14. Preparation

14.1 *Time of Inspection* — The final ultrasonic acceptance inspection shall be performed after at least an austenitizing heat treatment and preferably after machining. In order to avoid time loss in production, acceptance inspection of cast surfaces may be done prior to machining. Machined surfaces shall be acceptance inspected as soon as possible after machining. Repair welds may be inspected before the postweld heat treatment.

14.2 *Surface Finish:*

14.2.1 *Machined Surfaces* — Machined surfaces subject to ultrasonic inspection shall have a finish that will produce an ultrasonic response equivalent to that obtained from a 250 μin. (6.3 μm) surface. The surface finish shall also permit adequate movement of search units along the surface.

14.2.2 *Casting Surfaces* — Casting surfaces to be ultrasonically inspected shall be suitable for the intended type and quality level (Tables 3 and 4) of inspection as judged acceptable by a qualified individual as specified in 13.1.1.

14.2.3 *Surface Condition* — All surfaces to be inspected shall be free of scale, machining or grinding particles, excessive paint thickness, dirt, or other foreign matter that may interfere with the inspection.

14.3 *Position of Casting* — The casting shall be positioned such that the inspector has free access to the back wall for the purpose of verifying change in contour.

15. Calibration

15.1 *Calibration Blocks* — Determine the thickness of the material to be ultrasonically inspected. For material thickness of 3 in. [75 mm] or less, use the series of 3 blocks, ½, 2, 5 in. [13, 50, 125 mm] (Fig. 3, B dimension) for calibration. For a material thickness greater than 3 in., use the series of 3 blocks, 2, 5, 10 in. [50, 125, 250 mm] (Fig. 3, B dimension) for calibration.

15.2 *Calibration of Search Units* — For the thickness of material to be inspected, as determined in 15.1, use the following search units:

15.2.1 For materials 3 in. [75 mm] or less in thickness, use a 2¼ MHz, ½ in. [13 mm] diameter search unit.

15.2.2 For material greater than 3 in. [75 mm] in thickness, use a 2¼ MHz, 1 in. [25 mm] diameter search unit.

15.3 *Calibration Procedure:*

15.3.1 Set the frequency selector as required. Set the reject control in the "OFF" position.

15.3.2 Position the search unit on the entrant surface of the block that completely encompasses the metal thickness to be inspected (Fig. 3) and adjust the sweep control such that the back reflection signal appears approximately, but not more than three-quarters along the sweep line from the initial pulse signal.

15.3.3 Position the search unit on the entrant surface of the smallest block of the series of 3 blocks selected for calibration and adjust the gain until the back reflection signal height (amplitude) is 1.5 in. [40 mm] sweep to peak (S/P). Draw a line on the cathode-ray screen (CRT), parallel to the sweep line, through the peak of the 1.5 in. (S/P) amplitude.

15.3.4 Position the search unit on the entrant surface of the largest block of the series of 3 blocks selected for calibration, and adjust the distance amplitude control to provide a back reflection signal height of 1.5 in. [40 mm] (S/P).

15.3.5 Position the search unit on the entrant surface of the intermediate calibration block of the series of 3 blocks being used for calibration and confirm that the back reflection signal height is approximately 1.5 in. [40 mm] (S/P). If it is not, obtain the best compromise between this block and the largest block of the series of 3 blocks being used for calibration.

15.3.6 Draw a line on the cathode ray tube screen parallel to the sweep line at 0.5 in. [13 mm] (S/P) amplitude. This will be the reference line for reporting discontinuity amplitudes.

15.3.7 For tests on *machined surfaces*, position the search unit on a machined surface of casting where the walls are reasonably parallel and adjust the gain of the instrument until the back reflection signal height is 1.5 in. [40 mm] (S/P). Increase the inspection sensitivity by a factor of three times (10 dB gain) with the calibrated attenuator. Surfaces that do not meet the requirements of 14.2.1 shall be inspected as specified in 15.3.8.

15.3.8 For inspections on *cast surfaces*, position the search unit on the casting to be inspected at a location where the walls are reasonably parallel and smooth (inside and outside diameter) and the surface condition is representative of the surface being inspected. Adjust the gain of the instrument until the back reflection signal height is 1.5 in. [40 mm] (S/P). Increase the inspection sensitivity by a factor of six times (16 dB) by use of the calibrated control or attenuator. A significant change in surface finish requires a compensating adjustment to the gain.

15.3.8.1 Rejectable indications on as-cast surfaces may be reevaluated by surface preparation to 250 μin. [6.3 μm] finish or better, and re-inspected in accordance with 15.3.7 of this practice.

15.3.8.2 It should be noted that some instruments are equipped with decibel calibrated gain controls, in which case the decibel required to increase the sensitivity must be added. Other instruments have decibel calibrated attenuators, in which case the required decibel must be removed. Still other instruments do not have calibrated gains or attenuators. They require external attenuators.

16. Scanning

16.1 *Grid Pattern* — The surface of the casting shall be laid out in a 12 by 12 in. [300 by 300 mm] or any similar grid pattern for guidance in scanning. Grid numbers shall be stenciled on the casting for record purposes and for grid area identity. The stenciled grid number shall appear in the upper right hand corner of the grid. When grids are laid out on the casting surface and they encompass different quality levels, each specific area shall be evaluated in accordance with the requirements of the specific quality level designated for that area.

16.2 *Overlap* — Scan over the surface allowing 10% minimum overlap of the working diameters of the search unit.

16.3 *Inspection Requirements* — All surfaces specified for ultrasonic (UT) shall be completely inspected from both sides, whenever both sides are accessible. The same search unit used for calibration shall be used to inspect the casting.

17. Additional Transducer Evaluation

17.1 Additional information regarding any ultrasonic indication may be obtained through the use of other frequency, type, and size search unit.

18. Acceptance Criteria

18.1 *Rejectable Conditions* — The locations of all indications having amplitudes greater than the 0.5 in. [13 mm] line given in 15.3.6, when amplitude three times (machined surfaces) or six times (cast surfaces) shall be marked on the casting surface. The boundary limits of the indication shall be determined by marking a sufficient number of marks on the casting surfaces where the ultrasonic signal equals one half the reference amplitude, 0.25 in. [6 mm]. To completely delineate the indication, draw a line around the outer boundary of the center of the number of marks to form the indication area. Draw a rectangle or other regular shape through the indication in order to form a polygon from which the area may be easily computed. It is not necessary that the ultrasonic signal exceed the amplitude reference line over the entire area. At some locations within the limits of the indication, the signal may be less than the reference line, but nevertheless still present such that it may be judged as a continuous, signal indication. Rejectable conditions are as follows and when any of the conditions listed below are found, the indications shall be removed and repair welded to the applicable process specification.

18.2 *Linear Indications* — A linear indication is defined as one having a length equal to or greater than three times its width. An amplitude of $\frac{1}{2}$ in. [13 mm], such as would result from tears or stringer type slag inclusion, shall be removed.

18.3 *Non-Linear Indications:*

18.3.1 *Isolated Indications* — Isolated indications shall not exceed the limits of the quality level designated by the customer's purchase order listed in Table 3. An isolated indication may be defined as one for which the distance between it and an adjacent indication is greater than the longest dimension of the larger of the adjacent indications.

18.3.2 *Clustered Indications* — Clustered indications shall be defined as two or more indications that are confined in a 1 in. [25 mm] cube. Clustered indications shall not exceed the limits of the quality level designated by the customer purchase order in Table 4. Where the distance between indications is less than the lowest dimension of the largest indication in the group, the cluster shall be repair welded.

18.3.3 The distance between two clusters must be greater than the lowest dimension of the largest indication in either cluster. If they are not, the cluster having the largest single indication shall be removed.

18.3.4 All indications, regardless of their surface areas as indicated by transducer movement on the casting surface and regardless of the quality level required, shall not have a through wall distance greater than $\frac{1}{3}T$, where T is the wall thickness in the area containing the indication.

18.3.5 Repair welding of cluster-type indications need only be the extent necessary to meet the applicable quality level for that particular area. All other types of rejectable indications shall be completely removed.

18.3.6 Repair welds of castings shall meet the quality level designated for that particular area of the casting.

18.3.7 Any location that has a 75% or greater loss in back reflection and exceeds the area of the applicable quality level, and whose indication amplitudes may or may not exceed the 0.5 in. [13 mm] rejection line, shall be rejected unless the reason for the loss in back reflection can be resolved as not being caused by an indication. If gain is added and back echo is achieved without indication percent amplitude exceeding the 0.5 in. [13 mm] rejection line, the area should be accepted.

19. Records

19.1 *Stenciling* — Each casting shall be permanently stenciled to locate inspection zones or grid pattern for ease in locating areas where rejectable indications were observed.

19.2 *Sketch* — A report showing the exact depth and surface location in relation to the stencil numbers shall be made for each rejectable indicator found during each inspection.

19.2.1 The sketch shall also include, but not be limited to, the following:

19.2.1.1 Part identification numbers.

19.2.1.2 Purchase order numbers.

19.2.1.3 Type and size of supplemental transducers used.

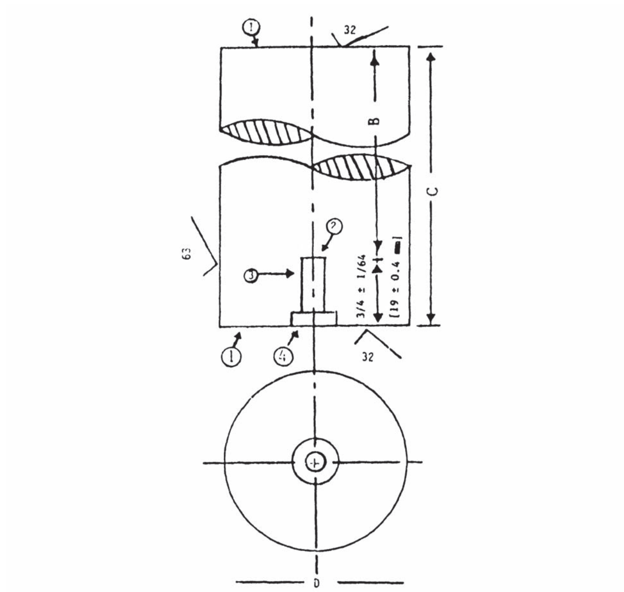
19.2.1.4 Name of inspector.

19.2.1.5 Date of inspection.

20. Product Marking

20.1 Any rejectable areas (those indications exceeding the limits of Section 19) shall be marked on the casting as the inspection progresses. The point of marking shall be the center of the search unit.

FIG. 1 ULTRASONIC STANDARD REFERENCE BLOCK



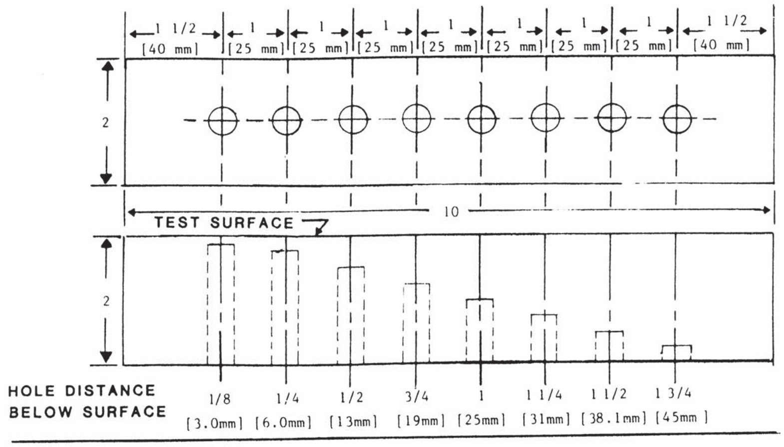
NOTE 1—Opposite ends of reference block shall be flat and parallel within 0.001 in. [0.025 mm].

NOTE 2—Bottom of flat-bottom hole shall be flat within 0.002-in. [0.051 mm] and the finished diameter shall be ¼ + 0.002 in. [6.4 + 0.050 mm].

NOTE 3—Hole shall be straight and perpendicular to entry surface within 0°, 30 min and located within 1⁄32 in. [0.80 mm] of longitudinal axis.

NOTE 4—Counter bore shall be ½ in. [15.0 mm] diameter by ⅛ in. [5 mm] deep.

FIG. 2 ULTRASONIC STANDARD REFERENCE BLOCK FOR DUAL-SEARCH UNIT CALIBRATION



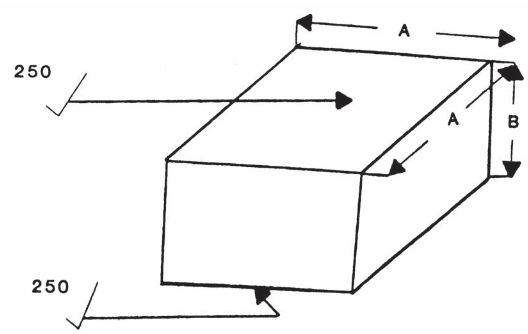
NOTE 1—Entrant surface shall be 250 µin. [6.3 µm] or finer.

NOTE 2— The 3⁄32-in. [2.4 mm] flat-bottom hole must be flat within 0.002 in. [0.05 mm]. Diameter must be within +0.005 in. [0.13 mm] of the required diameter. Hole axis must be perpendicular to the block and within an angle of 0°, 30 min.

NOTE 3—Hole shall be plugged following checking for ultrasonic response.

in.	[mm]	in.	[mm]
1⁄8	[3]	1 1⁄4	[32]
1⁄4	[6]	1 1⁄2	[38]
1⁄2	[13]	1 3⁄4	[44]
3⁄4	[19.0]	2	[50]
1	[25]	10	[254]

FIG. 3 CALIBRATION BLOCKS

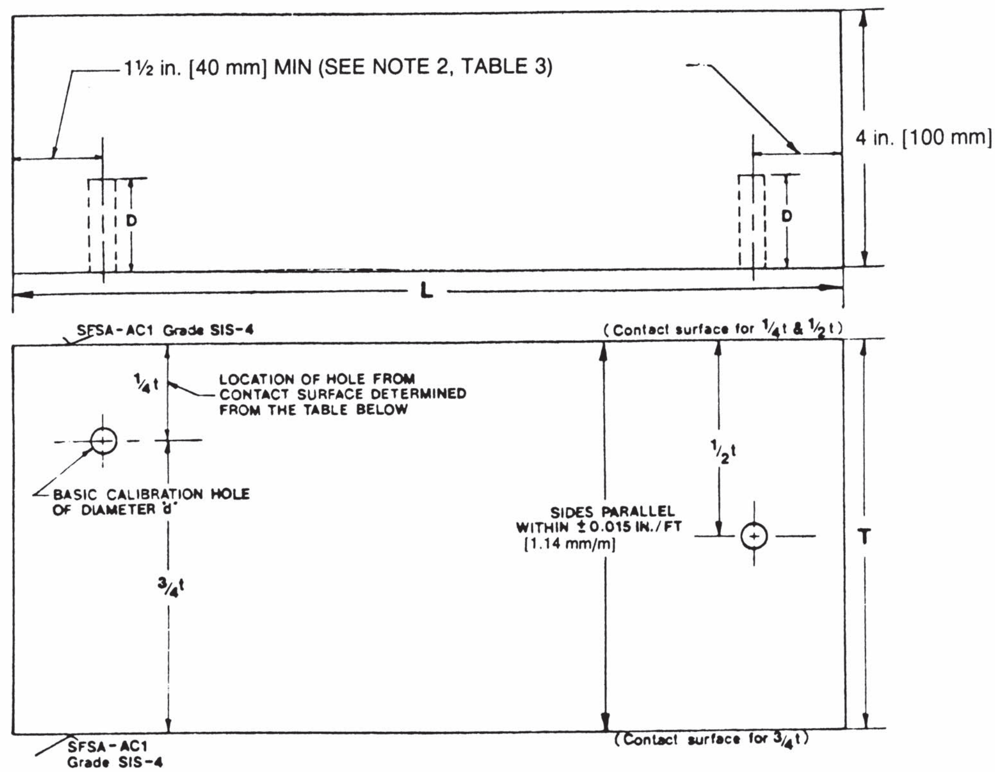


Dimensions, in. [mm]		Material
2 [50]	1⁄2 [13]	Specification A 217/A 217M, Grade WC6 or acoustically similar within ±20 % or 2 dB.
2 [50]	2 [50]	
3 [75]	5 [125]	
6 [150]	10 [250]	

Tolerance

All sides to be flat within 0.0002 in. [0.01 mm] and parallel with 0.001 in. [0.03 mm].

FIG. 4 BASIC CALIBRATION BLOCK FOR ANGLE BEAM EXAMINATION



L = length of block determined by the angle of search unit and the vee-path used,
T = thickness of basic calibration block (see Table 5),
D = depth of side-drilled hole (see Table 5),
d = diameter of side-drilled hole (see Table 5),
t = nominal production material thickness.

TABLE 1
DIMENSIONS AND IDENTIFICATION OF REFERENCE BLOCKS IN THE BASIC SET (SEE FIG. 1)

Hole Diameter in $^1/_{64}$ths, in. [mm]	Metal Distance (*B*), in.[A] [mm]	Overall Length (*C*), in.[A] [mm]	Width or Diameter (*D*), min, in. [mm]	Block Identification Number
16 [0.70]	1 [25]	$1^3/_4$ [45]	2 [50]	16-0100
16 [0.70]	2 [50]	$2^3/_4$ [70]	2 [50]	16-0200
16 [0.70]	3 [75]	$3^3/_4$ [95]	2 [50]	16-0300
16 [0.70]	6 [150]	$6^3/_4$ [170]	3 [75]	16-0600
16 [0.70]	10 [255]	$10^3/_4$ [275]	4 [100]	16-1000
16 [0.70]	B	B + $^3/_4$ [B + 20]	5 [125]	16-B00[B]

[A] Tolerance ± $^1/_8$ in. [3 mm].
[B] Additional supplemental blocks for testing thickness greater than 10 in. [250 mm], see 4.3.3.

TABLE 2
REJECTION LEVEL

Ultrasonic Testing Quality Level	Area, in.^{2} [cm^2] (see 10.2.1 and 10.2.2)	Length, max, in. [mm]
1	0.8 [5]	1.5 [40]
2	1.5 [20]	2.2 [55]
3	3 [20]	3.0 [75]
4	5 [30]	3.9 [100]
5	8 [50]	4.8 [120]
6	12 [80]	6.0 [150]
7	16 [100]	6.9 [175]

NOTE 1 — The areas in the table refer to the surface area on the casting over which a continuous indication exceeding the amplitude reference line or a continuous loss of back reflection of 75% or greater is maintained.
NOTE 2 — Areas shall be measured from the center of the search unit.
NOTE 3 — In certain castings, because of very long test distances or curvature of the test surface, the casting surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting; in such cases a graphic plot that incorporates a consideration of beam spread should be used for realistic evaluation of the discontinuity.

TABLE 3
ACCEPTANCE CRITERIA FOR SINGLE ISOLATED INDICATIONS

Quality Level	Maximum Non-Linear Indication, Area, in.^{2} [cm^2]	Position of Indication
1	0	E
2	1 [6]	E
3	1 [6]	O
	2 [13]	C
4	3 [19]	E
5	3 [19]	O
	5 [32]	C
6	5 [32]	E
7	5 [32]	O
	7 [45]	C
8	7 [45]	E
9	7 [45]	O
	9 [58]	C
10	9 [58]	E
11	9 [58]	O
	11 [71]	C

NOTES:
(*1*) The area measured by movement of the center of the transducer over the casting surface.
(*2*) O = outer wall $\frac{1}{3}$, or inner wall $\frac{1}{3}$.
C = mid wall $\frac{1}{3}$.
E = entire wall.

TABLE 4
ACCEPTANCE CRITERIA FOR CLUSTERED INDICATIONS

Quality Level	Cumulative Area of Indications, in.^{2} [cm^2]^{A,B}	Minimum Area in Which Indications Must be Dispersed, in.^{2} [cm^2]^{C}
1	0	0
2–3	2 [13]	36 [232]
4–5	4 [26]	36 [232]
6–7	6 [39]	36 [232]
8–9	8 [52]	36 [232]
10–11	10 [64]	36 [232]

^{A} Regardless of wall location, that is midwall $\frac{1}{3}$, innermost $\frac{1}{3}$, or outermost $\frac{1}{3}$.
^{B} Each indication that equals or exceeds the 0.5 in. [18 mm] reference line shall be traced to the position where the indication is equal to 0.25 in. [6 mm]. The area of the location, for the purpose of this evaluation, shall be considered the area that is confined within the outline established by the center of the transducer during tracing of the flaw as required. Whenever no discernible surface tracing is possible, each indication which equals or exceeds the 0.5 in. reference amplitude shall be considered 0.15 in.^{2} [1 cm^2] (three times the area of the $\frac{1}{4}$ diameter [6 mm] flat bottomed hole to compensate for reflectivity degradation of natural flaw) for the cumulative area estimates.
^{C} The indications within a cluster with the cumulative areas traced shall be dispersed in a minimum surface area of the casting equal to 36 in.^{2} [230 cm^2]. If the cumulative areas traced are confined with a smaller area of distribution, the area shall be repair welded to the extent necessary to meet the applicable quality level.

TABLE 5
DIMENSIONS OF CALIBRATION BLOCKS FOR ANGLE-BEAM EXAMINATION

Nominal Production Material Thickness (t), in. [mm]	Basic Calibration Block Thickness (T), in. [mm]	Hole Diameter (d), in 1.002 [mm ± 0.05]	Minimum Depth (D), in. [mm]
Up to 1 [25] incl	1 [25] or t	$\frac{3}{32}$ [2.4]	$1\frac{1}{2}$ [40]
Over 1 to 2 [25–50]	2 [50] or t	$\frac{1}{8}$ [3.2]	$1\frac{1}{2}$ [40]
Over 2 to 4 [50–100]	4 [100] or t	$\frac{3}{16}$ [4.8]	$1\frac{1}{2}$ [40]
Over 4 to 6 [100–150]	6 [150] or t	$\frac{1}{4}$ [6.3]	$1\frac{1}{2}$ [40]
Over 6 to 8 [150–200]	8 [200] or t	$\frac{5}{16}$ [7.9]	$1\frac{1}{2}$ [40]
Over 8 to 10 [200–250]	10 [250] or t	$\frac{3}{8}$ [9.5]	$1\frac{1}{2}$ [40]
Over 10 [250]	t	See Note 1	$1\frac{1}{2}$ [40]

NOTE 1 — For each increase in thickness of 2 in. [50 mm], or a fraction thereof, the hole diameter shall increase $\frac{1}{16}$ in. [1.6 mm].
NOTE 2 — For block sizes over 3 in. [75 mm] in thickness, T, the distance from the hole to the end of the block shall be $\frac{1}{2}$ T, min, to prevent coincident reflections from the hole and the corner. Block fabricated with a 2 in. [50 mm] minimum dimension need not be modified if the corner and hole indications can be easily resolved.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall be applied only when agreed upon between the purchaser and the supplier to achieve an effective examination of a critical casting area that cannot be effectively examined using a longitudinal beam as a result of casting design or possible discontinuity orientation.

S1. Angle Beam Examination of Steel Castings

S1.1 *Equipment:*

S1.1.1 *Examination Instrument* — Examination shall be conducted with an ultrasonic, pulsed-reflection type of system generating frequencies of at least 0.4 to 5 MHz. Properties of the electronic apparatus shall be the same as those specified in 4.1.

S1.1.2 *Search Units* — Angle-beam search units shall produce an angle beam in steel in the range from 30 to 75° inclusive, measured to the perpendicular of the entry surface of the casting being examined. It is preferred that search units shall have frequency of 0.4 to 5 MHz.

S1.1.3 *Calibration Blocks* — A set of blocks, as shown in Fig. 4, with as cast surface equivalent to SCRATA Comparator A3 and of a thickness comparable to the sections being examined with side-drilled holes at $\frac{1}{4}t$, $\frac{1}{2}t$, and $\frac{3}{4}t$ (where t = thickness of the block) shall be used to establish an amplitude reference line (ARL).

S1.2 *Calibration of Equipment:*

S1.2.1 Construct the distance amplitude correction curve by utilizing the responses from the side-drilled holes in the basic calibration block for angle beam examination as shown in Fig. 4 and Table 5.

S1.2.1.1 Resolve and mark the amplitudes of the $\frac{1}{4}t$ and $\frac{1}{2}t$ side-drilled holes from the same surface. The side-drilled hole used for the $\frac{1}{4}t$ amplitude may be used to establish the $\frac{3}{4}t$ amplitude from the opposite surface or a separate hole may be used.

S1.2.1.2 Connect the $\frac{1}{4}t$, $\frac{1}{2}t$, and $\frac{3}{4}t$ amplitudes to establish the applicable DAC.

S1.2.2 The basic calibration blocks shall be made of material that is acoustically similar to the casting being examined.

S1.2.3 Do not use basic calibration blocks with as cast surface equivalent to SCRATA Comparator A3 to examine castings with surface rougher than SCRATA Comparator A3. Use a machined calibration block for machined surfaces.

S1.2.4 The search unit and all instrument control settings remain unchanged except the attenuator or calibrated gain control.

S1.2.4.1 The attenuator or calibrated gain control may be used to change the signal amplitude during examination to permit small amplitude signals to be more readily detected. Signal evaluation is made by returning the attenuator or calibrated gain control to its original setting.

S1.3 *Data Reporting* — The supplier's report of final ultrasonic examination shall contain the following data:

S1.3.1 The total number, location, amplitude, and area of all indications equal to or greater than 100% of the distance amplitude curve.

S1.3.2 The examination frequency, type of instrument, type, and size of search units employed, couplant, transfer method, examination operator, supplier's identifying numbers, purchase order number, date, and authorized signature.

S1.3.3 A sketch showing the physical outline of the casting, including dimensions of all areas not examined due to geometric configuration, with the location of all indications in accordance with S1.3.1.

S1.4 *Acceptance Standards* — Acceptance quality levels shall be established between the purchaser and the manufacturer on the basis of one or more of the following criteria:

S1.4.1 No indication equal to or greater than the DAC over an area specified for the applicable quality level of Table 2.

S1.4.2 Other criteria agreed upon between the purchaser and the manufacturer.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, HIGH STRENGTH, FOR MODERATE AND LOWER TEMPERATURE SERVICE

SA-612/SA-612M

(Identical with ASTM Specification A612/A612M-12(2019).)

Standard Specification for Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service

1. Scope

1.1 This specification covers killed carbon-manganese-silicon steel plates intended for welded pressure vessels in service at moderate and lower temperatures.

1.2 The maximum thickness of plates supplied under this specification is 1 in. [25 mm].

1.3 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A20/A20M apply.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this product specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A20/A20M.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 Plates are normally supplied in the as-rolled condition. Plates may be ordered normalized or stress relieved, or both.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition given in Table 1 unless otherwise

TABLE 1 Chemical Requirements

Elements	Composition, %
Carbon, max:[A]	
Heat analysis	0.25
Product analysis	0.29
Manganese[A]	
Heat analysis	1.00–1.50
Product analysis	0.92–1.62
Phosphorus, max[B]	0.025
Sulfur, max[B]	0.025
Silicon	
Heat analysis	0.15–0.50
Product analysis	0.13–0.55
Copper, max:[C]	
Heat analysis	0.35
Product analysis	0.38
Nickel, max:[C]	
Heat analysis	0.25
Product analysis	0.28
Chromium, max:[C]	
Heat analysis	0.25
Product analysis	0.29
Molybdenum, max:[C]	
Heat analysis	0.08
Product analysis	0.09
Vanadium, max:[C]	
Heat analysis	0.08
Product analysis	0.09

[A] For each reduction of 0.01 percentage point below the specified carbon maximum, an increase of 0.06 percentage point manganese above the specified maximum is permitted up to a maximum of 1.65 % for heat analysis (1.70 % for product analysis).
[B] Applies to both heat and product analyses.
[C] When analysis shows that the amount of an element is 0.02 % or lower, the value may be reported as ≤0.02 %.

TABLE 2 Tensile Requirements

	Thickness	
	0.5 in [12.5 mm] and Under	Over 0.5 in. to 1 in. [Over 12.5 to 25 mm]
Tensile strength, ksi [MPa]	83–105 [570–725]	81–101 [560–695]
Yield strength, min,[A] ksi [MPa]	50 [345]	50 [345]
Elongation in 8 in. [200 mm], min, %[B]	16	16
Elongation in 2 in. [50 mm], min, %[B]	22	22

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[B] See Specification A20/A20M for elongation adjustments.

modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Properties

7.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 carbon steel; steel plates for pressure vessels; lower temperature service; high strength steel plates

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR PRECIPITATION HARDENING IRON BASE SUPERALLOY BARS, FORGINGS, AND FORGING STOCK FOR HIGH-TEMPERATURE SERVICE

SA-638/SA-638M

(Identical with ASTM Specification A638/A638M-00(2004) except for an editorial correction in 6.2.)

SPECIFICATION FOR PRECIPITATION HARDENING IRON BASE SUPERALLOY BARS, FORGINGS, AND FORGING STOCK FOR HIGH-TEMPERATURE SERVICE

SA-638/SA-638M

[Identical with ASTM Specification A 638/A 638M-00(2004) except for an editorial correction in 6.2.]

1. Scope

1.1 This specification covers hot-finished or cold-finished precipitation hardening iron base superalloy bars, forgings, and forging stock for high-temperature service. The mechanical properties of these alloys are developed by suitable solution treating and precipitation hardening treatments.

1.2 Two grades of iron base alloy are covered. Selection will depend upon design, service conditions, mechanical properties, and elevated temperature characteristics.

1.3 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 Unless the order specifies an "M" designation, the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

3.1.1 Quantity (weight or number of pieces).

3.1.2 Name of material (precipitation hardening iron base superalloy).

3.1.3 Form (bars, forgings, and forging stock).

3.1.4 Dimensions (in the case of rough or finished forgings the order shall be accompanied by a print or drawing or otherwise adequately described as to the shape and dimension).

3.1.5 Grade designation (Table 1).

3.1.6 Condition (Section 5).

3.1.7 Finish (Section 3).

3.1.8 Mechanical requirements (Section 8).

3.1.9 ASTM designation.

3.1.10 Special requirements.

4. General Requirements

4.1 In addition to the requirements of this specification, all requirements of the current edition of Specification A 484/A 484M shall apply. Failure to comply with the general requirements of Specification A 484/A 484M constitutes nonconformance with this specification.

5. Condition

5.1 The product forms covered in this specification may be furnished in one of the following conditions:

5.1.1 Hot-finished.

5.1.2 Solution treated (Grade 660 only — Type 1 or Type 2 solution treatment as specified).

5.1.3 Solution and precipitation treated (Grade 660 only — Type 1 or Type 2 solution treatment as specified), or

5.1.4 Other as specified.

6. Heat Treatment

6.1 Samples cut from bars, forgings, or a sample forged from the forging stock shall conform to the mechanical properties of Tables 1 and 2 when heat treated as prescribed in Table 3.

6.2 When a sample cut from the forging stock and heat treated as prescribed in Table 3 conforms to the properties in Tables 1 and 2, it shall be accepted as equivalent to a forged coupon.

7. Chemical Composition

7.1 The steel shall conform to the requirements for chemical composition specified in Table 4.

7.2 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751, except that for remelt material, product analysis tolerances may be used to determine conformance to this specification.

7.3 For referee purposes, Test Methods E 30 shall be used.

7.4 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Definitions A 751, except that for remelt material, product analysis tolerances may be used to determine conformance to this specification.

8. Mechanical Properties

8.1 The material shall conform to the mechanical property requirements specified in Table 1 after heat treatment as described in Table 3.

8.2 The material shall meet the requirements as to stress-rupture properties specified in Table 2 at the test temperature indicated after heat treatment as described in Table 3.

8.3 When specified in the ordering information (3.1.8), material may be ordered without stress-rupture testing. Material not stress-rupture tested shall be permanently stamped NR (See Section 10).

9. Metallurgical Properties

9.1 When specified, the grain size shall be 1 or finer.

10. Product Marking

10.1 Unless otherwise specified on the purchase order, each bundle shall be properly tagged with metal tags showing the purchase order number, heat number, name of alloy (or grade), *"NR" when material has not been stress-rupture tested,* specification number, and size.

10.1.1 Bars 1 in. [25 mm] and over in diameter, or 1 in. [25 mm] and over in thickness between parallel sides, shall be stamped with the heat number, *and if not stress-rupture tested, with the letters "NR"* within approximately 2 in. [50 mm] of one end. Smaller sizes shall be boxed or bundled and identified with metal tags as described in 10.1.

10.1.2 Forgings shall be identified as agreed upon between the seller and the purchaser.

11. Keywords

11.1 precipitation hardening superalloy steel; superalloy steel bars; superalloy steel billets; superalloy steel forgings; temperature service applications – high

TABLE 1
MECHANICAL PROPERTY REQUIREMENTS

	Grade 660	Grade 662 (bars)	Grade 662 (forgings)[A]
Heat treatment[B]	solution + precipitation harden	solution + precipitation harden	solution + precipitation harden
Tensile strength, min:			
psi	130 000	130 000	125 000
[MPa]	[895]	[895]	[860]
Yield strength (0.2% offset), min:			
psi	85 000	85 000	80 000
[MPa]	[585]	[585]	[550]
Elongation in 4D min, %	15	15	15
Reduction of area min, %	18	18	18
Brinell hardness	248 min	248 min	248 min

[A] The elongation of tensile specimens machined tangentially from near the center of large disk forgings over 50 in.^{2} [320 cm^2] in cross section may be as low as 10%. The reduction of area may be as low as 12%.
[B] Refer to Table 3 of heat treatment.

TABLE 2
STRESS-RUPTURE REQUIREMENTS

		Test Temperature		Stress			
Grade	Heat Treatment[A]	°F	[°C]	psi	[MPa]	Minimum Hours[B]	Minimum Elongation, %
660	solution + precipitation harden	1200	[650]	65 000	[450]	23	3
662	solution + precipitation harden	1200	[650]	60 000	[415]	15	3

[A] Refer to Table 2 for details of heat treatment.
[B] Test specimens meeting minimum requirements may be overloaded to produce rupture in a reasonable and practical time period.

TABLE 3
HEAT TREATMENT

Grade	Solution Treatment	Precipitation Hardening Treatment[A]
660	Type 1 1650 ± 25°F [900 ± 15°C], hold 2 h, oil or water quench	1300 to 1400°F [705 to 760°C], hold 16 h, air cool or furnace cool
660	Type 2 1800 ± 25°F [980 ± 15°C], hold 1 h, oil or water quench	1300 to 1400°F [705 to 760°C], hold 16 h, air cool or furnace cool
662	1750 to 1900°F [955 to 1040°C], hold 1 h, min, oil or water quench	1250 to 1400°F [675 to 760°C], hold 5 h, min, slow cooling in 5 h, min to 1200 ± 15°F [650 ± 10°C], hold 20 h, min, air cool or furnace cool

[A] Times refer to the minimum time material is required to be at temperature.

TABLE 4
CHEMICAL REQUIREMENTS

	Grade 660 (UNS S66286)[A]		Grade 662 (UNS S66220)[A]	
	Ladle Analysis Range, %	Check Analysis Over or Under	Ladle Analysis Range, %	Check Analysis Over or Under
Carbon	0.08 max	0.01 over	0.08 max	0.01 over
Manganese	2.00 max	0.04 over	1.50 max	0.04
Silicon	1.00 max	0.05 over	1.00 max	0.05
Phosphorus	0.040 max	0.005 over	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over	0.030 max	0.005 over
Chromium	13.50–16.00	0.20	12.00–15.00	0.15
Nickel	24.00–27.00	0.20	24.00–28.00	0.20
Molybdenum	1.00–1.50	0.05	2.50–3.50	0.10
Titanium	1.90–2.35	0.05	1.55–2.00	0.05
Copper	. . .	. . .	0.50 max	0.03 over
Aluminum	0.35 max	0.05 over	0.35 max	0.05 over
Vanadium	0.10–0.50	0.03	. . .	. . .
Boron	0.0010–0.010	0.0004 under 0.001 over	0.0010–0.010	0.0004 under 0.001 over

[A] New designation established in accordance with Practice E 527 and SAE J1086.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, 5% AND 5½% NICKEL ALLOY STEELS, SPECIALLY HEAT TREATED

SA-645/SA-645M

(Identical with ASTM Specification A645/A645M-10(2016).)

Standard Specification for Pressure Vessel Plates, 5 % and 5½ % Nickel Alloy Steels, Specially Heat Treated

1. Scope

1.1 This specification covers specially heat treated 5 % and 5 ½ % nickel alloy steel plates intended primarily for welded pressure vessels for service at low or cryogenic temperatures.

1.2 The maximum thickness of plates which can be supplied under this specification is limited only by the capacity of the material to meet the specified requirements.

1.3 This material is susceptible to magnetization. Use of magnets in handling after heat treatment should be avoided if residual magnetism would be detrimental to subsequent fabrication or service.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirements of Specification A20/A20M.

5. Heat Treatment

5.1 Grade A plates shall be heat treated in accordance with 5.2. Grade B plates shall be heat treated in accordance with 5.3. Shell plates and other parts, including heads and reinforcing pads that are heated above 1125°F [605°C] for forming, shall be heat treated after forming,

5.2 *Grade A, Procedure and Sequence:*

5.2.1 *Hardening*—The plates shall be heated to a temperature within the range from 1575 to 1675°F [855 to 915°C], held within that temperature range for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and then water-quenched to below 300°F [150°C].

5.2.2 *Intermediate Heat Treatment*—The plates shall be reheated to a temperature within the range from 1275 to

1400°F [690 to 760°C], held within that temperature range for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and then water-quenched to below 300°F [150°C].

5.2.3 *Tempering*—The plates shall be reheated to a temperature within the range from 1150 to 1225°F [620 to 665°C], held within that temperature range for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and then water-quenched or air cooled to below 300°F [150°C].

5.3 *Grade B, Procedure and Sequence:*

5.3.1 *Hardening*—The plates shall be heated to a temperature within the range from 1470 to 1600°F [800 to 870°C], held within that temperature range for a sufficient time to obtain uniform temperature throughout the plate thickness, and then quenched in a liquid medium.

5.3.2 *Intermediate Heat Treatment*—The plates shall be reheated to a temperature within the range from 1200 to 1330°F [650 to 720°C], held within that temperature range for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and then water-quenched to below 300°F [150°C] for nominal plate thicknesses over ⅝ in. [16 mm], or cooled in air or water-quenched to below 300°F [150°C] for nominal plate thicknesses of ⅝ in. [16 mm] and under.

5.3.3 *Tempering*—The plates shall be reheated to a temperature within the range from 1020 to 1150°F [550 to 620°C], held within that temperature range for a minimum of 30 min/in. [1.2 min/mm] of thickness, but in no case less than 15 min, and then water-quenched to below 300°F [150°C].

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Requirements

7.1 *Tension Tests*—The plates as represented by the tension test specimens shall conform to the requirements given in Table 2.

7.1.1 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½ in. [40 mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

7.2 *Impact Tests:*

7.2.1 Charpy V-notch tests shall be made in accordance with the general requirements of Specification A20/A20M.

7.2.2 The longitudinal axis of the test specimens shall be transverse to the final direction of rolling of the plate.

7.2.3 Unless otherwise agreed, the plates shall be impact tested at the following temperatures:

7.2.3.1 Grade A: –220°F [–140°C].

7.2.3.2 Grade B: –320°F [–195°C].

7.2.4 Each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

7.2.5 The values of energy absorption in foot-pounds-force [joules] and the fracture appearance in percent shear shall be recorded and reported for information.

8. Keywords

8.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

TABLE 1 Chemical Requirements

Element	Composition, %	
	Grade A	Grade B
Carbon, max		
Heat Analysis	0.13	0.13
Produce Analysis	0.15	0.15
Manganese		
Heat Analysis	0.30–0.60	0.90–1.50
Product Analysis	0.25–0.66	0.84–1.59
Phosphorus, max		
Heat Analysis	0.025	0.020
Product Analysis	0.025	0.025
Sulfur, max		
Heat Analysis	0.025	0.010
Product Analysis	0.025	0.015
Silicon		
Heat Analysis	0.20–0.40	0.15–0.30[A]
Product Analysis	0.18–0.45	0.13–0.33[A]
Nickel		
Heat Analysis	4.8–5.2	5.0–6.0
Product Analysis	4.7–5.3	4.9–6.1
Chromium		
Heat Analysis	...	0.10–1.00
Product Analysis	...	0.06–1.05
Molybdenum		
Heat Analysis	0.20–0.35	0.10–0.30
Product Analysis	0.17–0.38	0.09–0.33
Aluminum, total		
Heat Analysis	0.02–0.12	0.02–0.05
Product Analysis	0.01–0.16	0.015–0.06
Nitrogen, max		
Heat Analysis	0.020	0.010
Product Analysis	0.025	0.010

[A] The specified minimum limit does not apply if the total aluminum is 0.030 % or more, ore if the acid soluble aluminum content is 0.025 % or more.

TABLE 2 Tensile Requirements

	Grade A	Grade B
Yield strength, min, ksi [MPa][A]	65 [450]	85 [590]
Tensile strength, ksi [MPa]	95–115 [655 to 795]	100–120 [690–830]
Elongation in 2 in. [50 mm], min, %[B]	20.0	20

[A] At 0.2 % offset, or, if agreed between the purchaser and the manufacturer, at 0.5 % extension under load.

[B] See Specification A20/A20M for elongation adjustment.

SUPPLEMENTARY REQUIREMENTS

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Supplementary requirements shall not apply unless specified in the order. Those which are considered suitable for use with this specification are listed below by title. Others enumerated in Specification A20/A20M may be used with this specification subject to agreement by the supplier.

S1. Vacuum Treatment,

S2. Product Analysis,

S6. Drop-Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below are additional supplementary requirements which are considered suitable for use with this specification.

S64. Longitudinal Charpy Impact Energy Absorption Requirement

S64.1 When required, the purchaser may specify longitudinal Charpy V-notch impact testing to energy-absorption acceptance criteria.

S64.2 Tests shall be conducted in accordance with the general requirements of Specification A20/A20M.

S64.3 The longitudinal Charpy V-notch impact properties shall not be less than those shown in Table S1.1.

S64.4 The impact values obtained on subsize specimens shall not be less than the values listed in Table S1.1.

TABLE S1.1 Charpy Impact Requirements for Longitudinal Specimens

Size of Specimen, mm	Charpy V-notch Impact Value Required for Acceptance (Average of Three Specimens), ft·lbf [J]	Minimum Charpy V-notch Impact Value Without Requiring Retest (One Specimen Only of a Set), ft·lbf [J]
10 by 10	25 [34]	20 [27]
10 by 7.5	19 [26]	16 [22]
10 by 6.67	17 [23]	13 [18]
10 by 5.0	13 [18]	10 [14]
10 by 3.33	8 [11]	7 [10]
10 by 2.50	6 [8]	5 [7]

S65. Transverse Charpy Impact Energy Absorption Requirement

S65.1 When required, the purchaser may specify transverse Charpy V-notch impact testing to energy-absorption acceptance criteria.

S65.2 Tests shall be conducted in accordance with the general requirements of Specification A20/A20M.

S65.3 The transverse Charpy V-notch impact properties shall not be less than those shown in Table S2.1.

S65.4 The impact values obtained on subsize specimens shall not be less than the values listed in Table S2.1.

TABLE S2.1 Charpy Impact Requirements for Transverse Specimens

Size of Specimen, mm	Charpy V-notch Impact Value Required for Acceptance (Average of Three Specimens), ft·lbf [J]	Minimum Charpy V-notch Impact Value Without Requiring Retest (One Specimen Only of a Set), ft·lbf [J]
10 by 10	20 [27]	16 [22]
10 by 7.5	15 [20]	12 [16]
10 by 6.6	13 [18]	10 [14]
10 by 5.0	10 [14]	8 [11]
10 by 3.33	7 [10]	5 [7]
10 by 2.50	5 [7]	4 [5]

SPECIFICATION FOR FORGED STEEL ROLLS, USED FOR CORRUGATING PAPER MACHINERY

SA-649/SA-649M

(Identical with ASTM Specification A649/A649M-04.)

SPECIFICATION FOR FORGED STEEL ROLLS USED FOR CORRUGATING PAPER MACHINERY

SA-649/SA-649M

(Identical with ASTM Specification A 649/A 649M-04)

1. Scope

1.1 This specification covers two kinds of rolls used in machinery for producing corrugated paperboard. Rolls are fabricated of forged bodies and trunnions. The trunnions may be bolted or shrink assembled on one or both ends of the body. A seal weld may be made at the body/trunnion interface. Roll shells are made of carbon/manganese, or low alloy steel as hereinafter described, and are heat treated prior to assembly. Pressure rolls are surface hardened. Provision is made in Supplementary Requirement S1 for the optional surface hardening of corrugating rolls.

1.2 Corrugating and pressure rolls made to this specification shall not exceed 30 in. [760 mm] in inside diameter. The wall thickness of the roll body shall not be less than $\frac{1}{12}$ of the inside diameter or 1 in. [25 mm], whichever is greater, but shall not exceed 4 in. [100 mm]. The wall thickness of the corrugating roll is measured at the bottom of the corrugations in the location of the trunnion fit. The maximum design temperature (MDT) of the roll is 600°F [315°C] and the maximum allowable working pressure (MAWP) is 250 psi [1.7 MPa]. The minimum design temperature shall be 40°F [4°C] for roll wall thicknesses up to 3 in. [75 mm]. For roll wall thicknesses over 3 in. [75 mm] to 4 in. [100 mm], the minimum design temperature shall be 120°F [50°C]. The maximum stresses on the roll bodies from the combined internal and external loading are limited to 18 750 psi [129 MPa] for the Class 2 pressure roll bodies, and 20 000 psi [138 MPa] for Class 1A, 1B, or 5 pressure or corrugating roll bodies in Grades 1 or 2. For the trunnions, the maximum stresses from the combined internal and external loading are limited to 15 000 psi [103.4 MPa] for Classes 3 or 4, or 20 000 psi [138 MPa] for Classes 1A, 1B, or 5 in Grade 2 only. The Grade 1 strength level is not permissible for trunnions.

1.3 Referring to Table 1, material to Classes 1A, 1B, or 5 shall be used for the manufacture of corrugating or pressure roll shells, and Class 2 shall be used only for pressure roll shells. Trunnions shall be made from forgings in Classes 1A, 1B, or 5 in Grade 2 strength level as restricted by Footnote B in Table 2 or in forgings in either Class 3 or 4.

1.4 The values stated in either inch-pound units or SI [metric] units are to be regarded separately as standards. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

1.6 Except as specifically required in this standard, all of the provisions of Specification A 788 apply.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 788 Specification for Steel Forgings, General Requirements

E 165 Practice for Liquid Penetrant Examination

3. Ordering Information

3.1 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations and additional supplementary requirements.

3.2 In addition to the ordering requirements of Specification A 788, the purchaser shall include the maximum design temperature (MDT), if lower than 600°F [315 °C], and the maximum allowable working pressure (MAWP), if lower than 250 psi [1.7 MPa] as allowed in 1.2 of the Scope.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, then the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Forging Process:*

4.1.1 Roll body forgings may be made as solid forgings and subsequently bored.

4.1.2 Trunnions or gudgeons which are to be subsequently assembled to form the roll shall be made as a solid forging or where practical upset from segments cut from billets or bars.

4.2 *Heat Treatment:*

4.2.1 *Heat Treatment for Mechanical Properties (Requirements do not apply to surface treatment):*

4.2.1.1 *Machining* — The forged roll body shall have all surfaces rough machined, including boring, prior to heat treatment for mechanical properties.

4.2.1.2 Roll bodies shall be normalized, liquid quenched, and tempered to produce the required mechanical properties, except that for Class 2 forgings, and when Grade 2 strength requirements are specified, a normalize and temper heat treatment may be applied.

4.2.1.3 The trunnions shall be normalized and tempered or annealed to produce the required mechanical properties.

4.2.2 *Surface Hardening of Pressure Roll Forgings* — The working face of pressure rolls shall be surface hardened either before or after fitting the trunnions, at the manufacturer's option.

4.3 *Assembly and Weld* — Except for integrally forged or bolted-on trunnions, the assembly shall be made by shrink fitting trunnions into the prepared body ends. If used, welding of the trunnion to the roll body is restricted to a $\frac{3}{8}$ in. [9.5 mm] max. seal weld, made with low hydrogen materials. A minimum preheat of 400°F [205°C] and a minimum post weld heat treatment of 850°F [455°C] for 8 h shall be used. The maximum post weld heat treatment shall be not higher than t – 50°F [t – 28°C] where t is the final tempering temperature. All welds shall be machined or ground for the final magnetic particle or liquid penetrant examination.

5. Chemical Composition

5.1 The steel shall conform to the requirements for chemical composition prescribed in Table 1.

6. Mechanical Properties

6.1 *Tensile Requirements:*

6.1.1 The material shall conform to the requirements for tensile properties prescribed in Table 2 when tested in accordance with Test Methods and Definitions A 370. Tension test specimens shall be the standard round $\frac{1}{2}$ in. [12.5 mm] diameter, 2 in. [50 mm] gage length. The yield strength prescribed in Table 2 shall be determined by the 0.2% offset method.

6.1.1.1 Tests for acceptance shall be made after the heat treatment of the forgings, for mechanical properties in accordance with 4.2.1.

6.1.2 *Number, Location, and Orientation of Test Specimens:*

6.1.2.1 *Roll Body Forgings* — A full-size prolongation shall be provided on a roll body forging representing each heat of steel in each heat-treatment furnace charge. One longitudinal tension test specimen shall be taken from the prolongation and the axis of the specimen shall be located midway between the inner and outer surfaces of the wall body.

6.1.2.2 *Trunnions* — Test material shall be provided from each heat of steel in each heat-treatment furnace charge. One longitudinal tension specimen shall be taken from each test piece and the axis of the specimen shall be located at any point midway between the center and surface of the solid forging.

6.2 *Hardness:*

6.2.1 Roll body forgings shall have a Brinell hardness from 352 HB to 415 HB (Grade 1) or 207 HB to 285 HB (Grade 2). No less than three hardness determinations shall be made on each roll. The hardness readings are to be taken on the outside of the roll bodies using care to prepare locations for tests that are free of decarburization but not so deep as to affect the usefulness of the material.

6.2.2 The surface hardened pressure roll body forgings shall have a hardness of 58 HRC to 65 HRC or equivalent. No less than three hardness determinations shall be made on each roll. The hardness depth shall not exceed $\frac{1}{4}$ [6 mm].

7. Retreatment

7.1 If the results of the mechanical tests of any forging do not conform to the specified requirements, the manufacturer may retreat the forging one or more times, but not more than three additional times without approval of the purchaser.

8. Magnetic Particle Examination

8.1 The entire surface of the roll, including the seal weld area, shall be examined by either a wet continuous method in accordance with Test Method A 275/A 275M or by a liquid penetrant method in accordance with Practice E 165 after machining or grinding. The use of prods in the magnetic particle method is not permitted.

8.2 Only indications with major dimensions greater than $\frac{1}{8}$ in [3.2 mm] are considered relevant.

8.3 *Acceptance Standards* — The following relevant indications are unacceptable:

8.3.1 Any linear indications greater than $\frac{3}{16}$ in. [4.8 mm] long.

8.3.2 Rounded indications greater than $\frac{3}{16}$ in. [4.8 mm].

8.3.3 Four or more indications in a line separated by $\frac{1}{16}$ in. [1.6 mm] or less edge to edge.

8.3.4 Ten or more indications in any 6 in.^{2} [38.71 cm^2] of surface.

9. Hydrostatic Testing

9.1 The machined roll assembly shall be hydrostatic tested at $1\frac{1}{2}$ times the maximum allowable working pressure (MAWP). The MAWP pressure shall be furnished by the purchaser.

9.2 The recommended minimum hydrostatic test temperature is 70°F [21°C].

10. Marking, Packaging, and Loading

10.1 In addition to the marking requirements of Specification A 788, the MDT and the MAWP shall be included together with any required application code marking.

10.2 Packaging and loading shall be done so that the forging is not damaged during shipment to the purchaser.

11. Keywords

11.1 internal pressure; machinery—corrugating; roll assembly—forged; rolls—corrugating; rolls—pressure; steel forgings—alloy; steel forgings—carbon; steel rolls; surface-hardened; trunnions—bolted; trunnions—shrink-fitted

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %					
	Class 1A	Class 1B	Class 2	Class 3	Class 4	Class 5
Carbon	0.45–0.60	0.40–0.60	0.55 max	0.35 max	0.35 max	0.50–0.60
Manganese	0.55–1.05	0.60–0.95	0.50–0.90	0.40–0.70	0.60–1.05	0.90–1.50
Phosphorus	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max
Sulfur	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max
Silicon (A)	0.15–0.35	0.15–0.35	0.15–0.35 max	0.15–0.35	0.15–0.35 max	0.15–0.35
Nickel	. . .	1.55–2.00	. . .	. . .	. . .	0.60 max
Chromium	0.80–1.15	0.65–0.95	. . .	0.80–1.15	. . .	0.30 max
Molybdenum	0.15–0.50	0.20–0.45	. . .	0.15–0.25	. . .	0.15 max

NOTE:
(A) When vacuum carbon deoxidation (VCD) is used the silicon content shall be 0.10% maximum.

TABLE 2
TENSILE REQUIREMENTS

Class	Grade	Yield Strength, min (A)		Tensile Strength, min		Elongation in 2 in. or 50 mm, %, min	Reduction of Area, %, min
		ksi	MPa	ksi	MPa		
1A, 1B or 5	1	130	890	150	1030	12.0	30
1A, 1B or 5	2 (B)	65	450	100	690	14.0	30
2	. . .	37.5	260	75	515	20.0	50.0
3 or 4	. . .	30	205	60	415	22.0	55

NOTES:
(A) 0.2% offset.
(B) For trunnion application, a maximum tensile strength of 125 ksi [860 MPa] applies for Grade 2 of Classes 1A, 1B, or 5.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser on the order and agreed to by the manufacturer:

S1. Surface-Hardened Corrugating Rolls

S1.1 After all surfaces have been machined, the outer surface of the corrugating rolls may be surface-hardened to a surface hardness of Rockwell 53 HRC to 65 HRC. The depth of hardness shall not exceed $\frac{3}{8}$ in. [9.5 mm]. A minimum of three hardness determinations shall be made on the surface. Additional hardness tests shall be made to establish the depth of hardness. The hardened surface shall be magnetic particle tested (see Section 8).

S2. Notch Toughness

S2.1 For applications where minimum notch toughness limits are required, impact testing shall be specified for both roll bodies and trunnions. The following requirements shall be specified:

S2.1.1 Type of impact specimen and test standard (for example, ASTM Test Methods and Definitions A 370 specimen Type A or B).

S2.1.2 Minimum value for absorbed energy or lateral expansion.

S2.1.3 Test temperature.

S2.1.4 Frequency of testing.

S2.2 Trunnion and pressure rolls may be liquid quenched and tempered instead of the heat treatments specified in 4.2 when impact testing is required.

SPECIFICATION FOR HOT-ROLLED STRUCTURAL STEEL, HIGH-STRENGTH LOW-ALLOY PLATE WITH IMPROVED FORMABILITY

SA-656/SA-656M

(23)

(Identical with ASTM Specification A656/A656M-18.)

Specification for Hot-Rolled Structural Steel, High-Strength Low-Alloy Plate with Improved Formability

1. Scope

1.1 This specification covers three types and five strength grades of high-strength low-alloy, hot-rolled structural steel plate for use in truck frames, brackets, crane booms, rail cars, and similar applications. Steels that conform to this specification offer improved formability. These steels are normally furnished in the as-rolled condition. The type and strength grade furnished is as agreed upon between the manufacturer and the purchaser. The types and strength grades are shown in the tables.

1.2 The maximum thickness of plates shall be as follows:

Grade	Plate Thickness, max, in. [mm]
50	2 [50]
60	1½ [40]
70	1 [25]
80	1 [25]
100	½ [13]

1.3 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A6/A6M apply.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

3. General Requirements for Delivery

3.1 Plates furnished under this specification shall conform to the requirements of the current edition of Specification A6/A6M, for the specific plate ordered, unless a conflict exists, in which case this specification shall prevail.

3.2 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from a coil. The processor directly controls, or is responsible for, the operations involved in the processing of a coil into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, two test results are to be reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A6/A6M.

4. Materials and Manufacture

4.1 The steel shall be made to fine grain practice.

5. Chemical Composition

5.1 Heat analyses shall conform to the chemical requirements given in Table 1. Dependent upon thickness, grade, and intended application, variations in the chemical composition are permitted within the limits given in Table 1 for the applicable type. Where it is of particular importance, the manufacturer should be consulted for specific chemical composition.

5.2 *Product Analysis*—If a product analysis is made, it shall conform to the requirements given in Table 1, subject to the product analysis tolerances of Specification A6/A6M.

TABLE 1 Chemical Requirements

NOTE 1—An ellipsis (. . .) indicates that element is not defined for that Type.

Elements	Composition, %		
	Type 3	Type 7	Type 8
Carbon, max^{A}	0.18	0.18	0.18
Manganese, max^{A}	1.65	1.65	1.65
Phosphorus, max	0.025	0.025	0.025
Sulfur, max	0.030	0.030	0.030
Silicon, max	0.60	0.60	0.60
Vanadium, max	0.08	0.15^{B}	0.15^{C}
Nitrogen, max	0.030	0.030	0.030
Columbium (niobium)^{D}	0.008–0.10	0.10 max^{B}	0.10 max^{C}
Titanium, max	. . .	. . .	0.15^{C}

^{A} For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage points above the specified maximum for manganese is permitted, up to a maximum of 1.75 % for Grades 50, 60, and 70 [345, 415, and 485 MPa]; up to a maximum of 1.90 % for Grade 80 [550]; and up to a maximum of 2.10 % for Grade 100 [690].
^{B} The contents of columbium (niobium) and vanadium shall additionally be in accordance with one of the following:
Columbium (niobium) 0.008–0.10 % with vanadium <0.008 %;
Columbium (niobium) <0.008 % with vanadium 0.008–0.15 %; or
Columbium (niobium) 0.008–0.10 % with vanadium 0.008–0.15 % and columbium (niobium) plus vanadium not in excess of 0.20 %.
^{C} The sum of columbium (niobium), vanadium, and titanium shall be between 0.008 and 0.20 %.
^{D} Columbium and niobium are interchangeable names for the same element.

TABLE 2 Tensile Requirements^{A}

	Grade 50 [345]	Grade 60 [415]	Grade 70 [485]	Grade 80 [550]	Grade 100 [690]
Yield point, min, ksi [MPa]	50 [345]	60 [415]	70 [485]	80 [550]	100 [690]
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]	80 [550]	90 [620]	110 [760]
Elongation in 8 in. [200 mm], min, %	20^{B}	17^{B}	14^{B}	12^{B}	12^{B}
Elongation in 2 in. [50 mm], min, %	23^{B}	20^{B}	17^{B}	15^{B}	15^{B}

^{A} See Specimen Orientation under the Tension Tests section of Specification A6/A6M.
^{B} For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points for Grade 50 [345] and three percentage points for Grades 60, 70, 80, and 100 [415, 485, 550, and 690]. See Elongation Requirement Adjustments in the Tension Tests section of Specification A6/A6M.

5.3 Where steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X3 of Specification A6/A6M for information on weldability.

5.4 Unless specifically ordered, the type is at the discretion of the producer.

6. Mechanical Properties

6.1 *Tensile Properties:*

6.1.1 The plates as represented by the test specimens shall conform to the requirements given in Table 2.

7. Keywords

7.1 high-strength low-alloy steel; steel plates; structural applications

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SPECIFICATION FOR CENTRIFUGALLY CAST CARBON STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

SA-660

(Identical with ASTM Specification A660-96(2010).)

Standard Specification for Centrifugally Cast Carbon Steel Pipe for High-Temperature Service

1. Scope

1.1 This specification covers carbon steel pipe made by the centrifugal casting process intended for use in high-temperature, high-pressure service. Pipe ordered under this specification shall be suitable for fusion welding, bending, and other forming operations.

1.2 Several grades of carbon steels are covered. Their compositions are given in Table 1.

1.3 Supplementary requirements (S1 to S9) of an optional nature are provided. The supplementary requirements call for additional tests to be made, and when desired shall be so stated in the order, together with the number of such tests required.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E94 Guide for Radiographic Examination

E114 Practice for Ultrasonic Pulse-Echo Straight-Beam Contact Testing

E125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings

E142 Method for Controlling Quality of Radiographic Testing

E186 Reference Radiographs for Heavy-Walled (2 to 412-in. (50.8 to 114-mm)) Steel Castings

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness

TABLE 1 Chemical Requirements

	Composition, max,%		
	Grade WCA	Grade WCB	Grade WCC
Carbon	0.25^{A}	0.30	0.25^{B}
Manganese	0.70^{A}	1.00	1.20^{B}
Phosphorus	0.035	0.035	0.035
Sulfur	0.035	0.035	0.035
Silicon	0.60	0.60	0.60

^{A} For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted up to a maximum of 1.10 %.

^{B} For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted to a maximum of 1.40 %.

2.2 *ANSI Standards:*

B36.10 American Standard for Welded and Seamless Wrought Steel Pipe

B46.1 Surface Texture

2.3 *MSS Standards:*

SP-54 Quality Standard for Steel Castings—Radiographic Inspection Method

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (centrifugally cast pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (outside or inside diameter and minimum wall thickness),

3.1.5 Length (specific or random), (Permissible Variations in Length Section of Specification A530/A530M),

3.1.6 End finish (Ends Section of Specification A530/A530M),

3.1.7 Optional Requirements (Sections 7.2, 8.2, 8.3, 11.1, Section 12 and S1 to S9 (Supplementary Requirements), 3.1.8 Test report required (Certification Section of Specification A530/A530M),

3.1.9 Specification designation, and

3.1.10 Special requirements.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A530/A530M unless otherwise provided herein.

5. Materials and Manufacture

5.1 *Machining*:

5.1.1 All centrifugally cast pipe shall have both the inner and outer surfaces machined.

5.1.2 After heat treatment, the pipe shall be machined to a finish with a roughness value no greater than 250 µin. (6.35 µm) arithmetical average deviation (AA), terms as defined in ANSI B46.1 unless otherwise specified.

5.2 *Heat Treatment*:

5.2.1 All pipe shall receive a heat treatment proper for its design and chemical composition.

5.2.2 Castings shall be heat treated after they have been allowed to cool below the transformation range.

6. Temperature Control

6.1 Furnace temperatures for heat treating shall be effectively controlled by pyrometers.

7. Chemical Requirements

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7.2 *Product Analysis*:

7.2.1 At the request of the purchaser, a product analysis shall be made by the manufacturer on every heat.

7.2.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Table 1.

7.2.3 If the analysis of one of the tests specified in 7.2.1 does not conform to the requirements specified, an analysis of each pipe from the same heat may be made, and all pipes conforming to the requirements shall be accepted.

8. Mechanical Requirements

8.1 *Tensile Properties*:

8.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

TABLE 2 Tensile Requirements

	WCA		WCB		WCC	
	ksi	MPa	ksi	MPa	ksi	MPa
Tensile strength, min	60	414	70	483	70	483
Yield strength, min	30	207	36	248	40	276
Elongation in 2 in. or 50 mm, min, %	24		22		22	
Reduction of area, min, %	35		35		35	

8.1.2 *Transverse or Longitudinal Tension Test*—One test shall be made on a specimen from one end of one length of pipe representing each heat in each heat-treatment lot.

8.2 *Flattening Test*:

8.2.1 A flattening test shall be performed when requested by the purchaser or when stated by the purchaser on the order that the pipe is to be upset, swaged, expanded, bent, or formed by some other operation.

8.2.2 A flattening test need not be performed on heavy wall pipe which is not to be upset, swaged, expanded, bent, or formed in some other manner.

8.2.3 When required by 8.2, a test shall be made on specimens cut from one end of each length of pipe.

8.2.4 A flattening test when required shall be performed in accordance with the requirements for seamless and centrifugally cast pipe in the Flattening Test Requirements Section of Specification A530/A530M.

NOTE 1—In heavy-walled small-diameter tubing the flattening test specimen may be bored out so that the *OD/t* ratio will be greater than 11.0.

8.3 *Hydrostatic Test*:

8.3.1 Each length of pipe shall be hydrostatically tested in accordance with the Hydrostatic Test Requirements Section of Specification A530/A530M when requested by the purchaser and stated on the order. If performance of the hydrostatic test is not required by the purchaser, the manufacturer shall guarantee pipe to pass the test and mark each length of pipe with the letters "NH" immediately following the specification number, indicating that the pipe has not been hydrostatically tested.

8.3.2 When required by 8.3, each length of pipe shall be subjected to the hydrostatic test. The test pressure shall be maintained for not less than 5 min.

9. Permissible Variation in Wall Thickness

9.1 The wall thickness shall not vary over the specified minimum wall thickness by more than 10 %. There shall be no variation under the specified minimum wall thickness.

NOTE 2—A system of standard pipe sizes has been approved by the American National Standards Institute, as ANSI B36.10. This system may be used for obtaining pipe under this specification.

10. Workmanship and Finish

10.1 The pipe shall have a finish as provided in 5.2 and it shall be reasonably straight and free from injurious defects.

11. Rework and Retreatment

11.1 *Imperfections*—The surface of the casting shall be inspected visually for cracks and hot tears. These imperfections shall be removed, and their removal verified by visual inspection of the resultant cavities. Imperfections located by inspecting with Supplementary Requirements S7, S8, or S9 shall be removed or reduced to an acceptable size.

11.2 *Blending*—If removal of the imperfection does not infringe upon the minimum wall thickness, the depression may be blended uniformly into the surrounding surface.

11.3 *Repair by Welding*—Imperfections that infringe upon the minimum wall thickness may be repaired by welding subject to approval by the purchaser. Only qualified operators and procedures in accordance with ASME Boiler and Pressure Vessel Code, Section IX, shall be used. All weld repairs shall be inspected to the same quality standards used to inspect the pipe.

11.4 *Reheat Treatment*—Local or full heat treatment in accordance with 5.2 shall follow welding. Local grinding following welding and retreating shall be considered as meeting the requirements of 5.1.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A530/A530M, the marking shall include the wall thickness, piece mark, length and additional symbol "S" if the pipe conforms to one or more of the supplementary requirements specified in S1 to S9, and the heat number or manufacturer's number by which the heat can be identified. Identification stamping instead of stenciling will be permitted only with the written approval of the purchaser.

12.2 *Bar Coding*—In addition to the requirements in 12.1, bar coding is acceptable as a supplemental identification method. The purchaser may specifiy in the order a specific bar coding system to be used.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Additional Tension Tests

S2.1 An additional tension test shall be made on a specimen from one or each end of each pipe. If this supplementary requirement is specified, the number of tests per pipe required shall be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A530/A530M and satisfactory retest.

S3. Additional Flattening Tests

S3.1 The flattening test of Specification A530/A530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement that pipe shall be rejected subject to retreatment in accordance with Specification A530/A530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Metal Structure and Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Photomicrographs

S5.1 The manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of pipe in the as-finished condition representing each heat in each heat-treatment lot. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S6. Such photomicrographs are for information only, to show the actual metal structure of the pipe as furnished.

S6. Photographs for Individual Pieces

S6.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S5, the purchaser may specify that photomicrographs shall be furnished from one or both ends of each pipe. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S7. Radiographic Inspection

S7.1 The pipe shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Practice E94 or Method E142 and the types and severity levels of discontinuities considered shall be judged by Reference Radiographs E446, or Reference Radiographs E186. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser. A specification which may be used as a basis for such agreement is "Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping

Components (Radiographic Inspection Method SP-54)" of the Manufacturer's Standardization Society of the Valve and Fittings Industry.

S8. Ultrasonic Tests

S8.1 Each pipe shall be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Evidence of the existence of defects in excess of 5 % of the wall thickness shall be cause for rejection or repair.

S8.2 The ultrasonic test shall be made in accordance with Practice E114, or by any other established method mutually agreed upon between the manufacturer and the purchaser.

S9. Magnetic Particle or Fluid Penetrant Examination

S9.1 Each pipe along outside and inside surfaces shall be subjected, after machining, to examination by a magnetic particle method or a penetrant fluid and powder method.

S9.2 The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser. Reference Photographs E125 may be used to define acceptance criteria.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON-MANGANESE-SILICON STEEL, FOR MODERATE AND LOWER TEMPERATURE SERVICE

SA-662/SA-662M

(Identical with ASTM Specification A662/A662M-17.)

Standard Specification for
Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service

1. Scope

1.1 This specification covers three grades of carbon-manganese-silicon steel plates intended primarily for service in welded pressure vessels where improved low temperature notch toughness is important.

1.2 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.3 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A20/A20M apply.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A20/A20M.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

TABLE 1 Chemical Requirements

Element	Composition, %					
	Grade A		Grade B		Grade C	
	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis
Carbon, max	0.14	0.17	0.19	0.22	0.20	0.24
Manganese	0.90–1.35	0.84–1.46	0.85–1.50	0.79–1.62	1.00–1.60	0.92–1.72
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025
Silicon	0.15–0.40	0.13–0.45	0.15–0.40	0.13–0.45	0.15–0.50	0.13–0.55

TABLE 2 Tensile Properties

	Grade A	Grade B	Grade C
Tensile strength, ksi [MPa]	58–78 [400–540]	65–85 [450–585]	70–90 [485–620]
Yield strength,[A] min, ksi [MPa]	40 [275]	40 [275]	43 [295]
Elongation in 8 in. [200 mm], min, %[B]	20	20	18
Elongation in 2 in. [50 mm], min, %[B]	23	23	22

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[B] See Specification A20/A20M for elongation adjustments.

5. Heat Treatment

5.1 All plates of Grade A and plates of Grades B and C over 1½ in. [40 mm] in thickness shall be normalized.

5.2 Plates of Grades B and C, 1½ in. [40 mm] and under in thickness, are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 carbon steel; carbon steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessels

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,
S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S4.1 Additional Tension Test,
S5. Charpy V-Notch Impact Test (see Appendix X1),
S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),
S8. Ultrasonic Examination in accordance with Specification A435/A435M,
S9. Magnetic Particle Examination,
S11. Ultrasonic Examination in accordance with Specification A577/A577M,
S12. Ultrasonic Examination in accordance with Specification A578/A578M, and
S17. Vacuum Carbon-Deoxidized Steel.

APPENDIX

(Nonmandatory Information)

X1. NOTCH TOUGHNESS

X1.1 When Charpy V-notch testing is required, the minimum values listed in Table X1.1 will be guaranteed on normalized material for the temperature specified by the purchaser.

TABLE X1.1 Charpy V-Notch Requirements[A]

Testing Temperature, °F [°C]	Grade A		Grades B and C	
	Longitudinal Specimens, ft·lbf [J]	Transverse Specimens, ft·lbf [J]	Longitudinal Specimens, ft·lbf [J]	Transverse Specimens, ft·lbf [J]
−75 [−60]	20 [27]	15 [20]	15 [20]	...
−60 [−50]	30 [41]	18 [24]	20 [27]	...
−50 [−45]	35 [47]	19 [26]	22 [30]	15 [20]
−40 [−40]	40 [54]	20 [27]	25 [34]	20 [27]
−25 [−32]	45 [61]	25 [34]	30 [41]	20 [27]
0 [18]	55 [75]	30 [41]	35 [47]	25 [34]
32 [0]	70 [95]	35 [47]	40 [54]	25 [34]
75 [25]	75 [102]	40 [54]	50 [68]	30 [41]

[A] The above values apply to the average of three full size specimens. Values for subsize specimens are denoted as listed in Specification A20/A20M.

SPECIFICATION FOR ANNEALED OR COLD-WORKED AUSTENITIC STAINLESS STEEL SHEET, STRIP, PLATE, AND FLAT BAR

SA-666

(Identical with ASTM Specification A666-03.)

SPECIFICATION FOR ANNEALED OR COLD-WORKED AUSTENITIC STAINLESS STEEL SHEET, STRIP, PLATE, AND FLAT BAR

SA-666

(Identical with ASTM Specification A 666-03)

1. Scope

1.1 This specification covers austenitic stainless steels in the annealed and normally required cold-worked conditions for various structural, architectural, pressure vessel, magnetic, cryogenic, and heat-resisting applications. (This revision of Specification A 666 replaces prior Specifications A 412 and A 177.)

1.2 The application of this specification, or the use of material covered by this specification does not automatically allow usage in pressure vessel applications. Only annealed conditions of grades specifically approved by the ASME code are permitted for pressure vessel use.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 240/A 240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 484/A 484M Specification for General Requirements or Stainless Steel Bars, Billets, and Forgings

3. Material Test Report and Certification

3.1 In addition to the requirements of Specification A 480/A 480M, the cold-worked condition (annealed, $\frac{1}{4}$ H, $\frac{1}{2}$ H, and so forth) shall be noted.

4. Chemical Composition

4.1 The steel shall conform to the requirements as to chemical composition specified in Table 1, and shall conform to applicable requirements specified in the current edition of Specification A 480/A 480M.

5. Mechanical Properties

5.1 The material shall conform to the mechanical properties specified in Table 2 and Table 3, or Table 2 and Table 4.

6. General Requirements

6.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 480/A 480M or A 484/ /A 484M:

6.1.1 Definitions,

6.1.2 General requirements for delivery,

6.1.3 Ordering information,

6.1.4 Process,

6.1.5 Special tests,

6.1.6 Heat treatment,

6.1.7 Dimensions and permissible variations,

6.1.8 Workmanship, finish and appearance,

6.1.9 Number of tests/test methods,

6.1.10 Specimen preparation,

6.1.11 Retreatment,

6.1.12 Inspection,

6.1.13 Rejection and rehearing,

6.1.14 Material test report,

6.1.15 Certification, and

6.1.16 Packaging, marking, and loading.

7. Sampling

7.1 Tension and bend-test specimens of sheet, strip, and plate products shall be selected from finished material and shall be selected in the transverse direction, except in the case of strip under 9 in. (229 mm) in width, in which case tension test specimens shall be selected in the longitudinal direction.

7.2 Flat bar tension and bend-test specimens shall be selected from the finished material and shall be in the longitudinal direction.

7.3 Corrosion samples, if required, shall be taken from material after final annealing and descaling and prior to cold working.

8. Number of Tests

8.1 For cold-worked product produced in coil form, one tension test shall be made from each end of each coil. One bend test shall be made from one end of each coil.

8.2 For cold-worked flat bar and plate products, two tension test and one bend test shall be made on each size of flat bar and each thickness of plate from each heat in a lot annealed in a single charge or under the same conditions in a continuous furnace.

8.3 Annealed material produced to Table 2 requirements shall be tested in accordance with Specification A 480/A 480M.

9. Test Methods

9.1 *Tension Test:*

9.1.1 The yield strength shall be determined by the offset method as described in Test Methods and Definitions A 370. An alternative method of determining field strength may be used based on the following total extension under load:

Yield Strength, min. psi	Total Extension under Load in 2 in. Gage Length, incl.
45 000	0.0071
75 000	0.0098
110 000	0.0125
135 000	0.0144
140 000	0.0148

9.1.2 The requirement of this specification for yield strength will be considered as having been fulfilled if the extension under load for the specified yield strength does not exceed the specified values. The values obtained in this manner should not, however, be taken as the actual yield strength for 0.2%. In case of dispute, the offset method of determining yield strength shall be used.

9.2 *Bend Test:*

9.2.1 Bend-test specimens shall withstand cold bending without cracking when subjected to either the free-bend method or the controlled-bend (V-block) method at the condition specified by Table 3 or Table 4, respectively. Specimens shall be bent around a diameter equal to the product of the bend factor times the specified thickness of the test specimen. The choice of test method for materials in conditions other than annealed shall be at the option of the seller.

9.2.2 Free-bend test specimens shall be bent cold, either by pressure or by blows. However, in the case of dispute, tests shall be made by pressure.

9.2.3 Controlled-bend (V-block) test specimens shall be bent cold by means of V-blocks or a mating punch and die having an included angle of 45° and with proper curvature of surface at the bend areas to impart the desired shape and diameter of bend to the specimen.

10. Keywords

10.1 austenitic stainless steel; cold-worked stainless steel; stainless steel flat bar; stainless steel plate; stainless steel sheet; stainless steel strip

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS[A]

Type	UNS Designation	Composition, %[B] Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Other Elements
201	S20100	0.15	5.5–7.5	0.060	0.030	0.75	16.0–18.0	3.5–5.5	N 0.25
201L	S20103	0.03	5.5–7.5	0.045	0.030	0.75	16.0–18.0	3.5–5.5	N 0.25
201LN	S20153	0.03	6.4–7.5	0.045	0.015	0.75	16.0–17.5	4.0–5.0	N 0.10–0.25 Cu 1.00
202	S20200	0.15	7.5–10.0	0.060	0.030	0.75	17.0–19.0	4.0–6.0	N 0.25
. . .	S20400	0.030	7.0–9.0	0.040	0.030	1.00	15.0–17.0	1.50–3.00	N 0.15–0.30
205	S20500	0.12–0.25	14.0–15.0	0.060	0.030	0.75	16.5–18.0	1.00–1.75	N 0.32–0.40
301	S30100	0.15	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	N 0.10
301L	S30103	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	N 0.20
301LN	S30153	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	N 0.07–0.20
302	S30200	0.15	2.00	0.045	0.030	0.75	17.0–19.0	8.0–10.0	. . .
304	S30400	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	N 0.10
304L	S30403	0.030	2.00	0.045	0.030	0.75	18.0–20.0	8.0–12.0	N 0.10
304N	S30451	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	N 0.10–0.16
304LN	S30453	0.030	2.00	0.045	0.030	0.75	18.0–20.0	8.0–12.0	N 0.10–0.16
316	S31600	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	Mo 2.00–3.00
316L	S31603	0.030	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	Mo 2.00–3.00
316N	S31651	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	Mo 2.00–3.00 N 0.10–0.16
XM-11	S21904	0.04	8.0–10.0	0.060	0.030	0.75	19.0–21.5	5.5–7.5	N 0.15–0.40
XM-14	S21460	0.12	14.0–16.0	0.060	0.030	0.75	17.0–19.0	5.0–6.0	N 0.35–0.50

NOTES:

(A) Types XM-10 and XM-19, which appeared in Specification A 412, do not appear as XM-10 is no longer produced and XM-19 is covered in Specification A 240/A 240M.

(B) Maximum unless otherwise indicated.

TABLE 2
TENSILE PROPERTY REQUIREMENTS[A]

Annealed

Type	UNS Designation	Tensile Strength, min psi	Tensile Strength, min MPa	Yield Strength, min psi	Yield Strength, min MPa	Elongation in 2 in. or 50 mm, min, %	Hardness, max Brinell	Hardness, max Rockwell B
201-1[B]	S20100 Class 1	75 000	515	38 000	260	40	217	95
201-2	S20100 Class 2	95 000	655	45 000	310	40	241	100
201L	S20103	95 000	655	38 000	260	40	217	95
201LN	S20153	95 000	655	45 000	310	45	241	100
202	S20200	90 000	620	38 000	260	40	241	. . .
. . .	S20400	95 000	655	48 000	330	35	241	100
205	S20500	115 000	790	65 000	450	40	241	100
301	S30100	75 000	515	30 000	205	40	217	95
301L	S30103	80 000	550	32 000	220	45	241	100
301LN	S30153	80 000	550	35 000	240	45	241	100
302	S30200	75 000	515	30 000	205	40	201	92
304	S30400	75 000	515	30 000	205	40	201	92
304L	S30403	70 000	485	25 000	170	40	201	92
304N	S30451	80 000	550	35 000	240	30	217	95
304LN	S30453	75 000	515	30 000	250	40	217	95
316	S31600	75 000	515	30 000	205	40	217	95
316L	S31603	70 000	485	25 000	170	40	217	95
316N	S31651	80 000	550	35 000	240	35	217	95
XM-11	S21904	100 000	690	60 000	415	40	. . .	. . .
	Sheet, Strip							
	Plate	90 000	620	50 000	345	45	. . .	. . .
XM-14	S21460	105 000	725	55 000	380	40	. . .	. . .

1/16 Hard[C]

Type	UNS Designation	Tensile Strength, min psi	Tensile Strength, min MPa	Yield Strength, min psi	Yield Strength, min MPa	Elongation in 2 in. or 50 mm, min, % < 0.015 in.	≥ 0.015 to ≤ 0.030 in.	> 0.030 in.
201	S20100 PSS[D]	95 000	655	45 000	310	40	40	40
	FB[E]	75 000	515	40 000	275	. . .	. . .	40
201L	S20103	100 000	690	50 000	345	40	40	40
201LN	S20153	100 000	690	50 000	345	40	40	40
205	S20500	115 000	790	65 000	450	40	40	40
301	S30100	90 000	620	45 000	310	40	40	40
301L	S30103	100 000	690	50 000	345	40	40	40
301LN	S30153	100 000	690	50 000	345	40	40	40
302	S30200 PSS	85 000	585	45 000	310	40	40	40
	FB	90 000	620	45 000	310	. . .	. . .	40
304	S30400 PSS	80 000	550	45 000	310	35	35	35
	FB	90 000	620	45 000	310	. . .	. . .	40
304L	S30403	80 000	550	45 000	310	40	40	40
304N	S30451	90 000	620	45 000	310	40	40	40
304LN	S30453	90 000	620	45 000	310	40	40	40
316	S31600 PSS	85 000	585	45 000	310	35	35	35
	FB	90 000	620	45 000	310	. . .	. . .	40
316L	S31603	85 000	585	45 000	310	35	35	35
316N	S31651	90 000	620	45 000	310	35	35	35

TABLE 2
TENSILE PROPERTY REQUIREMENTS[A] (CONT'D)

$\frac{1}{8}$ Hard[C]

Type	UNS Designation	Tensile Strength, min psi	Tensile Strength, min MPa	Yield Strength, min psi	Yield Strength, min MPa	Elongation in 2 in. or 50 mm, min, % < 0.015 in.	Elongation ≥ 0.015 to ≤ 0.030 in.	Elongation > 0.030 in.
201	S20100	100 000	690	55 000	380	45	45	45
201L	S20103	105 000	725	55 000	380	35	35	35
201LN	S20153	110 000	760	60 000	415	35	35	35
205	S20500	115 000	790	65 000	450	40	40	40
301	S30100	100 000	690	55 000	380	40	40	40
301L	S30103	110 000	760	60 000	415	35	35	35
301LN	S30153	110 000	760	60 000	415	35	35	35
302	S30200	100 000	690	55 000	380	35	35	35
304	S30400	100 000	690	55 000	380	35	35	35
304L	S30403	100 000	690	55 000	380	30	30	30
304N	S30451	100 000	690	55 000	380	37	37	37
304LN	S30453	100 000	690	55 000	380	33	33	33
316	S31600	100 000	690	55 000	380	30	30	30
316L	S31603	100 000	690	55 000	380	25	25	25
316N	S31651	100 000	690	55 000	380	32	32	32

$\frac{1}{4}$ Hard

Type	UNS Designation	Tensile Strength, min psi	Tensile Strength, min MPa	Yield Strength, min psi	Yield Strength, min MPa	Elongation in 2 in. or 50 mm, min, % < 0.015 in.	Elongation ≥ 0.015 to ≤ 0.030 in.	Elongation > 0.030 in.
201	S20100	125 000	860	75 000	515	25	25	25
201L	S20103	120 000	825	75 000	515	25	25	25
201LN	S20153	120 000	825	75 000	515	25	25	25
202	S20200	125 000	860	75 000	515	12	12	...
...	S20400	140 000	965	100 000	960	20	20	20
205	S20500	125 000	860	75 000	515	45	45	45
301	S30100	125 000	860	75 000	515	25	25	25
301L	S30103	120 000	825	75 000	515	25	25	25
301LN	S30153	120 000	825	75 000	515	25	25	25
302	S30200	125 000	860	75 000	515	10	10	12
304	S30400	125 000	860	75 000	515	10	10	12
304L	S30403	125 000	860	75 000	515	8	8	10
304N	S30451	125 000	860	75 000	515	12	12	12
304LN	S30453	125 000	860	75 000	515	10	10	12
316	S31600	125 000	860	75 000	515	10	10	10
316L	S31603	125 000	860	75 000	515	8	8	8
316N	S31651	125 000	860	75 000	515	12	12	12
XM-11	S21904	130 000	895	115 000	795	15	15	...

$\frac{1}{2}$ Hard

Type	UNS Designation	Tensile Strength, min psi	Tensile Strength, min MPa	Yield Strength, min psi	Yield Strength, min MPa	Elongation in 2 in. or 50 mm, min, % < 0.015 in.	Elongation ≥ 0.015 to ≤ 0.030 in.	Elongation > 0.030 in.
201	S20100	150 000	1035	110 000	760	15	18	18
201L	S20103	135 000	930	100 000	690	22	22	20
201LN	S20153	135 000	930	100 000	690	22	22	20
205	S20500	150 000	1035	110 000	760	15	18	18
301	S30100	150 000	1035	110 000	760	15	18	18
301L	S30103	135 000	930	100 000	690	20	20	20
301LN	S30153	135 000	930	100 000	690	20	20	20
302	S30200	150 000	1035	110 000	760	9	10	10
304	S30400	150 000	1035	110 000	760	6	7	7
304L	S30403	150 000	1035	110 000	760	5	6	6

TABLE 2
TENSILE PROPERTY REQUIREMENTS(A) (CONT'D)

½ Hard (Cont'd)								
		Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
Type	UNS Designation	psi	MPa	psi	MPa	< 0.015 in.	≥ 0.015 to ≤ 0.030 in.	> 0.030 in.
304N	S30451	150 000	1035	110 000	760	6	8	8
304LN	S30453	150 000	1035	110 000	760	6	7	7
316	S31600	150 000	1035	110 000	760	6	7	7
316L	S31603	150 000	1035	110 000	760	5	6	6
316N	S31651	150 000	1035	110 000	760	6	8	8
¾ Hard								
		Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
Type	UNS Designation	psi	MPa	psi	MPa	< 0.015 in.	≥ 0.015 to ≤ 0.030 in.	> 0.030 in.
201	S20100	175 000	1205	135 000	930	10	12	12
205	S20500	175 000	1205	135 000	930	15	15	15
301	S30100	175 000	1205	135 000	930	10	12	12
302	S30200	175 000	1205	135 000	930	5	6	6
Full Hard								
		Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
Type	UNS Designation	psi	MPa	psi	MPa	< 0.015 in.	≥ 0.015 to ≤ 0.030 in.	> 0.030 in.
201	S20100	185 000	1275	140 000	965	8	9	9
205	S20500	185 000	1275	140 000	965	10	10	10
301	S30100	185 000	1275	140 000	965	8	9	9
302	S30200	185 000	1275	140 000	965	3	4	4

NOTES:
(A) This specification defines minimum properties only and does not imply a range. Depending on the work hardening characteristics of the particular grade, either the yield or the tensile strength can be the controlling factor in meeting the properties. The noncontrolling factor normally will exceed considerably the specified minimum.
(B) Type 201 is generally produced with a chemical composition balanced for rich side (Type 201-1) or lean side (Type 201-2) austenite stability depending on the properties required for specific applications.
(C) Annealed material that naturally meets mechanical properties may be applied.
(D) PSS means plate, strip, sheet.
(E) FB means flat bar.

TABLE 3
FREE BEND REQUIREMENTS

		Annealed and 1⁄16 and 1⁄8 Hard			
		Thickness ≤ 0.050 in.		Thickness > 0.050 to ≤ 0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	1	180	1
201L	S20103	180	1	180	1
201LN	S20153	180	1	180	1
202	S20200	180	1	180	1
. . .	S20400	180	1	180	1
205	S20500	180	1	180	1
301	S30100	180	1	180	1
301L	S30103	180	1	180	1
301LN	S30133	180	1	180	1
302	S30200	180	1	180	1
304	S30400	180	1	180	1
304L	S30403	180	1	180	2
304N	S30451	180	1	180	1
304LN	S30453	180	1	180	2
316	S31600	180	1	180	2
316L	S31603	180	1	180	2
316N	S31651	180	1	180	1
XM-11	S21904	180	1	180	1
XM-14	S21460	180	1	180	2

		1⁄4 Hard			
		Thickness ≤ 0.050 in.		Thickness > 0.050 to ≤ 0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	1	90	2
201L	S20103	180	1.5	135	1.5
201LN	S20153	180	1.5	135	1.5
202	S20200	180	2	90	2
. . .	S20400	180	1	90	2
205	S20500	180	1	90	2
301	S30100	180	1	90	2
301L	S30103	180	1.5	90	1.5
301LN	S30153	180	1.5	90	1.5
302	S30200	180	1	90	2
304	S30400	180	1	90	2
304L	S30403	180	2	90	3
304N	S30451	180	1	90	2
304LN	S30453	180	2	90	3
316	S31600	180	2	90	2
316L	S31603	180	2	90	3
316N	S31651	180	1	90	2
XM-11	S21904	90	2	90	2

TABLE 3
FREE BEND REQUIREMENTS (CONT'D)

½ Hard					
		Thickness ≤ 0.050 in.		Thickness > 0.050 to ≤ 0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	2	90	2
201L	S20103	180	2	135	2
201LN	S20153	180	2	135	2
205	S20500	180	2	90	2
301	S30100	180	2	90	2
301L	S30103	180	2	90	2
301LN	S30153	180	2	90	2
302	S30200	180	2	90	2
304	S30400	180	2	90	2
304L	S30403	180	3	90	3
304N	S30451	180	2	90	2
304LN	S30453	180	3	90	3
316	S31600	180	3	90	3
316L	S31603	180	3	90	3
316N	S31651	180	2	90	2

¾ Hard					
		Thickness ≤ 0.050 in.		Thickness > 0.050 to ≤ 0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	3	90	3
205	S20500	180	3	90	3
301	S30100	180	3	90	3
302	S30200	180	4	90	5

Full Hard					
		Thickness ≤ 0.050 in.		Thickness > 0.050 to ≤ 0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	4	90	5
205	S20500	180	4	90	5
301	S30100	180	4	90	5
302	S30200	180	6	90	8

TABLE 4
V-BLOCK BEND REQUIREMENTS

Type	UNS Designation	Thickness ≤ 0.050 in. Included Bend Angle,°	Thickness ≤ 0.050 in. Bend Factor	Thickness > 0.050 to ≤ 0.1874 in. Included Bend Angle,°	Thickness > 0.050 to ≤ 0.1874 in. Bend Factor
Annealed and 1⁄8 Hard					
201	S20100	135	2	135	3
201L	S20103	135	2	135	3
201LN	S20153	135	2	135	3
202	S20200	135	4	135	4
205	S20500	135	2	135	3
301	S30100	135	2	135	3
301L	S30103	135	2	135	3
301LN	S30153	135	2	135	3
302	S30200	135	2	135	3
304	S30400	135	2	135	3
304L	S30403	135	5	135	6
304N	S30451	135	3	135	4
304LN	S30453	135	4	135	5
316	S31600	135	5	135	6
316L	S31603	135	6	135	7
316N	S31651	135	5	135	6
1⁄4 Hard					
201	S20100	135	2	135	3
201L	S20103	135	2	135	3
201LN	S20153	135	2	135	3
205	S20500	135	2	135	3
301	S30100	135	2	135	3
301L	S30103	135	2	135	3
301LN	S30153	135	2	135	3
302	S30200	135	2	135	3
304	S30400	135	2	135	3
304L	S30403	135	5	135	6
304N	S30451	135	3	135	4
304LN	S30453	135	4	135	5
316	S31600	135	5	135	6
316L	S31603	135	6	135	7
316N	S31651	135	5	135	6

TABLE 4
V-BLOCK BEND REQUIREMENTS (CONT'D)

½ Hard					
		Thickness ≤ 0.050 in.		Thickness > 0.050 to ≤ 0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	4	135	4
201L	S20103	135	4	135	4
201LN	S20153	135	4	135	4
205	S20500	135	4	135	4
301	S30100	135	4	135	4
301L	S30103	135	4	135	4
301LN	S30153	135	4	135	4
302	S30200	135	4	135	4
304	S30400	135	4	135	4
304L	S30403	135	7	135	8
304N	S30451	135	5	135	6
304LN	S30453	135	6	135	7
316	S31600	135	7	135	8
316L	S31603	135	8	135	9
316N	S31651	135	7	135	8

¾ Hard					
		Thickness ≤ 0.050 in.		Thickness > 0.050 to ≤ 0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	6	135	7
205	S20500	135	6	135	7
301	S30100	135	6	135	7
302	S30200	135	8	135	9

Full Hard					
		Thickness ≤ 0.050 in.		Thickness > 0.050 to ≤ 0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	6	135	8
205	S20500	135	6	135	8
301	S30100	135	6	135	8
302	S30200	135	8	135	10

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SPECIFICATION FOR CENTRIFUGALLY CAST DUAL METAL (GRAY AND WHITE CAST IRON) CYLINDERS

SA-667/SA-667M

(Identical with ASTM Specification A667/A667M-87(2018).)

Standard Specification for Centrifugally Cast Dual Metal (Gray and White Cast Iron) Cylinders

1. Scope

1.1 This specification covers centrifugally cast cylinders with an outer layer of white cast iron and the remainder of the material of gray cast iron. These castings are suitable for pressure containing parts the design strength of which is based on the gray iron portion of the cylinder. These castings are suitable for service at temperatures up to 450°F [230°C].

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The following safety hazards caveat pertains only to the test method portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A278/A278M Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (350°C)

3. Materials and Manufacture

3.1 The melting procedures shall be optional with the foundry.

3.2 The white iron portion of the cylinder shall be made to a minimum hardness of 55 Scleroscope "C". The gray iron portion of the cylinder shall conform to Specification A278/A278M, Class 20 or Class 150.

3.3 The casting process shall be controlled to produce a metallurgical bond between the two metal layers.

4. Finish

4.1 All surfaces shall be machined prior to the cylinders being placed into service.

5. Physical Requirements

5.1 *Tensile Requirements*—Tension test specimens removed from the casting shall have a tensile strength not less than 80 % of that specified in 3.2.

5.2 *Thickness of White Cast Iron:*

5.2.1 The thickness of the white cast iron shall be not less than 5 % nor more than 30 % of the total finished wall thickness.

5.2.2 The thickness of the white cast iron shall be determined by ultrasonic testing.

6. Number of Tests

6.1 The number of tension tests shall be in conformance with Specification A278/A278M.

7. Specimen Preparation

7.1 Separately cast test bars may be used to represent the gray iron portion of the castings. The test bars shall be cast in core sand and have a nominal diameter of 2 in. [50 mm]. Tension test specimens shall be machined from test bars to the dimensions given for Specimen C in Specification A278/A278M.

7.2 At the option of the manufacturer he may substitute test bars taken from the gray iron portion of the casting. The test bars shall be taken midway between the inside diameter of the casting and the interface between the two layers. Tension test specimens machined from these test bars shall conform to the dimensions shown for Specimen C in Specification A278/A278M.

8. Test Method

8.1 Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial. The use of self-aligning shackles is suggested. After reaching a stress equivalent to 15 000 psi [100 MPa] the speed of the moving head of the testing machine shall not exceed ⅛ in. [3.2 mm]/min.

9. Inspection

9.1 The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector without charge all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections shall be made at the place of manufacture prior to the shipment unless otherwise specified and shall be so conducted as not to interfere unnecessarily with the operation of the works.

10. Acceptance and Certification

10.1 Final acceptance of the casting shall follow complete machining of the casting. Upon request of the purchaser and when so specified in the purchase order, a certification shall be made on the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier accompanied by a copy of the test results that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

11. Product Marking

11.1 Pressure containing castings made in accordance with this specification shall have the name of the manufacturer or his recognized trademark and the class of iron to which it conforms cast or indelibly stamped on the surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

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SPECIFICATION FOR ELECTRIC-FUSION-WELDED STEEL PIPE FOR ATMOSPHERIC AND LOWER TEMPERATURES

SA-671/SA-671M

(Identical with ASTM Specification A671/A671M-19 except that the following additional requirements apply, and for editions prior to -16, certifications for designations CF and CJ shall include the appropriate ASTM plate specification grade. For products ordered to Section III, Division 1, Supplementary Requirement S15 is mandatory.)

Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures

1. Scope

1.1 This specification covers electric-fusion-welded steel pipe with filler metal added, fabricated from pressure vessel quality plate of several analyses and strength levels and suitable for high-pressure service at atmospheric and lower temperatures. Heat treatment may or may not be required to attain the desired properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. [400 mm] in outside diameter or larger and of ¼ in. [6 mm] wall thickness or greater. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 Grade designates the type of plate used as listed in 5.1.

1.3.2 Class designates the type of heat treatment performed during manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in 1.3.3.

1.3.3 Class designations are as follows (Note 1):

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see:
10	none	none	none
11	none	9	none
12	none	9	8.3
13	none	none	8.3
20	stress relieved, see 5.3.1	none	none
21	stress relieved, see 5.3.1	9	none
22	stress relieved, see 5.3.1	9	8.3
23	stress relieved, see 5.3.1	none	8.3
30	normalized, see 5.3.2	none	none
31	normalized, see 5.3.2	9	none
32	normalized, see 5.3.2	9	8.3
33	normalized, see 5.3.2	none	8.3
40	normalized and tempered, see 5.3.3	none	none
41	normalized and tempered, see 5.3.3	9	none
42	normalized and tempered, see 5.3.3	9	8.3
43	normalized and tempered, see 5.3.3	none	8.3
50	quenched and tempered, see 5.3.4	none	none
51	quenched and tempered, see 5.3.4	9	none
52	quenched and tempered, see 5.3.4	9	8.3
53	quenched and tempered, see 5.3.4	none	8.3
70	quenched and precipitation heat treated	none	none
71	quenched and precipitation heat treated	9	none
72	quenched and precipitation heat treated	9	8.3
73	quenched and precipitation heat treated	none	8.3

NOTE 1—Selection of materials should be made with attention to temperature of service. For such guidance, Specification A20/A20M may be consulted.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
E110 Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers
E165/E165M Practice for Liquid Penetrant Testing for General Industry
E709 Guide for Magnetic Particle Testing

2.2 *Plate Steels:*
A203/A203M Specification for Pressure Vessel Plates, Alloy Steel, Nickel
A285/A285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
A299/A299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
A353/A353M Specification for Pressure Vessel Plates, Alloy Steel, Double-Normalized and Tempered 9 % Nickel
A515/A515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
A516/A516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
A517/A517M Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered
A537/A537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
A553/A553M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 7, 8, and 9 % Nickel
A736/A736M Specification for Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium (Niobium) Alloy Steel

2.3 *ASME Boiler and Pressure Vessel Code:*
Section II
Section III
Section VIII
Section IX

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*
3.1.1 *lot*—a lot shall consist of 200 ft [60 m] or fraction thereof of pipe from the same heat of steel.

4. Ordering Information

4.1 The inquiry and order for material under this specification should include the following information:
4.1.1 Quantity (feet, metres, or number of lengths),
4.1.2 Name of material (steel pipe, electric-fusionwelded),
4.1.3 Specification number,
4.1.4 Grade and class designations (see 1.3),
4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),
4.1.6 Length (specific or random),
4.1.7 End finish (11.4),
4.1.8 Purchase options, if any (see 5.2.3 and 11.3 of this specification. See also Specification A530/A530M),
4.1.9 Supplementary requirements, if any.

5. Materials and Manufacture

5.1 *Materials*—The steel plate material shall conform to the requirement of the applicable plate specification for the pipe grade ordered as listed in Table 1.

5.2 *Welding:*
5.2.1 The joints shall be double-welded, full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.
5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.
5.2.3 As welded, the welded joint shall have positive reinforcement at the center of each side of the weld, but no more than ⅛ in. [3 mm]. This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be smooth and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.3 *Heat Treatment*—All classes other than 10, 11, 12, and 13 shall be heat treated in furnace controlled to ± 25 °F [± 15 °C] and equipped with a recording pyrometer so that heating records are available. Heat treating after forming and welding shall be to one of the following:

TABLE 1 Plate Specifications

Pipe Grade	Type of Steel	ASTM Specification No.	ASTM Specification Grade / Class / Type
CA 55	plain carbon	A285/A285M	Gr C
CB 60	plain carbon, killed	A515/A515M	Gr 60
CB 65	plain carbon, killed	A515/A515M	Gr 65
CB 70	plain carbon, killed	A515/A515M	Gr 70
CC 60	plain carbon, killed, fine grain	A516/A516M	Gr 60
CC 65	plain carbon, killed, fine grain	A516/A516M	Gr 65
CC 70	plain carbon, killed, fine grain	A516/A516M	Gr 70
CD 70	manganese-silicon, normalized	A537/A537M	Cl 1
CD 80	manganese-silicon, quenched and tempered	A537/A537M	Cl 2
CFA 65	nickel steel	A203/A203M	Gr A
CFB 70	nickel steel	A203/A203M	Gr B
CFD 65	nickel steel	A203/A203M	Gr D
CFE 70	nickel steel	A203/A203M	Gr E
CG 100	9 % nickel	A353/A353M	
CH 115	9 % nickel	A553/A553M	Type 1
CJA 115	alloy steel, quenched and tempered	A517/A517M	Gr A
CJB 115	alloy steel, quenched and tempered	A517/A517M	Gr B
CJE 115	alloy steel, quenched and tempered	A517/A517M	Gr E
CJF 115	alloy steel, quenched and tempered	A517/A517M	Gr F
CJH 115	alloy steel, quenched and tempered	A517/A517M	Gr H
CJP 115	alloy steel, quenched and tempered	A517/A517M	Gr P
CK 75	carbon-manganese-silicon	A299/A299M	Gr A
CP85	alloy steel, age hardening, quenched and precipitation heat treated	A736/A736M	Gr A, Class 3

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range indicated in Table 2 for a minimum of 1 h/in. [0.4 h/cm] of thickness or for 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33, pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in Table 2 and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of ½ h/in. [0.2 h/cm] of thickness or for ½ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in Table 2 and subsequently quenched in water or oil. After quenching, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at that temperature for a minimum of ½ h/in. [0.2 h/cm] of thickness or for ½ h, whichever is greater, and air cooled.

5.3.5 Classes 70, 71, 72, and 73 pipe shall be uniformly heated to a temperature in the austenitizing range, not exceeding the maximum quenching temperature indicated in Table 2, and subsequently quenched in water or oil. After quenching the pipe shall be reheated into the precipitation heat treating range indicated in Table 2 for a time to be determined by the manufacturer.

6. General Requirements for Delivery

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A530/A530M unless otherwise provided herein.

7. Chemical Composition

7.1 *Product Analysis of Plate*—The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

TABLE 2 Heat Treatment Parameters[A]

Pipe Grade[B]	ASTM Specification and Grade / Class / Type	Post-Weld Heat-Treatment Temperature Range °F [°C]	Normalizing Temperature, max, unless otherwise noted °F [°C]	Quenching Temperature, max, unless otherwise noted °F [°C]	Tempering Temperature, min, °F [°C]	Precipitation Heat Treatment Temperature Range °F [°C]
CA 55	A285/A285M (C)	1100–1250 [590–680]	1700 [925]	...	...	...
CB 60	A515/A515M (60)	1100–1250 [590–680]	1750 [950]	...	...	...
CB 65	A515/A515M (65)	1100–1250 [590–680]	1750 [950]	...	...	...
CB 70	A515/A515M (70)	1100–1250 [590–680]	1750 [950]	...	...	...
CC 60	A516/A516M (60)	1100–1200 [590–650][C]	1700 [925]	1700 [925]	1100 [590][D]	...
CC 65	A516/A516M (65)	1100–1200 [590–650][C]	1700 [925]	1700 [920]	1100 [590][D]	...
CC 70	A516/A516M (70)	1100–1200 [590–650][C]	1700 [925]	1700 [925]	1100 [590][D]	...
CD 70	A537/A537M (Cl 1)	1100–1250 [590–680]	1700 [925]	...	...	...
CD 80	A537/A537M (Cl 2)	1100–1250 [590–680][C]	...	1650 [900]	1100 [590]	...
CFA 65	A203/A203M (A)	1100–1175 [590–635]	1750 [950]	...	...	...
CFB 70	A203/A203M (B)	1100–1175 [590–635]	1750 [950]	...	...	...
CFD 65	A203/A203M (D)	1100–1175 [590–635]	1750 [950]	...	...	...
CFE 70	A203/A203M (E)	1100–1175 [590–635]	1750 [950]	...	...	...
CG 100	A353/A353M	1025–1085 [550–580]	1650 ± 25 [900 ± 15] plus[E] 1450 ± 25 [790 ± 15]	...	1050–1125 [560–605]	...
CH 100	A553/A553M (Type 1)	1025–1085 [550–580]		1475–1700 [800–925]	1050–1175 [560–635][F]	...
CJA 115	A517/A517M (A)	1000–1100 [540–590]	...	1650–1725 [900–940]	1150 [620]	...
CJB 115	A517/A517M (B)	1000–1100 [540–590]	...	1650–1725 [900–940]	1150 [620]	...
CJE 115	A517/A517M (E)	1000–1100 [540–590]	...	1650–1725 [900–940]	1150 [620]	...
CJF 115	A517/A517M (F)	1000–1100 [540–590]	...	1650–1725 [900–940]	1150 [620]	...
CJH 115	A517/A517M (H)	1000–1100 [540–590]	...	1650–1725 [900–940]	1150 [620]	...
CJP 115	A517/A517M (P)	1000–1100 [540–590]	...	1650–1725 [900–940]	1150 [620]	...
CK 75	A299/A299M (A)	1100–1250 [590–680]	1700 [925]	...	...	...
CP85	A736/A736M (A, Class 3)	1000–1175 [540–635]	...	1725 [940]	...	1000–1225 [540–665]

[A] Where ellipses (...) appear in this table, there is no requirement.
[B] Numbers indicate minimum tensile strength in ksi.
[C] In no case shall the post-weld heat-treatment temperature exceed the mill tempering temperature.
[D] Tempering range 1100 to 1300 [590 to 705], if accelerated cooling utilized per Specification A516/A516M.
[E] If hot forming is performed after heating to a temperature in the range from 1650 to 1750°F [900 to 955°C], the first normalize may be omitted.
[F] Prior to the tempering treatment, the plates may be subjected to an intermediate heat treatment consisting of heating to a temperature in the range from 1165 to 1290°F [630 to 700°C] and either air-cooled or water quenched. See Specification A553/A553M for hold times and cooling instructions.

7.2 *Product Analyses of Weld*—The pipe manufacturer shall make an analysis of finished deposited weld material from each 200 ft [60 m] or fraction thereof. Analyses shall conform to the welding procedure for deposited weld metal.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

8. Mechanical Requirements

8.1 *Tension Test:*

8.1.1 *Requirements*—Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material. In addition for Grades CD and CJ, when these are of Class 3x, 4x, or 5x, and Grade CP of 7x, the transverse tensile properties of the base plate shall be determined on specimens cut from the heat-treated pipe. These properties shall meet the mechanical test requirements of the plate specification.

8.1.2 *Number of Tests*—One test specimen of weld metal and one specimen of base metal, if required by 8.1.1, shall be made and tested to represent each lot of finished pipe.

8.1.3 *Test Specimen Location and Orientation*—The test specimens shall be taken transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

8.1.4 *Test Method*—The test specimen shall be made in accordance with QW-150 in Section IX of the ASME Boiler and Pressure Vessel Code. The test specimen shall be tested at room temperature in accordance with Test Methods and Definitions A370.

8.2 *Transverse Guided Weld Bend Test:*

8.2.1 *Requirements*—The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. [3 mm] in any direction are present in the weld metal or between the weld and the base metal after bending. Cracks that originate along the edges of the specimen during testing, and that are less than ¼ in. [6 mm] measured in any direction shall not be considered.

8.2.2 *Number of Tests*—One test (two specimens) shall be made to represent each lot of finished pipe.

8.2.3 *Test Specimen Location and Orientation*—Two bend test specimens shall be taken transverse to the weld at the end of the finished pipe. As an alternative, by agreement between the purchaser and the manufacturer, the test specimens may be taken from a test plate of the same material as the pipe, the test plate being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

8.2.4 *Test Method*—The test requirements of A370, A2.5.1.7 shall be met. For wall thicknesses over ⅜ in. [10 mm] but less than ¾ in. [19 mm] side-bend tests may be made instead of the face and root-bend tests. For wall thicknesses ¾ in. [19 mm] and over both specimens shall be subjected to the side-bend test.

8.3 *Pressure Test*—Classes X2 and X3 pipe shall be tested in accordance with Specification A530/A530M, Hydrostatic Test Requirements.

9. Radiographic Examination

9.1 The full length of each weld of Classes X1 and X2 shall be radiographically examined in accordance with and meet the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW–51.

9.2 Radiographic examination may be performed prior to heat treatment.

10. Rework

10.1 *Elimination of Surface Imperfections*—Unacceptable surface imperfections shall be removed by grinding or machining. The remaining thickness of the section shall be no less than the minimum specified in Section 11. The depression after grinding or machining shall be blended uniformly into the surrounding surface.

10.2 *Repair of Base Metal Defects by Welding:*

10.2.1 The manufacturer may repair, by welding, base metal where defects have been removed, provided the depth of the repair cavity as prepared for welding does not exceed ⅓ of the nominal thickness and the requirements of 10.2.2, 10.2.3, 10.2.4, 10.2.5 and 10.2.6 are met. Base metal defects in excess of these may be repaired with prior approval of the customer.

10.2.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair welding.

10.2.3 The welding procedure and welders or welding operators are to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.2.4 The full length of the repaired pipe shall be heat treated after repair in accordance with the requirements of the pipe class specified.

10.2.5 Each repair weld of a defect where the cavity, prepared for welding, has a depth exceeding the lesser of ⅜ in. [10 mm] or 10 % of the nominal thickness shall be examined by radiography in accordance with the methods and the acceptance standards of Section 9.

10.2.6 The repair surface shall be blended uniformly into the surrounding base metal surface and examined and accepted in accordance with Supplementary Requirements S6 or S8.

10.3 *Repair of Weld Metal Defects by Welding:*

10.3.1 The manufacturer may repair weld metal defects if he meets the requirements of 10.2.3, 10.2.4, 10.3.2, 10.3.3 and 10.4.

10.3.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the repair cavity examined and accepted in accordance with Supplementary Requirements S7 or S9.

10.3.3 The weld repair shall be blended uniformly into the surrounding metal surfaces and examined and accepted in accordance with 9.1 and with Supplementary Requirements S7 or S9.

10.4 *Retest*—Each length of repaired pipe of a class requiring a pressure test shall be hydrostatically tested following repair.

11. Dimensions, Mass and Permissible Variations

11.1 The wall thickness and weight for welded pipe furnished to this specification shall be governed by the requirements of the specification to which the manufacturer ordered the plate.

11.2 Permissible variations in dimensions at any point in a length of pipe shall not exceed the following:

11.2.1 *Outside Diameter*—Based on circumferential measurement ± 0.5 % of the specified outside diameter.

11.2.2 *Out-of-Roundness*—Difference between major and minor outside diameters, 1 %.

11.2.3 *Alignment*—Using a 10-ft [3-m] straight edge placed so that both ends are in contact with the pipe, ⅛ in. [3 mm].

11.2.4 *Thickness*—The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. [0.3 mm] under the specified nominal thickness.

11.3 Circumferential welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

11.4 Lengths with unmachined ends shall be within −0, +½ in. [−0, +13 mm] of that specified. Lengths with machined ends shall be as agreed between the manufacturer and the purchaser.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish. This requirement is to mean the same as the identical requirement that appears in Specification A20/A20M with respect to steel plate surface finish.

13. Product Marking

13.1 In addition to the marking provision of Specification A530/A530M, class marking in accordance with 1.3.3 shall follow the grade marking, for example, CC 70–10.

13.2 *Bar Coding*—In addition to the requirements in 13.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Tension and Bend Tests

S1.1 Tension tests in accordance with 8.1 and bend tests in accordance with 8.2 shall be made on specimens representing each length of pipe.

S2. Charpy V-Notch Test

S2.1 *Requirements*—The acceptable test energies for material shown in Specification A20/A20M shall conform to the energy values shown in Specification A20/A20M.

S2.1.1 Materials not listed in Specification A20/A20M shall be in accordance with the purchase order requirements.

S2.2 *Number of Specimens*—Each test shall consist of at least three specimens.

S2.2.1 One base metal test shall be made from one pipe length per heat per heat-treat charge per nominal wall thickness. For pipe from Classes 10, 11, 12, and 13, one base metal test shall be made per heat per size and per wall thickness.

S2.2.2 One weld-metal test shall be made in accordance with UG–84 of Section VIII of the ASME Boiler and Pressure Vessel Code.

S2.2.3 One heat-affected-zone test shall be made in accordance with UG–84 of Section VIII of the ASME Boiler and Pressure Vessel Code.

S2.3 *Test Specimen Location and Orientation:*

S2.3.1 Specimens for base-metal tests in Grades CA, CB, and CC in the as rolled stress relieved or normalized condition (classes of the 10, 20, 30, and 40 series) shall be taken so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the pipe.

S2.3.2 Base-metal specimens of quench and tempered pipe, when the quenching and tempering follows the welding operation, shall be taken in accordance with the provision of N330 of Section III of the ASME Boiler and Pressure Vessel Code.

S2.4 *Test Method*—The specimen shall be Charpy-V Type A in accordance with Test Methods and Definitions A370. The specimens shall be tested in accordance with Test Methods and Definitions A370. Unless otherwise indicated by the purchaser, the test temperature shall be as given in Specification A20/A20M for those base materials covered by Specification A20/A20M. For materials not covered by Specification A20/A20M the test temperature shall be 10 °F [−12 °C] unless otherwise stated in the purchase order.

S3. Hardness Test

S3.1 Hardness tests shall be made in accordance with Test Methods and Definitions A370 or Test Method E110 across the welded joint of both ends of each length of pipe. In addition, hardness tests shall be made to include the heat-affected zone if so required by the purchaser. The maximum acceptable hardness shall be as agreed upon between the manufacturer and the purchaser.

S3.2 As an alternative to the heat-affected zone hardness, by agreement between the manufacturer and purchaser, maximum heat-affected zone hardness may be specified for the procedure test results.

S4. Product Analysis

S4.1 Product analyses in accordance with 7.1 shall be made on each 500 ft [150 m] of pipe or fraction thereof, or alternatively, on each length of pipe as designated in the order.

S5. Metallography

S5.1 The manufacturer shall furnish one photomicrograph to show the microstructure at 100× magnification of the weld metal or base metal of the pipe in the as-finished condition. The purchaser shall state in the order: the material, base metal or weld, and the number and locations of tests to be made. This test is for information only.

S6. Magnetic Particle Examination of Base Metal

S6.1 All accessible surfaces of the pipe shall be examined in accordance with Guide E709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. [600 mm] in diameter and greater, and inside surfaces of pipe less than 24 in. [600 mm] in diameter for a distance of 1 pipe diameter from the ends.

S6.2 *Acceptance Standards*—The following relevant indications are unacceptable:

S6.2.1 Any linear indications greater than ¹⁄₁₆ in. [1 mm] long for materials less than ⅝ in. [16 mm] thick; greater than ⅛ in. [3 mm] long for materials from ⅝ in. [16 mm] thick to under 2 in. [50 mm] thick; and greater than ³⁄₁₆ in. [5 mm] long for materials 2 in. [50 mm] thick or greater.

S6.2.2 Rounded indications with dimensions greater than ⅛ in. [3 mm] for thicknesses less than ⅝ in. [16 mm], and greater than ³⁄₁₆ in. [5 mm] for thicknesses ⅝ in. [16 mm] and greater.

S6.2.3 Four or more indications in any line separated by ¹⁄₁₆ in. [1 mm] or less edge-to-edge.

S6.2.4 Ten or more indications in any 6 in.^{2} [39 cm^2] of surface with the major dimension of this area not to exceed 6 in. [150 mm] when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S7. Magnetic Particle Examination of Weld Metal

S7.1 All accessible welds shall be examined in accordance with Guide E709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. [600 mm] in diameter and greater, and inside surfaces of pipe less than 24 in. [600 mm] in diameter for a distance of one pipe diameter from the ends.

S7.2 *Acceptance Criteria*—The following relevant indications are unacceptable:

S7.2.1 Any cracks and linear indications.

S7.2.2 Rounded indications with dimensions greater than ³⁄₁₆ in. [5 mm].

S7.2.3 Four or more indications in any line separated by ¹⁄₁₆ in. [1 mm] or less edge-to-edge.

S7.2.4 Ten or more indications in any 6 in.^{2} [39 cm^2] of surface with the major dimension of this area not to exceed 6 in. [150 mm] when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S8. Liquid Penetrant Examination of Base Metal

S8.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E165/E165M. Accessible is as defined in S7.1.

S8.2 The acceptance criteria shall be in accordance with S6.2.

S9. Liquid Penetrant Examination of Weld Metal

S9.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E165/E165M. Accessible is as defined in S7.1.

S9.2 The acceptance criteria shall be in accordance with S7.2.

S10. Straight Beam Ultrasonic Examination of Flat Plate—UT 1

S10.1 The plate shall be examined and accepted in accordance with Specification A435/A435M except that 100 % of one surface shall be scanned by moving the search unit in parallel paths with not less than 10 % overlap.

S11. Straight Beam Ultrasonic Examination of Flat Plate—UT 2

S11.1 The plate shall be examined in accordance with Specification A578/A578M except that 100 % of one surface shall be scanned and the acceptance criteria shall be as follows:

S11.1.1 Any area, where one or more discontinuities produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. [76.2 mm] or one half of the plate thickness, whichever is greater, is unacceptable.

S11.1.2 In addition, two or more discontinuities on the same plane and having the same characteristics but smaller than described above shall be unacceptable unless separated by a minimum distance equal to the largest diameter of the larger discontinuity or unless they may be collectively encompassed by the circle described above.

S12. Angle Beam Ultrasonic Examination (Plate Less than 2 in. [50 mm] Thick)—UT 3

S12.1 The plate shall be examined in accordance with Specification A577/A577M except that the calibration notch shall be vee shaped and the acceptance criteria shall be as follows: Any area showing one or more reflections producing indications whose amplitude exceeds that of the calibration notch is unacceptable.

S13. Repair Welding

S13.1 Repair of base metal defects by welding shall be done only with customer approval.

S14. Description of Term

S14.1 *lot*—all pipe of the same mill heat of plate material and wall thickness (within ±¼ in. [6 mm]) heat treated in one furnace charge. For pipe that is not heat treated or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft [60 m] or fraction thereof of all pipe of the same mill heat of plate material and wall thickness (within ±¼ in. [6 mm]), subjected to the same heat treatment. For pipe heat treated in a batch-type furnace that is automatically controlled within a 50 °F [30 °C] range and is equipped with recording pyrometers so that heating records are available, a lot shall be defined the same as for continuous furnaces.

S15. ASME Section III Construction

S15.1 Products furnished under this specification that are intended for application under the rules of Section III of the ASME Boiler and Pressure Vessel Code shall be manufactured by holders of the appropriate ASME Certificate of Authorization and Certification Mark. The product is subject to all applicable requirements of Section III, including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Certification Mark.

S15.2 The applicable ASME Partial Data Report form, signed by an Authorized Nuclear Inspector, and a material test report shall be furnished for each lot of pipe.

S15.3 The plate used to fabricate the pipe shall conform to the applicable SA specification in ASME Boiler and Pressure Vessel Code, Section II. The welded joints shall be full penetration butt welds as obtained by double welding or by other means that will obtain the same quality of deposited weld metal on the inside and outside. Welds using metal backing strips that remain in place are prohibited.

S15.4 In addition to the requirements of S14 and Section 13 Product Marking, each length of pipe shall be so marked as to identify each such piece of pipe with the lot and the material test report.

SPECIFICATION FOR ELECTRIC-FUSION-WELDED STEEL PIPE FOR HIGH-PRESSURE SERVICE AT MODERATE TEMPERATURES

SA-672/SA-672M

(Identical with ASTM Specification A672/A672M-19.)

For products ordered to Section III, Division 1 of the ASME Boiler and Pressure Vessel Code, Supplementary Requirement S15 is mandatory.

Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures

1. Scope

1.1 This specification covers steel pipe: electric-fusion-welded with filler metal added, fabricated from pressure-vessel quality plate of any of several analyses and strength levels and suitable for high-pressure service at moderate temperatures. Heat treatment may or may not be required to attain the desired properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. [400 mm] in outside diameter or larger with wall thicknesses up to 3 in. [75 mm], inclusive. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 *Grade* designates the type of plate used.

1.3.2 *Class* designates the type of heat treatment performed during manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in 1.3.3.

1.3.3 Class designations are as follows (Note 1):

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see Section
10	none	none	none
11	none	9	none
12	none	9	8.3
13	none	none	8.3
20	stress relieved, see 5.3.1	none	none
21	stress relieved, see 5.3.1	9	none
22	stress relieved, see 5.3.1	9	8.3
23	stress relieved, see 5.3.1	none	8.3
30	normalized, see 5.3.2	none	none
31	normalized, see 5.3.2	9	none
32	normalized, see 5.3.2	9	8.3
33	normalized, see 5.3.2	none	8.3
40	normalized and tempered, see 5.3.3	none	none
41	normalized and tempered, see 5.3.3	9	none
42	normalized and tempered, see 5.3.3	9	8.3
43	normalized and tempered, see 5.3.3	none	8.3
50	quenched and tempered, see 5.3.4	none	none
51	quenched and tempered, see 5.3.4	9	none
52	quenched and tempered, see 5.3.4	9	8.3
53	quenched and tempered, see 5.3.4	none	8.3

NOTE 1—Selection of materials should be made with attention to temperature of service. For such guidance, Specification A20/A20M may be consulted.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic

Examination of Rolled Steel Plates for Special Applications

E109 Method for Dry Powder Magnetic Particle Inspection; Replaced by E 709 (Withdrawn 1981)

E138 Method for Wet Magnetic Particle Inspection; Replaced by E 709 (Withdrawn 1981)

E110 Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers

E165 Practice for Liquid Penetrant Testing for General Industry

E709 Guide for Magnetic Particle Testing

2.1.1 *Plate Steel Specifications (*Table 1*)*

A204/A204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum

A285/A285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength

A299/A299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon

A302/A302M Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel

A515/A515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service

A516/A516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

A533/A533M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel

A537/A537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel

2.2 *ASME Boiler and Pressure Vessel Code:*

Section II

Section III

Section VIII

Section IX

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 A *lot* shall consist of 200 ft [60 m] or fraction thereof of pipe from the same heat of steel.

3.1.2 The description of a lot may be further restricted by use of Supplementary Requirement S14.

4. Ordering Information

4.1 The inquiry and order for material under this specification should include the following information:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (steel pipe, electric-fusionwelded),

4.1.3 Specification number,

4.1.4 Grade and class designations (see 1.3),

4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish (11.4),

4.1.8 Purchase options, if any (see 5.2.3, 11.3, 14.1 and Sections 16, 20.1, 21, 22 of Specification A530/A530M), and

4.1.9 Supplementary requirements, if any (refer to S1 through S15).

5. Materials and Manufacture

5.1 *Materials*—The steel plate material shall conform to the requirements of the applicable plate specification for pipe grade ordered as listed in Table 1.

5.2 *Welding:*

5.2.1 The joints shall be double-welded, full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.

5.2.3 The welded joint shall have positive reinforcement at the center of each side of the weld, but not more than ⅛ in. [3 mm]. This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be smooth, and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.2.4 When radiographic examination in accordance with 9.1 is to be used, the weld reinforcement shall be governed by the more restrictive provisions of UW–51 of Section VIII of the ASME Boiler and Pressure Vessel Code instead of 5.2.3 of this specification.

5.3 *Heat Treatment*—All classes other than 10, 11, 12 and 13 shall be heat treated in furnace controlled to ± 25 °F [15 °C] and equipped with a recording pyrometer so that heating records are available. Heat treating after forming and welding shall be to one of the following:

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range indicated in Table 2 for a minimum of 1 h/in. [0.4 hr/cm] of thickness or 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33 pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in Table 2 and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of ½ h/in. [0.2 hr/cm] of thickness or ½ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in Table 2 and subsequently quenched in water or oil. After quenching the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of ½ h/in. [0.2 hr/cm] of thickness or ½ h, whichever is greater, and air cooled.

TABLE 1 Plate Specification

Pipe Grade	Type of Steel	ASTM Specification	
		No.	Grade
A 45	plain carbon	A285/A285M	A
A 50	plain carbon	A285/A285M	B
A 55	plain carbon	A285/A285M	C
B 60	plain carbon, killed	A515/A515M	60
B 65	plain carbon, killed	A515/A515M	65
B 70	plain carbon, killed	A515/A515M	70
C 55	plain carbon, killed, fine grain	A516/A516M	55
C 60	plain carbon, killed, fine grain	A516/A516M	60
C 65	plain carbon, killed, fine grain	A516/A516M	65
C 70	plain carbon, killed, fine grain	A516/A516M	70
D 70	manganese-silicon—normalized	A537/A537M	Cl-1
D80	manganese-silicon—Q&T[A]	A537/A537M	Cl-2
H 75	manganese-molybdenum—normalized	A302/A302M	A
H 80	manganese-molybdenum—normalized	A302/A302M	B, C or D
J 80	manganese-molybdenum—Q&T[A]	A533/A533M	Cl-1[B]
J 90	manganese-molybdenum—Q&T[A]	A533/A533M	Cl-2[B]
J 100	manganese-molybdenum—Q&T[A]	A533/A533M	Cl-3[B]
L 65	molybdenum	A204/A204M	A
L 70	molybdenum	A204/A204M	B
L 75	molybdenum	A204/A204M	C
N 75	manganese-silicon	A299/A299M	A

[A] Q&T = quenched and tempered.
[B] Any grade may be furnished.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A530/A530M unless otherwise provided herein.

7. Chemical Composition

7.1 *Product Analysis of Plate*—The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

7.2 *Product Analysis of Weld*—The pipe manufacturer shall make an analysis of the finished deposited weld material from each 500 ft [150 m] or fraction thereof. Analysis shall conform to the welding procedure for deposited weld metal.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

7.4 If the analysis of one of the tests specified in 7.1 or 7.2 does not conform to the requirements specified, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified. Nonconforming pipe shall be rejected.

8. Mechanical Properties

8.1 *Tension Test:*

8.1.1 *Requirements*—Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material. In addition for Grades Dxx, Hxx, Jxx, and Nxx in Classes 3x, 4x, and 5x transverse tensile properties of the base plate, shall be determined on specimens cut from the heat-treated pipe. These properties shall meet the mechanical test requirements of the plate specification.

8.1.2 *Number of Tests*—One test specimen shall be made to represent each lot of finished pipe.

8.1.3 *Test Specimen Location and Orientation*—The test specimens shall be taken transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

8.1.4 *Test Method*—The test specimen shall be made in accordance with QW-150 in Section IX of the ASME Boiler and Pressure Vessel Code. The test specimen shall be tested at room temperature in accordance with Test Methods and Definitions A370.

8.2 *Transverse-Guided-Weld-Bend Tests:*

8.2.1 *Requirements*—The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. [3 mm] in any direction are present in the weld metal or between the weld and the base metal after bending. Cracks that originate along the edges of the specimen during testing, and that are less than ¼ in. [6 mm] measured in any direction shall not be considered.

8.2.2 *Number of Tests*—One test (two specimens) shall be made to represent each lot of finished pipe.

8.2.3 *Test Specimen Location and Orientation*—Two bend test specimens shall be taken transverse to the weld at the end of the finished pipe. As an alternative by agreement between the purchaser and the manufacturer, the test specimens may be taken from a test plate of the same material as the pipe, the test plate being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

8.2.4 *Test Method*—The test requirements of Test Methods and Definitions A370, paragraph A2.5.1.7 shall be met. For wall thickness over ⅜ in. [10 mm] but less than ¾ in. [19 mm] side-bend tests may be made instead of the face and root-bend tests. For wall thicknesses ¾ in. [19 mm] and over both specimens shall be subjected to the side-bend test.

8.3 *Pressure Test*—Classes X2 and X3 pipe shall be tested in accordance with Specification A530/A530M, Hydrostatic Test Requirements.

9. Radiographic Examination

9.1 The full length of each weld of Classes X1 and X2 shall be radiographically examined in accordance with and meet the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, paragraph UW–51.

9.2 Radiographic examination may be performed prior to heat treatment.

10. Rework

10.1 *Elimination of Surface Imperfections*—Unacceptable surface imperfections shall be removed by grinding or machining. The remaining thickness of the section shall be no less than

TABLE 2 Heat Treatment Parameters[A]

Pipe Grade[B]	Specification and Grade[C]	Post-Weld Heat-Treat Temperature Range, °F (°C)	Normalizing Temperature, max, °F (°C)	Quenching Temperature, max, °F (°C)	Tempering Temperature, min, °F (°C)
A 45	A 285A	1100–1250 [590–680]	1700 [925]	. . .	. . .
A 50	A 285B	1100–1250 [590–680]	1700 [925]	. . .	. . .
A 55	A 285C	1100–1250 [590–680]	1700 [925]	. . .	. . .
B 60	A515-60	1100–1200 [590–650]	1750 [950]	. . .	. . .
B 65	A515-65	1100–1200 [590–650]	1750 [950]	. . .	. . .
B 70	A515-70	1100–1200 [590–650]	1750 [950]	. . .	. . .
C 55	A516-55	1100–1200 [590–650]	1700 [925]	1650 [900]	1100 [590]
C 60	A516-60	1100–1200 [590–650]	1700 [925]	1650 [900]	1100 [590]
C 65	A516-65	1100–1200 [590–650]	1700 [925]	1650 [900]	1100 [590]
C 70	A516-70	1100–1200 [590–650]	1700 [925]	1650 [900]	1100 [590]
D 70	A537-Cl 1	1100–1250 [590–680]	1700 [925]	. . .	. . .
D 80	A537-Cl 2	1100–1250 [590–680]	. . .	1650 [900]	1100 [590]
H 75	A 302-A	1100–1250 [590–680]	1800 [980]	. . .	1100 [590]
H 80	A 302-B, C or D	1100–1250 [590–680]	1800 [980]	. . .	1100 [590]
J 80	A 533-C1 1[C]	1100–1250 [590–680]	. . .	1800 [980]	1100 [590]
J 90	A 533-C1 2[C]	1100–1250 [590–680]	. . .	1800 [980]	1100 [590]
J 100	A 533-C1 3[C]	1100–1250 [590–680]	. . .	1800 [980]	1100 [590]
L 65	A 204A	1100–1200 (590–650)	. . .	. . .	. . .
L 70	A 204B	1100–1200 (590–650)	. . .	. . .	. . .
L 75	A 204C	1100–1200 (590–650)	. . .	. . .	. . .
N 75	A299 A	1100–1200 [590–650]	1700 [925]	. . .	. . .

[A]Where ellipses (...) appear in this table, there is no requirement.
[B] Numbers indicate minimum tensile strength in ksi.
[C] Any grade may be used.

the minimum specified in Section 11. The depression after grinding or machining shall be blended uniformly into the surrounding surface.

10.2 *Repair of Base Metal Defects by Welding:*

10.2.1 The manufacturer may repair, by welding, base metal where defects have been removed, provided the depth of the repair cavity as prepared for welding does not exceed ⅓ of the nominal thickness and the requirements of 10.2.2 – 10.2.6 are met. Base metal defects in excess of these may be repaired with proper approval of the customer.

10.2.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair welding.

10.2.3 The welding procedure and welders or welding operators are to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.2.4 The full length of the repaired pipe shall be heat treated after repair in accordance with the requirements of the pipe class specified.

10.2.5 Each repair weld of a defect where the cavity, prepared for welding, has a depth exceeding the lesser of ⅜ in. [10 mm] or 10 % of the nominal thickness shall be examined by radiography in accordance with the methods and the acceptance standards of Section 9.

10.2.6 The repair surface shall be blended uniformly into the surrounding base metal surface and examined and accepted in accordance with Section S6 or S8.

10.3 *Repair of Weld Metal Defects by Welding:*

10.3.1 The manufacturer may repair weld metal defects if he meets the requirements of 10.2.3, 10.2.4, 10.3.2, 10.3.3, and 10.4.

10.3.2 The defects shall be removed by suitable mechanical or thermal cutting or gouging methods and the repair cavity examined and accepted in accordance with Sections S7 or S9.

10.3.3 The weld repair shall be blended uniformly into the surrounding metal surfaces and examined and accepted in accordance with 9.1 and Sections S7 or S9.

10.4 *Retest*—Each length of repaired pipe of a class requiring a pressure test shall be hydrostatically tested following repair.

11. Dimensions, Mass and Permissible Variations

11.1 The wall thickness and weight for welded pipe furnished to this specification shall be governed by the requirements of the specification to which the manufacturer ordered the plate.

11.2 Permissible variations in dimensions at any point in a length of pipe shall not exceed the following:

11.2.1 *Outside Diameter*—Based on circumferential measurement ± 0.5 % of the specified outside diameter.

11.2.2 *Out-of-Roundness*—Difference between major and minor outside diameters, 1 %.

11.2.3 *Alignment*—Using a 10-ft [3-m] straightedge placed so that both ends are in contact with the pipe, ⅛ in. [3 mm].

11.2.4 *Thickness*—The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. [0.3 mm] under the specified nominal thickness.

11.3 Circumferential welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

11.4 Lengths with unmachined ends shall be within −0, +½ in. [−0, +13 mm] of that specified. Lengths with machined ends shall be as agreed upon between the manufacturer and the purchaser.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish. This requirement is to mean the same as the identical requirement that appears in Specification A20/A20M with respect to steel plate surface finish.

13. Product Marking

13.1 In addition to the marking provision of Specification A530/A530M, class marking in accordance with 1.3.3 shall follow the grade marking; for example, C 70–10.

13.2 *Bar Coding*—In addition to the requirements in 13.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Tension and Bend Tests

S1.1 Tension tests in accordance with 8.1 and bend tests in accordance with 8.2 shall be made on specimens representing each length of pipe.

S2. Charpy V-Notch Test (For pipe with nominal wall thickness of ½ in. [13 mm] and greater)

S2.1 *Requirements*—The acceptable test energies shall be as shown in Table A1.15 of Specification A20/A20M for the applicable plate specification unless otherwise stated in the order. As an alternative, the test temperature may be 10 °F [−12 °C].

S2.2 *Number of Specimens*—Each test shall consist of at least three specimens.

S2.2.1 One base-metal test shall be made from one pipe length per heat, per heat-treat charge, and per nominal wall thickness. For pipe from Classes 10, 11, 12, and 13, one base metal test shall be made per heat per size and per wall thickness.

S2.2.2 One weld-metal and one heat-affected zone (HAZ) metal test shall be made in accordance with NB 4335 of Section III of the ASME Boiler and Pressure Vessel Code.

S2.3 *Test Specimen Location and Orientation:*

S2.3.1 Base-metal specimens of stress-relieved, normalized, and normalized and tempered pipe shall be taken in accordance with the provisions for tension specimens in the body of this specification.

S2.3.2 Base-metal specimens of quenched and tempered pipe shall be taken in accordance with the provisions of NB 2225 of Section III of the ASME Boiler and Pressure Vessel Code.

S3. Hardness Test

S3.1 Hardness measurements in accordance with Test Methods and Definitions A370 or Test Method E110 shall be made across the welded joint at both ends of each length of pipe. The maximum acceptable hardness shall be as agreed upon between the manufacturer and the purchaser.

S4. Product Analysis

S4.1 Product analyses in accordance with 7.1 shall be made on each 500 ft [150 m] of pipe or fraction thereof or alternatively, on each length of pipe as designated in the order.

S5. Metallography

S5.1 The manufacturer shall furnish one photomicrograph to show the microstructure of 100× magnification of the weld metal or base metal of the pipe in the as-finished condition. The purchaser shall state in the order: the material, base metal or weld, and the number and locations of tests to be made. This test is for information only.

S6. Magnetic Particle Examination of Base Metal

S6.1 All accessible surfaces of the pipe shall be examined in accordance with Methods E109 or E138. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. [600 mm] in diameter and greater, and inside surfaces of pipe less than 24 in. [600 mm] in diameter for a distance of one pipe diameter from the ends.

S6.2 *Acceptance Standards*—The following relevant indications are unacceptable:

S6.2.1 Any linear indications greater than 1⁄16 in. [1 mm] long for materials less than ⅝ in. [16 mm] thick; greater than ⅛ in. [3 mm] long for materials ⅝ in. [16 mm] thick to under

2 in. [50 mm] thick; and greater than 3⁄16 in. [5 mm] long for materials 2 in. [50 mm] thick or greater.

S6.2.2 Rounded indications with dimensions greater than 1⁄8 in. [3 mm] for thicknesses less than 5⁄8 in. [16 mm] and greater than 3⁄16 in. [5 mm] for thicknesses 5⁄8 in. [16 mm] and greater.

S6.2.3 Four or more indications in any line separated by 1⁄16 in. [1 mm] or less edge-to-edge.

S6.2.4 Ten or more indications in any 6 in.^{2} [39 cm^2] of surface with the major dimension of this area not to exceed 6 in. [150 mm] when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S7. Magnetic Particle Examination of Weld Metal

S7.1 All accessible weld shall be examined in accordance with Practice E709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe less than 24 in. [600 mm] in diameter for a distance of one pipe diameter from the ends.

S7.2 *Acceptance Criteria*—The following relevant indications are unacceptable:

S7.2.1 Any cracks and linear indications.

S7.2.2 Rounded indications with dimensions greater than 3⁄16 in. [5 mm].

S7.2.3 Four or more indications in any line separated 1⁄16 in. [1 mm] or less edge-to-edge.

S7.2.4 Ten or more indications in any 6 in.^{2} [39 cm^2] of surface with the major dimension of this area not to exceed 6 in. [150 mm] when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S8. Liquid Penetrant Examination of Base Metal

S8.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E165. Accessible is as defined in S6.1.

S8.2 The acceptance criteria shall be in accordance with S6.2.

S9. Liquid Penetrant Examination of Weld Metal

S9.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E165. Accessible is as defined in S7.1

S9.2 The acceptance criteria shall be in accordance with S7.2

S10. Straight Beam Ultrasonic Examination of Flat Plate—UT 1

S10.1 The plate shall be examined and accepted in accordance with Specification A435/A435M except that 100 % of one surface shall be scanned by moving the search unit in parallel paths with not less than 10 % overlap.

S11. Straight Beam Ultrasonic Examination of Flat Plate—UT 2

S11.1 The plate shall be examined in accordance with Specification A578/A578M except that 100 % of one surface shall be scanned and the acceptance criteria shall be as follows:

S11.2 Any area, where one or more discontinuities produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. [75 mm] or 1⁄2 of the plate thickness, whichever is greater, is unacceptable. In addition, two or more discontinuities on the same plane and having the same characteristics but smaller than described above shall be unacceptable unless separated by a minimum distance equal to the largest diameter of the larger discontinuity or unless they may be collectively encompassed by the circle described above.

S12. Angle-Beam Ultrasonic Examination (Plate Less than 2 in. [50 mm)] Thick)—UT 3

S12.1 The plate shall be examined in accordance with Specification A577/A577M except that the calibration notch shall be V-shaped and the acceptance criteria shall be as follows: Any area showing one or more reflectors producing indications whose amplitude exceeds that of the calibration notch is unacceptable.

S13. Repair Welding

S13.1 Repair of base metal defects by welding shall be done only with customer approval.

S14. Description of Term

S14.1 *lot*—all pipe of the same mill heat of plate material and wall thickness (within ±1⁄4 in. [6 mm]) heat treated in one furnace charge. For pipe that is not heat treated or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft [60 m] or fraction thereof of all pipe of the same mill heat of plate material and wall thickness (within ±1⁄4 in. [6 mm]), subjected to the same heat treatment. For pipe heat treated in a batch-type furnace that is automatically controlled within a 50 °F [30 °C] range and is equipped with recording pyrometers so that heating records are available, a lot shall be defined the same as for continuous furnaces.

S15. ASME Section III Construction

S15.1 Products furnished under this specification that are intended for application under the rules of Section III of the ASME Boiler and Pressure Vessel Code shall be manufactured by holders of the appropriate ASME Certificate of Authorization and Certification Mark. The product is subject to all applicable requirements of Section III, including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Certification Mark.

S15.2 The applicable ASME Partial Data Report form, signed by an Authorized Nuclear Inspector, and a material test report shall be furnished for each lot of pipe.

S15.3 The plate used to fabricate the pipe shall conform to the applicable SA specification in ASME Boiler and Pressure Vessel Code, Section II. The welded joints shall be full penetration butt welds as obtained by double welding or by other means that will obtain the same quality of deposited weld metal on the inside and outside. Welds using metal backing strips that remain in place are prohibited.

S15.4 In addition to the requirements of S14 and Section 13 (Product Marking), each length of pipe shall be so marked as to identify each such piece of pipe with the lot and the material test report.

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SPECIFICATION FOR STEEL BARS, CARBON, HOT-WROUGHT, SPECIAL QUALITY, MECHANICAL PROPERTIES

SA-675/SA-675M

(Identical with ASTM Specification A675/A675M-03(2009) except that Supplementary Requirement S7 has Grades 65 and 70 added, and S7 is mandatory. Sections 4.1.9 and 10 revised to make certification mandatory.)

SPECIFICATION FOR STEEL BARS, CARBON, HOT-WROUGHT, SPECIAL QUALITY, MECHANICAL PROPERTIES

SA-675/SA-675M

[Identical with ASTM Specification A 675/A 675M-03(2009) except that Supplementary Requirement S7 has Grades 65 and 70 added, and S7 is mandatory. Sections 4.1.9 and 10 revised to make certification mandatory.]

1. Scope

1.1 This specification covers hot-wrought special quality carbon steel bars and bar size shapes produced to mechanical property requirements and intended for general constructional applications.

1.2 The bars are available in nine strength grades designated 45, 50, 55, 60, 65, 70, 75, 80, and 90 [310, 345, 380, 415, 450, 485, 515, 550, and 620] corresponding to the minimum ultimate tensile strength in ksi [MPa]. The chemical composition is selected by the manufacturer to develop the required mechanical properties.

1.3 Hot-wrought special quality carbon steel bars subject to mechanical property requirements are hot wrought in straight lengths only. Sections and sizes available are covered in Specification A 29/A 29M.

1.4 Some applications may require one or more of the available designations shown under Supplementary Requirements.

NOTE 1 — Merchant-quality hot-wrought carbon steel bars subject to mechanical property requirements are covered in Specification A 663/A 663M.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not equivalents, therefore each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 663/A 663M Specification for Steel Bars, Carbon, Merchant Quality, Mechanical Properties

E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *special quality* — Special quality bars are used when end use, method of fabrication, or subsequent processing treatment requires quality characteristics not available in merchant quality. Typical applications involve bending or machining for general constructional uses. Some end uses or fabricating procedures can necessitate one or more requirements which are described in the Supplementary Requirements.

4. Ordering Information

4.1 Orders for material under this specification should include the following information:

4.1.1 Quantity (weight or number of pieces),

4.1.2 Name of material (hot-wrought special quality bars),

4.1.3 Dimensions, including length,

4.1.4 Cross section (round, square, hexagon, equal leg angle, etc.),

4.1.5 Specification designation and date of issue,

4.1.6 Grade designation (Table 1),

4.1.7 Leaded steel, if required (6.2),

4.1.8 Copper bearing steel, if required (6.3),

4.1.9 Test report (Section 10),

4.1.10 Supplementary Requirements or special requirements if required, and

4.1.11 Application and processing.

NOTE 2 — A typical ordering description is as follows: 10 000 lb, [5000 kg] Hot Wrought Special Quality Carbon Steel Bars, 1 in. diameter × 10 ft, [25 m × 3 m] Round, ASTM A 675/A 675M dated ______ , Grade 50, [345] Copper Bearing, Test Report Required, S3 Special Straightness, Boiler Supports.

5. Materials and Manufacture

5.1 *Melting Practice* — The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting using electroslag remelting or vacuum-arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

5.2 *Deoxidation:*

5.2.1 Unless otherwise specified, the steel shall be rimmed, capped, semi-killed, or killed at the producer's option.

5.2.2 When required, the purchaser may specify the required deoxidation practice, dependent upon strength grade specified, purchaser's methods of fabrication, and end use requirements. Killed steels can be produced to coarse or fine austenitic grain size (Supplementary Requirement S1).

5.3 *Condition* — Unless otherwise specified, the bars shall be furnished as-rolled and not pickled, blast cleaned, or oiled. At the producer's option, bars may be cleaned for inspection.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements specified in Table 2.

6.2 *Leaded Steel* — When required, lead may be specified as an added element. When lead is specified as an added element, a range from 0.15 to 0.35 % inclusive shall be furnished. Such a steel is identified by adding the letter L after the grade designation, for example 60L [415L].

6.3 *Copper-Bearing Steel* — When required copper may be specified as an added element. Copper-bearing steel is identified by stating "copper-bearing" on the purchase order.

6.4 When tension tests are waived in accordance with 7.1.1.2, chemistry consistent with the mechanical properties desired shall be applied.

7. Mechanical Properties

7.1 *Tension Tests*

7.1.1 *Requirements:*

7.1.1.1 The material as represented by the test specimen shall conform to the applicable requirements in Table 1.

7.1.1.2 Shapes less than 1 in.^{2} [645 mm^2] in cross section and bars (other than flats) less than $\frac{1}{2}$ in. [12.5 mm] in thickness or diameter need not be subject to tension tests by the manufacturer.

7.1.1.3 For material over $\frac{3}{4}$ in. [19 mm] in thickness or diameter, a deduction of 0.25% from the percentage of elongation in 8 in. [200 mm] specified in Table 1 shall be made for each increase of $\frac{1}{32}$ in. [0.8 mm] in the specified thickness or diameter above $\frac{3}{4}$ in. [19 mm].

7.1.1.4 For material under $\frac{5}{16}$ in. [8 mm] in thickness or diameter, a deduction of 2.00% from the percentage of elongation in 8 in. [200 mm] specified in Table 1 shall be made for each decrease of $\frac{1}{32}$ in. [0.8 mm] in the specified thickness or diameter below $\frac{5}{16}$ in. [8 mm].

7.1.1.5 For Grades 45, 50, 55, 60, and 65 [310, 345, 380, and 415] for material over 2 in. [50 mm] in thickness or diameter, a deduction of 1.00% from the percentage of elongation in 2 in. [50 mm] specified in Table 1 shall be made for each 1 in. [25 mm] of specified thickness or diameter or fraction thereof over 2 in. [50 mm] in thickness or diameter.

7.1.1.6 For Grades 70, 75, 80, and 90 [485, 515, 550 and 620] for material over 2 in. [50 mm] in thickness or diameter, a deduction of 1.00% from the percentage of elongation in 2 in. [50 mm] specified in Table 1 shall be made for each 1 in. [25 mm] of specified thickness or diameter, or fraction thereof, over 2 in. [50 mm] in diameter or thickness, to a maximum deduction of 3%.

7.1.2 *Test Specimens:*

7.1.2.1 Test specimens shall be prepared for testing from the material in its as-rolled condition unless otherwise specified (see Supplementary Requirements). The tension specimen may be aged as described in Test Methods and Definitions A 370.

7.1.2.2 Test specimens shall be taken longitudinally and may be tested in full thickness or section, or they may be machined to the dimensions shown in Fig. 4 or Fig. 5 of Test Methods and Definitions A 370. If test specimens are selected conforming to the dimensions of Fig. 5, they shall be machined from a position midway between the center and the surface of the bar.

7.1.2.3 Test specimens for shapes and flats may be machined to the form and dimensions shown in Fig. 4 of Test Methods and Definitions A 370 or with both edges parallel. Test specimens for material over $1\frac{1}{2}$ in. [40 mm]

in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. [20 mm] for a length of at least 9 in. [230 mm], or they may conform to the dimensions shown in Fig. 5 of Test Methods and Definitions A 370.

7.1.3 *Number of Tests* — Two tension tests shall be made from each heat, unless the finished material from a heat is less than 50 tons [45 Mg], when one tension test will be sufficient. However, for material 2 in. [50 mm] and under in thickness, when the material from one heat differs $\frac{3}{8}$ in. [9.5 mm] or more in thickness, one tension test shall be made from both the thickest and the thinnest material rolled (larger than the sizes in 7.1.1.2) regardless of the weight represented. For material over 2 in. [50 mm] thick, when the material from heat differs 1 in. [25 mm] or more in thickness, one tension test shall be made from both the thickest and the thinnest material rolled that is more than 2 in. [50 mm] thick regardless of the weight represented.

7.1.4 *Test Method* — Tension tests shall be made in accordance with Test Methods and Definitions A 370 using the applicable method for determining yield point.

7.2 *Bend Tests:*

7.2.1 *Requirements:*

7.2.1.1 Bend requirements apply only to flat bars (all sizes), bars other than flats less than $\frac{1}{2}$ in. [12.5 mm] in thickness or diameter, and shapes less than 1 in.^{2} [645 mm^2] in cross section. When bend tests are required for other sizes, Supplementary Requirement S6 must be specified.

7.2.1.2 The bend test specimen shall stand being bent at room temperature through 180° without cracking on the outside of the bent portion, to an inside diameter which shall have the relation to the thickness or diameter of the specimen as given in Table 3.

7.2.2 *Test Specimens:*

7.2.2.1 Bend test specimens for material $1\frac{1}{2}$ in. [40 mm] and under in diameter or thickness may be the full thickness of the section. For flat bars over 2 in. [50 mm] in width, the width may be reduced by milling to $1\frac{1}{2}$ in. [40 mm].

7.2.2.2 Bend test specimens for material over $1\frac{1}{2}$ in. [40 mm] in diameter or thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. [20 mm] or to 1 by $\frac{1}{2}$ in. [25 by 12.5 mm] in section. Machined sides of bend test specimens may have the corners rounded to a radius of not over $\frac{1}{16}$ in. [1.6 mm] for material 2 in. [50 mm] and under in thickness, and not over $\frac{1}{8}$ in. [3.2 mm] in radius for material over 2 in. [50 mm] in thickness.

7.2.3 *Number of Tests* — When subject to bend test, two bend tests shall be made from each heat, unless the finished material from a heat is less than 50 tons [45 Mg], when one bend test will be sufficient. However, for material 2 in. [50 mm] and under in thickness, when the material from one heat differs $\frac{3}{8}$ in. [9.5 mm] or more in thickness, one bend test shall be made from both the thickest and the thinnest material rolled regardless of the weight represented. For material over 2 in. [50 mm] thick, when the material from one heat differs 1 in. [25 mm] or more in thickness, one bend test shall be made from both the thickest and the thinnest material rolled that is more than 2 in. [50 mm] thick regardless of the weight represented.

7.2.4 *Test Methods* — Bend tests shall be made in accordance with Test Method E 290.

8. Workmanship, Finish, and Appearance

8.1 Bars shall be free of visible pipe, undue segregation, and injurious surface imperfections.

8.2 *Surface Finish* — The bars shall have a commercial hot-wrought finish obtained by conventional hot rolling. See 5.3 for producer's descaling option.

9. General Requirements

9.1 Material furnished under this specification shall conform to the applicable requirements for the current edition of Specification A 29/A 29M.

10. Certification

10.1 The manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis, tensile requirements, and bend test (if applicable) test results shall be furnished. Only one test need be reported when the amount of material from a heat in a shipment is less than 10 tons [9 Mg] and when the thickness variations described in (7.1.3) and (7.2.3) are not exceeded. The report shall include the name of the manufacturer, ASTM designation number and year date and revision letter, if any, grade, heat number, and size.

10.2 The thickness of the product tested may not necessarily be the same as an individual ordered thickness since it is the heat that is tested rather than each ordered item.

10.3 When Supplementary Requirements are specified, the report shall include a statement of compliance with the requirement or the results of tests when the requirement involves measured test values.

11. Keywords

11.1 carbon steel bars; hot-wrought steel bars; steel bars

TABLE 1
TENSILE REQUIREMENTS

Grade Designation[A]	Tensile Strength ksi	Tensile Strength [MPa]	Yield Point, min.[B] ksi	Yield Point, min.[B] [MPa]	Elongation, min., %[C] 8 in. or [200 mm] Gage Length	Elongation, min., %[C] 2 in. or [50 mm] Gage Length
45 [310]	45 to 55	[310 to 380]	22.5	[155]	27	33
50 [345]	50 to 60	[345 to 415]	25	[170]	25	30
55 [380]	55 to 65	[380 to 450]	27.5	[190]	23	26
60 [415]	60 to 72	[415 to 495]	30	[205]	21	22
65 [450]	65 to 77	[450 to 530]	32.5	[225]	17	20
70 [485]	70 to 85	[485 to 585]	35	[240]	14	18
75 [515]	75 to 90	[515 to 620]	37.5	[260]	14	18
80 [550]	80 min.	[550 min.]	40	[275]	13	17
90 [620]	90 min.	[620 min.]	55	[380]	10	14

[A] When lead is required, add the letter "L" after the grade designation, for example 45L.
[B] When the tension test does not show a yield point (drop of the beam, halt of the pointer or sharp-kneed stress-strain diagram), yield strength shall be determined by either 0.5% extension-under-load or 0.2% offset. The minimum ksi (MPa) requirement does not change. The test report, if required, shall show yield strength.
[C] See 7.1.1.3 through 7.1.1.6 for deduction in elongation due to section size.

TABLE 2
CHEMICAL REQUIREMENTS (HEAT ANALYSIS)

Element	
Phosphorus, max.	0.040
Sulfur, max.	0.050
Copper, when copper steel is specified, min.	0.20
Lead	[A]

[A] When required, lead may be specified as an added element. See 6.2.

TABLE 3
BEND REQUIREMENTS

Grade Designation	Ratio of Bend Diameter to Thickness of Specimen for Thickness or Diameter of Bar, in. (mm): ¾ [20] and Under	Over ¾ [20] to 1 [25], incl	Over 1 [25] to 1½ [40], incl	Over 1½ [40] to 2 [50], incl	Over 2 [50] to 3 [75], incl	Over 3 [75] to 5 [125], incl	Over 5 [125]
45 [310]	flat	flat	½	1	1	2	3
50 [345]	flat	½	1	1½	2½	3	3½
55 [380]	½	1	1½	3	2½	3	3½
60 [415]	½	1	1½	2½	3	3½	4
65 [450]	1	1½	2	3	3½	4	5
70 [485]	1½	2	2½	3	3½	4	5
75 [515]	2	2	3	3½	4	4½	6
80 [550]	2	2½	3	3½	4	4½	6
90 [620][A]	...	...	...	...	...	...	...

[A] Bend requirements are not required for Grade 90 [620], but may be specified by agreement between purchaser and manufacturer (see Supplementary Requirement S6).

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirements of the specification itself.

S1. Grain Size

S1.1 The steel shall conform to the coarse austenitic grain size requirement, or the fine austenitic grain size requirement of Specification A 29/A 29M.

S2. Thermal Treatment

S2.1 When required, the purchaser may specify that the material be stress relieved.

S3. Special Straightness

S3.1 Bars may be specified to special straightness tolerance (refer to Specification A 29/A 29M).

S4. Cleaning

S4.1 The purchaser may specify that the surface of bars be descaled by pickling or blast cleaning.

S5. Coating

S5.1 The purchaser may specify oil on bars that have been descaled.

S6. Bend Requirement

S6.1 Bend requirements for Grade 90 [620] may be specified. The bend ratio shall be as agreed upon. Bend requirements for all other grades, when specified, shall be as specified in Table 3.

S7. Carbon Restriction

S7.1 On Grades 45 [310], 50 [345], 55 [380], 60 [415], 65 [450], and 70 [485], carbon shall be 0.35% max.

SPECIFICATION FOR SEAMLESS AND WELDED AUSTENITIC STAINLESS STEEL FEEDWATER HEATER TUBES

SA-688/SA-688M

(Identical with ASTM Specification A688/A688M-15.)

Standard Specification for
Seamless and Welded Austenitic Stainless Steel Feedwater Heater Tubes

1. Scope

1.1 This specification covers seamless and welded austenitic stainless steel feedwater heater tubes including those bent, if specified, into the form of U-tubes for application in tubular feed-water heaters.

1.2 The tubing sizes covered shall be ⅝ to 1 in. [15.9 to 25.4 mm] inclusive outside diameter, and average or minimum wall thicknesses of 0.028 in. [0.7 mm] and heavier.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E112 Test Methods for Determining Average Grain Size

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 *Definitions Of Terms*—For definitions of terms used in this specification, refer to Terminology A941.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (length or number of pieces),

4.1.2 Material description (seamless or welded),

4.1.3 Dimensions—Outside diameter, wall thickness (minimum or average wall), and length,

4.1.4 Grade (chemical composition) (Table 1),

4.1.5 U-bend requirements, if order specifies bending, U-bend schedules or drawings shall accompany the order,

4.1.6 Optional requirements—Purchaser shall specify if annealing of the U-bends is required or whether tubes are to be hydrotested or air tested (see 11.8)

4.1.7 Supplementary requirements—Purchaser shall specify on the purchase order if material is to be eddy current tested in accordance with Supplementary Requirements S1 or S2, and if special test reports are required under Supplementary Requirement S3, and,

4.1.8 Any additional special requirements.

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the latest published edition of Specification A1016/A1016M unless otherwise provided herein.

6. Materials and Manufacture

6.1 The tube shall be manufactured by either the seamless or welded and cold worked process.

TABLE 1 Chemical Requirements

Element	Grade..............	TP 304	TP 304L	TP 304LN	TP 316	TP 316L	TP 316LN	TP XM-29	TP 304N	TP 316N	. . .	800	800H	. . .	. . .	. . .	. . .
	UNS Designation[A]	S30400	S30403	S30453	S31600	S31603	S31653	S24000	S30451	S31651	N08367	N08800	N08810	N08811	N08926	S31254	S32654
		Composition, %															
Carbon, max		0.08	0.035	0.035	0.08	0.035	0.035	0.060	0.08	0.08	0.030	0.10	0.05–0.10	0.06–0.10	0.020	0.020	0.020
Manganese, max[B]		2.00	2.00	2.00	2.00	2.00	2.00	11.50–14.50	2.00	2.00	2.00	1.50	1.50	1.50	2.00	1.00	2.0–4.0
Phosphorus, max		0.040	0.040	0.040	0.040	0.040	0.040	0.060	0.040	0.040	0.040	0.045	0.045	0.045	0.03	0.030	0.030
Sulfur, max		0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.015	0.015	0.015	0.01	0.010	0.005
Silicon, max		0.75	0.75	0.75	0.75	0.75	0.75	1.00	0.75	0.75	1.00	1.00	1.00	1.00	0.5	0.80	0.50
Nickel		8.00–11.00	8.00–13.00	8.00–13.00	10.00–14.00	10.00–15.00	10.00–15.00	2.25–3.75	8.00–11.0	10.00–14.00	23.50–25.50	30.0–35.0	30.0–35.0	30.0–35.0	24.00–26.00	17.5–18.5	21.0–23.0
Chromium		18.00–20.00	18.00–20.00	18.00–20.00	16.00–18.00	16.00–18.00	16.00–18.00	17.00–19.00	18.0–20.0	16.0–18.0	20.00–22.00	19.00–23.0	19.00–23.0	19.00–23.0	19.00–21.00	19.5–20.5	24.0–25.0
Molybdenum		...	...	...	2.00–3.00	2.00–3.00	2.00–3.00	...	...	2.00–3.00	6.00–7.00	...	...	...	6.0–7.0	6.0–6.5	7.0–8.0
Nitrogen[C]		...	...	0.10–0.16	...	...	0.10–0.16	0.20–0.40	0.10–0.16	0.10–0.16	0.18–0.25	...	...	...	0.15–0.25	0.18–0.22	0.45–0.55
Copper		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.75 max	0.75	0.75	0.75	0.5–1.5	0.50–1.00	0.30–0.60
Titanium		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.15–0.60	0.15–0.60	0.25–0.60[D]	. . .	. . .	. . .
Aluminum		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.15–0.60	0.15–0.60	0.25–0.60[D]	. . .	. . .	. . .
Others		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Fe 39.5 Min.[E]	Fe 39.5 Min.[E]	Fe 39.5 Min.[E]	. . .	. . .	. . .

[A] New designation established in accordance with Practice E527 and SAE J1086.
[B] Maximum, unless otherwise noted.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
[D](Al + Ti) = 0.85 – 1.20.
[E]Fe shall be determined arithmethically by difference of 100 minus the sum of the other specified elements.

6.2 *Seamless Tubing:*

6.2.1 Seamless tubing shall be supplied from a cold finishing process. Hot finishing as the final sizing process is not allowed.

6.3 *Welded Tubing:*

6.3.1 The tube shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

6.3.2 Subsequent to welding and prior to final heat treatment, the tubes shall be cold worked either in both the weld and base metal, or in the weld metal only. The method of cold work may be specified by the purchaser. When cold drawn, the purchaser may specify the minimum amount of reduction in cross-sectional area or wall thickness, or both.

6.4 Many surface contaminants may have detrimental effects on high temperature properties or corrosion resistance of tubing. Contamination by copper, lead, mercury, zinc, chlorides, or sulfur may be detrimental to stainless steels. The manufacturer shall employ techniques that minimize surface contamination by these elements.

7. Cleaning Before Annealing

7.1 All lubricants of coatings used in the manufacture of straight-length tube or in the bending shall be removed from all surfaces prior to any annealing treatments. U-bends on which a lubricant had been applied to the inside surface during bending shall have the cleanness of their inside surface confirmed by blowing close fitting acetone-soaked felt plugs through 10 % of the tubes of each bend radius. Dry, oil-free, air or inert gas shall be used to blow the plugs through the tubes. If the plugs blown through any tube shows more than a light gray discoloration, all tubes that have had a lubricant applied to the inside surface during bending shall be recleaned. After recleaning 10 % of the tubes of each bend radius whose inside surface had been subjected to bending lubricants shall be retested.

8. Heat Treatment

8.1 All finished straight tubing or straight tubing ready for U-bending shall be furnished in the solution-annealed condition. The annealing procedure, except for N08367, S31254, S32654, N08810, N08811, and N08926, shall consist of heating the material to a minimum temperature of 1900 °F [1040 °C] followed by a rapid cooling to below 700 °F [370 °C]. The cooling rate shall be sufficiently rapid to prevent harmful carbide precipitation as determined in Section 13.

8.2 UNS N08367 shall be solution annealed at 2025 °F [1107 °C] minimum followed by rapid quenching.

8.3 N08926 shall be heat-treated at a minimum temperature of 2010 °F [1100 °C] followed by quenching in water or rapidly cooling by other means.

8.4 S31254, S32654, and N08811 shall be solution annealed at 2100 °F [1150 °C] minimum followed by rapid quenching.

8.5 N08810 shall be heat-treated to a minimum temperature of 2050 °F [1120 °C] minimum followed by rapid quenching.

8.6 If heat treatment of U-bends is specified, it shall satisfy the annealing procedure described above, and shall be done as follows:

8.6.1 The heat treatment shall be applied to the U-bend area plus approximately 6 in. [150 mm] of each leg beyond the tangent point of the U-bend.

8.6.2 If the heat treatment specified in 8.6 is accomplished by resistance-heating methods wherein electrodes are clamped to the tubes, the clamped areas shall be visually examined for arc burns. Burn indications shall be cause for rejection unless they can be removed by local polishing without encroaching upon minimum wall thickness.

8.6.3 Temperature control shall be accomplished through the use of optical or emission pyrometers, or both. No temperature-indicating crayons, lacquers, or pellets shall be used.

8.6.4 The inside of the tube shall be purged with a protective or an inert gas atmosphere during heating and cooling to below 700 °F [370 °C] to prevent scaling of the inside surface. The atmosphere should be noncarburizing.

9. Surface Condition

9.1 The straight tubes, after final annealing, shall be pickled using a solution of nitric and hydrofluoric acids followed by flushing and rinsing in water. If bright annealing is performed, this requirement does not apply.

9.2 A light oxide scale on the outside surface of U-bend area shall be permitted for tubes which have been electric-resistance heat treated after bending.

10. Chemical Composition

10.1 *Product Analysis:*

10.1.1 When requested in the purchase order, a product analysis shall be made by the supplier from one tube or coil of steel per heat. The chemical composition shall conform to the requirements shown in Table 1.

10.1.2 A product analysis tolerance of Specification A480/A480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04 % or less.

10.1.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of this specification; otherwise all remaining material in the heat or lot shall be rejected, or at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of this specification shall be rejected.

11. Mechanical Requirements

11.1 *Tensile Properties:*

11.1.1 The material shall conform to the tensile properties shown in Table 2.

11.1.2 One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes.

11.2 *Hardness:*

11.2.1 Grade TP XM-29 and N08367 tubes shall have a hardness number not exceeding 100 HRB or its equivalent. Tubes of all other grades shall have a hardness number not

TABLE 2 Tensile Requirements

Grade	304, 316	304L, 316L	XM-29	304N, 316N	304LN, 316LN	. . .	. . .	800	800H	. . .	. . .	. . .	. . .	. . .
UNS Designation	S30400, S31600	S30403, S31603	S24000	S30451, S31651	S30453, S31653	N08367 t ≤ 0.187	N08367 t > 0.187	N08800	N08810	N08811	N08926	S31254 t ≤ 0.187	S31254 t > 0.187	S32654
Tensile strength, min ksi [MPa]	75 [515]	70 [485]	100 [690]	80 [550]	75 [515]	100 [690]	95 [655]	75 [520]	65 [450]	65 [450]	94 [650]	100 [690]	95 [655]	120 [825]
Yield strength, min ksi [MPa]	30 [205]	25 [175]	55 [380]	35 [240]	30 [205]	45 [310]	45 [310]	30 [205]	25 [170]	25 [170]	43 [295]	45 [310]	45 [310]	65 [450]
Elongation in 2 in. or 50 mm, min, %	35	35	35	35	35	30	30	30	30	30	35	35	35	40

exceeding 90 HRB or its equivalent. This hardness requirement is not to apply to the bend area of U-bend tubes which are not heat treated after bending.

11.2.2 Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot.

11.3 *Reverse Bend Test (Welded Product):*

11.3.1 One reverse bend test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

11.3.2 A section 4 in. [100 mm] minimum in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a maximum thickness of four times the wall thickness, with the mandrel parallel to the weld and against the original outside surface of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks, or of overlaps resulting from the reduction in thickness of the weld area by cold working. When the geometry or size of the tubing make it difficult to test the sample as a single piece, the sample may be sectioned into smaller pieces provided a minimum of 4 in. of weld is subjected to reverse bending.

11.3.3 The reverse bend test is not applicable when specified wall is 10 % or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter size is less than 0.375 in. [9.5 mm]. Under these conditions, the reverse flattening test of Specification A1016/A1016M shall apply.

11.4 *Flattening Test (Seamless and Welded Products)*—Flattening tests shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot.

11.5 *Flange Test (Welded Product)*—Flange tests shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot.

11.6 *Flaring Test (Seamless Product)*—Flaring tests shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot.

11.7 *Grain Size:*

11.7.1 The grain size of grades N08810 and N08811, as determined in accordance with Test Methods E112, shall be No. 5 or coarser.

11.8 *Pressure Test:*

11.8.1 Each straight tube or each U-tube after completion of the bending and post-bending heat treatment, shall be pressure tested in accordance with one of the following paragraphs as specified by the purchaser.

11.8.1.1 *Hydrostatic Test*—Each tube shall be given an internal hydrostatic test in accordance with Specification A1016/A1016M, except that the test pressure and hold time, when other than that stated in Specification A1016/A1016M, shall be agreed upon between purchaser and manufacturer.

11.8.1.2 *Pneumatic Test*—Each tube shall be examined by a pneumatic test (either air underwater or pneumatic leak test) in accordance with Specification A1016/A1016M.

11.9 *Lot Definitions:*

11.9.1 For flattening, flange, and flaring requirements, the term "lot" applies to 125 tube groupings, prior to cutting to length, of the same nominal size and wall thickness, produced from the same heat of steel and annealed in a continuous furnace.

11.9.2 For tension and hardness, the term "lot" applies to all tubes, prior to cutting to length, of the same nominal diameter and wall thickness, produced from the same heat of steel and annealed in a continuous furnace at the same temperature, time at temperature, and furnace speed.

12. Nondestructive Test (Electric Test)

12.1 Each straight tube shall be tested after the finish heat treatment by passing it through a nondestructive tester capable of detecting defects on the entire cross section of the tube, in accordance with Specification A1016/A1016M.

13. Corrosion Resisting Properties

13.1 One full section sample 1 in. [25.4 mm] long from the center of a sample tube of the smallest radius bend which is heat treated shall be tested in the heat treated condition in accordance with Practices A262.

13.2 One full-section sample 1 in. [25.4 mm] long from each lot of straight tubes shall be tested in the finished condition in accordance with Practices A262.

13.3 The appearance of any fissures or cracks in the test specimen when evaluated in accordance with Practices A262 indicating the presence of intergranular attack, shall be cause for rejection of that lot.

13.4 Lot definitions: For corrosion test requirements, the term "lot" applies to all tubes, prior to cutting to length, of the same nominal diameter and wall thickness, produced from the same heat of steel and annealed in a continuous furnace at the same temperature, time at temperature, and furnace speed.

13.5 *High Carbon Grades*—The high carbon grades of N08810 and N08811 shall not be subjected to the intergranular corrosion test.

14. Permissible Variations in Dimensions (Fig. 1)

14.1 Permissible variations from the specified outside diameter shall be in accordance with Specification A1016/A1016M. Those tolerances do not apply to the bent portion of the U-tubes. At the bent portion of a U-tube for $R = 2 \times D$ or greater, neither the major nor minor diameter of the tube shall deviate from the nominal diameter prior to bending by more than 10 %. If less than $2 \times D$ is specified, tolerances could be greater.

14.2 *Permissible Variations from the Specified Wall Thickness:*

14.2.1 Permissible variations from the specified minimum wall thickness shall not exceed +20 % − 0.

14.2.2 Permissible variations from the specified average wall thickness are ±10 % of the nominal wall thickness.

14.2.3 The wall thickness of the tube in the U-bent section shall not be less than value determined by the equation:

$$t_f = \frac{4RT}{4\,R + D}$$

where:

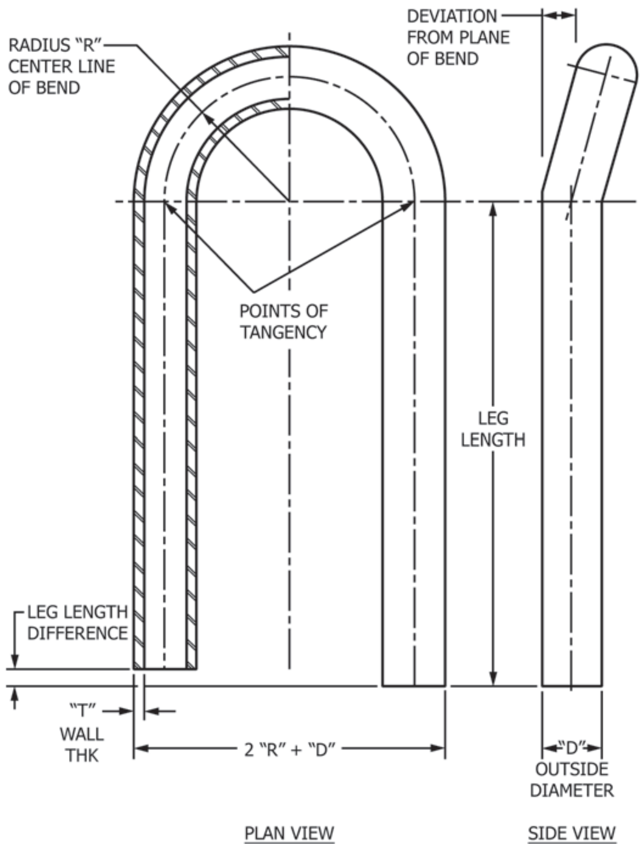

FIG. 1 Plane Bend for U-Tube

t_f = wall thickness after bending, in. [mm],
T = minimum wall thickness of 14.2.1 or 14.2.2, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

14.3 *Permissible Variations from the Specified Length:*

14.3.1 *Straight Lengths*—The maximum permissible variations for lengths 24 ft [7.3 m] and shorter shall be +⅛ in. [3 mm], −0; for lengths longer than 24 ft [7.3 mm], an additional over tolerance of +⅛ in. [3 mm] for each 10 ft [3 m], or fraction thereof, shall be permitted up to a maximum of +½ in. [13 mm].

14.3.2 *U-Bends*—In the case of U-tubes, the length of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg, shall not be less than specified, but may exceed the specified values by the amount given in Table 3. The difference in lengths of the tube legs shall not be greater than ⅛ in. unless otherwise specified.

14.4 The end of any tube may depart from square by not more than the amount given in Table 4.

TABLE 3 Tube Leg Length Tolerance

Leg Length, ft [m]	Plus Tolerance, in. [mm]
Up to 20 [6], incl	⅛ [3.2]
Over 20 to 30 [6 to 9], incl	5⁄32 [4.0]
Over 30 to 40 [9 to 12.2], incl	3⁄16 [4.8]

TABLE 4 Squareness of Ends Tolerance

Tube OD, in. [mm]	Tolerance, in. [mm]
⅝ [15.9], incl	0.010 [0.25]
Over ⅝ to 1 in. [15.9 to 25.4], incl	0.016 [0.4]

14.5 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value (2 R − specified tube outside diameter) by more than 1⁄16 in. [1.5 mm] where R is the center-line bend radius.

14.6 The bent portion of the U-tube shall be substantially uniform in curvature, and not to exceed ± 1⁄16 in. [1.5 mm] of the nominal center-line radius.

14.7 Permissible deviation from the plane of bend (Fig. 1) shall not exceed 1⁄16 in. [1.5 mm] as measured from the points of tangency.

15. Workmanship, Finish, and Appearance

15.1 Tubing purchased to this specification is intended for use in heat exchangers, and will be inserted through close-fitting holes in baffles or support plates, or both, spaced along the tube length. The tube ends will also be inserted into very close-fitting holes in a tubesheet and expanded and may be welded therein. The tubes shall be able to stand expanding and bending without showing cracks and flaws, and shall be finished reasonably straight and suitable for the intended purpose.

15.2 The residual chloride salt contamination of the inside and outside surface of the tubing at the time of packing for shipment from the mill shall not exceed a concentration of 1 mg/ft^2 [10.7 mg/m^2] of tube surface. One tube in each five hundred pieces shall be checked immediately prior to packing for shipment for chloride salt contamination by a procedure agreed upon by the manufacturer and purchaser.

16. Inspection

16.1 The inspector representing the purchaser shall have entry, at all times, to those areas where inspection and testing is being performed on the purchaser's ordered material. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

17. Rejection

17.1 Each length of tubing received from the manufacturer may be inspected by the purchaser, and, if it does not meet the requirements of the specification based on the inspection and test method outlined in the specification, the tubing may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

17.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective, shall be set aside, and the manufacturer shall be notified. Disposition of such material shall be a matter for agreement between the manufacturer and the purchaser.

18. Certification

18.1 A test report, signed by an authorized employee or representative of the manufacturer, shall be furnished to the purchaser to indicate the specification and grade, seamless or welded, the results of the heat analysis, hardness and tensile properties. Product analysis will be reported only when requested on the purchase order as provided in 4.1.7.

19. Product Marking

19.1 All tubes shall be marked with the heat number.

19.2 Containers and packages shall be marked or tagged to show the purchaser's order number, the manufacturer's order number, specification, seamless or welded, grade, size and wall thickness, minimum or average, number of pieces contained in the package, and item number (if appropriate).

20. Packaging

20.1 All tubing shall be packaged and blocked in such a manner as to prevent damage in ordinary handling and transportation. The boxes shall be constructed in such a manner that no nails, staples, screws, or similar fasteners are required to close and secure the box after the tubes have been placed in the box. The box shall be lined with plastic sheet or vapor barrier materials so as to prevent chloride contamination of the tube during handling, transportation, and storage.

20.2 The U-bent tubes shall be arranged in boxes so that the smaller radius bends may be removed without disturbing larger radius bends. Tubes for an item number shall be boxed together.

21. Keywords

21.1 austenitic stainless steel; feedwater heater tubes; seamless tube; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement or requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which event the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

S1. Nondestructive Eddy-Current Test

S1.1 Each tube in the finished condition, except for bending if that is required, shall be tested by passing it through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation shall be used to clearly distinguish the artificial defects. The outside and inside surfaces of the tubes shall be free of loose scale, metallic particles, or other material which would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding it longitudinally through an inspection coil or coils with a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from an appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed at which the inspection of the tubing is performed.

S1.2 The factors listed in S1.3 shall be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions, for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portions of the tube.

S1.3 The following as well as other factors involved shall not be used in such a manner that they detract from the overall ability of the instrument to detect defects: test frequency, direct-current saturation level, filter networks, phase-analysis circuits, coil diameter, and instrument gain.

S1.4 The reference standard shall consist of a defect-free sample of the same size, alloy, and condition (temper) as that being tested, and shall contain longitudinal and circumferential notches on the outside diameter establishing the rejection level of the tubing to be tested. Inside diameter notches, both longitudinal and transverse, shall also be a part of the reference standard. These inside notches may be larger than the outside notches, and are intended for use only to assure instrument phase settings capable of yielding optimum inside surface sensitivity.

S1.4.1 All notches shall be produced by EDM methods. The outside diameter notches shall be of the dimensions shown in Table S1.1 and Fig. S1.1.

S1.5 All tubing shall meet this specification. The instrument calibration shall be verified at the start of testing, after any shut down of the test equipment, after any test equipment adjustment, or at least every ½ h of continuous production testing or both. Tubes generating a signal above the outside diameter calibration standard sensitivity level shall be rejected.

TABLE S1.1 Notch Depth

OD, in. [mm]	Wall, in. [mm]	Depth,[A] in. [mm]	Length, max, in. [mm]	Width, max
⅝ to 1 [15.9 to 25.4], incl	0.028 [0.7] and heavier	0.0045 [0.11] or 10 % of wall thickness whichever is greater	0.375 [9.5]	wall thickness but not greater than 0.062 in. [1.6 mm]

[A] The tolerance of notch depth shall be ± 8 % or ± 0.0005 in. [0.01 mm], whichever is greater. Refer to Fig. S1.1 for notch location orientation and length of calibration standard.

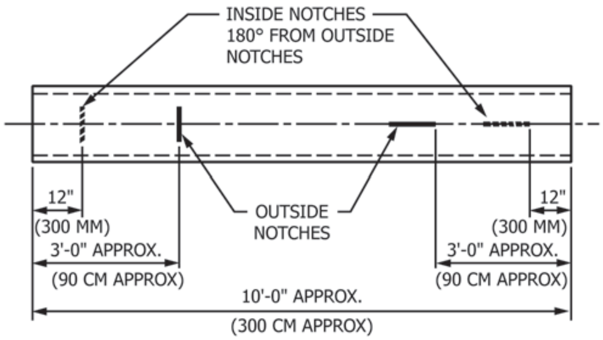

FIG. S1.1 Eddy-Current Test Standard

S1.6 Tubes may be reconditioned and retested provided reconditioning does not adversely effect the minimum wall thickness or other properties of the tube specification requirements. Upon agreement between purchaser and manufacturer, the referee method, employing ultrasonic testing, may be employed for retesting tubes rejected by the eddy-current test. The calibration standard for this test shall be identical to that required for the eddy-current test.

S2. Nondestructive Eddy-Current Testing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch standards, which shall be as indicated in Table S2.1.

TABLE S2.1 Notch Depth for Select Commercial Grade

OD, in. [mm]	Wall, in. [mm]	Depth,[A] in. [mm]	Length, max, in. [mm]	Width, max
⅝ to 1 [15.9 to 25.4], incl	0.035 [0.9] and heavier	0.0045 [0.11] or 10 % of wall thickness, whichever is greater	0.375 [9.5]	3 times notch depth
⅝ to 1 [15.9 to 25.4], incl	less than 0.035 [0.9]	0.0045 [0.11] or 10 % of wall thickness, whichever is greater	0.375 [9.5]	wall thickness

[A]The tolerance of notch depth shall be ± 8 % or ± 0.0005 in. [0.1 mm], whichever is greater. Refer to Fig. S1.1 for notch location orientation and length of calibration standard.

S3. Report

S3.1 A report shall be furnished by the manufacturer to include a record of all tests performed to qualify material to this specification. This record shall include numbers of tests performed and qualitative or quantitative results as is applicable.

S4. Intergranular Corrosion Tests

S4.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A262, Practice E.

NOTE S4.1—Practice E requires testing on the sensitized condition for low carbon grades, and on the as-shipped condition for other grades.

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SPECIFICATION FOR CARBON AND ALLOY STEEL PIPE, ELECTRIC-FUSION-WELDED FOR HIGH-PRESSURE SERVICE AT HIGH TEMPERATURES

SA-691/SA-691M

(**23**)

(Identical with ASTM Specification A691/A691M-19 except that the following additional requirements apply.)

For products ordered to Section III, Division 1 of the ASME Boiler and Pressure Vessel Code, Supplementary Requirement S13 is mandatory.

Specification for
Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures

1. Scope

1.1 This specification covers carbon and alloy steel pipe, electric-fusion-welded with filler metal added, fabricated from pressure-vessel-quality plate of several analyses and strength levels and suitable for high-pressure service at high temperatures. Heat treatment may or may not be required to attain the desired mechanical properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. [400 mm] in outside diameter and larger with wall thicknesses up to 3 in. [75 mm] inclusive. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 *Grade* designates the type of plate used as listed in Table 1.

1.3.2 *Class* designates the type of heat treatment performed in the manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in 1.3.3.

1.3.3 Class designations are as follows (Note 1):

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see Section
10	none	none	none
11	none	9	none
12	none	9	8.3
13	none	none	8.3
20	stress relieved, see 5.3.1	none	none
21	stress relieved, see 5.3.1	9	none
22	stress relieved, see 5.3.1	9	8.3
23	stress relieved, see 5.3.1	none	8.3
30	normalized, see 5.3.2	none	none
31	normalized, see 5.3.2	9	none
32	normalized, see 5.3.2	9	8.3
33	normalized, see 5.3.2	none	8.3
40	normalized and tempered, see 5.3.3	none	none
41	normalized and tempered, see 5.3.3	9	none
42	normalized and tempered, see 5.3.3	9	8.3
43	normalized and tempered, see 5.3.3	none	8.3
50	quenched and tempered, see 5.3.4	none	none
51	quenched and tempered, see 5.3.4	9	none
52	quenched and tempered, see 5.3.4	9	8.3
53	quenched and tempered, see 5.3.4	none	8.3

NOTE 1—Selection of materials should be made with attention to temperature of service. For such guidance, Specification A20/A20M may be consulted.

1.4 Optional requirements of a supplementary nature are provided, calling for additional tests and control of repair welding, when desired.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

TABLE 1 Plate Materials

Pipe Grade	Type of Steel	ASTM Specification		HB, max[A]
		Number	Grade	
CM-65	carbon-molybdenum steel	A204/A204M	A	201
CM-70	carbon-molybdenum steel	A204/A204M	B	201
CM-75	carbon-molybdenum steel	A204/A204M	C	201
CMSH-70	carbon-manganese-silicon steel, normalized	A537/A537M	1	
CMS-75	carbon-manganese-silicon steel	A299/A299M	. . .	. . .
CMSH-80	carbon-manganese-silicon steel, quenched and tempered	A537/A537M	2	
½ CR	½ % chromium, ½ % molybdenum steel	A387/A387M	2	201
1CR	1 % chromium, ½ % molybdenum steel	A387/A387M	12	201
1¼ CR	1¼ % chromium, ½ % molybdenum steel	A387/A387M	11	201
2¼ CR	2¼ % chromium, 1 % molybdenum steel	A387/A387M	22	201
3CR	3 % chromium, 1 % molybdenum steel	A387/A387M	21	201
5CR	5 % chromium, ½ % molybdenum steel	A387/A387M	5	225
9CR	9 % chromium, 1 % molybdenum steel	A387/A387M	9	241
91	9 % chromium, 1 % molybdenum, vanadium, niobium[C]	A387/A387M	91[B]	241

[A] Hardness values listed are applicable to S3.
[B] Grade 91 shall be designated by Type 1 or Type 2 when required by the prevalent specification.
[C] Element 41 has been identified as columbium or niobium. A01 considers them interchangeable and both acceptable. Subcommittee A01.09 has chosen to use niobium.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels
A204/A204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum
A299/A299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A387/A387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A537/A537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
E165/E165M Practice for Liquid Penetrant Testing for General Industry
E709 Guide for Magnetic Particle Testing

2.2 *ASME Boiler and Pressure Vessel Code:*

Section II
Section III
Section VIII
Section IX

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 A *lot* shall consist of 200 ft [60 m] or fraction thereof of pipe from the same heat of steel.

3.1.1.1 The description of a lot may be further restricted by use of Supplementary Requirement S12.

4. Ordering Information

4.1 The inquiry and order for material under this specification should include the following information:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of the material (steel pipe, electric-fusion-welded),

4.1.3 Plate Specification number, including Grade and Type if applicable,

4.1.4 Pipe Grade and class designations (see 1.3),

4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish,

4.1.8 Purchase options, if any (see 5.2.3, 11.3, 11.4, 13.1), and

4.1.9 Supplementary requirements, if any (refer to S1 through S13).

5. Materials and Manufacture

5.1 *Materials*—The steel plate material shall conform to the requirements of the applicable plate specification for the pipe grade ordered as listed in Table 1.

5.2 *Welding:*

5.2.1 The joints shall be double-welded full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.

5.2.3 The welded joints shall have positive reinforcement at the center of each side of the weld, but no more than ⅛ in. [3 mm]. This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be smooth, and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.2.4 When radiographic examination in accordance with 9.1 is to be used, the weld reinforcement shall be governed by the more restrictive provisions of UW-51 of Section VIII of the ASME Boiler and Pressure Vessel Code instead of 5.2.3 of this specification.

5.3 *Heat Treatment*—All classes other than 10, 11, 12, and 13 shall be heat treated in a furnace controlled to ± 25 °F [15 °C] and equipped with a recording pyrometer so that heating records are available. Heat treating after forming and welding shall be to one of the following:

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range indicated in Table 2 for a minimum of 1 h/in. [0.4 hr/cm] of thickness or for 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33 pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in Table 2 and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of ½ h/in. [0.2 hr/cm] of thickness or for ½ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in Table 2 and subsequently quenched in water or oil. After quenching, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at that temperature for a minimum of ½ h/in. [0.2 hr/cm] of thickness or for ½ h, whichever is greater, and air cooled.

5.4 Grade 91 shall be produced only to classes 4X and 5X. In addition, post-weld heat treatment is required after weld repair.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A530/A530M, unless otherwise provided herein.

7. Chemical Requirements

7.1 *Product Analysis of Plate*—The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

7.2 *Product Analysis of Weld*—The pipe manufacturer shall make an analysis of finished deposited weld metal from each 200 ft [60 m] or fraction thereof. Analysis shall conform to the welding procedure for deposited weld metal.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

7.4 If the analysis of one of these tests specified in 7.1 or 7.2 does not conform to the requirements specified, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified. Nonconforming pipe shall be rejected.

8. Mechanical Requirements

8.1 *Tension Test:*

8.1.1 *Requirements*—Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material.

8.1.2 *Number of Tests*—One test specimen shall be made to represent each lot of finished pipe.

TABLE 2 Heat Treatment Parameters[A]

Pipe Grade	ASTM Specification	Post-Weld Heat-Treat Temperature Range (Stress Relieving), °F (°C)	Normalizing Temperature, max unless otherwise noted, °F (°C)	Quenching Temperature, max unless otherwise noted, °F (°C)	Tempering Temperature, min, °F (°C)
CM-65	A204/A204M	1100 to 1200 [590 to 650]	1700 [925]	. . .	. . .
CM-70	A204/A204M	1100 to 1200 [590 to 650]	1700 [925]	. . .	. . .
CM-75	A204/A204M	1100 to 1200 [590 to 650]	1700 [925]	. . .	. . .
CMSH-70	A537/A537M	1100 to 1200 [590 to 650]	1700 [925]	. . .	. . .
CMS-75	A299/A299M	1100 to 1200 [590 to 650]	1700 [925]	. . .	. . .
CMSH-80	A537/A537M	1100 to 1200 [590 to 650]	[B]	1700 [925]	1100 to 1250 [590 to 675]
½ CR	A387/A387M	1100 to 1300 [590 to 705]	1850 [1010]	1700 [925]	1150 to 1375 [620 to 745]
1CR	A387/A387M	1100 to 1350 [590 to 730]	1850 [1010]	1700 [925]	1150 to 1375 [620 to 745]
1¼ CR	A387/A387M	1100 to 1375 [590 to 745]	1850 [1010]	1700 [925]	1150 to 1375 [620 to 745]
2¼ CR	A387/A387M	1200 to 1400 [650 to 760]	1850 [1010]	1700 [925]	1250 to 1400 [675 to 760]
3CR	A387/A387M	1200 to 1400 [650 to 760]	1850 [1010]	1700 [925]	1250 to 1400 [675 to 760]
5CR	A387/A387M	1200 to 1400 [650 to 760]	1850 [1010]	1650 [900]	1300 to 1400 [705 to 760]
9CR	A387/A387M	1325 to 1375 [715 to 745]	[C]	. . .	1325 to 1375 [715 to 745]
91	A387/A387M	1350 to 1420 [730 to 770]	1900 to 2000 [1040 to 1095]	1900 min [1040 min]	1350 to 1440 [730 to 780]

[A] Where ellipses (...) appear in the table, there is no requirement.
[B] Requires quenching and tempering.
[C] 9CR steel is an air-hardenable steel, at times retaining austenite down to near atmospheric temperature. Good practice is to allow the steel to cool to 150 °F or lower before subjecting the steel to a tempering treatment or post-weld heat treatment.

8.1.3 *Test Specimen Location and Orientation*—The test specimen shall be made transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

8.1.4 *Test Method*—The test specimen shall be made in accordance with QW-150 in Section IX of the ASME Boiler and Pressure Vessel Code. The test specimen shall be tested at room temperature in accordance with Test Methods and Definitions A370.

8.2 *Transverse-Guided-Weld-Bend Tests:*

8.2.1 *Requirements*—The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. [3 mm] in any direction be present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along the edges of the specimens during testing, and that are less than ¼ in. [6 mm] in any direction shall not be considered.

8.2.2 *Number of Tests*—One test (two specimens) shall be made to represent each lot of finished pipe.

8.2.3 *Test Specimen Location and Orientation*—Two bend test specimens shall be taken transverse to the weld at the end of the finished pipe. As an alternative, by agreement between the purchaser and the manufacturer, the test specimens may be taken from a test plate of the same material as the pipe, the test plate being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal weld seam.

8.2.4 *Test Method*—Bend tests shall be made in accordance with Test Methods and Definitions A370, A 2.5.1.7. For wall thicknesses over ⅜ in. [10 mm] but less than ¾ in. [19 mm] side-bend tests may be made instead of the face and root-bend tests. For wall thicknesses ¾ in. [19 mm] and over both specimens shall be subjected to the side-bend test.

8.3 *Pressure Test*—Classes X2 and X3, pipe shall be tested in accordance with Specification A530/A530M, Hydrostatic Test Requirements.

9. Radiographic Examination

9.1 The full length of each weld of classes X1 and X2 shall be radiographically examined in accordance with requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW-51.

9.2 Radiographic examination may be performed prior to heat treatment.

10. Rework

10.1 *Elimination of Surface Imperfections*—Unacceptable surface imperfections shall be removed by grinding or machining. The remaining thickness of the section shall be no less than the minimum specified in Section 11. The depression after grinding or machining shall be blended uniformly into the surrounding surface.

10.2 *Repair of Base Metal Defects by Welding:*

10.2.1 The manufacturer may repair, by welding, base metal where defects have been removed, provided the depth of the repair cavity as prepared for welding does not exceed ⅓ of the nominal thickness, and the requirements of 10.2.2, 10.2.3, 10.2.4, 10.2.5, and 10.2.6 are met. Base metal defects in excess of these may be repaired with prior approval of the customer.

10.2.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair welding.

10.2.3 The welding procedure and welders or welding operators are to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.2.4 The full length of the repaired pipe shall be heat treated after repair in accordance with the requirements of the pipe class specified.

10.2.5 Each repair weld of a defect where the cavity, prepared for welding, has a depth exceeding the lesser of ⅜ in. [10 mm] or 10 % of the nominal thickness shall be examined by radiography in accordance with the methods and the acceptance standards of Section 9.

10.2.6 The repair surface shall be blended uniformly into the surrounding base metal surface and examined and accepted in accordance with Supplementary Requirements S6 or S8.

10.3 *Repair of Weld Metal Defects by Welding:*

10.3.1 The manufacturer may repair weld metal defects if he meets the requirements of 10.2.3, 10.2.4, 10.3.2, 10.3.3, and 10.4.

10.3.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the repair cavity examined and accepted in accordance with Supplementary Requirements S7 or S9.

10.3.3 The weld repair shall be blended uniformly into the surrounding metal surfaces and examined and accepted in accordance with 9.1 and with Supplementary Requirements S7 or S9.

10.4 *Retest*—Each length of repaired pipe of a class requiring a pressure test shall be hydrostatically tested following repair.

11. Dimensions, Mass, and Permissible Variations

11.1 The wall thickness and weight for welded pipe furnished to this specification shall be governed by the requirements of the specification to which the manufacturer ordered the plate.

11.2 Permissible variations in dimensions at any point in a length of pipe shall not exceed the following:

11.2.1 *Outside Diameter*—Based on circumferential measurement, ± 0.5 % of the specified outside diameter.

11.2.2 *Out-of-Roundness*—The difference between major and minor outside diameters, 1 %.

11.2.3 *Alignment*—Using a 10-ft [3-m] straightedge placed so that both ends are in contact with the pipe, ⅛ in. [3 mm].

11.2.4 *Thickness*—The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. [0.3 mm] under the specified nominal thickness.

11.3 Circumferential welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

11.4 Lengths with unmachined ends shall be within −0, +½ in. [−0, +13 mm] of that specified. Lengths with machined ends shall be as agreed between the manufacturer and the purchaser.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish. This requirement is to mean the same as the identical requirement that appears in Specification A20/A20M with respect to steel plate surface finish.

13. Product Marking

13.1 The marking shall be stenciled using a suitable heat-resistant paint or metal stamped using low-stress stamps. Wall thicknesses under 0.500 in. [13 mm] shall not be metal stamped without prior approval. The purchaser may specify that material 0.500 in. [13 mm] and over shall not be metal stamped.

13.2 In addition to the marking provision of Specification A530/A530M, the class marking in accordance with 1.3.3 shall follow the grade marking, for example, 3CR-33.

13.3 A387/A387M Grade 91 shall additionally be marked with the appropriate Type, 1 or 2, when applicable based on the ordered specification.

13.4 *Bar Coding*—In addition to the requirements in 13.1, 13.2, and 13.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser, Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Tension and Bend Tests

S1.1 Tension tests in accordance with 8.1 and bend tests in accordance with 8.2 shall be made on specimens representing each length of pipe.

S2. Charpy V-Notch Test (for pipe with nominal wall thickness of ½ in. [13 mm] and greater)

S2.1 *Requirements*—The acceptable test energies shall be as shown in Table A1.15 of Specification A20/A20M for the applicable plate specification unless otherwise stated in the order. As an alternative, the test temperature may be 10 °F [−12 °C].

S2.2 *Number of Specimens*—Each test shall consist of at least three specimens.

S2.2.1 One base-metal test shall be made from one pipe length per heat, per heat-treat charge, and per nominal wall thickness.

S2.2.2 One weld-metal and one heat-affected zone (HAZ) metal test shall be made in accordance with NB 4335 of Section III of the ASME Boiler and Pressure Vessel Code.

S2.3 *Test Specimen Location and Orientation:*

S2.3.1 Base-metal specimens of stress-relieved, normalized, and normalized and tempered pipe shall be taken in accordance with the provisions for tension specimens in the body of this specification.

S2.3.2 Base-metal specimens of quenched and tempered pipe shall be taken in accordance with the provisions of NB 2225 of Section III of the ASME Boiler and Pressure Vessel Code.

S3. Hardness Tests

S3.1 Hardness determination shall be made on both ends of each length of pipe to the parent metal, weld, and the heat-affected zone and must meet the hardness requirements in Table 1.

S4. Product Analysis

S4.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical requirements prescribed in the applicable specification listed in Table 1 shall be rejected.

S5. Metallography

S5.1 The manufacturer shall furnish one photomicrograph to show the microstructure at 100× magnification of the weld metal or base metal of the pipe in the as-finished condition. The purchaser shall state in the order: the material, base metal or weld, and the number and locations of tests to be made. This test is for information only.

S6. Magnetic Particle Examination of Base Metal

S6.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. [600 mm] in diameter and greater, and inside surfaces of pipe less than 24 in. [600 mm] in diameter for a distance of one pipe diameter from the ends.

S6.2 Butt-weld end preparations are to be completely magnetic-particle examined in accordance with Practice E709.

S6.3 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S7. Magnetic Particle Examinations of Weld Metal

S7.1 All accessible welds shall be examined in accordance with Practice E709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. [600 mm] in diameter and greater, and inside surfaces of pipe less than 24 in. [600 mm] in diameter for a distance of one pipe diameter from the ends.

S7.2 Butt-weld end preparations are to be completely magnetic-particle examined in accordance with Practice E709.

S7.3 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S8. Liquid Penetrant Examination of Base Metal

S8.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E165/E165M. Accessible is as defined in S7.1.

S8.2 Butt-weld end preparations are to be completely liquid penetrant examined in accordance with Test Method E165/E165M.

S8.3 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S9. Liquid Penetrant Examination of Weld Metal

S9.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E165/E165M. Accessible is as defined in S6.1.

S9.2 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S10. Ultrasonic Test

S10.1 *Plate in Flat:*

S10.1.1 One hundred percent on one surface shall be scanned.

S10.1.2 Straight search shall be used in accordance with Specification A435/A435M.

S10.1.3 Acceptance standards shall be in accordance with Specification A435/A435M or as by agreement between the manufacturer and the purchaser.

S11. Repair Welding

S11.1 Repair of base metal defects by welding shall be done only with customer approval.

S12. Description of Term

S12.1 *lot*—all pipe of the same mill heat of plate material and wall thickness (within ±¼ in. [6 mm]) heat treated in one furnace charge. For pipe that is not heat treated or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft [60 m] or fraction thereof of all pipe of the same mill heat of plate material and wall thickness (within ±¼ in. [6 mm]), subjected to the same heat treatment. For pipe heat treated in a batch-type furnace that is automatically controlled within a 50 °F [30 °C] range and is equipped with recording pyrometers so that heating records are available, a lot shall be defined the same as for continuous furnaces.

S13. ASME Section III Construction

S13.1 Products furnished under this specification that are intended for application under the rules of Section III of the ASME Boiler and Pressure Vessel Code shall be manufactured by holders of the appropriate ASME Certificate of Authorization and Certification Mark. The product is subject to all applicable requirements of Section III, including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Certification Mark.

S13.2 The applicable ASME Partial Data Report form, signed by an Authorized Nuclear Inspector, and a material test report shall be furnished for each lot of pipe.

S13.3 The plate used to fabricate the pipe shall conform to the applicable SA specification in the ASME Boiler and Pressure Vessel Code, Section II. The welded joints shall be full penetration butt welds as obtained by double welding or by other means that will obtain the same quality of deposited weld metal on the inside and outside. Welds using metal backing strips that remain in place are prohibited.

S13.4 In addition to the requirements of S12 and Section 13 (Product Marking), each length of pipe shall be so marked as to identify each such piece of pipe with the lot and the material test report.

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SPECIFICATION FOR PRECIPITATION-HARDENING STAINLESS AND HEAT-RESISTING STEEL PLATE, SHEET, AND STRIP

SA-693

(Identical with ASTM Specification A693-02$^{\varepsilon 1}$ except for aligning the elongation requirements for Gr. XM-16 and correction of the max. hardness for Gr. XM-12 and 630 in Table 5. Also there is a revision to Note B of Table 1.)

SPECIFICATION FOR PRECIPITATION-HARDENING STAINLESS AND HEAT-RESISTING STEEL PLATE, SHEET, AND STRIP

SA-693

(Identical with ASTM Specification A 693-02$^{\epsilon 1}$ except for aligning the elongation requirements for Gr. XM-16 and correction of the max. hardness for Gr. XM-12 and 630 in Table 5. Also there is a revision to Note B of Table 1.)

1. Scope

1.1 This specification covers precipitation-hardening stainless steel plate, sheet, and strip. The mechanical properties of these steels are developed by suitable low-temperature heat treatments generally referred to as precipitation hardening.

1.2 These steels are used for parts requiring corrosion resistance and high strength at room temperature or at temperatures up to 600°F (315°C). Some of these steels are particularly suitable for moderate to severe drawing and forming in the solution-treated condition. Others are capable of mild forming only. They are suitable for machining in the solution-annealed condition, after which they may be hardened to the mechanical properties specified in this standard without danger of cracking or distortion.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *SAE Standard:*

SAE J 1086 Recommended Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 480/A 480M or as specified in the following:

3.1.1 Definitions,

3.1.2 General requirements for delivery.

3.1.3 Ordering Information:

3.1.3.1 In addition to the requirements of A 480/A 480M, the heat treatment (see 6) must be specified on the purchase order.

4. Materials and Manufacture

4.1 The steel shall be melted by one of the following processes:

4.1.1 Electric furnace (with separate degassing and refining optional),

4.1.2 Vacuum furnace, and

4.1.3 One of the former followed by:

4.1.3.1 Consumable remelting in vacuum, inert gas, or electroslag, or

4.1.3.2 Electron beam refining.

4.1.4 Other commercial melting methods as agreed upon between purchaser and seller are acceptable.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition specified in Table 1, and shall conform to applicable requirements specified in the current edition of Specification A 480/A 480M.

6. Heat Treatment of Product

6.1 Material shall be furnished in the solution-annealed condition as noted in Table 2 and Table 3 unless otherwise specified by the purchaser on the purchase order.

7. Mechanical Properties

7.1 The material, as represented by mechanical test specimens, shall conform to the mechanical property requirements specified in Table 4 and shall be capable of developing the properties in Table 5 when heat treated as specified in 9.1.

8. Bending Requirements

8.1 Samples cut from the solution-annealed plate, sheet, or strip shall withstand cold bending as specified in Table 6 without cracking on the outside of the bent portion.

9. Heat Treatment of Test Specimens

9.1 Samples cut from the plate, sheet, or strip shall conform to the mechanical properties of Table 5 when precipitation hardened as specified in Table 2 and Table 3.

TABLE 1
CHEMICAL REQUIREMENTS[A]

UNS Designation[B]	Type	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Aluminum	Molybdenum	Titanium	Copper	Other Elements[C]
		Composition, %											
S 17400	630	0.07	1.00	0.040	0.030	1.00	15.00–17.50	3.00–5.00	. . .	. . .	. . .	3.00–5.00	[D]
S 17700	631	0.09	1.00	0.040	0.030	1.00	16.00–18.00	6.50–7.75	0.75–1.50	. . .	. . .	. . .	. . .
S 15700	632	0.09	1.00	0.040	0.030	1.00	14.00–16.00	6.50–7.75	0.75–1.50	2.00–3.00	. . .	. . .	. . .
S 35000	633	0.07–0.11	0.50–1.25	0.040	0.030	0.50	16.00–17.00	4.00–5.00	. . .	2.50–3.25	. . .	. . .	[E]
S 35500	634	0.10–0.15	0.50–1.25	0.040	0.030	0.50	15.00–16.00	4.00–5.00	. . .	2.50–3.25	. . .	. . .	[F]
S 17600	635	0.08	1.00	0.040	0.030	1.00	16.00–17.50	6.00–7.50	0.40	. . .	0.40–1.20	. . .	. . .
S 36200	XM-9	0.05	0.50	0.030	0.030	0.30	14.00–14.50	6.25–7.00	0.10	0.30	0.60–0.90	. . .	. . .
S 15500	XM-12	0.07	1.00	0.040	0.030	1.00	14.00–15.50	3.50–5.50	. . .	. . .	. . .	2.50–4.50	[D]
S 13800	XM-13	0.05	0.20	0.010	0.008	0.10	12.25–13.25	7.50–8.50	0.90–1.35	2.00–2.50	. . .	. . .	[G]
S 45500	XM-16	0.05	0.50	0.040	0.030	0.50	11.00–12.50	7.50–9.50	. . .	0.50	0.80–1.40	1.50–2.50	[F]
S 45000	XM-25	0.05	1.00	0.030	0.030	1.00	14.00–16.00	5.00–7.00	. . .	0.50–1.00	. . .	1.25–1.75	[H]
S 46500	. . .	0.02	0.25	0.015	0.010	0.25	11.0–12.5	10.8–11.2	. . .	0.75–1.25	1.50–1.80	. . .	[G]

[A] Limits are in percent maximum unless shown as a range or stated otherwise.
[B] Designation established in accordance with Practice E 527 and SAE J1086.
[C] The terms Columbium (Cb) and Niobium (Nb) both relate to the same element.
[D] Columbium plus tantalum 0.15–0.45.
[E] Nitrogen 0.07–0.13.
[F] Columbium plus tantalum 0.10–0.50.
[G] Nitrogen 0.01.
[H] Columbium 8 times carbon minimum.

TABLE 2
HEAT TREATMENT, °F

UNS Designation	Type	Solution Treatment	Precipitation Hardening Treatment[A]
S17400	630	1925 ± 50°F (cool as required)	900 ± 15°F, 1 h, air cool. 925 ± 15°F, 4 h, air cool. 1025 ± 15°F, 4 h, air cool. 1075 ± 15°F, 4 h, air cool. 1100 ± 15°F, 4 h, air cool. 1150 ± 15°F, 4 h, air cool. (1400 ± 15°F, 2 h, air cool + 1150 ± 15°F, 4 h, air cool).
S17700	631	1950 ± 25°F (cool as required)	1750 ± 15°F, hold 10 min, cool rapidly to room temperature. Cool within 24 h, to −100 ± 10°F, hold not less than 8 h. Warm in air to room temperature. Heat to 950 ± 10°F, hold 1 h, air cool.
		Alternative Treatment:	
		1400 ± 25°F, hold 90 min, cool to 55 ± 5°F within 1 h. Hold not less than 30 min, heat to 1050 ± 10°F, hold for 90 min, air cool.	
S15700	632	1950 ± 25°F (cool as required)	Same as Type 631
S35000	633	1710 ± 25°F (water quench), hold not less than 3 h at −100°F or lower.	850 ± 15°F, 3 h, air cool. 1000 ± 15°F, 3 h, air cool.
S35500	634[B]	1900 ± 25°F (quench), hold not less than 3 h at −100°F or lower.	1750 −10°F for not less than 10 min, but not more than 1 h, water quench. Cool to not higher than −100°F, hold for not less than 3 h. Temper at 1000 ± 25°F, holding for not less than 3 h.
S17600	635	1900 ± 25°F (air cool)	950 ± 15°F, 30 min, air cool. 1000 ± 15°F, 30 min, air cool. 1050 ± 15°F, 30 min, air cool.
S36200	XM-9	1550 ± 25°F (air cool)	900 ± 10°F, 8 h, air cool.
S15500	XM-12	1900 ± 25°F (cool as required)	Same as Type 630
S13800	XM-13	1700 ± 25°F (cool as required to below 60°F)	950 ± 10°F, 4 h, air cool. 1000 ± 10°F, 4 h, air cool.
S45500	XM-16	1525 ± 25°F (water quench)	900 ± 10°F, 4 h, air cool, or 950 ± 10°F, 4 h, air cool.
S45000	XM-25	1900 ± 25°F (cool rapidly)	900 ± 15°F, 4 h, air cool. 1000 ± 15°F, 4 h, air cool. 1150 ± 15°F, 4 h, air cool.
S46500	. . .	1875 ± 25°F (cool rapidly to room temperature) followed by subzero cooling within 24 h after solution treatment; −100 ± 10°F, hold not less than 8 h; warm in air to room temperature	900 ± 15°F, 4 h, air cool. 950 ± 15°F, 4 h, air cool. 1000 ± 15°F, 4 h, air cool. 1050 ± 15°F, 4 h, air cool. 1100 ± 15°F, 4 h, air cool.

[A] Times refer to time material is at temperature.

[B] Equalization and over-tempering treatment: 1425 ± 50°F for not less than 3 h, cool to room temperature, heat to 1075 ± 25°F for not less than 3 h.

TABLE 3
HEAT TREATMENT, °C

UNS Designation	Type	Solution Treatment	Precipitation Hardening Treatment[A]
S17400	630	1050 ± 25°C (cool as required)	482 ± 8°C, 1 h, air cool. 496 ± 8°C, 4 h, air cool. 552 ± 8°C, 4 h, air cool. 579 ± 8°C, 4 h, air cool. 593 ± 8°C, 4 h, air cool. 621 ± 8°C, 4 h, air cool. (760 ± 8°C, 2 h, air cool + 621 ± 8°C, 4 h, air cool).
S17700	631	1065 ± 15°C (water quench)	954 ± 8°C, hold 10 min, cool rapidly to room temperature. Cool within 24 h to −73°C ± 6°C, hold not less than 8 h. Warm in air to room temperature. Heat to 510 ± 6°C, hold 1 h, air cool.
		Alternative Treatment	
		760 ± 15°C, hold 90 min, cool to 15 ± 3°C within 1 h. Hold not less than 30 min, heat to 566 ± 6°C, hold for 90 min, air cool.	
S15700	632	1038 ± 15°C (water quench)	Same as Type 631
S35000	633	930 ± 15°C (water quench), hold not less than 3 h at −75°C or lower.	455 ± 8°C, 3 h, air cool. 540 ± 8°C, 3 h, air cool.
S35500	634[B]	1038 ± 15°C (quench), hold not less than 3 h at −73°C or lower.	954 ± 6°C for not less than 10 min, but not more than 1 h, water quench. Cool to not higher than −73°C, hold for not less than 3 h. Temper at 538 ± 15°C, holding for not less than 3 h.
S17600	635	1038 ± 15°C (air cool)	510 ± 8°C, 30 min, air cool. 538 ± 8°C, 30 min, air cool. 566 ± 8°C, 30 min, air cool.
S36200	XM-9	843 ± 15°C (air cool)	482 ± 8°C, 8 h, air cool.
S15500	XM-12	1038 ± 15°C (cool as required)	Same as Type 630
S13800	XM-13	927 ± 15°C (cool as required to below 60°C)	510 ± 6°C, 4 h, air cool. 538 ± 6°C, 4 h, air cool.
S45500	XM-16	829 ± 15°C (water quench)	482 ± 6°C, 4 h, air cool, or 510 ± 6°C, 4 h, air cool.
S45000	XM-25	1038 ± 15°C (cool rapidly)	482 ± 8°C, 4 h, air cool. 538 ± 8°C, 4 h, air cool. 621 ± 8°C, 4 h, air cool.
S46500	. . .	1024 ± 15°C (cool rapidly to room temperature) followed by subzero cooling within 24 h after solution treatment; −73 ± 6°C; hold not less than 8 h; warm in air to room temperature	482 ± 6°C, 4 h, air cool. 510 ± 8°C, 4 h, air cool. 538 ± 8°C, 4 h, air cool. 566 ± 8°C, 4 h, air cool. 593 ± 8°C, 4 h, air cool.

[A] Times refer to time material is at temperature.
[B] Equalization and over-tempering treatment: 774 ± 25°C for not less than 3 h, cool to room temperature, heat to 579 ± 15°C for not less than 3 h.

TABLE 4
MECHANICAL TEST REQUIREMENTS IN SOLUTION-TREATED CONDITION

Type		Tensile Strength, max		Yield Strength, max		Elongation in 2 in. or 50 mm, min, %	Hardness, max	
		ksi	MPa	ksi	MPa		Rockwell	Brinell
630	0.015 to 4.0 in. (0.38 to 102 mm)	. . .	. . .	. . .	. . .	. . .	C38	363
631	0.010 in. (0.25 mm) and under	150	1035	65	450	. . .	. . .	. . .
	Over 0.010 to 4.0 in. (0.25 to 102 mm)	150	1035	55	380	20	B92	. . .
632	0.0015 to 4.0 in. (0.038 to 102 mm)	150	1035	65	450	25	B100	. . .
633	0.001 to 0.0015 in. (0.03 to 0.038 mm), excl	200	1380	90	620	8	C30	. . .
	0.0015 to 0.002 in. (0.03 to 0.05 mm), excl	200	1380	88	605	8	C30	. . .
	0.002 to 0.005 in. (0.05 to 0.13 mm), excl	200	1380	86	595	8	C30	. . .
	0.005 to 0.010 in. (0.13 to 0.25 mm), excl	200	1380	85	585	8	C30	. . .
	Over 0.010 in. (0.254 mm)	200	1380	85	585	12	C30	. . .
634[A]	Plate	. . .	. . .	. . .	. . .	. . .	C40	. . .
635	0.030 in. (0.76 mm) and under	120	825	75	515	3	C32	. . .
	Over 0.030 to 0.060 in. (0.76 to 1.52 mm)	120	825	75	515	4	C32	. . .
	Over 0.060 in. (1.52 mm)	120	825	75	515	5	C32	. . .
XM-9	Over 0.010 in. (0.25 mm)	150	1035	125	860	4	C28	. . .
XM-12	0.0015 to 4.00 in. (0.038 to 101.6 mm)	. . .	. . .	. . .	. . .	. . .	C38	363
XM-13	0.0015 to 4.00 in. (0.038 to 101.6 mm)	. . .	. . .	. . .	. . .	. . .	C38	363
XM-16	0.010 in. (0.25 mm) and greater	175	1205	160	1105	3	C36	331
XM-25[B]	0.010 in. (0.25 mm) and greater	165	1205	150	1035	4	C33	311
S46500	0.140 in. (3.56 mm) and under	160	1105	150	1035	4	C33	. . .

[A] Solution-treated, equalized, and over-tempered plate only.

[B] XM-25 also furnished to the following minimum properties:	130	895	90	620	4	C25	255

TABLE 5
MECHANICAL TEST REQUIREMENTS AFTER PRECIPITATION HARDENING TREATMENT

Grade	Hardening or Precipitation Treatment or both, °F (°C)	Thickness, in. (mm)	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %[A]	Reduction of Area, min, %[A]	Hardness, min		Impact Charpy V, min[B]	
			ksi	MPa	ksi	MPa			Rockwell, min/max	Brinell, min/max	ft·lbf	J
630 and XM-12	900 (482)	Under 0.1875 (4.762)	190	1310	170	1170	5	. . .	C40/C48	. . .	. . .	. . .
		0.1875 to 0.625 (4.762 to 15.88)	190	1310	170	1170	8	25	C40/C48	388/477	. . .	. . .
		0.626 to 4.0 (15.90 to 102)	190	1310	170	1170	10	30	C40/C48	388/477	. . .	. . .
	925 (496)	Under 0.1875 (4.762)	170	1170	155	1070	5	. . .	C38/C48	. . .	. . .	. . .
		0.1875 to 0.625 (4.762 to 15.88)	170	1170	155	1070	8	25	C38/C47	375/477	. . .	. . .
		0.626 to 4.0 (15.90 to 102)	170	1170	155	1070	10	30	C38/C47	375/477	. . .	. . .
	1025 (552)	Under 0.1875 (4.762)	155	1070	145	1000	5	. . .	C35/C43	. . .	. . .	. . .
		0.1875 to 0.625 (4.762 to 15.88)	155	1070	145	1000	8	30	C33/C42	321/415	10	14
		0.626 to 4.0 (15.90 to 102)	155	1070	145	1000	12	35	C33/C42	321/415	15	20
	1075 (579)	Under 0.1875 (4.762)	145	1000	125	860	5	. . .	C31/C40	. . .	. . .	. . .
		0.1875 to 0.625 (4.762 to 15.88)	145	1000	125	860	9	30	C29/C38	293/375	15	20
		0.626 to 4.0 (15.88 to 102)	145	1000	125	860	13	35	C29/C38	293/375	20	27
	1100 (593)	Under 0.1875 (4.762)	140	965	115	790	5	. . .	C31/C40	. . .	. . .	. . .
		0.1875 to 0.625 (4.762 to 15.88)	140	965	115	790	10	30	C29/C38	293/375	15	20
		0.626 to 4.0 (15.88 to 102)	140	965	115	790	14	35	C29/C38	293/375	20	27
	1150 (621)	Under 0.1875 (4.762)	135	930	105	725	8	. . .	C28/C38	. . .	. . .	. . .
		0.1875 to 0.625 (4.762 to 15.88)	135	930	105	725	10	35	C26/C36	269/352	25	34
		0.626 to 4.0 (15.88 to 102)	135	930	105	725	16	40	C26/C36	269/352	30	41
	1400 + 1150 (760 + 621)	Under 0.1875 (4.762)	115	790	75	515	9	. . .	C26/C36	255/331	. . .	. . .
		0.1875 to 0.625 (4.762 to 15.88)	115	790	75	515	11	40	C24/C34	248/321	55	75
		0.626 to 4.0 (15.88 to 102)	115	790	75	515	18	45	C24/C34	248/321	55	75
631	1400 (760) + plus 55 (15) + 1050 (566)	0.0015 to 0.0049 (0.038 to 0.124)	180	1240	150	1035	3	. . .	C38	. . .	. . .	. . .
		0.0050 to 0.0099 (0.127 to 0.251)	180	1240	150	1035	4	. . .	C38	. . .	. . .	. . .
		0.010 to 0.0199 (0.25 to 0.505)	180	1240	150	1035	5	. . .	C38	. . .	. . .	. . .
		0.020 to 0.1874 (0.51 to 4.760)	180	1240	150	1035	6	. . .	C38	. . .	. . .	. . .
		0.1875 to 0.625 (4.762 to 15.88)	170	1170	140	965	7	20	C38	352	. . .	. . .
	1750 (954) + minus 100 (73) + 950 (510)	0.0015 to 0.0049 (0.038 to 0.124)	210	1450	190	1310	1	. . .	C44	. . .	. . .	. . .
		0.0050 to 0.0099 (0.127 to 0.251)	210	1450	190	1310	2	. . .	C44	. . .	. . .	. . .
		0.010 to 0.0199 (0.25 to 0.505)	210	1450	190	1310	3	. . .	C44	. . .	. . .	. . .
		0.020 to 0.1874 (0.51 to 4.760)	210	1450	190	1310	4	. . .	C44	. . .	. . .	. . .
		0.1875 to 0.625 (4.762 to 15.88)	200	1380	180	1240	6	20	C43	401	. . .	. . .
	Cold rolled at mill	0.0015 to 0.050 (0.038 to 1.27)	200	1380	175	1205	1	. . .	C41	. . .	. . .	. . .
	Cold rolled at mill + 900 (492)	0.0015 to 0.050 (0.038 to 1.27)	240	1655	230	1580	1	. . .	C46	. . .	. . .	. . .
632	1400 (760) + plus 55 (15) + 1050 (566)	0.0015 to 0.0049 (0.038 to 0.124)	190	1310	170	1170	2	. . .	C40	. . .	. . .	. . .
		0.0050 to 0.0099 (0.127 to 0.251)	190	1310	170	1170	3	. . .	C40	. . .	. . .	. . .
		0.010 to 0.0199 (0.25 to 0.505)	190	1310	170	1170	4	. . .	C40	. . .	. . .	. . .
		0.020 to 0.1874 (0.51 to 4.760)	190	1310	170	1170	5	. . .	C40	. . .	. . .	. . .
		0.1875 to 0.625 (4.762 to 15.88)	190	1310	170	1170	4	20	C40	375	. . .	. . .
	1750 (954) + minus 100 (73) + 950 (510)	0.0015 to 0.0049 (0.038 to 0.124)	225	1550	200	1380	1	. . .	C46	. . .	. . .	. . .
		0.0050 to 0.0099 (0.127 to 0.251)	225	1550	200	1380	2	. . .	C46	. . .	. . .	. . .
		0.010 to 0.0199 (0.25 to 0.505)	225	1550	200	1380	3	. . .	C46	. . .	. . .	. . .
		0.020 to 0.1874 (0.51 to 4.760)	225	1550	200	1380	4	. . .	C46	. . .	. . .	. . .
		0.1875 to 0,625 (4.762 to 15.88)	225	1550	200	1380	4	20	C45	429	. . .	. . .
	Cold rolled at mill	0.0015 to 0.050 (0.038 to 0.13)	200	1380	175	1205	1	. . .	C41	. . .	. . .	. . .
	Cold rolled at mill + 900 (482)	0.0015 to 0.050 (0.038 to 0.13)	240	1655	230	1585	1	. . .	C46	. . .	. . .	. . .

TABLE 5
MECHANICAL TEST REQUIREMENTS AFTER PRECIPITATION HARDENING TREATMENT (CONT'D)

Grade	Hardening or Precipitation Treatment or both, °F (°C)	Thickness, in. (mm)	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %[A]	Reduction of Area, min, %[A]	Hardness, min		Impact Charpy V, min[B]	
			ksi	MPa	ksi	MPa			Rockwell, min/max	Brinell, min/max	ft·lbf	J
633	850 (455)	0.0005 to 0.0015 (0.022 to 0.038)	185	1275	150	1035	2	. . .	C42	. . .	. . .	. . .
		0.0015 to 0.0020 (0.038 to 0.041)	185	1275	150	1035	4	. . .	C42	. . .	. . .	. . .
		0.0020 to 0.0100 (0.041 to 0.254)	185	1275	150	1035	6	. . .	C42	. . .	. . .	. . .
		0.0100 to 0.1875 (0.254 to 4.762)	185	1275	150	1035	8	. . .	C42	. . .	. . .	. . .
	1000 (540)	0.0005 to 0.0015 (0.022 to 0.038)	165	1140	145	1000	2	. . .	C36	. . .	. . .	. . .
		0.0015 to 0.0020 (0.038 to 0.041)	165	1140	145	1000	4	. . .	C36	. . .	. . .	. . .
		0.0020 to 0.0100 (0.0.41 to 0.254)	165	1140	145	1000	6	. . .	C36	. . .	. . .	. . .
		0.0100 to 0.1875 (0.254 to 4.762)	165	1140	145	1000	8	. . .	C36	. . .	. . .	. . .
634	850 (455)		190	1310	165	1140	10	. . .	. . .	. . .	. . .	. . .
	1000 (540)		170	1170	150	1035	12	. . .	C37	. . .	. . .	. . .
635	950 (510)	0.030 (0.76) and under	190	1310	170	1170	3	. . .	C39	. . .	. . .	. . .
		0.030 to 0.060 (0.76 to 1.52)	190	1310	170	1170	4	. . .	C39	. . .	. . .	. . .
		Over 0.060 (1.52)	190	1310	170	1170	5	. . .	C39	. . .	. . .	. . .
		Plate	190	1310	170	1170	8	25	C39	363	. . .	. . .
	1000 (540)	0.030 (0.76) and under	180	1240	160	1105	3	. . .	C37	. . .	. . .	. . .
		0.030 to 0.060 (0.76 to 1.52)	180	1240	160	1105	4	. . .	C37	. . .	. . .	. . .
		Over 0.060 (1.52)	180	1240	160	1105	5	. . .	C37	. . .	. . .	. . .
		Plate	180	1240	160	1105	8	30	C38	352	. . .	. . .
	1050 (565)	0.030 (0.76) and under	170	1170	150	1035	3	. . .	C35	. . .	. . .	. . .
		0.030 to 0.060 (0.76 to 1.52)	170	1170	150	1035	4	. . .	C35	. . .	. . .	. . .
		Over 0.060 (1.52)	170	1170	150	1035	5	. . .	C35	. . .	. . .	. . .
		Plate	170	1170	150	1035	8	30	C36	331	. . .	. . .
XM-13	950 (510)	Under 0.020 (0.51)	220	1515	205	1410	6	. . .	C45	. . .	. . .	. . .
		0.020 to 0.1874 (0.51 to 4.760)	220	1515	205	1410	8	. . .	C45	. . .	. . .	. . .
		0.1875 to 0.625 (4.760 to 15.88)	220	1515	205	1410	10	. . .	C45	. . .	. . .	. . .
		0.626 to 4.0 (15.90 to 102)	220	1515	205	1410	10	. . .	C45	429	. . .	. . .
	1000 (538)	Under 0.020 (0.51)	200	1380	190	1310	6	. . .	C43	. . .	. . .	. . .
		0.020 to 0.1874 (0.51 to 4.760)	200	1380	190	1310	8	. . .	C43	. . .	. . .	. . .
		0.1875 to 0.625 (4.760 to 15.88)	200	1380	190	1310	10	. . .	C43	. . .	. . .	. . .
		0.626 to 4.0 (15.90 to 102)	200	1380	190	1310	10	. . .	C43	401	. . .	. . .
XM-16	950 (510)	Up to 0.020 (0.51)	222	1525	205	1410	. . .	. . .	C44	. . .	. . .	. . .
		Over 0.020 to 0.062 (0.51 to 1.57)	222	1525	205	1410	3	. . .	C44	. . .	. . .	. . .
		Over 0.062 (1.57)	222	1525	205	1410	4	. . .	C44	. . .	. . .	. . .
XM-25	900 (482)	Up to 0.020 (0.51)	180	1240	170	1170	3	. . .	C40	. . .	. . .	. . .
		Over 0.020 to 0.062 (0.51 to 1.57)	180	1240	170	1170	4	. . .	C40	. . .	. . .	. . .
		Over 0.062 (1.57)	180	1240	170	1170	5	. . .	C40	. . .	. . .	. . .
	1000 (538)	Up to 0.020 (0.51)	160	1105	150	1035	5	. . .	C36	. . .	. . .	. . .
		Over 0.020 to 0.062 (0.51 to 1.57)	160	1105	150	1035	6	. . .	C36	. . .	. . .	. . .
		Over 0.062 (1.57)	160	1105	150	1035	7	. . .	C36	. . .	. . .	. . .
	1150 (621)	Up to 0.020 (0.51)	125	860	75	515	8	. . .	C26	. . .	. . .	. . .
		Over 0.020 to 0.062 (0.51 to 1.57)	125	860	75	515	9	. . .	C26	. . .	. . .	. . .
		Over 0.062 (1.57)	125	860	75	515	10	. . .	C26	. . .	. . .	. . .
XM-9	900 (482)	Over 0.010 (0.25)	180	1240	160	1105	3	. . .	C38	. . .	. . .	. . .
S46500	900 (482)	0.140 (3.56) and under	245	1690	235	1620	2	. . .	C48	. . .	. . .	. . .
	950 (510)	0.140 (3.56) and under	235	1620	225	1550	3	. . .	C47	. . .	. . .	. . .
	1000 (538)	0.140 (3.56) and under	220	1515	210	1445	4	. . .	C45	. . .	. . .	. . .
	1050 (566)	0.140 (3.56) and under	200	1380	185	1275	5	. . .	C43	. . .	. . .	. . .
	1100 (593)	0.140 (3.56) and under	180	1240	145	1000	6	. . .	C39	. . .	. . .	. . .

[A] Applicable to tests in the long transverse direction. Transverse to the direction of rolling and parallel to the product surface.
[B] Impact test is not required unless specified on the purchase order.

TABLE 6
BEND TEST REQUIREMENTS IN SOLUTION-TREATED CONDITION

Type	Size, in. (mm)	Cold Bend Degrees	Bend Test Mandrel
630		none required	
631	0.187 (4.76) and under	180	1*T*[A]
	Over 0.187 to 0.275 (4.76 to 6.98)	180	3*T*
632	0.187 (4.76) and under	180	1*T*
	Over 0.187 to 0.275 (4.76 to 6.98)	180	3*T*
633	Under 0.1875 (4.762)	180	2*T*
634	0.187 to 0.249 (4.76 to 6.32)	130	3*T*
	Over 0.249 to 0.750 (6.32 to 19.08)	90	3*T*
635		none required	
XM-9	0.109 (2.77) and under	180	9*T*
XM-12		none required	
XM-13		none required	
XM-16	Under 0.1875 (4.762)	180	6*T*
XM-25	Under 0.1875 (4.762)	180	6*T*
S46500	0.140 (3.56) and under	180	6*T*

[A] *T* = thickness of sheet being tested.

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SPECIFICATION FOR STEEL BARS, CARBON, HOT-WROUGHT OR COLD-FINISHED, SPECIAL QUALITY, FOR PRESSURE PIPING COMPONENTS

SA-696

(Identical with ASTM Specification A696-90a(2012).)

Standard Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components

1. Scope

1.1 This specification covers hot-wrought and cold-finished special quality carbon steel bars, in straight lengths only, subject to mechanical property requirements and intended for use in manufacturing components for pressure piping and other pressure-containing applications.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A29/A29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

3. Classification

3.1 The bars are furnished in two grades as follows:

3.1.1 *Grade B*—Tensile strength 60 000 psi (415 MPa), minimum; yield strength 35 000 psi (240 MPa), minimum.

3.1.2 *Grade C*—Tensile strength 70 000 psi (485 MPa), minimum; yield strength 40 000 psi (275 MPa), minimum.

3.2 The bars are intended for machining, welding, hot forming, and threading by machining or cold rolling.

4. Ordering Information

4.1 Orders for material under this specification should include the following information:

4.1.1 Quantity (weight or number of bars),

4.1.2 Name of material (carbon steel bars),

4.1.3 Condition: hot wrought or cold finished (5.4.1),

4.1.4 Finish (if descaled required, so state) (9.1),

4.1.5 Dimensions (diameter, thickness, width, and length),

4.1.6 Cross section (round, square, hexagon),

4.1.7 ASTM designation and date of issue,

4.1.8 Grade (Table 1 and Table 2),

4.1.9 End use, and

4.1.10 Additions to the specification and supplementary requirements, if required.

NOTE 1—A typical ordering description is as follows: 10 000 lb, Carbon Steel Bars, Hot Wrought, Descaled, 1.000-in. diameter by 10 ft, Round, ASTM A696 dated ______, Grade B; Supplementary Requirement S1 Straightness 0.125 in. in any 5 ft.

5. Materials and Manufacture

5.1 *Melting Practice*—The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting using electroslag remelting or vacuum arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

5.2 *Deoxidation*—The steel shall be fully killed.

5.3 *Quality*—The bars shall be special quality.

5.4 *Hot or Cold Working:*

5.4.1 The bars shall be hot wrought or cold finished as specified by the purchaser.

5.4.2 Cold-finished bars reduced in cross-sectional area more than 10 % by cold drawing or rolling shall be heat treated as specified in 5.5.2.

5.5 *Heat Treatment:*

5.5.1 Except as provided in 5.5.2, the bars shall be furnished as-hot wrought or as-cold finished.

5.5.2 Cold-finished bars cold worked in excess of 10 % (see 5.4.2) shall be stress relief annealed at not less than 1200°F (649°C), normalized, or fully annealed. The specific heat treatment shall be at the option of the manufacturer.

TABLE 1 Chemical Requirements (Heat Analysis), %

	Grades B and C
Carbon, max[A]	0.32
Manganese, max	1.04
Phosphorus, max	0.035[B]
Sulfur, max	0.045[B]
Silicon	0.15 to 0.35
Lead	[B]

[A] For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.35 %.

[B] Phosphorus, sulfur, or lead, or a combination thereof, shall not be added.

TABLE 2 Tensile Requirements

	Grade B	Grade C
Tensile strength, min, ksi (MPa)	60 (415)	70 (485)
Yield strength, min, ksi (MPa)	35 (240)	40 (275)
Elongation in 2.0 in. or 50 mm, min, %	20.0	18.0
Elongation in 8.0 in. or 200 mm, min, %[A]	17.0	15.0

[A] Applicable to bars 1½ in. (38 mm) in diameter tested full size.

6. Chemical Composition

6.1 The heat analysis shall conform to the requirements for chemical composition specified in Table 1.

6.2 A product analysis of the steel may be made by the purchaser and shall conform to the requirements of Table 1 subject to the product analysis tolerances specified in Specification A29/A29M.

7. Tensile Requirements

7.1 *Requirements:*

7.1.1 The material, as represented by the test specimens, shall conform to the tensile requirements specified in Table 2.

7.1.2 A deduction from the percentage of elongation specified in Table 2 of 1.0 % shall be made for each 1.0 in. (25.4 mm) of specified diameter over 2.0 in. (51 mm) or fraction thereof to a maximum of 3 %.

7.2 *Specimens:*

7.2.1 Tension test specimens shall be taken longitudinally from a position midway between the center and the surface of the bar or as close as practical to this location for small sizes.

7.2.2 When it is impractical to remove specimens in accordance with 7.2.1, they shall be taken in accordance with Test Methods and Definitions A370.

7.3 *Number of Tests*—One tension test shall be made from each lot. A lot shall consist of all bars of one size from one heat processed at one time and subjected to the same heat treatment when heat treated.

7.4 *Test Methods*—Tension tests shall be made in accordance with Test Methods and Definitions A370. The yield strength shall be determined by the 0.2 % offset or 0.5 % extension under load methods.

8. Workmanship, Finish, and Appearance

8.1 *Descaling*—When descaled bars are required, Supplementary Requirement S7 must be specified.

8.2 The bars shall be free of visible pipe and conditioned as necessary to remove injurious surface imperfections.

9. General Requirements

9.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A29/A29M unless otherwise provided herein.

10. Certification and Test Reports

10.1 A manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis and tension test results shall be furnished at the time of shipment. The report shall include the name of the manufacturer, ASTM designation number and grade, shape, size, and finish.

11. Packaging and Package Marking

11.1 Bars less than 2.0 in. (51 mm) in diameter or thickness shall be tightly banded with a sufficient number of bands of adequate strength to minimize bundle breakage during handling and shipping. Larger sizes shall be packaged in accordance with Specification A29/A29M.

11.2 For bars less than 2.0 in. (51 mm) in diameter or thickness, each bundle shall bear a weather-resistant tag showing the purchase order number, ASTM designation number and grade, heat number, size, and name of manufacturer.

11.3 Bars 2.0 in. (51 mm) and larger in diameter or thickness shall have the heat number steel stamped on one end.

12. Keywords

12.1 pressure piping components; special quality steel bars; steel bars

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Special Straightness

S1.1 Bars shall be within the tolerances for special straightness.

S2. Stress Relief Anneal

S2.1 Bars shall be stress relief annealed (may be specified for bars that have been ordered to special straightness tolerance).

S3. Surface Quality

S3.1 Bars shall be produced to special surface quality requirements which shall be negotiated between the purchaser and the supplier.

S4. Special Internal Soundness

S4.1 Bars shall be produced with special internal soundness to be verified by one or more macro-etch samples. Acceptance limits shall be negotiated between the purchaser and the seller.

S5. Fine Grain Practice

S5.1 The steel shall conform to the fine austenitic grain size requirement of Specification A29/A29M.

S6. Restricted Size Tolerances for Hot-Wrought Bars

S6.1 Bars shall be furnished with tolerances on dimensions more restrictive than specified in Specification A29/A29M. Tolerance requirements to apply shall be negotiated between the purchaser and the manufacturer.

S7. Descaling

S7.1 Bars shall be furnished descaled and oiled.

SPECIFICATION FOR STEEL CASTINGS, GENERAL REQUIREMENTS, FOR PRESSURE-CONTAINING PARTS

SA-703/SA-703M (23)

(Identical with ASTM Specification A703/A703M-18a.)

Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

1. Scope

1.1 This specification covers a group of common requirements that, unless otherwise specified in an individual specification, shall apply to steel castings for pressure-containing parts under each of the following ASTM specifications:

Title of Specification	ASTM Designation
Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service	A216/A216M
Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service	A217/A217M
Castings, Austenitic, for Pressure-Containing Parts	A351/A351M
Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service	A352/A352M
Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service	A389/A389M
Steel Castings Suitable for Pressure Service	A487/A487M
Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure Retaining Parts for Corrosive Service	A990/A990M
Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts	A995/A995M

1.2 This specification also covers a group of supplementary requirements which may be applied to the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 In case of conflict between the requirements of the individual specification and this general specification, the former shall prevail.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A216/A216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A217/A217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A351/A351M Specification for Castings, Austenitic, for Pressure-Containing Parts

A352/A352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A380/A380M Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems

A389/A389M Specification for Steel Castings, Alloy, Specially Heat Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service

A487/A487M Specification for Steel Castings Suitable for Pressure Service

A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A609/A609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A800/A800M Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof
A802/A802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
A903/A903M Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A967/A967M Specification for Chemical Passivation Treatments for Stainless Steel Parts
A990/A990M Specification for Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure-Retaining Parts for Corrosive Service
A991/A991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
A995/A995M Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts
A1058 Test Methods for Mechanical Testing of Steel Products—Metric
A1067/A1067M Specification for Test Coupons for Steel Castings
A1080 Practice for Hot Isostatic Pressing of Steel, Stainless Steel, and Related Alloy Castings
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E94/E94M Guide for Radiographic Examination Using Industrial Radiographic Film
E125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E165/E165M Practice for Liquid Penetrant Examination for General Industry
E186 Reference Radiographs for Heavy-Walled (2 to 4½ in. (50.8 to 114 mm)) Steel Castings
E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
E280 Reference Radiographs for Heavy-Walled (4½ to 12 in. (114 to 305 mm)) Steel Castings
E340 Practice for Macroetching Metals and Alloys
E353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
E354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness
E709 Guide for Magnetic Particle Testing

2.2 *ANSI Standard:*
B16.5 Pipe Flanges and Flanged Fittings

2.3 *Standards of the Manufacturers Standardization Society of the Valve and Fitting Industry:*
MSS SP 53 Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components (Magnetic Particle Exam Method)
MSS SP 54 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Radiographic Examination Method)

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Test Methods and Definitions A370, Terminology A941, and Test Methods A1058 are applicable to this specification and to those listed in 1.1.

3.1.2 *chaplet, n*—a chaplet is a metallic support placed in a mold cavity to maintain the spacing between a core and the mold.

3.1.3 *electronic data interchange (EDI), n*—the computer-to-computer exchange of business information in a standard format such as ANSI ASC X12.

3.1.4 *heat, n*—all the molten metal poured from a single furnace or all the molten metal from two or more furnaces poured into a single ladle or casting prior to the replenishing of the furnace(s).

3.1.5 *internal chill, n*—an internal chill is a metallic device placed in a mold cavity to increase the rate of heat removal at that location.

3.1.6 *test coupon, n*—the part from which the test specimen will be extracted.

3.1.7 *test specimen, n*—the part that will be acted upon in a mechanical test.

4. Materials and Manufacture

4.1 *Melting Process*—The steel shall be made by open-hearth or electric-furnace process, with or without separate refining such as argon-oxygen-decarburization (AOD), unless otherwise designated by the individual specification.

4.2 *Heat Treatment:*

4.2.1 Ferritic and martensitic steel shall be cooled after pouring to provide substantially complete transformation of austenite prior to heat treatment to enhance mechanical properties.

4.2.2 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A991/A991M.

4.2.2.1 When castings are heat treated at temperatures above 2000 °F [1100 °C], then the working zone shall have been established by a survey performed at not more than 25 °F [15 °C] below nor more than 200 °F [110 °C] above the minimum heat treatment temperature specified for the grade. If a minimum heat treatment temperature is not specified for the grade, then the survey temperature shall be not more than 50 °F

[30 °C] below nor more than 175 °F [100 °C] above the furnace set point used.

4.2.2.2 The maximum variation in measured temperature as determined by the difference between the highest temperature and the lowest temperature shall be as agreed between the purchaser and producer, except that during production heat treatment no portion of the furnace shall be below the minimum specified temperature nor above the maximum specified temperature for the grade being processed.

5. Chemical Composition

5.1 *Chemical Analysis*—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods A751.

5.2 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified. The analysis shall be made from a test sample preferably taken during the pouring of the heat. When drillings are used, they shall be taken not less than ¼ in. [6.4 mm] beneath the surface. The chemical composition thus determined shall be reported to the purchaser, or their representative, and shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis*—A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Due to the possibility of decarburization, samples for carbon analysis shall be taken no closer than ¼ in. [6.4 mm] to a cast surface, except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low-alloy steel and stainless steel castings may vary from the specified limits by the amounts shown in Table 1 and Table 2, respectively. The product analysis tolerances of Tables 1 and 2 are not applicable as acceptance criteria for heat analysis by the casting manufacturer. When comparing product and heat analysis for other than carbon and low-alloy steels and stainless steels, the reproducibility data R_2, in Test Methods E353 or E354, as applicable, shall be taken into consideration.

5.4 *Unspecified Elements*—When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S1 may be specified.

5.5 *Grade Substitution*—Grade substitution is not permitted. Grade substitution occurs when the material being supplied contains one or more elements that are not specified for the supplied material such that the material conforms to the requirements of a different grade.

5.6 Where more than one ladle is poured into a single casting, the molten metal in each ladle must conform to the specified chemical requirements.

6. Mechanical Test Methods

6.1 All mechanical tests shall be conducted in accordance with Test Methods and Definitions A370. When material is ordered to an M-suffix (SI units) standard, then in accordance with Test Methods A1058.

6.2 Choice of testing track from the options listed in Test Methods A1058 when material is ordered to an M-suffix (SI units) product standard, should be identified by the purchaser in the ordering information. If the choice of test track is not specified in the order, then the default ASTM track shall be used as noted in Test Methods A1058.

7. Tensile Requirements

7.1 One tension test shall be made from each heat, and shall conform to the tensile requirements specified. Test coupons shall be cast from the same heat as the castings represented, except that for investment castings, the test coupons shall be cast in the same type of mold as the castings.

TABLE 1 Product Analysis Tolerances – Carbon and Low-Alloy Steels

Element	Range[A]	Tolerances[B,C] over max or under min, Limit, %
Carbon (C)	up to 0.65 %	$0.03 \times \% C_L + 0.02$
	above 0.65 %	0.04 %
Manganese (Mn)	up to 1 %	$0.08 \times \% Mn_L + 0.01$
	above 1 %	0.09
Silicon (Si)	up to 0.60 %	$0.22 \times \% Si_L - 0.01$
	above 0.60 %	0.15 %
Phosphorus (P)	all	$0.13 \times \% P_L + 0.005$
Sulfur (S)	all	$0.36 \times \% S_L + 0.001$
Nickel (Ni)	up to 2 %	$0.10 \times \% Ni_L + 0.03$
	above 2 %	0.25 %
Chromium (Cr)	up to 2 %	$0.07 \times \% Cr_L + 0.04$
	above 2 %	0.18 %
Molybdenum (Mo)	up to 0.6 %	$0.04 \times \% Mo_L + 0.03$
	above 0.6 %	0.06 %
Vanadium (V)	up to 0.25 %	$0.23 \times \% V_L + 0.004$
	above 0.25 %	0.06 %
Tungsten (W)	up to 0.10 %	$0.08 \times \% W_L + 0.02$
	above 0.10 %	0.02 %
Copper (Cu)	up to 0.15 %	$0.18 \times \% Cu_L + 0.02$
	above 0.15 %	0.05 %
Aluminum (Al)	up to 0.03 %	0.01 %
	0.03 to 0.10 %, incl.	$0.08 \times \% Al + 0.02$
	above 0.10 %	0.03 %

[A] The range denotes the composition limits up to which the tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript $_L$ for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit, if applicable, respectively. Examples of computing tolerances are presented in the footnote *C*.

[C] To compute the tolerances, consider the manganese limits 0.50 – 80 % of Grade WC4 of Specification A217/A217M. In accordance with Table 1, the maximum permissible deviation of a product analysis below the lower limit 0.50 is 0.05 % = (0.08 × 0.50 + 0.01). The lowest acceptable product analysis of Grade WC4, therefore, is 0.45 %. Similarly, the maximum permissible deviation above the upper limit of 0.80 % is 0.074 % = (0.08 × 0.80 + 0.01). The highest acceptable product analysis of Grade WC4, therefore, is 0.874. For Grade WCC of Specification A216/A216M, the maximum manganese content is 1.40 % if the carbon content is 0.20 %. In this case, the highest acceptable product analysis is 1.49 = (1.40 + 0.09).

TABLE 2 Product Analysis Tolerances – Stainless Steels

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit	Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	to 0.010, incl	0.002	Titanium	to 1.00, incl	0.05
	over 0.010 to 0.030, incl	0.005		over 1.00 to 3.00, incl	0.07
	over 0.030 to 0.20, incl	0.01			
	over 0.20 to 0.60, incl	0.02	Cobalt	over 0.05 to 0.50, incl	0.01[A]
	over 0.60 to 1.20, incl	0.03		over 0.50 to 2.00, incl	0.02
				over 2.00 to 5.00, incl	0.05
Manganese	to 1.00, incl	0.03			
	over 1.00 to 3.00, incl	0.04	Columbium plus tantalum	to 1.50, incl	0.05
	over 3.00 to 6.00, incl	0.05			
	over 6.00 to 10.00, incl	0.06			
	over 10.00 to 15.00, incl	0.10			
	over 15.00 to 20.00, incl	0.15	Tantalum	to 0.10, incl	0.02
Phosphorus	to 0.040, incl	0.005	Copper	to 0.50, incl	0.03
	over 0.040 to 0.20, incl	0.010		over 0.50 to 1.00 incl	0.05
				over 1.00 to 3.00, incl	0.10
Sulfur	to 0.040, incl	0.005		over 3.00 to 5.00, incl	0.15
	over 0.040 to 0.20, incl	0.010		over 5.00 to 10.00, incl	0.20
	over 0.20 to 0.50, incl	0.020			
			Aluminum	to 0.15, incl	–0.005, +0.01
Silicon	to 1.00, incl	0.05		over 0.15 to 0.50, incl	0.05
	over 1.00 to 3.00, incl	0.10		over 0.50 to 2.00, incl	0.10
	over 3.00 to 6.00, incl	0.15			
Chromium	over 4.00 to 10.00, incl	0.10			
	over 10.00 to 15.00, incl	0.15	Nitrogen	to 0.02, incl	0.005
	over 15.00 to 20.00, incl	0.20		over 0.02 to 0.19, incl	0.01
	over 20.00 to 30.00, incl	0.25		over 0.19 to 0.25, incl	0.02
				over 0.25 to 0.35, incl	0.03
Nickel	to 1.00, incl	0.03		over 0.35 to 0.45, incl	0.04
	over 1.00 to 5.00, incl	0.07		over 0.45 to 0.55, incl	0.05
	over 5.00 to 10.00, incl	0.10	Tungsten	to 1.00, incl	0.03
	over 10.000 to 20.00, incl	0.15		over 1.00 to 2.00, incl	0.05
	over 20.00 to 30.00, incl	0.20			
			Vanadium	to 0.50 incl	0.03
Molybdenum	over 0.20 to 0.60, incl	0.03		over 0.50 to 1.50, incl	0.05
	over 0.60 to 2.00, incl	0.05			
	over 2.00 to 8.00, incl	0.10	Selenium	all	0.03

[A] Product analysis limits for cobalt under 0.05 % have not been established, and the manufacturer should be consulted for those limits.

7.2 The coupon from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents.

7.3 Test specimens may be cut from heat-treated castings, at the producer's option, instead of from test coupons.

7.4 *Investment Castings*—For investment castings, the coupons may be cast to shape or machined from coupons to dimensions in accordance with Test Methods and Definitions A370 or the ICI coupon shown in Specification A1067/A1067M, Fig. 1.

7.5 *Other Castings*—Unless otherwise specified by the purchaser, test coupons may be cast integrally with the castings or separately in accordance with Specification A1067/A1067M, Fig. 1 and Table 1, with Fig. 2, or with Fig. 4, except when Supplementary Requirement S26 is specified. The test coupon in Specification A1067/A1067M, Fig. 4 shall be employed only for austenitic alloy castings with cross sections less than 2½ in. [63.5 mm]. Tension test specimens shall be prepared in accordance with Test Methods and Definitions A370 or Test Methods A1058 as applicable.

7.6 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E29 to the nearest 500 psi [5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area.

8. Repair by Welding

8.1 Repair by welding shall be in accordance with the requirements of individual specification using procedures and welders qualified in accordance with Practice A488/A488M.

9. Flanges

9.1 When a flange from a flanged casting is removed to make a weld end casting, discontinuities may be observed that would not have been detrimental in a flanged casting. The disposition of the casting shall be subject to agreement between the purchaser and manufacturer.

10. Quality

10.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A802/A802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

10.2 The castings shall not be peened, plugged, or impregnated to stop leaks or disguise rejectable indications.

10.3 Internal chills and chaplets may be used in the manufacture of castings. However, the chills, chaplets, and affected cast material must be completely removed.

11. Hydrostatic Tests

11.1 Each casting shall be tested after machining to the hydrostatic shell test pressures prescribed in ANSI B16.5 for the applicable steel rating for which the casting is designed. Casting shall show no leaks. Castings ordered for working pressures other than those in the standard ANSI ratings, or those listed for which test pressures are not specified by ANSI B16.5, shall be tested at a pressure agreed upon between manufacturer and the purchaser.

11.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. However, the foundry is responsible for the satisfactory performance of the castings under the final test required in 11.1.

12. Workmanship, Finish, and Appearance

12.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. When the pattern is supplied by the purchaser, the dimensions of the casting shall be as predicated by the pattern unless otherwise agreed upon.

12.2 Machined welding ends shall be suitably protected against damage during shipping.

13. Retests

13.1 If a specimen is machined improperly or if flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

13.2 If the results of the mechanical tests for any heat, lot, or casting do not conform to the requirements specified, castings may be reheat treated and retested. When castings are reheat treated, they may not be re-austenitized more than three times without the approval of the purchaser. Testing after reheat treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

NOTE 1—Test Methods and Definitions A370, paragraph 4.4 and Test Methods A1058, paragraph 3.5 address retesting because of mechanical reasons such as failure of the test equipment. Test Methods and Definitions A370, paragraph 14.4.2 addresses retesting for reasons such as fracture outside of the middle half of the gauge length or at a punch mark.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.2), shall be made at the place of manufacture unless otherwise agreed.

15. Rejection and Rehearing

15.1 Any rejection based on test reports shall be reported to the manufacturer within 30 days from the receipt of the test reports by the purchaser.

15.2 Material that shows unacceptable discontinuities as determined by the acceptance standards specified in the order subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified within 30 days after discovery of the rejectable condition.

15.3 Samples that represent rejected material shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

16. Certification

16.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year of issue) and was found to meet the requirements. When the purchaser imposes the requirements of this specification, the manufacturer is responsible for compliance with the specification requirements during the production and processing of the casting by themselves and any of their subcontractors.

16.2 As applicable, the certification shall also include:

16.2.1 Material specification and grade,

16.2.2 Pattern number,

16.2.3 Heat number or serial number traceable to a heat number,

16.2.4 Chemical analysis of the heat,

16.2.5 Mechanical property results required by the specification and supplementary requirements specified in the purchase order,

16.2.6 Statement of satisfactory inspection, visual, and nondestructive testing specified in the purchase order,

16.2.7 Manufacturer's name, and

16.2.8 Additional purchase order requirements.

16.3 A signature is not required on the certification. However, the document shall clearly identify the organization submitting the certification. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

16.4 A manufacturer's certification printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility, provided it conforms to any existing EDI agreement between the purchaser and the supplier.

17. Product Marking

17.1 Castings shall be marked for material identification with grade symbols (WCB, WC9, CF8M, and so forth). In addition, heat numbers, or serial numbers that are traceable to heat numbers, shall be marked on all pressure-containing castings individually weighing 50 lb [22.7 kg] or more. Pressure-containing castings weighing less than 50 lb [22.7 kg] shall be marked with either the heat number or a lot number that will identify the casting as to the month in which it was poured. Marking shall be in such position as not to injure the usefulness of the casting.

17.2 On castings for which impact property requirements are specified, stamped markings using low-stress stamps shall be on a raised pad when such pad can be made a part of the castings.

17.3 Castings shall be marked with the manufacturer's identification or symbol except when other provisions have been made between the manufacturer and purchaser.

18. Keywords

18.1 castings; general requirements; pressure containing; steel

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon between the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Unspecified Elements

S1.1 Limits may be established for elements not specified for the grade ordered by agreement between the manufacturer and purchaser. The results of the analysis for the agreed-upon elements shall be reported.

S2. Destruction Tests

S2.1 Purchaser may select representative castings from each heat, and cut up and etch, or otherwise prepare, the sections for examination for internal defects. Should injurious defects be found that evidence unsound steel or faulty foundry technique, all the castings made from that particular pattern, heat, and heat treatment charge may be rejected. All the rejected castings, including those cut up, shall be replaced by the manufacturer without charge.

S3. Bend Test

S3.1 One bend test shall be made from a test coupon from each heat in accordance with Test Methods and Definitions A370, and shall be machined to a 1 by ½-in. [25 by 13-mm] section with corners rounded to a radius not over 1⁄16 in. [1.6 mm]. When material is ordered to an M-suffix (SI units) product standard, the bend test requirements shall be in accordance with Test Methods A1058.

S3.2 The specimen shall withstand being bent longitudinally at room temperature through an angle of 90° about a pin, the diameter of which shall be the specimen thickness for carbon steels, and 1 in. [25 mm] for other steels. The specimen shall show no cracks on the outside of the bent portion of the specimen.

S3.3 Bend test specimens may be cut from heat-treated castings instead of from test specimens when agreed upon between manufacturer and purchaser.

S3.4 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

S4. Magnetic Particle Inspection

S4.1 Castings shall be examined for surface and near-surface discontinuities by magnetic particle inspection. The examination shall be in accordance with Guide E709, and types and degrees of discontinuities considered shall be judged by Reference Photographs E125. Extent of examination, time of examination, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification which may be used as a basis for such agreement is MSS SP 53.

S4.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S5. Radiographic Inspection

S5.1 Castings shall be examined for internal defects by means of X-rays or gamma rays. The procedure shall be in accordance with Guide E94/E94M, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E446, E186, or E280. Extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification that may be used as a basis for such agreement is MSS SP 54.

S5.2 Radiographic examination of castings may be performed before or after any heat treatment.

S5.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S6. Liquid Penetrant Inspection

S6.1 Castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The examination shall be in accordance with Practice E165/E165M. Areas to be inspected, time of inspection, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification that may be used as a basis for such agreement is Specification A903/A903M.

S6.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S7. Ultrasonic Inspection

S7.1 Castings shall be examined for internal defects by means of ultrasonic inspection. The inspection procedure shall be in accordance with Practice A609/A609M. Extent of examination, methods of testing, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A practice that may be used as a basis for such agreement is Practice A609/A609M.

S7.2 Ultrasonic examination of castings shall be performed after at least one heat treatment above the critical temperature range but need not be repeated after subsequent heat treatment.

S7.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S8. Charpy Impact Test

S8.1 Charpy impact test properties shall be determined on each heat from a set of three Charpy V-notch specimens made from a test coupon in accordance with Test Methods and Definitions A370 or Test Methods A1058, as applicable, and tested at a test temperature agreed upon by the manufacturer and purchaser. The acceptance requirements shall be either energy absorbed, lateral expansion, or percent shear area, or all three, and shall be those agreed upon by the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A370 or Test Methods A1058, as applicable.

S8.2 *Absorbed Energy*—Average energy value of three specimens shall be not less than specified, with not more than one value permitted to fall below the minimum specified, and no value permitted below the minimum specified for a single specimen.

S8.3 *Lateral Expansion*—Lateral expansion value shall be agreed upon by the manufacturer and purchaser.

S8.4 *Percent Shear Area*—Percent shear area shall be agreed upon by the manufacturer and purchaser.

S9. Drop Weight Tests

S9.1 Drop weight test properties shall be determined from each heat by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Method E208. The crack starter weld shall be deposited on the surface of the specimen that was nearest to the casting surface. Each test shall consist of at least two specimens tested at a temperature agreed upon by the manufacturer and purchaser. Each specimen shall exhibit "no break" performance.

S10. Examination of Weld Preparation

S10.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing magnetic particle or liquid penetrant examination shall be in accordance with Guide E709 or Practice E165/E165M. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E125, of Degree 2 in sections up to 2 in. [50 mm] thick and of Degree 3 in sections over 2 in. [50 mm] thick shall be acceptable.

S11.

(This number not assigned to a supplementary requirement.)

S12. Prior Approval of Major Weld Repairs

S12.1 Major weld repairs shall be subject to the prior approval of the purchaser.

S13. Hardness Test

S13.1 A hardness test shall be made in accordance with Test Methods and Definitions A370 or Test Methods A1058, as applicable. The test location and the hardness requirements shall be agreed upon between the manufacturer and the purchaser.

S14. Tension Test from Each Heat and Heat Treatment Charge

S14.1 One tension test shall be made for each heat and heat treatment charge.

S15. Quench and Temper Heat Treatment

S15.1 The castings shall be quenched and tempered. Castings so treated shall be marked "QT."

S16.

(This number not assigned to a supplementary requirement.)

S17. Tension Test from Castings

S17.1 In addition to the tensile test required in Section 6, test material shall be cut from heat-treated castings. The mechanical properties and location for the test material shall be agreed upon by the manufacturer and purchaser.

S18. Tension Test for Castings Each Weighing 10 000 lb [4500 kg] or More

S18.1 Two tensile tests shall be made for each casting. The test specimens shall be prepared in accordance with Section 6. The location of the test specimens shall be agreed upon by the manufacturer and purchaser.

S19.

(This number not assigned to a supplementary requirement.)

S20. Weld Repair Charts

S20.1 Unless other criteria are agreed upon between the manufacturer and the purchaser, weld repairs made to correct leakage on hydrostatic testing, or weld repairs for which the depth of the cavity required for welding exceeds 40 % of the actual wall thickness, or weld repairs for which the area of the cavity required for welding:

(1) Exceeds approximately 10 in.^{2} [65 cm^2] for castings weighing up to 10 000 lb [4.5 tonnes];

(2) Exceeds 20 in.^{2} [130 cm^2] for castings weighing from 10 000 lb to 30 000 lb [4.5 to 13.5 tonnes];

(3) Exceeds approximately 30 in.^{2} [200 cm^2] for pieces weighing more than 30 000 lb [13.5 tonnes].

shall be documented.

S20.2 Weld repairs requiring documentation shall be documented on sketches or photographs, or both. The sketches or photographs shall show the location and major dimensions of cavities prepared for weld repair. The weld repair documentation shall be submitted to the purchaser at the completion of the order.

S21. Heat Treatment Furnace Record

S21.1 A heat treatment chart showing time and temperature shall be prepared and be available for inspection by the purchaser.

S22. Heat Treatment

S22.1 Test specimens shall be heat treated together with the castings they represent. Heat-treated specimens shall be tested and shall meet the tensile and impact properties specified.

S22.2 The remaining test specimens from Supplementary Requirement S22.1 representing the casting shall be treated thermally after the final (foundry) heat treatment to simulate heat treatments below the critical temperature that the casting may receive during fabrication, and then tested for mechanical properties. Time, temperature, and cooling rate shall be as stated in the order. In the case of post-weld heat treatment, the total time at temperature or temperatures for the test material shall be at least 80 % of the total time at temperature or temperatures during actual post-weld heat treatment of the fabrication of which the casting or castings are a part. The total time at temperature or temperatures for the test material may be performed in a single cycle. When this supplementary requirement is specified, the welding qualification test metal must be processed in the same manner.

S23. Macroetch Test

S23.1 Apply Supplementary Requirement S1 for the spectrographic determination and reporting of the total residual aluminum content of all heats of ferritic and martensitic steels subjected to this macroetch test.

S23.2 When the heat analysis indicates a total residual aluminum content in excess of 0.08 %, the manufacturer shall etch a cross section of the casting with the heaviest section for which this supplementary requirement is invoked, or a coupon attached to that heaviest section or an area directly under a riser (Note S23.1). Cross sections, from a separately cast test block from the same heat and of a thickness representative of the heaviest section of castings purchased under this supplementary requirement, may also be used for macroetch testing. The etching shall be performed on the selected section after its heat treatment, that is, after heat treatment as defined in the product specification.

NOTE S23.1—High-strength martensitic castings, in particular, may be damaged beyond use if the etch is applied directly to the casting.

S23.3 The preparation of the surface and the macroetching procedure with solution No. 1 (1:1 HCl) of Table 5 in Practice E340 shall be followed. The resulting etched surface shall be compared and rated with the reference photographs in Fig. S23.1 depicting ten levels of severity of intergranular network structures indicative of the presence of aluminum nitride, or other constituents prone toward precipitating at grain boundaries during solidification and subsequent cooling. Table S23.1 relates the severity levels shown in these photographs with specific delineation widths and percent of boundary outlining in the etched structures.

S23.4 Castings represented by etched structures exhibiting a network rating in excess of Severity Level 4 shall be considered unacceptable until further evaluations are completed. The acceptability of individual castings may be determined by etching sections of each casting to ascertain the network severity level. Disposition of unacceptable castings shall be a matter of agreement between the manufacturer and purchaser. Those castings exhibiting etched severity levels greater than four may be further evaluated by any of the following agreed-upon methods:

S23.4.1 Fracture testing to determine the amount of "rock candy" structure.

S23.4.2 Mechanical testing (bend, tensile, and so forth) to determine the ductility characteristics.

S23.4.3 Weld testing to determine crack susceptibility in the heat-affected zone of a circular groove welded with cellulose coated electrodes.

S23.5 Alternatively, by agreement, it is permissible to subject castings from an unacceptable heat to a high-temperature homogenizing cycle prior to the normal production heat treatment and subsequently macroetch test each casting.

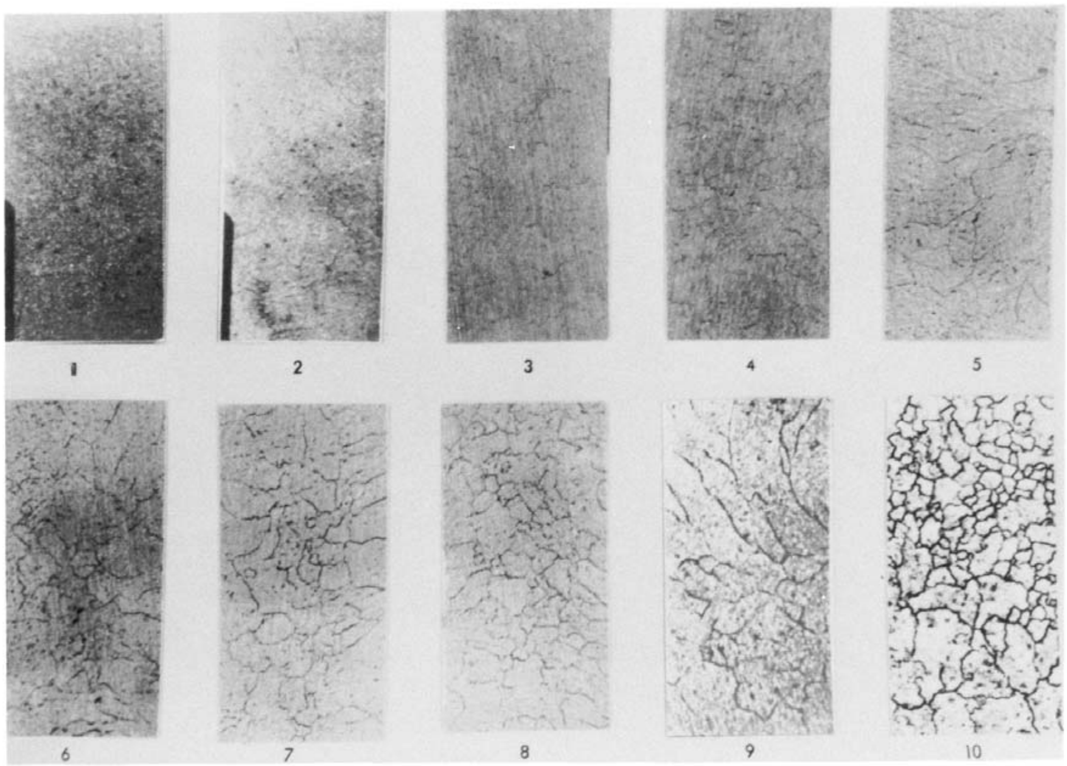
S23.6 Heavy section castings (3) whose configurations are amenable to the attachment of test coupons representative of the section thickness involved and from which standard 0.505-in. [12.827-mm] diameter tension specimens may be machined are exempt from this macroetch test if the results of the tension test on the coupon after heat treatment of the casting meet the minimum requirements specified for the grade of steel involved.

NOTE S23.2—For purposes of this supplementary requirement, a heavy section casting is defined as one having a wall thickness of 1½ in. [37 mm] or greater in combination with a casting weight of at least 1000 lb [455 kg].

S24. Specified Ferrite Content Range

S24.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the chemical composition procedure of Practice A800/A800M, shall be in accordance with the specified ferrite content range.

S24.2 The specified ferrite content range shall be as agreed upon between the manufacturer and the purchaser. The minimum specified ferrite content range shall be 10 %, with the minimum ferrite content being no lower than the percent necessary to achieve the minimum mechanical properties required for the alloy.



NOTE 1—The ten levels of severity of intergranular network structures shown are indicative of the presence of aluminum nitride precipitation in the primary austenitic grain boundaries.

FIG. S23.1 Reference Photographs of Macroetched Cast Steel

TABLE S23.1 Descriptive Data Applicable to Network Structures Shown in Fig. S23.1

NOTE 1—These ratings are based on the physical width and continuity of the precipitate pattern developed by the acid etchant on the primary austenitic grain boundaries of the cast steel. Supplementary testing is normally conducted to determine the final disposition of castings with ratings of 5 or greater.

Rating	Delineation Width, in.	Boundary Outline, %
1	Fine–0.001	20
2	Fine–0.001	40
3	Fine–0.001	60
4	Fine–0.002	80
5	Fine–0.002	100
6	Medium–0.005	100
7	Heavy–0.010	100
8	0.020	100
9	1⁄32	100
10	1⁄16	100

S24.3 Should the purchaser wish to have the ferrite content determined by either magnetic response or metallographic methods, the purchaser should impose Supplementary Requirement S1 or S2 of Practice A800/A800M.

S25. Heat Treatment Certification

S25.1 Heat treatment temperature and cycle times shall be shown on the certification report.

S26. Alternate Tension Test Coupons and Specimen Locations for Castings

S26.1 Test coupons may be cast integrally with the castings or separately. Separately cast coupons shall be heat treated together with the castings they represent.

S26.2 The casting thickness, T, is the maximum thickness of the pressure-containing wall of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension, T, is for the casting.

S26.3 One of the following shall apply:

S26.3.1 The longitudinal centerline of the test specimen shall be taken at least ¼ T from the T dimension surface and all of the gage length must be at least 1 T from any other heat-treated surface, exclusive of the surface opposite the T dimension surface. (See Specification A1067/A1067M, Fig. 5 (a).) For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least ¼ T from the outside or inside and all of the gage length must be at least T from the as-heat-treated end. (See Specification A1067/A1067M, Fig. 5 (b).)

S26.3.2 For ferritic and martensitic castings, partial severing of test coupons prior to final heat treatment is permitted.

S26.3.3 Where separately cast test coupons are used, the dimension shall not be less than 3 T by 3 T by T and each specimen shall meet the requirements of S26.3.1, except that when T exceeds 5 in. [125 mm], the dimension may be 15 by 15 by 5 in. [375 by 375 by 125 mm], by agreement between the manufacturer and the purchaser. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents. Centrifugal castings may be represented by statically cast coupons. (See Specification A1067/A1067M, Fig. 6.)

S26.3.4 When agreed upon between the manufacturer and the purchaser, castings that are cast or machined to essentially the finished configuration prior to heat treatment shall have test specimens removed from a prolongation or other stock on the casting at a location below the nearest heat-treated surface indicated on the order. The specimen location shall be at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high-tensile-stress surface will be from the nearest heat-treated surface and a minimum of twice this distance from a second heat-treated surface, except that the test specimens shall be no nearer than ¾ in. [19 mm] to a heat-treated surface and 1½ in. [38 mm] from a second heat-treated surface. (See Specification A1067/A1067M, Fig. 7.)

S26.3.5 Where specimens are to be removed from the body of quenched and tempered castings, either the requirements of S26.3.1 shall be met or a steel thermal buffer pad or thermal insulation or other thermal barriers shall be used during heat treatment. Steel thermal buffer pads shall be a minimum of T by T by 3 T in length and shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface. Test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of ½ in. [13 mm] from the buffered surface and ¼ T from other heat-treated surfaces (see Specification A1067/A1067M, Fig. 7). When thermal insulation is used, it shall be applied adjacent to the casting surface where the test specimens are to be removed. The producer shall demonstrate that the cooling rate of the test specimen location is no faster than that of specimens taken by the method described in S26.3.1

S27. Hot Isostatic Pressing (HIPing)

S27.1 Castings shall be processed by hot isostatic pressing (HIPing) according to Practice A1080. Unless specified by the purchaser in the purchase order or contract, the HIPing time, temperature, pressure, and other parameters shall be at the discretion of the producer.

S28. Cleaning of Stainless Steels

S28.1 Final cleaning of the casting surfaces shall be performed in accordance with one of the cleaning methods in Practice A380/A380M or Specification A967/A967M as agreed upon between the purchaser and supplier. Acceptance testing shall be subject to agreement between the purchaser and supplier.

S29.

(This number not assigned to a supplementary requirement.)

S30.

(This number not assigned to a supplementary requirement.)

S31.

(This number not assigned to a supplementary requirement.)

S32.

(This number not assigned to a supplementary requirement.)

S33. Stabilization Heat Treatment of CF8C

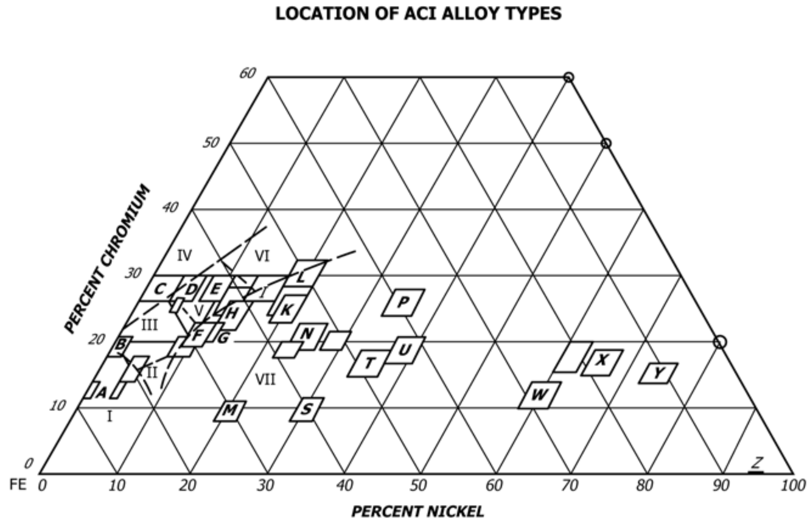
S33.1 CF8C shall be stabilized at 1600 to 1650 °F [870 to 900 °C] for a minimum time of 1 h/in. [25 mm] of thickness and water quenched or rapidly cooled by other means. The grade designation symbol shall be followed by the symbol "S33."

S34. Stabilization Heat Treatment of CF10MC

S34.1 CF10MC shall be stabilized at 1600 to 1650 °F [870 to 900 °C] for a minimum time of 1 h/in. [25 mm] of thickness and water quenched or rapidly cooled by other means. The grade designation symbol shall be followed by the symbol "S34."

S50–S69.

(These numbers reserved for assignment by individual product standards.)



NOTE 1—The approximate areas of microstructures to be expected at room temperature are indicated as follows:
I—Martensite
II—Martensite and untransformed austenite
III—Ferrite plus martensite and untransformed austenite
IV—Ferrite
V—Ferrite plus austenite
VI—Ferrite plus austenite plus sigma
VII—Austenite

NOTE 2—Carbides also may be present depending on carbon content and thermal history.

FIG. X1.1 Letters Assigned to Chromium and Nickel Ranges in ACI Designation System

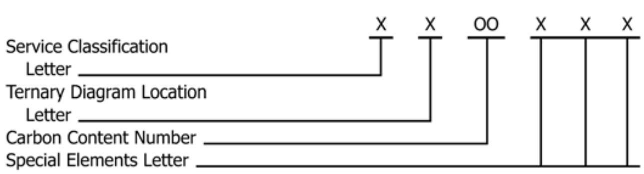
APPENDIXES

(Nonmandatory Information)

X1. ALLOY DESIGNATIONS FOR CAST STAINLESS STEELS

X1.1 Cast stainless steels are usually specified on the basis of composition using the alloy designation system established by the Alloy Casting Institute (ACI). The ACI designations, for example, CF8M, have been adopted by ASTM and are preferred for cast alloys over the designations used by the American Iron and Steel Institute for similar wrought steels.

X1.2 This nomenclature system has served successfully to accommodate changes in old alloys and to designate new ones.



X1.2.1 *Service Classification Letter*—The first letter of the cast stainless steel designation system identifies the intended service application of the alloy. The letter C indicates corrosion-resistant service, and the letter H indicates the heat-resistant service at and above 1200 °F [649 °C].

X1.2.2 *Ternary Diagram Location Letter*—The second letter indicates the approximate location of the nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram shown in Fig. X1.1.

X1.2.3 *Carbon Content Number*—For C service classifications, this single or dual-digit numeral represents the maximum carbon content in units of 0.01 %. For H service classifications, this number represents the midpoint of the range of carbon content in terms of 0.01 % with a ±0.05 % limit.

X1.2.4 *Special Elements Letter*—Additional letters following the numeral represent special chemical elements in the alloy grade, such as M for molybdenum, C for columbium (Nb for niobium), Mn for manganese, S for silicon, N for nitrogen, Cu for copper, and W for tungsten. There are two exceptions: the letter A indicates "Controlled Ferrite," and the letter F indicates "Free Machining."

X1.3 In Fig. X1.1, unlettered NiCr ranges are associated with the nearest lettered location. They may be the result of differences between corrosion and heat-resistant types or because of the influence of additional elements; for example, the precipitation hardening grade CB-7Cu.

X2. ADDITION OF NEW GRADES TO PRODUCT SPECIFICATIONS COVERED BY SPECIFICATION A703/A703M

X2.1 Where grades are already included in other A01.18 standards, they may be added to other A01.18 standards. In this case, the information described in X2.2 and X2.3 is not required.

X2.2 For grades not already included in A01.18 standards, the following data should be provided from a minimum of ten production heats. This data should include:

X2.2.1 Chemical composition.

X2.2.2 Mechanical properties, as applicable to the product specification being cited. These may include, but are not limited, to the following:

X2.2.2.1 Ultimate tensile strength,

X2.2.2.2 Yield strength or yield point,

X2.2.2.3 Elongation,

X2.2.2.4 Reduction of area,

X2.2.2.5 Hardness, and

X2.2.2.6 Impact properties (Charpy V-notch).

X2.2.3 The test coupon size from which the test specimens were removed, stated for each test.

X2.2.4 Heat treatment requirements.

X2.2.5 Welding procedure. (Welding should be carried out using commercially available consumables.)

X2.2.6 Whether the material is covered by any patents.

X2.3 The inclusion of the proposed material should be supported by written request from at least one purchaser or user indicating the need for the new grade.

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SPECIFICATION FOR AGE-HARDENING STAINLESS STEEL FORGINGS

SA-705/SA-705M

(Identical with ASTM Specification A705/A705M-95(2009).)

SPECIFICATION FOR AGE-HARDENING STAINLESS STEEL FORGINGS

SA-705/SA-705M

[Identical with ASTM Specification A 705/A 705M-95(2009).]

1. Scope

1.1 This specification covers age-hardening stainless steel forgings for general use.

1.2 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 Unless the order specifies an "M" designation, the material shall be furnished to inch-pound units.

NOTE 1 —Bar products are covered by Specification A 564/A 564M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

A 564/A 564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *Other Documents:*

SAE J 1086 Recommended Practice for Numbering Metals and Alloys (UNS)

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include but are not limited to the following:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Name of material (age-hardening stainless steel forgings),

3.1.3 Dimensions, including prints or sketches,

3.1.4 Type or UNS designation (Table 1),

3.1.5 Heat treated condition (Section 5),

3.1.6 Transverse properties when required (7.4),

3.1.7 ASTM designation and date of issue, and

3.1.8 Special requirements (5.3, 5.4).

3.2 If possible the intended end use of the item should be given on the purchase order, especially when the item is ordered for a specific end use or uses.

NOTE 2 — A typical ordering description is as follows: 5 age-hardening stainless steel forgings, Type 630, solution-annealed, ASTM Specification A 705 dated ____. End use: pump blocks for oil well equipment.

4. General Requirements

4.1 In addition to the requirements of this specification, all requirements of the current edition of Specification A 484/A 484M shall apply. Failure to comply with the general requirements of Specification A 484/A 484M, constitutes nonconformance with this specification.

5. Materials and Manufacture

5.1 Material for forgings shall consist of billets or bars, either forged, rolled or cast, or a section cut from an ingot. The cuts shall be made to the required length by a suitable process. This material may be specified to Specification A 564/A 564M.

5.2 The material shall be forged by hammering, pressing, rolling, extruding, or upsetting to produce a wrought structure throughout and shall be brought as nearly as possible to the finished shape and size by hot working.

5.3 When specified on the order, sample forging may be sectioned and etched to show flow lines and the condition in regard to internal imperfections. When so specified, the question of acceptable and unacceptable metal flow shall be subject to agreement between the manufacturer and the purchaser prior to order entry.

5.4 When specified on the order, the manufacturer shall submit for approval of the purchaser a sketch showing the shape of the rough forging before machining, or before heat treating for mechanical properties.

5.5 The grain size shall be as fine as practicable and precautions shall be taken to minimize grain growth.

5.6 Material of types other than XM-9 shall be furnished in the solution-annealed condition, or in the equalized and over-tempered condition, as noted in Table 2, unless otherwise specified by the purchaser.

5.6.1 Types 630, XM-16, and XM-25 may be furnished in the solution-annealed or age-hardened condition.

6. Chemical Composition

6.1 The steel shall conform to the chemical composition limits specified in Table 1.

6.2 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties

7.1 The material, as represented by mechanical test specimens, shall conform to the mechanical property requirements specified in Table 2 and shall be capable of developing the properties in Table 3 when heat treated as specified in Table 3.

7.2 The yield strength shall be determined by the offset method as described in the current edition of Test Methods and Definitions A 370. The limiting permanent offset shall be 0.2% of the gage length of the specimen.

7.3 The impact strength shall be determined at 70 to 80°F [20 to 25°C], by Charpy V-notch specimen Type A as described in Test Methods and Definitions A 370.

7.4 Material tensile tested and, when specified, impact tested in the transverse direction (perpendicular to the forging flow lines) and meeting the requirements shown in Table 3 need not be tested in the longitudinal direction.

7.5 Samples cut from forging shall conform to the mechanical properties of Table 3 when heat treated as specified in Table 2 and Table 3 and tested in accordance with Test Methods and Definitions A 370.

8. Prolongations for Tests

8.1 Subject to Section 7, the forgings shall be produced with prolongations for testing, unless otherwise specified. The producer may elect to submit an extra forging to represent each test lot instead of prolongations, or the test specimens can be taken from the forgings themselves.

9. Number of Tests

9.1 For all classes of forgings weighing from 5000 to 7000 lb [2300 to 3200 kg] each, at least one tension test shall be made from each forging.

9.2 For all classes of forgings weighing more than 7000 lb [3200 kg] each, one tension test shall be made from each end of each forging. In the case of ring forgings, the tension test specimen shall be removed from each of two locations on the periphery, approximately 180° apart, or insofar as practicable, from opposite ends of the forging.

9.3 For forgings weighing less than 5000 lb [2300 kg] each, one tension test shall be made from each size classification for each heat in each heat treating charge. Where continuous heat treating furnaces are used, tests shall be made on 10% of the forgings of each size classification from each heat subjected to the same heat treatment practice.

10. Keywords

10.1 age-hardening stainless steel; precipitation hardening stainless steel; stainless steel forgings

TABLE 1
CHEMICAL REQUIREMENTS[A]

		Composition, %											
UNS Designation[B]	Type	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Aluminum	Molybdenum	Titanium	Copper	Other Elements
S17400	630	0.07	1.00	0.040	0.030	1.00	15.00–17.50	3.00–5.00	. . .	. . .	. . .	3.00–5.00	[C]
S17700	631	0.09	1.00	0.040	0.030	1.00	16.00–18.00	6.50–7.75	0.75–1.50	. . .	. . .	. . .	. . .
S15700	632	0.09	1.00	0.040	0.030	1.00	14.00–16.00	6.50–7.75	0.75–1.50	2.00–3.00	. . .	. . .	. . .
S35500	634	0.10–0.15	0.50–1.25	0.040	0.030	0.50	15.00–16.00	4.00–5.00	. . .	2.50–3.25	. . .	. . .	[D]
S17600	635	0.08	1.00	0.040	0.030	1.00	16.00–17.50	6.00–7.50	0.40	. . .	0.40–1.20	. . .	. . .
S15500	XM-12	0.07	1.00	0.040	0.030	1.00	14.00–15.50	3.50–5.50	. . .	. . .	. . .	2.50–4.50	[C]
S13800	XM-13	0.05	0.20	0.010	0.008	0.10	12.25–13.25	7.50–8.50	0.90–1.35	2.00–2.50	. . .	. . .	[E]
S45500	XM-16	0.03	0.50	0.015	0.015	0.50	11.00–12.50	7.50–9.50	. . .	0.50	0.90–1.40	1.50–2.50	[F]
S45503	. . .	0.010	0.50	0.010	0.010	0.20	11.00–12.50	7.50–9.50	. . .	0.50	1.00–1.35	1.50–2.50	[F]
S45000	XM-25	0.05	1.00	0.030	0.030	1.00	14.00–16.00	5.00–7.00	. . .	0.50–1.00	. . .	1.25–1.75	[G]

[A] Limits are in percent maximum unless shown as a range or stated otherwise.
[B] New designation established in accordance with Practice E 527 and SAE J1086, Recommended Practice for Numbering Metals and alloys (UNS).
[C] Columbium plus tantalum 0.15–0.45.
[D] Nitrogen 0.07–0.13.
[E] Nitrogen 0.01.
[F] Columbium plus tantalum 0.10–0.50.
[G] Columbium 8 times carbon minimum.

TABLE 2
SOLUTION HEAT TREATMENT

Type	Condition	Solution Treatment	Mechanical Test Requirements in Solution Treated Condition[A]							
			Tensile Strength, min		Yield Strength, min		Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min %	Hardness[B]	
			ksi	[MPa]	ksi	[MPa]			Rockwell C, max	Brinell, max
630	A	1900 ± 25°F [1040 ± 15°C] (cool as required to below 90°F [32°C])	...	...	...	...	...	...	38	363
631	A	1900 ± 25°F [1040 ± 15°C] (water quench)	...	...	...	...	...	...	Rb89	229
632	A	1900 ± 25°F [1040 ± 15°C] (water quench)	...	...	...	...	...	...	Rb100	269[C]
634[D]	A	1900 ± 25°F [1040 ± 15°C] quench, hold not less than 3 h at minus 100°F or lower	...	...	...	...	...	...	...	363[D]
635	A	1900 ± 25°F [1040 ± 15°C] (air cool)	120	[825]	75	[515]	10	45	32	302
XM-12	A	1900 ± 25°F [1040 ± 15°C] (cool as required to below 90°F [32°C])	...	...	...	...	...	...	38	363
XM-13	A	1700 ± 25°F [925 ± 15°C] (cool as required to below 60°F [16°C])	...	...	...	...	...	...	38	363
XM-16	A	1525 ± 25°F [830 ± 15°C] (cool rapidly)	...	...	...	...	...	...	36	331
S45503	A	1525 ± 25°F [830 ± 15°C] (cool rapidly)	...	...	...	...	...	...	36	331
XM-25	A	1900 ± 25°F [1040 ± 15°C] (cool rapidly)	125[E]	[860]	95	[655]	10	40	33	311

[A] See 6.1.
[B] Either Rockwell C hardness or Brinell is permissible. On sizes of ½ in. (12.70 mm) and smaller. Rockwell C is preferred.
[C] 321 BHN for rounds cold drawn after solution treating.
[D] Equalization and over-tempering treatment 1425 ± 50°F [775 ± 30°C] for not less than 3 h, cool to room temperature, heat to 1075 ± 25°F [580 ± 15°C] for not less than 3 h.
[E] 125 – 165 ksi [860 – 1140 MPa] for sizes up to ½ in. [13 mm].

TABLE 3
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A]

Type	Condition	Suggested Hardening or Aging Treatment, or both[B,C,D]: Temperature, °F [°C]	Time, h	Quench	Applicable Thickness, in. and Test Direction[E]	Tensile Strength, min: ksi	[MPa]	Yield Strength, min[F]: ksi	[MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Hardness[G]: Rockwell C, min	Brinell, min	Impact Charpy-V, min: ft·lbf	J
630	H900	900 [480]	1.0	air cool	Up to 3 in. incl [75 mm] (L)	190	[1310]	170	[1170]	10	40	40	388	...	...
					Over 3 in. [75 mm] to 8 in. incl [200 mm] (L)						35				
	H925	925 [495]	4.0	air cool	Up to 3 min. incl [75 mm] (L)	170	[1170]	155	[1070]	10	44	38	375	5	6.8
					Over 3 in. [75 mm] to 8 in. incl [200 mm] (L)						38				
	H1025	1025 [550]	4.0	air cool	Up to 8 in. incl [200 mm] (L)	155	[1070]	145	[1000]	12	45	35	331	15	20
	H1075	1075 [580]	4.0	air cool		145	[1000]	125	[860]	13	45	32	311	20	27
	H1100	1100 [595]	4.0	air cool		140	[965]	115	[795]	14	45	31	302	25	34
	H1150	1150 [620]	4.0	air cool		135	[930]	105	[725]	16	50	28	277	30	41
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool				115	[795]	75	[520]	18	55	24	255	55	75
631	RH950	1750°F [955°C] for not less than 10 min, but not more than 1 h, cool rapidly to room temperature. Cool within 24 h to minus 100 ± 10°F [75°C], hold not less than 8 h. Warm in air to room temperature. Heat to 950°F [510°C], hold 1 h, air cool			Up to 4 in. incl. [100 mm] (L)	185	[1280]	150	[1030]	6	10	41	388	...	...
	TH1050	Alternative treatment: 1400°F [760°C] hold 90 min, cool to 55 ± 5°F [15 ± 3°C] within 1 h. Hold not less than 30 min, heat to 1050°F [565°C] hold for 90 min, air cool			Up to 6 in. incl [150 mm] (L)	170	[1170]	140	[965]	6	25	38	352	...	...
632	RH950	Same as Type 631			Up to 4 in. incl [100 mm] (L)	200	[1380]	175	[1210]	7	25	...	415	...	...
	TH1050				Up to 6 in. incl [150 mm] (L)	180	[1240]	160	[1100]	8	25	...	375	...	...

TABLE 3
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A] (CONT'D)

Type	Condition	Suggested Hardening or Aging Treatment, or both[B,C,D]			Applicable Thickness, in. and Test Direction[E]	Tensile Strength, min		Yield Strength, min[F]		Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Hardness[G]		Impact Charpy-V, min	
		Temperature, °F [°C]	Time, h	Quench		ksi	[MPa]	ksi	[MPa]			Rockwell C, min	Brinell, min	ft·lbf	J
634[H]	H1000	1750 [955] for but not less than 10 min, but not more than 1 h. Water quench. Cool to not higher than minus 100°F [75°C]. Hold for not less than 3 h. Temper at 1000°F [540°C], holding for not less than 3 h.				170	[1170]	155	[1070]	12	25	37	341	. . .	. . .
635	H950	950 (510)	0.5	air cool		190	[1310]	170	[1170]	8	25	39	363	. . .	. . .
	H1000	1000 [540]	0.5	air cool		180	[1240]	160	[1100]	8	30	37	352	. . .	. . .
	H1050	1050 [565]	0.5	air cool		170	[1170]	150	[1035]	10	40	35	331	. . .	. . .
XM-12	H900	900 [480]	1.0	air cool	Up to 12 in. incl [300 mm][I] (L)	190	[1310]	170	[1170]	10	35	40	388	. . .	. . .
					Up to 12 in. incl [300 mm][I] (T)					6	15				
	H925	925 [495]	4.0	air cool	Up to 12 in. incl [300 mm][I] (L)	170	[1170]	155	[1070]	10	38	38	375	5	6.8
					Up to 12 in. incl [300 mm][I] (T)					7	20			. . .	. . .
	H1025	1025 [550]	4.0	air cool	Up to 12 in. incl [300 mm][I] (L)	155	[1070]	145	[1000]	12	45	35	331	15	20
					Up to 12 in. incl [300 mm][I] (T)					8	27			10	14
	H1075	1075 [580]	4.0	air cool	Up to 12 in. incl [300 mm][I] (L)	145	[1000]	125	[860]	13	45	32	311	20	27
					Up to 12 in. incl [300 mm][I] (T)					9	28			15	20
	H1100	1100 [595]	4.0	air cool	Up to 12 in. incl [300 mm][I] (L)	140	[965]	115	[795]	14	45	31	302	25	34
					Up to 12 in. incl [300 mm][I] (T)					10	29			15	20
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm][I] (L)	135	[930]	105	[725]	16	50	28	277	30	41
					Up to 12 in. incl [300 mm][I] (T)					11	30			20	27
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool			Up to 12 in. incl [300 mm][I] (L)	115	[795]	75	[515]	18	55	24	255	55	75
					Up to 12 in. incl [300 mm][I] (T)					14	35			35	47

TABLE 3
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A] (CONT'D)

		Suggested Hardening or Aging Treatment, or both[B,C,D]				Tensile Strength, min		Yield Strength, min[F]		Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Hardness[G]		Impact Charpy-V, min	
Type	Condition	Temperature, °F [°C]	Time, h	Quench	Applicable Thickness, in. and Test Direction[E]	ksi	[MPa]	ksi	[MPa]			Rockwell C, min	Brinell, min	ft·lbf	J
XM-13	H950	950 [510]	4.0	air cool	Up to 12 in. incl [300 mm][I] (L)	220	[1520]	205	[1420]	10	45	45	430	. . .	. . .
					Up to 12 in. incl [300 mm][I] (T)						35				
	H1000	1000 [540]	4.0	air cool	Up to 12 in. incl [300 mm][I] (L)	205	[1420]	190	[1310]	10	50	43	400	. . .	. . .
					Up to 12 in. incl [300 mm][I] (T)					10	40				
	H1025	1025 [550]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	185	[1280]	175	[1210]	11	50	41	380	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						45				
	H1050	1050 [565]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	175	[1210]	165	[1140]	12	50	40	372	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						45				
	H1100	1100 [595]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	150	[1030]	135	[930]	14	50	34	313	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						50				
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	135	[930]	90	[620]	14	50	30	283	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						50				
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool			Up to 12 in. incl [300 mm] (L)	125	[860]	85	[585]	16	55	26	259	. . .	. . .
					Up to 12 in. incl [300 mm] (T)						55				
XM-16[I]	H900	900 [480]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	235	[1620]	220	[1520]	8	30	47	444	. . .	. . .
	H950	950 [510]	4.0	air cool		220	[1520]	205	[1410]	10	40	44	415	. . .	. . .
	H1000	1000 [540]	4.0	air cool		205	[1410]	185	[1280]	10	40	40	363	. . .	. . .
S45503[J]	H900	900 [480]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	235	[1620]	220	[1520]	8	30	47	444	. . .	. . .
					Up to 6 in. incl [150 mm][K] (T)					4	15				
	H950	950 [510]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	220	[1520]	205	[1410]	10	40	44	415	. . .	. . .
					Up to 6 in. incl [150 mm][K] (T)					5	20				
	H1000	1000 [540]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	205	[1410]	185	[1280]	10	40	40	363	. . .	. . .
					Up to 6 in. incl [150 mm] (T)					6	25				
XM-25[J]	H900	900 [480]	4.0	air cool	Up to 8 in. incl [200 mm]	180	[1240]	170	[1170]	10	40	39	363	. . .	. . .
					Up to 12 in. incl [300 mm][K] (L)					10	40				
					Up to 12 in. incl [300 mm][K] (T)					6	20				
	H950	950 [510]	4.0	air cool	Up to 8 in. incl [200 mm]	170	[1170]	160	[1100]	10	40	37	341	. . .	. . .
					Up to 12 in. incl [300 mm][K] (L)					10	40				
					Up to 12 in. incl [300 mm][K] (T)					7	22				

TABLE 3
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A] (CONT'D)

Type	Condition	Suggested Hardening or Aging Treatment, or both[B,C,D]: Temperature, °F [°C]	Time, h	Quench	Applicable Thickness, in. and Test Direction[E]	Tensile Strength, min: ksi	[MPa]	Yield Strength, min[F]: ksi	[MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Hardness[G]: Rockwell C, min	Brinell, min	Impact Charpy-V, min: ft·lbf	J
XM-25[J]	H1000	1000 [540]	4.0	air cool	Up to 8 in. incl [200 mm]	160	[1100]	150	[1030]	12	45	36	331	...	...
					Up to 12 in. incl [300 mm][K] (L)					12	45				
					Up to 12 in. incl [300 mm][K] (T)					6	27				
	H1025	1025 [550]	4.0	air cool	Up to 8 in. incl [200 mm]	150	[1030]	140	[965]	12	45	34	321	...	...
	H1050	1050 [565]	4.0	air cool	Up to 8 in. incl [200 mm]	145	[1000]	135	[930]	12	45	34	321	...	...
					Up to 12 in. incl [300 mm][K] (L)					12	45				
					Up to 12 in. incl [300 mm][K] (T)					9	30				
	H1100	1100 [595]	4.0	air cool	Up to 8 in. incl [200 mm]	130	[895]	105	[725]	16	50	30	285	...	...
					Up to 12 in. incl [300 mm][K] (L)					16	50				
					Up to 12 in. incl [300 mm][K] (T)					11	30				
	H1150	1150 [620]	4.0	air cool	Up to 8 in. incl [200 mm]	125	[860]	75	[515]	15	50	26	262	...	...
					Up to 12 in. incl [300 mm][K] (L)					18	55				
					Up to 12 in. incl [300 mm][K] (T)					12	35				

[A] See 6.1.
[B] Time refers to minimum time material is at temperature and may be extended to obtain required ductility properties.
[C] Unless otherwise noted, temperatures shown are suggested temperatures and may be varied to obtain required tensile properties.
[D] Intermediate temperatures must meet the ductility requirements of the next highest suggested hardening or aging temperature, or both. Example: Type 630 at 1050°F [565°C] must have 13% elongation and 45% reduction, same as for age hardening at 1075°F [580°C].
[E] (L) — Longitudinal axis of specimen parallel to direction of grain flow during rolling or forging. (T) — Transverse axis of specimen perpendicular to direction of grain flow during rolling or forging.
[F] See 6.2.
[G] Either Rockwell C hardness or Brinell is permissible. On sizes $\frac{1}{2}$ in. (12.70 mm) and smaller, Rockwell C is preferred.
[H] Refer to Table 2 for details on equalize and over temper heat treatment.
[I] Applies to consumable electrode vacuum remelted.
[J] Only tensile strength applicable to sizes up to $\frac{1}{2}$ in. (13 mm).
[K] Consumable electrode remelted only.

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SPECIFICATION FOR ALLOY STEEL FORGINGS FOR HIGH-STRENGTH PRESSURE COMPONENT APPLICATION

SA-723/SA-723M

(Identical with ASTM Specification A723/A723M-10(2015).)

Standard Specification for Alloy Steel Forgings for High-Strength Pressure Component Application

1. Scope

1.1 This specification covers requirements for high-strength quenched and tempered alloy steel forgings for pressure vessels, isostatic presses, shock tubes, and similar components.

1.2 These materials are not intended for welded construction.

1.3 Three grades of nickel-chromium-molybdenum steels and six classes of increasing tensile strength are included. The strength class, section size, and configuration of the forging will largely dictate the applicable type(s) of steel.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

A788/A788M Specification for Steel Forgings, General Requirements

2.2 *Other Standards:*

ASME Boiler and Pressure Vessel Code

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A788/A788M, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging and the method of selecting test location (see 6.2). When appropriate, the areas of significant loading in the forging shall be designated. The purchaser may also include appropriate supplementary requirements from Specification A788/A788M as well as from this specification.

3.2 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, the requirements of this specification shall prevail.

3.4 When forgings are required to be in compliance with Division 3 of the ASME Boiler and Pressure Vessel Code, Supplementary Requirement S6 should be specified.

4. Materials and Manufacture

4.1 *Melting Practice*—The steel melting procedures of Specification A788/A788M shall apply except that the open-hearth process shall not be used, and that the steel shall be vacuum degassed prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen.

4.1.1 Use of secondary remelting or refining operations may be considered for particularly demanding applications.

4.2 *Discard*—Sufficient discard shall be taken from each ingot to secure freedom from piping and excessive segregation.

4.3 *Heat Treatment:*

4.3.1 Forgings shall be rough-machined prior to final heat treatment if it is necessary to reduce the mass to ensure full hardening or to meet the requirements of 6.2. The risk of cracking during heat treatment with high-hardenability steels of the type covered by this specification should be borne in mind when deciding on the degree of surface preparation before heat treatment.

4.3.2 *Heat Treatment for Mechanical Properties*—Heat treatment shall consist of normalizing (which may be part of the preliminary treatment), reaustenitization, liquid quenching, and tempering. The forgings shall be quenched in a suitable liquid medium by spraying or immersion. Quenching shall be followed by tempering at a minimum temperature of 1000°F [540°C]. The minimum time at tempering temperature shall be ½ h/in. [½ h/25 mm] of maximum section thickness, unless otherwise agreed between supplier and purchaser.

5. Chemical Composition

5.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A788/A788M shall comply with Table 1.

5.1.1 *Temper Embrittlement Control*—The purchaser's attention is drawn to Supplementary Requirement S24 in Specification A788/A788M for application of the J Factor which may be of assistance in the control of temper embrittlement in forgings produced to Specification A723/A723M.

5.2 *Product Analysis*—The manufacturer shall use the product analysis provision of Specification A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat. The purchaser may also make this determination in accordance with Specification A788/A788M.

6. Mechanical Properties

6.1 *General Requirements*—The forging shall conform to the requirements of Table 2 and Table 3. The largest obtainable tension test specimen as specified in Test Methods and Definitions A370 (that is, standard round 0.500-in. [12.5-mm] diameter specimen) shall be used. Charpy V-notch Type A impact specimens, as shown in Test Methods and Definitions A370, shall be used.

6.2 *Sampling*—The mid-point of the gage length of tension test specimens and the area under the notch of impact specimens shall be located in accordance with one of the following methods as specified by the purchaser, or suggested by the supplier and approved by the purchaser. Wherever practical, all testing shall be from integral prolongations of the forging.

6.2.1 *Method 1*—This method shall always be used when the maximum quenched thickness does not exceed 4 in. [100 mm]. Datum points of the specimens, as described in 6.2, shall be located in the forging or test forging (6.2.4) at mid-thickness and at least ⅔ T (T is the maximum heat-treated thickness) from the quenched end surface or nearest adjacent surfaces.

6.2.2 *Method 2—t* by 2*t*, where *t* is the distance from the area of significant loading (3.1) to the nearest quenched surface. However, the datum points of the specimens as described in 6.2 shall not be nearer to one quenched surface than ¾ in. [20 mm] and to the second quenched surface than 1 ½ in. [40 mm]. When this method of testing is employed, forgings are usually manufactured in accordance with a purchaser-approved drawing showing prequenched dimensions and the location of mechanical test specimens. It is commonly used for disk-type forgings such as tube sheets and covers.

6.2.3 *Method 3*—For maximum quenched thicknesses in excess of 4 in. [100 mm] as heat treated. Where this method of testing is employed, the datum points of the test specimen, as described in 6.2, shall be removed ¼ *T* from the nearest quenched surface and ⅔ *T* from the quenched end surface or nearest adjacent surface.

6.2.4 *Method 4*—Test specimens shall be taken from a representative separate test forging made from the same heat of steel, which shall receive substantially the same reduction and type of hot working, and have a cross section not less than the production forgings which it represents. It shall be heat treated in the same furnace charge and under the same conditions as the production forgings. The test specimen shall be removed using the Method 3 procedure.

6.3 *Thermal Buffers:*

6.3.1 Thermal buffer rings, at least *T* by *T* in cross section or sections of such a ring at least 3 *T* in length, shall be welded to the test end(s) of a forging prior to heat treatment for mechanical properties. The buffer material may be any weldable carbon or low-alloy steel and shall be joined to the forging with a partial penetration-type weld which completely seals the buffered surface. The test coupons shall be removed from the forging in the region buffered by the ring or ring segments. If the latter are used, the test coupons shall be removed from the forging in the area under the center ⅓ of the buffer ring segment length. In either case, the test specimens shall be located at a minimum distance of ½ in. [13 mm] from the buffered surface of the forging and at least ¼ *T* from a quenched surface of the forging. Buffered weld areas must be at least 1 in. [25 mm] from any finished machining surface of the complete forging.

6.3.2 Bearing in mind the characteristics of the base materials included in this specification, precautions should be taken, such as the use of pre- and post-weld heating and austenitic weld metal, to minimize the occurrence of crack-like defects.

6.3.3 Approval of the purchaser should be obtained for the use of this method.

6.4 Samples shall be removed from the forgings after quenching and tempering.

TABLE 1 Chemical Requirements

	Composition, %		
	Grade 1	Grade 2	Grade 3
Carbon, max	0.35	0.40	0.40
Manganese, max	0.90	0.90	0.90
Phosphorus, max	0.015	0.015	0.015
Sulfur, max	0.015	0.015	0.015
Silicon, max	0.35	0.35	0.35
Nickel	1.5 to 2.25	2.3 to 3.3	3.3 to 4.5
Chromium	0.80 to 2.00	0.80 to 2.00	0.80 to 2.00
Molybdenum	0.20 to 0.40	0.30 to 0.50	0.40 to 0.80
Vanadium, max	0.20	0.20	0.20

TABLE 2 Tensile Requirements

	Class 1	Class 2	Class 2a	Class 3[A]	Class 4[B]	Class 5[C]
Tensile strength, min, ksi [MPa]	115 [795]	135 [930]	145 [1000]	155 [1070]	175 [1205]	190 [1310]
Yield strength, 0.2 % offset, min, ksi [MPa]	100 [690]	120 [825]	130 [895]	140 [965]	160 [1105]	180 [1240]
Elongation in 2 in. or 50 mm, min, %	16	14	13.5	13	12	10
Reduction of area, min, %	50	45	43	40	35	30

[A] Typical maximum section size of 10 in. [255 mm] for open-ended vessels, or 7 in. [180 mm] for blind-ended vessels.
[B] Typical maximum section size of 6 in. [150 mm] for open-ended vessels, or 4 in. [100 mm] for blind-ended vessels.
[C] Typical maximum section size of 4 in. [100 mm].

TABLE 3 Charpy V-Notch Impact Requirements at 40°F [4.5°C] max[A]

	Class 1	Class 2	Class 2a[A]	Class 3[B]	Class 4[C]	Class 5[D]
Minimum average value of set of three specimens, ft·lbf[E] [J]	35 [47]	30 [41]	28 [38]	25 [34]	20 [27]	12 [16]
Minimum value of one specimen, ft·lbf [J]	30 [41]	25 [34]	23 [31]	20 [27]	15 [20]	10 [14]

[A]Or such other lower temperature as is specified when supplementary requirement S3 is involved.
[B]Typical maximum section size of 10 in. [255 mm] for open-ended vessels, or 7 in. [180 mm] for blind-ended vessels.
[C]Typical maximum section size of 6 in. [150 mm] for open-ended vessels, or 4 in. [100 mm] for blind-ended vessels.
[D]Typical maximum section size of 4 in. [100 mm].
[E]Not more than one specimen from a set may be below this value.

6.5 *Orientation*—For upset disk forgings, the longitudinal axis of all test specimens shall be oriented in the tangential or radial direction. For all other forgings, the longitudinal axis of the specimens shall be oriented in the direction of maximum working of the forging, or as agreed between manufacturer and purchaser.

6.6 *Number of Tests:*

6.6.1 For forgings weighing 1000 lb [455 kg] or less, as heat treated but not exceeding 80 in. [2030 mm] in length, excluding test material, one tension test and one set of impact tests (three specimens) shall be taken to represent each heat in each heat-treatment charge. This testing shall be repeated at the opposite end of the same test forging, if the heat-treated length excluding test material exceeds 80 in. [2030 mm]. When heat treatment is performed in continuous-type furnaces with suitable temperature control and equipped with recording pyrometers so that complete heat-treatment records are available, a heat-treatment charge shall be considered as any continuous run not exceeding 8 h in duration.

6.6.2 Forgings weighing over 1000 lb [455 kg] but not over 5000 lb [2270 kg] as heat treated and not over 80 in. [2030 mm] in length excluding test material, one tension test and one set of three impact tests shall be removed from each forging. When the length of the forging exceeds 80 in. [2030 mm] this testing shall be repeated at the opposite end of the forging.

6.6.3 Forgings exceeding 5000 lb [2270 kg] and not over 80 in. [2030 mm] in length, excluding test material, shall have one tension test and one set of three impact tests removed from each of two locations, 180° apart. For forgings with lengths exceeding 80 in. [2030 mm] this testing shall be repeated at the opposite end of the forging. Supplementary Requirement S6 is applicable for forgings intended for use under the rules of Section VIII, Division 3 of the ASME Boiler and Pressure Vessel Code.

7. Nondestructive Examination Requirements

7.1 *Ultrasonic Examination:*

7.1.1 Forgings shall be ultrasonically examined in accordance with the procedures of Practice A388/A388M.

7.1.1.1 *Straight-Beam Examination:* (*a*)Unless otherwise specified, the back-reflection method of tuning shall be used in accordance with Practice A388/A388M.

(*b*) In addition to the reportable conditions of Practice A388/A388M, indications exceeding the resultant back-reflection shall be recorded.

(*c*) A forging shall be unacceptable when one or more reflections are present producing indications accompanied by a complete loss of back-reflection, not attributable to nor associated with the geometric configuration. For this purpose, a back-reflection of less than 5 % of full screen height shall be considered complete loss of back-reflection.

7.1.1.2 *Angle-Beam Examination:* (*a*) Calibration notches shall be cut into the inside diameter and outside diameter surfaces in accordance with Practice A388/A388M.

(*b*) A forging that contains a discontinuity which results in an indication exceeding the amplitude of the reference line is subject to rejection.

(*c*) The report of the ultrasonic test shall be in compliance with Practice A388/A388M.

(*d*) Additional nondestructive examination or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious defects that will not be removed in final machining.

7.2 *Magnetic Particle Examination:*

7.2.1 Each forging shall be examined by magnetic particle methods described in Practice A275/A275M. Acceptance and rejection standards shall be as follows: Only indications with major dimensions greater than 1⁄16 in. [1.6 mm] shall be considered relevant. The following relevant indications are unacceptable:

7.2.1.1 Any linear indications greater than 1⁄16 in. [1.6 mm] long for materials less than 5⁄8 in. [16 mm] thick; greater than 1⁄8 in. [3.2 mm] long for materials from 5⁄8 in. to under 2 in. [50 mm] thick; and 3⁄16 in. [4.8 mm] long for materials 2 in. [50 mm] thick and greater. A linear indication is defined as one whose length is three times its width.

7.2.1.2 Rounded indications with dimensions greater than 1⁄8 in. [3.2 mm] for thicknesses less than 5⁄8 in. [16 mm], and greater than 3⁄16 in. [4.8 mm] for thicknesses 5⁄8 in. [16 mm] and greater.

7.2.1.3 Four or more relevant indications in a line separated by 1⁄16 in. [1.6 mm] or less, edge to edge.

7.2.1.4 Ten or more relevant indications in any 6 in.^{2} [3870 mm^2] of surface with the major dimension of this area not to exceed 6 in. [150 mm] when it is taken in the most unfavorable orientation relative to the indications being evaluated.

8. Rework and Retreatment

8.1 Repair welding shall not be permitted. For retreatment, see 7.2.1.

9. Certification and Reports

9.1 In addition to the certification requirements of Specification A788/A788M, the manufacturer shall include the following in the certification data:

9.1.1 Results of the product analysis,

9.1.2 Method used to locate mechanical test specimens (see Section 6), and

9.1.3 Sketches or drawings as necessary to supplement the nondestructive examination report.

10. Packaging and Package Marking

10.1 Marking shall be in accordance with Specification A788/A788M but stamping shall be permitted only in areas designated by the purchaser. If no such suitable area is available, a separate nameplate, with the required stamping, shall be permanently affixed to the vessel in a manner that will not be injurious to the vessel.

11. Keywords

11.1 alloy steel forgings; high pressure vessels; high strength; impact tested; isostatic presses; nonweldable; quenched and tempered; vacuum-treated steel

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Charpy V-Notch Impact Transition Curve

S1.1 Sufficient impact tests shall be made from the forging test material to establish a temperature-absorbed energy curve. The test temperature range shall be wide enough to establish the upper and lower shelf foot·pound-force energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S1.2 Instead of plotting an impact transition curve, impact requirements may be specified as 50 % fibrous fracture at a specified maximum temperature.

S2. Additional Charpy Data

S2.1 The percent shear fracture and mils of lateral expansion, defined in Test Methods and Definitions A370, shall be reported for each Charpy specimen tested.

S3. Charpy Impact Tests

S3.1 Charpy impact tests shall be made in accordance with the provisions of Section 6 of this specification, except that the tests shall be at a specified temperature lower than 40°F [4.5°C]. These tests shall be instead of those specified in Section 6, and shall meet the requirements of Table 3.

S4. Impact Testing

S4.1 For Class 2a forgings, impact tests shall be made in accordance with the provisions of Section 6 of this specification except that the acceptance criteria shall be a minimum of 45 ft·lbf [61 J] and 25 mils [0.635 mm] lateral expansion at a test temperature specified by the purchaser.

S5. Mechanical Test Location Discard

S5.1 Instead of the discard of 1⁄4 *T* x 2⁄3 *T* required by 6.2.3, a minimum discard of 1⁄4 *T* x *T* shall be employed for Method 3.

S6. Alternate Mechanical Testing

S6.1 Forgings exeeding 5000 lb [2270kg] at the time of heat treatment, and not over 80 in. [2030 mm] in length, excluding test material, require one set of test specimens to be taken from each end of the forging. Each test specimen set shall consist of one tension test and three Charpy V-notch specimens. The test specimen set locations shall be spaced 180º apart, end to end. When the forging length exceeds 80 in. [2030 mm] excluding test material two sets of mechanical test specimens shall be removed from each end of the forging, and spaced 180º apart at the same end, and rotated 90º end to end.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON-MANGANESE-SILICON STEEL, QUENCHED AND TEMPERED, FOR WELDED PRESSURE VESSELS

SA-724/SA-724M

(Identical with ASTM Specification A724/A724M-09(2018).)

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON-MANGANESE-SILICON STEEL, QUENCHED AND TEMPERED, FOR WELDED PRESSURE VESSELS

SA-724/SA-724M

[Identical with ASTM Specification A724/A724M-09(2018).]

1. Scope

1.1 This specification covers three grades of carbon-manganese-silicon steel, designated Grades A, B, and C. Grade C may be produced with a boron addition. The plates are quenched and tempered and are intended for welded-layered pressure vessels.

1.2 The maximum thickness of plates supplied under this specification is limited only by the capability of the chemical composition to meet the specified mechanical requirements. However, current practice normally limits the maximum thickness to $\frac{7}{8}$ in. [22 mm] for Grades A and B, and to 2 in. [50 mm] for Grade C.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions and weight, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Process* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be quenched from a temperature in the range from 1600 to 1700°F [870 to 925°C]. Grades A and B shall then be tempered at not less than 1100°F [595°C], and Grade C shall then be tempered at not less than 1150°F [620°C]. The tempering soaking time shall be not less than $\frac{1}{2}$ h.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Mechanical Properties

7.1 *Tension Test Requirements:*

7.1.1 The material as represented by the tension test specimens shall conform to the requirements given in Table 2.

7.1.2 For nominal plate thicknesses of $\frac{3}{4}$ in. [20 mm] and under, the $1\frac{1}{2}$ in. [40 mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and shows the greatest elongation.

8. Keywords

8.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessels

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max:			
Heat analysis	0.18	0.20	0.22
Product analysis	0.22	0.24	0.26
Manganese:			
Heat analysis	1.00–1.60	1.00–1.60	1.10–1.60
Product analysis	0.92–1.72	0.92–1.72	1.02–1.72
Phosphorus, max[A]	0.025	0.025	0.025
Sulfur, max[A]	0.025	0.025	0.025
Silicon, max:			
Heat analysis	0.55	0.50	0.20–0.60
Product analysis	0.60	0.55	0.18–0.65
Copper, max:[B]			
Heat analysis	0.35	0.35	0.35
Product analysis	0.38	0.38	0.38
Nickel, max:[B]			
Heat analysis	0.25	0.25	0.25
Product analysis	0.28	0.28	0.28
Chromium, max:[B]			
Heat analysis	0.25	0.25	0.25
Product analysis	0.29	0.29	0.29
Molybdenum, max:[B]			
Heat analysis	0.08	0.08	0.08
Product analysis	0.09	0.09	0.09
Vanadium, max:[B]			
Heat analysis	0.08	0.08	0.08
Product analysis	0.09	0.09	0.09
Boron, max	. . .	. . .	0.005[C]

[A] Applies to both heat and product analyses.
[B] When analysis shows that the amount of an element is 0.02% or lower, the value may be reported as <0.02%.
[C] If boron is less than 0.001 %, the analysis report for the element may be stated as "<0.001."

NOTE 1 — Where ". . ." appears in this table, there is no requirement.

TABLE 2
TENSILE REQUIREMENTS

	Grades A and C, ksi [MPa]	Grade B, ksi [MPa]
Tensile strength	90–110 [620–760]	95–115 [655–795]
Yield strength, min	70 [485]	75 [515]
Elongation in 2 in. [50 mm], min, %[A,B]	19	17

[A] See Specification A 20/A 20M for elongation requirement adjustment.
[B] See 7.1.2.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Several of those that are considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination,

S9. Magnetic Particle Examination

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SPECIFICATION FOR CARBON STEEL FORGINGS FOR PIPING COMPONENTS WITH INHERENT NOTCH TOUGHNESS

SA-727/SA-727M

(23)

(Identical with ASTM Specification A727/A727M-14(2019).)

Specification for Carbon Steel Forgings for Piping Components with Inherent Notch Toughness

1. Scope

1.1 This specification covers forged carbon steel piping components intended primarily for service in pressure piping systems from −20 to +650 °F [−30 to +345 °C] where inherent notch toughness is desired, but where notch toughness testing is not required. Included are forged or ring-rolled flanges, forged fittings, and valves made to specified dimensions, or to dimensional standards such as the ASME and API specifications referenced in Section 2.

1.2 This specification is limited to forgings with maximum finished section thicknesses no larger than 2 in. [51 mm].

1.3 It shall be the responsibility of the purchaser to determine whether material meeting the requirements of this specification is satisfactory for the service application.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified by the purchaser in the order.

NOTE 1—There are no provisions for impact testing in this specification. When impact testing is required, refer to Specification A350/A350M.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A961/A961M, the following list of standards apply to this specification.

2.2 *ASTM Standards:*

A350/A350M Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components

A788/A788M Specification for Steel Forgings, General Requirements

A961/A961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

E59 Practice for Sampling Steel and Iron for Determination of Chemical Composition (Withdrawn 1996)

2.3 *ASME Boiler and Pressure Vessel Codes:*

Section II, Material Specifications, Part C

SFA 5.5 Low-Alloy Steel Covered Arc-Welding Electrodes

B 16.5 Steel Pipe Flanges and Flanged Fittings

B 16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves

B 16.11 Forged Steel Fittings, Socket-Welding and Threaded

B 16.30 Unfired Pressure Vessel Flange Dimensions

2.4 *API Standards:*

600 Steel Gate Valves with Flanged or Butt-Welding Ends

602 Compact Design Carbon Steel Gate Valves for Refinery Use

605 Large Diameter Carbon Steel Flanges

2.5 *MSS Standard:*

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

3. General Requirements and Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A961/A961M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A961/A961M constitutes nonconformance with this specification. In case of a conflict between the requirements of this specification and Specification A961/A961M, this specification shall prevail.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.2.1 Additional requirements (see 16.1).

4. Materials and Manufacture

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace, and shall be fully killed, fine-grain practice.

4.2 Forgings shall be manufactured from ingots, blooms, billets, slabs, or bars. These items shall be forged, rolled, or strandcast.

4.3 A sufficient discard shall be made from the ingot to secure freedom from injurious piping and undue segregation.

4.4 The finished product shall be a forging as defined by the Terminology section of Specification A788/A788M.

5. Heat Treatment

5.1 Following plastic working, the forging manufacturer shall heat treat the forgings by normalizing, or normalizing and tempering, or quenching and tempering.

5.1.1 *Normalizing*—The procedure for normalizing shall consist of uniformly heating the forgings to a temperature between 1550 and 1700 °F [845 and 925 °C], holding a sufficient time to attain uniform temperature throughout, and cooling in still air. The forging shall be at a temperature below 1000 °F [540 °C] before heating for normalizing.

5.1.2 *Quenching*—The procedure for quenching shall consist of uniformly heating the forging to a temperature between 1550 and 1700 °F [845 and 925 °C], holding a sufficient time to attain uniform temperature throughout, and quenching into a suitable liquid medium. The forging shall be at a temperature below 1000 °F [540 °C] before heating for quenching.

5.1.3 *Tempering*—The procedure for tempering shall consist of reheating the forging subsequent to normalizing or quenching to a temperature of at least 1100 °F [595 °C], but not above the lower transformation temperature, for 30 min/in. [30 min/25 mm] of maximum section thickness, with minimum holding time at tempering temperature not less than 30 min.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 Steels to which lead has been added shall not be used.

7. Mechanical Requirements

7.1 *Tension Tests:*

7.1.1 *Requirements*—The material shall conform to requirements for tensile properties prescribed in Table 2.

7.1.1.1 The test specimen shall be obtained from a rough or finished production forging, or prolongation thereof, or it may be obtained from separately forged test blanks from the same heat of steel as the production forging. The test blank shall be reduced by forging in a manner similar to that for the products represented, shall receive approximately the same hot working and reduction, be of the same nominal thickness, and receive the same heat treatment as the finished products represented. The test material shall be treated in the same furnace at the same time as the forging it represents, subject to the requirements of 7.1.2.1.

TABLE 1 Chemical Requirements

Elements	Composition, %
Carbon	
Heat Analysis	0.25 max
Product Analysis	0.28 max
Manganese	
Heat Analysis	0.90 to 1.35
Product Analysis	0.84 to 1.41
Phosphorus	
Heat Analysis	0.035 max
Product Analysis	0.043 max
Sulfur	
Heat Analysis	0.025 max
Product Analysis	0.033 max
Silicon	
Heat Analysis	0.15 to 0.30
Product Analysis	0.13 to 0.32
Nickel	
Heat Analysis	0.40[A]
Product Analysis	0.43
Chromium	
Heat Analysis	0.30[A,B]
Product Analysis	0.34
Molybdenum	
Heat Analysis	0.12[A,B]
Product Analysis	0.13
Copper	
Heat Analysis	0.40[A]
Product Analysis	0.43
Niobium (Nb)[C]	
Heat Analysis	0.02
Product Analysis	0.03
Vanadium	
Heat Analysis	0.05
Product Analysis	0.055

[A] The sum of copper, nickel, chromium and molybdenum shall not exceed 1.00 % on heat analysis.

[B] The sum of chromium and molybdenum shall not exceed 0.32 % on heat analysis.

[C] Niobium and columbium are interchangeable names for the same element and both names are acceptable for use in A01.22 specifications.

TABLE 2 Tensile Requirements

Tensile strength, ksi [MPa]	60.0 to 85.0 [415 to 585]
Yield strength, min, ksi [MPa][A]	36.0 [250]
Elongation in 2 in. or 50 mm, min, %	22
Reduction of area, min, %	30

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

7.1.2 *Number of Tests*—One tension test at room temperature shall be made for each nominal wall thickness ± ¼ in. [± 6 mm] from each heat in each heat treatment charge.

7.1.2.1 If heat treatment is performed in either a continuous or a batch-type furnace controlled within ± 25 °F [± 14 °C] of the required heat-treatment temperature, and equipped with recording pyrometers so that complete records of heat treatment are available and if the same heat treating cycles are used on the forgings represented by the tension test, then one tension test per nominal wall thickness ± ¼ in. [± 6 mm] from each heat shall be required, instead of one tension test per nominal wall thickness from each heat in each heat-treatment charge.

7.1.3 *Test Locations and Orientations*—The test specimen shall be removed from the midwall of the heaviest section of the forging or test blank.

7.1.3.1 The test specimen shall have its longitudinal axis located parallel to the direction of major working of the forging or test blank, except for flanges and rings the test specimen shall be in the tangential direction.

7.1.4 *Test Method*—Testing shall be performed as specified in Specification A961/A961M using the largest feasible of the round specimens.

7.2 *Hardness Test:*

7.2.1 *Requirements*—If the production forgings are liquid-quenched and tempered, hardness of the forgings shall not exceed 187 HBW after heat treatment. The purchaser may verify that the requirement has been met by testing at any location on the forgings provided such testing does not render the forgings useless.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made from samples taken preferably during the pouring of the heat. The results shall conform to Table 1.

9. Product Analysis

9.1 A product analysis may be made by the purchaser on samples taken in accordance with Practice E59. The results shall conform to Table 1.

10. Hydrostatic Test

10.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished forging. Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S8 in Specification A961/A961M is specified.

11. Rework and Retreatment

11.1 If the results of mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings represented, and shall retest to the applicable requirements.

11.2 Individually tested forgings meeting all requirements shall be acceptable.

12. Surface Finish, Appearance, and Corrosion Protection

12.1 The requirements of Specification A961/A961M apply to forgings and finished parts.

13. Repair by Welding

13.1 Repair of defects by welding shall be permitted at the discretion of the forging manufacturer.

13.2 Repair by welding shall be made using welding procedures and welders qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. When forgings are heat treated after repair welding, the qualification test plates shall be subjected to the same heat treatment. The mechanical properties of the qualification test plates shall conform to Section 7.

13.3 Only electrode classifications with the -A1 designator shall be used (for example, E71T1-A1). SMAW, GMAW, FCAW or GTAW may be used. The GMAW process is limited to either the spray transfer or pulsed arc process. The FCAW process is limited to repair of carbon or carbon-molybdenum base materials only. Electrodes shall conform to the applicable AWS A5 electrode specification.

13.4 Forgings repair welded in the normalized, normalized and tempered, or the quenched and tempered conditions shall be stress-relieved after repair welding at 1100 °F [595 °C] minimum, but not higher than the temperature previously used for tempering the base metal of the same forging, or shall be reheat treated in accordance with Section 5.

14. Inspection

14.1 All tests and inspections shall be made at the place of manufacture, unless otherwise agreed, except for product analysis (see 9.1).

15. Rejection and Rehearing

15.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

16. Certification

16.1 In addition to the certification requirements of Specification A961/A961M, test reports shall be furnished to the purchaser or his representative. Test reports shall provide the following where applicable:

16.1.1 Type heat treatment, Section 5,

16.1.2 Chemical analysis results, Section 6, (Table 1), reported results shall be to the same number of significant figures as the limits specified in Table 1 for that element, 16.1.3 Product analysis results, Section 9 (Table 1),

16.1.4 Tensile properties results, Section 7 (Table 2), report the yield strength and tensile strength in ksi [MPa], and elongation and reduction of area in percent,

16.1.5 Hardness results, 7.2, and

16.1.6 Any supplementary testing required by the purchase order.

17. Product Marking

17.1 In addition to marking requirements of Specification A961/A961M, the following additional marking requirements shall apply:

17.1.1 If the forgings have been quenched and tempered the letters "QT" shall be stamped on the forgings following the Specification designation.

17.1.2 Forgings repaired by welding shall be marked with the letter "W" following the specification designation.

17.2 *Bar Coding*—In addition to the requirements in 17.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 carbon equivalent; pipe fittings; steel; piping applications; pressure containing parts; steel flanges; steel forgings; carbon; steel valves; temperature service applications; low

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification.

S1. Carbon Equivalent

S1.1 The maximum carbon equivalent, based on heat analysis shall be 0.45 for forgings with a maximum section thickness of 2 in. or less, and 0.46 for forgings with a maximum section thickness of greater than 2 in.

S1.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S1.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

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SPECIFICATION FOR SEAMLESS, WELDED FERRITIC, AND MARTENSITIC STAINLESS STEEL PIPE

SA-731/SA-731M (23)

(Identical with ASTM Specification A731/A731M-91 .)
except for an editorial correction in Table 2

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SPECIFICATION FOR PRESSURE VESSEL PLATES, LOW-CARBON AGE-HARDENING NICKEL-COPPER-CHROMIUM-MOLYBDENUM-COLUMBIUM (NIOBIUM) ALLOY STEEL

SA-736/SA-736M

(Identical with ASTM Specification A736/A736M-17.)

Standard Specification for Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium (Niobium) Alloy Steel

1. Scope

1.1 This specification covers low-carbon age-hardening alloy steel plates for welded pressure vessels and piping components. The specification covers nickel-copper-chromium-molybdenum-columbium (niobium) steel.

1.2 Plates under this specification are available as follows:

1.2.1 Available in Grade A, Class 3 only.

1.2.1.1 Quenched and precipitation heat treated with a minimum specified tensile strength of 85 ksi for thinner plates and 75 and 70 ksi for thicker plates, with the minimum tensile strength dependent upon the plate thickness. The maximum thickness of Grade A, Class 3 plates is limited only by the capacity of the chemical composition and heat treatment to meet the specified mechanical property requirements.

1.3 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished in inch-pound units.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality, and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 The plates shall be quenched in a liquid medium from a temperature in the range from 1600 to 1700°F [870 to 930°C]

TABLE 1 Chemical Requirements

Element	Composition, % Grade A
Carbon, max	
Heat analysis	0.07
Product analysis	0.09
Manganese	
Heat analysis	0.40–0.70
Product analysis	0.35–0.78
Phosphorus, max[A]	0.025
Sulfur, max[A]	0.025
Silicon, max	
Heat analysis	0.40
Product analysis	0.45
Chromium	
Heat analysis	0.60–0.90
Product analysis	0.56–0.94
Nickel	
Heat analysis	0.70–1.00
Product analysis	0.67–1.03
Molybdenum	
Heat analysis	0.15–0.25
Product analysis	0.12–0.28
Copper	
Heat analysis	1.00–1.30
Product analysis	0.95–1.35
Columbium (Niobium),[B] min	
Heat analysis	0.02
Product analysis	0.01

[A] Applies to both heat analysis and product analysis.
[B] Columbium and niobium are interchangeable names for the same element and both names are acceptable in A01 specifications.

TABLE 2 Tensile Requirements

	Grade A Class 3, ksi [MPa]
Yield strength, min	
¾ in. and under	75
[20 mm and under]	[515]
Over ¾ to 1 in., incl	75
[Over 20 to 25 mm, incl]	[515]
Over 1 to 2 in., incl	75
[Over 25 to 50 mm, incl]	[515]
Over 2 to 4 in., incl	65
[Over 50 to 100 mm, incl]	[450]
Over 4 in.	60
[Over 100 mm]	[415]
Tensile strength	
¾ in. and under	85–105
[20 mm and under]	[585–725]
Over ¾ to 1 in., incl	85–105
[Over 20 to 25 mm, incl]	[585–725]
Over 1 to 2 in., incl	85–105
[Over 25 to 50 mm, incl]	[585–725]
Over 2 to 4 in., incl	75–95
[Over 50 to 100 mm, incl]	[515–655]
Over 4 in.	70–90
[Over 100 mm]	[485–620]
Elongation	
2 in. [50 mm], min, %[A]	20

[A] See Specification A20/A20M for elongation adjustment.

and then precipitation heat treated at a temperature in the range from 1000 to 1300°F [540 to 705°C] for a time to be determined by the manufacturer or processor.

5.2 If the purchaser elects to perform the thermal treatment, the plates shall be accepted on the basis of mill tests made from test coupons heat treated as specified in the purchase order. If the test coupon heat treatment requirements are not specified in the purchase order, the manufacturer or processor shall heat treat the test coupons under conditions it considers appropriate. The manufacturer or processor shall inform the purchaser of the procedure followed in thermally treating the test coupons at the mill.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition given in Table 1.

7. Mechanical Properties

7.1 *Tension Test:*

7.1.1 The plates, as represented by the test specimens, shall conform to the requirements given in Table 2.

7.1.2 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½-in. [40-mm] wide rectangular test specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and shows the greatest elongation.

7.2 *Notch-Toughness Test:*

7.2.1 Charpy V-notch impact tests shall be made in accordance with Specification A20/A20M.

7.2.2 The test results of 10 by 10-mm specimens shall meet an average minimum value of 20 ft·lbf [27 J] at –50°F [–45°C].

8. Keywords

8.1 alloy steel; alloy steel plate; pressure vessel plate; low carbon; age hardening; pressure vessels; piping components; precipitation heat treated; nickel-copper-chromium-molybdenum-columbium (niobium)

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post Weld Heat Treatment of Mechanical Test Coupons,

S4. Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop-Weight Test (for Material 0.625 in. [16 mm] and Over in Thickness),

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S10. Charpy V-Notch Test Curve,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M,

S13. NDT Temperature Determination,

S15. Reduction of Area Measurement,

S17. Vacuum Carbon-Deoxidized Steel,

S19. Restricted Chemical Requirements,

S24. Strain Age Test, and

S25. Weldability.

SPECIFICATION FOR PRESSURE VESSEL PLATES, HIGH-STRENGTH LOW-ALLOY STEEL

SA-737/SA-737M

(Identical with ASTM Specification A737/A737M-17.)

Standard Specification for Pressure Vessel Plates, High-Strength, Low-Alloy Steel

1. Scope

1.1 This specification covers high-strength low-alloy steel plates for service in welded pressure vessels and piping components.

1.2 This material is particularly intended for piping and pressure vessel applications where high strength and improved toughness are required.

1.3 Two grades, designated B and C, are covered by this specification. Grade B provides a minimum yield strength of 50 ksi [345 MPa]. Grade C provides a minimum yield strength of 60 ksi [415 MPa].

1.4 The maximum thickness of plates is limited only by the capacity of the chemical composition and heat treatment to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness to 4 in. [100 mm] for each grade.

1.5 Grade C in the as-rolled condition is sensitive to cracking during flame cutting, transit, and handling, particularly in thicknesses over 2 in. [50 mm]. Plates should not be shipped in the as-rolled condition only except by mutual agreement between the manufacturer and the purchaser.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this specification shall conform to the requirements of Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions and mass, quality, repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 The material shall be normalized by heating to a suitable temperature which produces an austenitic structure, but not exceeding 1700°F [925°C], holding a sufficient time to attain uniform heat throughout the material, and cooling in air.

TABLE 1 Chemical Requirements

NOTE 1—Where "…" appears in this table, there is no requirement.

Element	Composition, %			
	Grade B		Grade C	
	Heat	Product	Heat	Product
Carbon, max	0.20	0.22	0.22	0.24
Manganese	1.15–1.50[A]	1.07–1.62[A]	1.15–1.50	1.07–1.62
Phosphorus, max	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025
Silicon	0.15–0.50	0.10–0.55	0.15–0.50	0.10–0.55
Vanadium	. . .	. . .	0.04–0.11	0.03–0.12
Columbium (Niobium),[B] max	0.05	0.05	0.05	0.05
Nitrogen, max	. . .	. . .	0.03	0.03

[A] The maximum manganese may be increased to 1.60 % on heat analysis and 1.72 % on product analysis, provided that the carbon content on heat analysis does not exceed 0.18 %.
[B] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.

TABLE 2 Tensile Requirements

	Grade B	Grade C
Yield strength, min, ksi [MPa]	50 [345]	60 [415]
Tensile strength, ksi [MPa]	70–90 [485–620]	80–100 [550–690]
Elongation in 8 in. [200 mm], min, %[A]	18	18
Elongation in 2 in. [50 mm], min, %[A]	23	23

[A] See Specification A20/A20M for elongation adjustment.

5.2 If approved by the purchaser, cooling rates faster than air cooling are permitted for improvement of strength or toughness, provided the plates are subsequently tempered in the temperature range from 1100 to 1300°F [595 to 705°C].

5.3 When the fabricator elects to perform the heat treatment in 5.1 and 5.2, the manufacturer shall normalize plates conforming to Grade C within the range from 1650 to 1850oF [900 to 1010oC] prior to shipment for plates exceeding 2 in. [50 mm] in thickness unless otherwise agreed to.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Requirements

7.1 *Tension Tests*—The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

7.1.1 For nominal plate thicknesses of ¾ in. [20 mm] and under, when requirements for elongation in 2 in. [50 mm] are to be determined, the 1½-in. [40-mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Tests,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and

S17. Vacuum Carbon-Deoxidized Steel.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, HEAT-TREATED, CARBON-MANGANESE-SILICON STEEL, FOR MODERATE AND LOWER TEMPERATURE SERVICE

SA-738/SA-738M

(23)

(Identical with ASTM Specification A738/A738M-19.)

Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service

1. Scope

1.1 This specification covers heat-treated carbon-manganese-silicon steel plates intended for use in welded pressure vessels at moderate and lower temperature service.

1.2 Material under this specification is available in four strength levels, 75 ksi [515 MPa], 85 ksi [585 MPa], 80 ksi [550 MPa], and 90 ksi [620 MPa] minimum ultimate tensile strengths.

1.3 The maximum thickness of plates for Grades A, B, and C is limited only by the capacity of the chemical composition and heat treatment to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification to 6 in. [150 mm] for Grade A, 4 in. [100 mm] for Grade B, and 6 in. [150 mm] for Grade C. The maximum permitted nominal thickness is 1.5 in. [40 mm] for Grade D and 2 in. [50 mm] for Grade E.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 Grade A plates 2.5 in. [65 mm] and under in thickness shall be supplied in the normalized condition or in the quenched and tempered condition at the option of the manufacturer.

5.2 Grade A plates over 2.5 in. [65 mm] in thickness and Grade B, Grade C, Grade D, and Grade E plates in all thicknesses shall be quenched-and-tempered.

TABLE 1 Chemical Requirements

NOTE 1—Where "..." appears there is no requirement.

Element	Composition, %				
	Grade A	Grade B	Grade C	Grade D	Grade E
Carbon, max[A]	0.24	0.20	0.20	0.10	0.12[B]
Manganese:					
Heat analysis					
1.5 in. [40 mm] and under	1.50 max	0.90–1.50	1.50 max	1.00–1.60	1.10–1.60[B]
Over 1.5 to 2.0 in. [40 to 50 mm]	1.50 max	0.90–1.50	1.50 max	[C]	1.10–1.60[B]
Over 2.0 to 2.5 in. [50 to 65 mm], incl	1.50 max	0.90–1.50	1.50 max	[C]	[C]
Over 2.5 in. [65 mm]	1.60 max	0.90–1.60	1.60 max	[C]	[C]
Product analysis					
1.5 in. [40 mm] and under	1.62 max	0.84–1.62	1.62 max	0.92–1.72	1.02–1.72[B]
Over 1.5 to 2.0 in. [40 to 50 mm], incl	1.62 max	0.84–1.62	1.62 max	[C]	1.02–1.72[B]
Over 2.0 to 2.5 in. [50 to 65 mm], incl	1.62 max	0.84–1.62	1.62 max	[C]	[C]
Over 2.5 in. [65 mm]	1.72 max	0.84–1.72	1.72 max	[C]	[C]
Phosphorus, max[A]	0.025	0.025	0.025	0.015	0.015
Sulfur, max[A]	0.025	0.025	0.025	0.006	0.006
Silicon:					
Heat analysis	0.15–0.50	0.15–0.55	0.15–0.50	0.15–0.50	0.15–0.50
Product analysis	0.13–0.55	0.13–0.60	0.13–0.55	0.13–0.55	0.13–0.55
Copper, max:					
Heat analysis	0.35	0.35	0.35	0.35	0.35
Product analysis	0.38	0.38	0.38	0.38	0.38
Nickel, max:					
Heat analysis	0.50	0.60	0.50	0.60	0.70
Product analysis	0.53	0.63	0.53	0.63	0.73
Chromium, max:					
Heat analysis	0.25	0.30	0.25	0.25	0.30
Product analysis	0.29	0.34	0.29	0.29	0.34
Molybdenum, max:					
Heat analysis					
1.5 in. [40 mm] and under	0.08	0.20	0.08	0.30	0.35
Over 1.5 in. [40 mm]	0.08	0.30	0.08	[C]	[C]
Product analysis					
1.5 in. [40 mm] and under	0.09	0.21	0.09	0.33	0.38
Over 1.5 in. [40 mm]	0.09	0.33	0.09	[C]	[C]
Vanadium, max:					
Heat analysis	0.07[D]	0.07	0.05	0.08	0.09
Product analysis	0.08[D]	0.08	0.05	0.09	0.10
Columbium (niobium),[G] max:					
Heat analysis	0.04[D]	0.04	...	0.05	0.05
Product analysis	0.05[D]	0.05	...	0.06	0.06
Columbium (niobium)[G] plus vanadium, max:					
Heat analysis	0.08[D]	0.08	...	0.11	0.12
Product analysis	0.10[D]	0.10	...	0.12	0.13
Titanium, max[A]	...	...	...	[E]	[F]
Boron, max[A]	...	...	...	0.0007	0.0007
Aluminum, min[A]	...	...	...	0.020 total or 0.015 acid soluble[E]	0.020 total or 0.015 acid soluble[F]

[A] Applies to both heat and product analyses.
[B] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.85 % by heat analysis, and 1.99 % by product analysis.
[C] Not applicable because of maximum thickness.
[D] Vanadium and columbium (niobium)[G] may be added only by agreement between the manufacturer and the purchaser.
[E] By agreement between the manufacturer and the purchaser, the steel may be produced with titanium, in which case the minimum aluminum content shall not apply. If this option is exercised, the titanium content, by heat analysis, shall be 0.006 % to 0.03 %, and the titanium content for the heat and product analyses shall be reported on the test report.
[F] By agreement between the manufacturer and the purchaser, the steel may be produced with titanium, in which case the minimum aluminum content shall not apply. If this option is exercised, the titanium content, by heat analysis, shall be 0.006 % to 0.03 % inclusive and the titanium content for the heat and product analyses shall be reported on the test report.
[G] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.

TABLE 2 Tensile Requirements

NOTE 1—t = plate nominal thickness.

	Grade A	Grade B	Grade C	Grade D	Grade E
Tensile strength, ksi [MPa]					
1.5 in. [40 mm] and under	75–95 [515–655]	85–102 [585–705]	80–100 [550–690]	85–105 [585–724]	90–110 [620–760]
Over 1.5 to 2.0 in. [40 to 50 mm], incl	75–95 [515–655]	85–102 [585–705]	80–100 [550–690]	[A]	90–110 [620–760]
Over 2.0 to 2.5 in. [50 to 65 mm]	75–95 [515–655]	85–102 [585–705]	80–100 [550–690]	[A]	[A]
Over 2.5 to 4 in. [65 to 100 mm], incl	75–95 [515–655]	85–102 [585–705]	75–95 [515–655]	[A]	[A]
Over 4 in. [100 mm]	75–95 [515–655]	85–102 [585–705]	70–90 [485–620]	[A]	[A]
Yield strength, min, ksi [MPa]					
1.5 in. [40 mm] and under	45 [310]	60 [415]	60 [415]	70 [485]	75 [515]
Over 1.5 to 2.0 in. [40 to 50 mm], incl	45 [310]	60 [415]	60 [415]	[A]	75 [515]
Over 2.0 to 2.5 in. [50 to 65 mm], incl	45 [310]	60 [415]	60 [415]	[A]	[A]
Over 2.5 to 4 in. [65 to 100 mm], incl	45 [310]	60 [415]	55 [380]	[A]	[A]
Over 4 in. [100 mm]	45 [310]	60 [415]	46 [315]	[A]	[A]
Elongation in 2 in. [50 mm], min, %[B]					
1.5 in. [40 mm] and under	20	20	22	20	20
Over 1.5 to 4 in. [40 to 100 mm], incl	20	20	22	[A]	[A]
Over 4 in. [100 mm]	20	20	20	[A]	[A]

[A] Not applicable.
[B] See Specification A20/A20M for elongation requirement adjustments.

5.3 When plates are tempered, the minimum tempering temperature shall be 1100°F [595°C].

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S 17, Vacuum Carbon-Deoxidized Steel in Specification A20/A20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The plates as represented by the tension test specimens shall conform to the requirements of Table 2.

7.1.1 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1.5-in. [40-mm] wide rectangular specimen may be used for the tension test and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and shows the greatest elongation.

8. Keywords

8.1 pressure-containing parts; pressure vessel steel; steel plates; steel plates for pressure vessel applications

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between the supplier and the purchaser:

S1. Vacuum Treatment

S2. Product Analysis.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons.

S4. Additional Tension Test.

S5. Charpy V-Notch Impact Test.

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and Over in Thickness).

S9. Magnetic Particle Examination.

S12. Ultrasonic Examination in accordance with Specification A578/A578M.

S20. Maximum Carbon Equivalent for Weldability

APPENDIX

(Nonmandatory Information)

X1. CHARPY V-NOTCH IMPACT TEST

X1.1 The energy values below are shown only for information as to the guarantees that are generally available. Mandatory conformance to any of the values listed is a matter of agreement between the purchaser and the manufacturer.

X1.1.1 *Longitudinal*—20 ft·lbf [27 J] at −50°F [–45°C].

X1.1.2 *Transverse*—20 ft·lbf [27 J] at −20°F [–30°C].

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SPECIFICATION FOR STEEL BARS, ALLOY, HOT-WROUGHT, FOR ELEVATED TEMPERATURE OR PRESSURE-CONTAINING PARTS, OR BOTH

SA-739

(Identical with ASTM Specification A739-90a(2016).)

Standard Specification for
Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both

1. Scope

1.1 This specification covers hot-wrought, ferritic alloy steel bars for elevated temperature or pressure-containing parts suitable for fusion welding or both.

1.2 The bars are furnished in the following grades:

Grade B 11: 1.25 % chromium, 0.55 % molybdenum
Grade B 22: 2.25 % chromium, 1.00 % molybdenum

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A29/A29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

3. Ordering Information

3.1 Orders for material under this specification should include the following information:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Name of material (ferritic alloy steel bars),

3.1.3 Condition (hot wrought, normalized and tempered, machine straightened and descaled),

3.1.4 Dimensions (cross-sectional shape, size, and length),

3.1.5 ASTM designation and date of issue,

3.1.6 Grade (Table 1),

3.1.7 Additions to the specification, and

3.1.8 End use.

NOTE 1—A typical description is as follows: 10 000 lb, Ferritic Alloy Steel Bars, Hot Wrought Normalized and Tempered, and Descaled, 1.000-in. diameter by 10 ft, ASTM A739 dated____, Grade B11, Special Straightened, Special Machined Fittings.

4. Materials and Manufacture

4.1 *Melting Practice*—The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting using electroslag remelting or vacuum arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.2 *Condition*—Unless otherwise specified, bars shall be hot wrought, heat treated, and descaled.

4.3 *Heat Treatment:*

4.3.1 The bars shall be normalized and tempered.

4.3.2 Austenitizing temperature shall be within the range from 1700 to 1800°F (927 to 982°C).

4.3.3 Cooling from the austenitizing temperature may be accomplished by cooling in still air or moving air, at the producer's option. When permitted by the purchaser, cooling from the austenitizing temperature may be accelerated by spray or liquid quenching.

4.3.4 The minimum tempering temperature shall be 1200°F (649°C) for Grade B11 and 1250°F (677°C) for Grade B22.

5. Chemical Composition

5.1 The heat analysis shall conform to the limits for chemical composition specified in Table 1 for the grade ordered.

6. Mechanical Properties

6.1 *Tensile Requirements*—The bars as represented by the test specimens shall conform to the tensile requirements specified in Table 2.

6.2 *Specimens*—Tension test specimens shall be taken longitudinally and machined from the locations specified in Test Methods and Definitions A370.

TABLE 1 Chemical Requirements

Element	Composition, %	
	Grade B 11	Grade B 22
Carbon, max	0.05–0.20	0.05–0.15
Manganese	0.40–0.65	0.30–0.60
Phosphorus, max	0.035	0.035
Sulfur, max	0.040	0.040
Silicon	0.50–0.80	0.50 max
Chromium	1.00–1.50	2.00–2.50
Molybdenum	0.45–0.65	0.90–1.10

TABLE 2 Tensile Requirements

	Grade B 11	Grade B 22
Tensile strength, ksi (MPa)	70.0–95.0 (483–655)	75.0–95.0 (517–655)
Yield strength, min, ksi (MPa)	45.0 (310)	45.0 (310)
Elongation in 2 in. or 50 mm, min, %	18	18
Reduction of area, min, %	45	45

6.3 *Number of Tests:*

6.3.1 Two tension tests shall be made to represent bars of the same size from each heat in each heat treatment charge. For continuous heat-treated material, not fewer than two tension tests shall represent a lot selected on the basis of one tension test from each 10 000 lb (4500 kg).

6.3.2 When heat treated without interruption in continuous furnaces, the material in a lot shall be from the same heat, same prior condition, same size, and subjected to the same heat treatments.

6.4 *Test Methods*—Tension tests shall be made in accordance with Test Methods and Definitions A370. The yield strength shall be determined by the 0.2 % offset method.

7. Workmanship, Finish, and Appearance

7.1 *Workmanship*—The bars shall be free of pipe, cracks, and flakes. Within the limits of good manufacturing and inspection practices the bars shall be free of injurious seams, laps, segregation, or other imperfections which, due to their nature, degree or extent, will interfere with the use of the material in machining or fabrication.

7.2 *Descaling*—Unless otherwise specified, the bars shall be descaled.

8. General Requirements

8.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A29/A29M.

9. Certification and Test Reports

9.1 A manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the analysis and tension test results shall be furnished at the time of shipment. The report shall include the name of the manufacturer, ASTM designation number and year date and revision letter, if any, grade, heat number, and size.

10. Product Marking

10.1 The bars shall be marked in accordance with Specification A29/A29M except as modified or supplemented by 10.2 through 10.4 of this specification.

10.2 When specified by the purchaser, the heat number shall be permanently stamped on one end of each bar 2.50 in. and larger in nominal diameter (or equivalent cross-sectional area).

10.3 The bars shall neither be hot nor cold stamped on the sides unless approved by the purchaser on the purchase order.

10.4 Each lift, regardless of size, shall be tagged with the information required by Specification A29/A29M.

11. Keywords

11.1 alloy steel bars; high-temperature applications; hot-wrought steel bars; pressure-containing parts; steel bars; temperature service application—high

SPECIFICATION FOR STEEL CASTINGS, STAINLESS, PRECIPITATION HARDENING

SA-747/SA-747M

(Identical with ASTM Specification A747/A747M-04 except for the revision of the mandatory ordering requirements of para. 4.1.6 and the mandatory use of Supplementary Requirement S15 of SA-781/SA-781M.)

SPECIFICATION FOR STEEL CASTINGS, STAINLESS, PRECIPITATION HARDENING

SA-747/SA-747M

(Identical with ASTM Specification A 747/A 747M-04 except for the revision of the mandatory ordering requirements of para. 4.1.6 and the mandatory use of Supplementary Requirement S15 of SA-781/SA-781M.)

1. Scope

1.1 This specification covers iron-chromium-nickel-copper corrosion-resistant steel castings, capable of being strengthened by precipitation hardening heat treatment.

1.2 These castings may be used in services requiring corrosion resistance and high strengths at temperatures up to 600°F [315°C]. They may be machined in the solution-annealed condition and subsequently precipitation hardened to the desired high-strength mechanical properties specified in Table S14.1 with little danger of cracking or distortion.

1.3 The material is not intended for use in the solution-annealed condition.

NOTE 1 — If the service environment in which the material is to be used is considered conducive to stress-corrosion cracking, precipitation hardening should be performed at a temperature that will minimize the susceptibility of the material to this type of attack.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 732/A 732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use

E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys

E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys

2.2 *ASME Standard:*

ASME Boiler and Pressure Vessel Code, Supplementary Requirements S6, S14, and S27

3. General Conditions for Delivery

3.1 Material furnished to this specification shall be in accordance with the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 Orders for material to this specification should include the following:

4.1.1 Specification number and grade (Table 1),

4.1.2 Heat treatment condition (SA, H900, and so forth), Table 2,

4.1.3 Drawing or pattern,

4.1.4 Options in the specification, if any, in accordance with 5.2, 6.3, and Section 7, and

4.1.5 Supplementary requirements, if any, including the standards of acceptance.

4.1.6 Supplementary Requirements S6, S14, and S27 are mandatory, together with S15 from Specification

SA-781/SA-781M, and must be specified in the purchase order,

5. Materials and Manufacture

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

5.2 *Heat Treatment* — Castings may be given a homogenization heat treatment in accordance with 5.2.1 at the producer's option or when specified by the purchaser (see S26) prior to solution heat treatment. All castings, whether homogenized or not, shall be given a solution treatment in accordance with 5.2.2 and unless ordered in the solution-annealed condition shall be precipitation hardened to the ordered condition (Table 2).

5.2.1 Homogenization heat treatment shall consist of heating the castings and test material to a minimum of 1900°F [1040°], holding for a minimum of 1½ h, and cooling to below 90°F [30°C].

5.2.2 Solution annealing heat treatment shall consist of heating the castings and test material to 1925°F ± 50°F [1050°C ± 30°C], holding the 30 min/in. [1.2 min/mm] of section but not less than 30 min, and cooling to below 90°F [30°C].

5.2.3 Temperature used for precipitation hardening shall be maintained within the range of ± 25°F [± 15°C] of that listed in Table 2 for the heat-treatment condition ordered. (See Note 1).

5.2.4 When the order of contract specifies a minimum columbium content, the minimum precipitation hardening temperature shall be 925°F [495°C].

6. Chemical Composition

6.1 The steel shall be in accordance with the requirements as to chemical composition prescribed in Table 1.

6.2 When the H900 condition is ordered, the minimum columbium content (Table 1) shall not apply. It is recommended that columbium other than that in revert material not be added.

6.3 *Methods of Analysis* — Analytical procedures for nitrogen analysis are not included in Methods E 38 or Test Methods E 353, so if the contract or order specifies that the nitrogen content is to be reported, the method of analysis shall be agreed upon by purchaser and producer.

7. Repair by Welding

7.1 Repairs shall be made only in one of the following conditions: homogenized, solution annealed, H1100, H1150, H1150M, H1150DBL, or stress relieved at 1150°F ± 25°F [620°C ± 15°C] for a minimum of 4 h.

7.2 Castings welded in one of the aged conditions noted in 7.1 shall be post weld heat treated by the same aging treatment used prior to welding, or, where necessary to meet mechanical property requirements, shall be solution annealed and aged after welding. Castings welded in the stress-relieved condition shall receive the specification heat treatment after welding.

8. Keywords

8.1 precipitation hardening stainless steel; stainless steel; steel castings

TABLE 1
CHEMICAL REQUIREMENTS[A]

Grade UNS Type	CB7Cu-1 J92180 17-4	CB7Cu-2 J92110 15-5
Carbon	0.07	0.07
Manganese	0.70	0.70
Phosphorus	0.035	0.035
Sulfur	0.03	0.03
Silicon	1.00	1.00
Chromium	15.50–17.70	14.0–15.50
Nickel	3.60–4.60	4.50–5.50
Copper	2.50–3.20	2.50–3.20
Columbium	0.15–0.35[B]	0.15–0.35[B]
Nitrogen[C]	0.05	0.05

[A] Limits are percent maximum unless shown as a range or stated otherwise.
[B] See 6.2. When the H900 condition is ordered, the minimum columbium content shall not apply.
[C] To be determined and reported when specified by the order or contract.

TABLE 2
PRECIPITATION HARDENING HEAT TREATMENT[A,B]

Condition	PH[C] Temperature, °F [°C]	Time, h and min	Cooling Treatment
SA	Not precipitation hardened (see 5.2.3)		
H900	900 [480]	1.5	air cool
H925	925 [495]	1.5	air cool
H1025	1025 [550]	4.0	air cool
H1075	1075 [580]	4.0	air cool
H1100	1100 [595]	4.0	air cool
H1150	1150 [620]	4.0	air cool
H1150M	1400 [760]	2.0	air cool
	1150 [620]	4.0	air cool
H1150 DBL	1150 [620]	4.0	air cool
	1150 [620]	4.0	air cool

[A] The furnace and controls used shall be calibrated and capable of uniformity of heating in order to ensure consistent results.
[B] See Note 1.
[C] ±25°F [15°C].

SUPPLEMENTARY REQUIREMENTS

A list of standardized supplementary requirements for use at the option of the purchaser is described in Specification A 781/A 781M. Those that are considered suitable for use with this specification are listed below by title only. Additional supplementary requirements suitable for use with this specification at the option of the purchaser are described below. One or more of the supplementary requirements indicated below may be included in the purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirements details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Magnetic Particle Examination

NOTE — When CB7CU-1 alloy is inspected by magnetic particle method, false indications may be caused by ferrite stingers or traces of retained austenite in the microstructure. Liquid penetrant methods may be used to confirm the presence or absence of a discontinuity when such indications are noted.

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S5. Examination of Weld Preparation

S6. Certification

S13. Hardness Test

S13.1 Brinell hardness test shall be made from each heat-treatment load for each heat. The results shall be in accordance with the requirements in Table S14.1 and shall be reported to the purchaser or his representative.

S13.2 The test may be made on the end of the tension specimen unless the order requires it to be made on a casting, in which case, where possible, the test shall be made on a boss or extension located on the casting suitable for testing in the Brinell tester.

S13.3 The test shall be conducted in accordance with Test Methods and Definitions A 370.

S14. Tension Test

S14.1 Tensile properties shall be determined from material representing each heat. The bar from which the test specimen is taken shall be heat treated with production castings to the same procedure as the castings it represents, unless the castings are ordered in the solution-annealed condition (5.2.2). The results shall be in accordance with the requirements specified in Table S14.1 and shall be reported to the purchaser or his representative.

S14.2 When the contract or order specifies that the castings are to be furnished in the solution-annealed condition, the manufacturer shall test specimens representing the castings that have been given the precipitation heat treatment specified by the purchaser in accordance with Table 2.

S14.3 Test coupons and tests shall be made in accordance with Test Methods and Definitions A 370. Where possible, the standard 2 in. [50 mm] gage length specimens shall be used, unless the purchase order is for investment castings. Standard subsize specimens may be used when a 2 in. gage length specimen is not feasible. When subsize specimens are used, the gage length shall be four times the gage diameter. When investment castings are ordered, the specimens shall be prepared in accordance with S3.2 of Specification A 732/A 732M.

S14.4 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same lot. A retest shall be allowed if the percentage elongation of any tension test specimen is less than that specified in Table S14.1, or if any part of the fracture is more than $\frac{3}{4}$ in. [19 mm] from the center of a standard 2 in. [50 mm] gage length established by scribe scratches on the untested specimen.

S26. Homogenization Heat Treatment

S26.1 The homogenization heat treatment shall consist of heating the castings and test material to a minimum of 1900°F [1040°C], holding for a minimum of $1\frac{1}{2}$ h, and cooling to below 90°F [30°C].

S27. Product Marking

S27.1 The manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings except those of such small size as to make such marking impractical. To minimize small defects caused by dislodged particles of molding sand, the number of cast identification marks should be minimized. When further specified, the heat numbers shall be marked on individual castings.

S27.2 When the castings are too small to mark individually, a symbol traceable to the lot shall be placed on the castings and the required identification then placed on a tag affixed to the container in which these castings are shipped.

TABLE S14.1
MECHANICAL PROPERTIES

Alloy Type	PH Heat Treatment	Hardness, HB	Yield Strength 0.2% Offset, min, ksi [MPa]	Tensile Strength, ksi [MPa]	Elongation in 2 in. [51 mm], min, %[A]
CB7Cu-1	H900	375 min	145 [1000]	170 [1170]	5
	H925	375 min	150 [1035]	175 [1205]	5
	H1025	311 min	140 [965]	150 [1035]	9
	H1075	277 min	115 [795]	145 [1000]	9
	H1100	269 min	110 [760]	135 [930]	9
	H1150	269 min	97 [670]	125 [860]	10
	H1150M	310 max	...	...	
	H1150 DBL	310 max	...	...	...
CB7Cu-2	H900	375 min	145 [1000]	170 [1170]	5
	H925	375 min	150 [1035]	175 [1205]	5
	H1025	311 min	140 [965]	150 [1035]	9
	H1075	277 min	115 [795]	145 [1000]	9
	H1100	269 min	110 [760]	135 [930]	9
	H1150	269 min	97 [670]	125 [860]	10
	H1150M	310 max	...	...	...
	H1150 DBL	310 max	...	...	...

[A] If sub-size tension test bars are used, the gage length/gage diameter ratio must be 4 to 1 to assure elongation values comparable to those of the standard test specimen.

SPECIFICATION FOR STATICALLY CAST CHILLED WHITE IRON-GRAY IRON DUAL METAL ROLLS FOR PRESSURE VESSEL USE

SA-748/SA-748M

(Identical with ASTM Specification A748/A748M-87(2018).)

Standard Specification for
Statically Cast Chilled White Iron-Gray Iron Dual Metal Rolls for Pressure Vessel Use

1. Scope

1.1 This specification covers statically cast dual metal rolls with the outer layer of the roll body being chilled white iron of different chemical composition than the core and journals of the roll which is gray cast iron. The castings are suitable for pressure containing parts, the design strength of which is based on the gray iron portion of the cylinder. The castings are suitable for service at temperatures up to 450°F [232°C].

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The following safety hazards statement pertains only to the test method portion, 9, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A278/A278M Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (350°C)

A667/A667M Specification for Centrifugally Cast Dual Metal (Gray and White Cast Iron) Cylinders

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 ASTM designation and year of issue,

3.1.2 Dimensions of dual rolls,

3.1.3 Class of gray iron in the roll core (see 4.2),

3.1.4 Inspection requirements, if different (see 10.1),

3.1.5 Certification, if required (see 11.1), and

3.1.6 Special position of marking information, if required (see 12.1).

3.2 Any additional requirements not covered in this specification are subject to agreement between the manufacturer and purchaser.

4. Materials and Manufacture

4.1 The melting procedure shall be optional with the foundry.

4.2 The chilled white iron exterior of the roll body shall be made to a minimum hardness of 60 Scleroscope “C”. The gray iron portion of the roll shall conform to the applicable class of Specification A278/A278M, as determined by design requirements. The scope of this specification shall include Nos. 20, 25, 30, 35, 150, 175, 200, and 250 of Specification A278/A278M.

4.3 The casting process shall be controlled to produce a metallurgical bond between the chilled white iron exterior and gray iron interior of the roll body.

5. Test Requirements

5.1 *Tensile Requirements*—Tensile bars removed from a prolongation at one end of the roll journal, in accordance with Specification A278/A278M, shall have a tensile strength not less than 80 % of that specified by the applicable class of Specification A278/A278M.

5.2 *Thickness of Chilled White Iron:*

5.2.1 The thickness of the clear chilled white iron plus the mottled iron at the roll face shall not be more than 30 % of the total finished wall thickness.

5.2.2 The thickness of the chilled white iron exterior of the roll body shall be determined by measuring the chill depth at the ends of the roll face.

6. Finish

6.1 All surfaces shall be machined or ground, or both, prior to the rolls being placed into service.

7. Number of Tests

7.1 The number of tension tests shall be in accordance with Specification A278/A278M.

8. Specimen Preparation

8.1 Test bars representing the gray iron portion of the roll shall be made from a prolongation at one end of the roll journal in accordance with Specification A278/A278M. Tension test specimens machined from this prolongation shall conform to the dimensions shown for Specimen "C" in Specification A278/A278M.

9. Test Method

9.1 Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial. The use of self-aligning shackles is suggested. After reaching a stress equivalent to 15 000 psi [100 MPa], the speed of the moving head of the testing machine shall not exceed ⅛ in. [3.2 mm]/min.

10. Inspection

10.1 The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. Unless otherwise specified, all tests and inspections shall be made at the place of manufacture prior to the shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

11. Acceptance and Certification

11.1 Final acceptance of the casting shall follow complete machining of the casting. Upon request of the purchaser and when so specified in the purchase order, a certification shall be made on the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier, accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

12. Product Marking

12.1 Pressure-containing castings made in accordance with this specification shall have the name of the manufacturer or his recognized trademark and the class of iron to which it conforms, cast or indelibly stamped on the surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

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SPECIFICATION FOR STEEL, STRIP, CARBON AND HIGH-STRENGTH, LOW-ALLOY, HOT-ROLLED, GENERAL REQUIREMENTS FOR

SA-749/SA-749M

(Identical with ASTM Specification A749/A749M-97(2002).)

SPECIFICATION FOR STEEL, STRIP, CARBON AND HIGH-STRENGTH, LOW-ALLOY, HOT-ROLLED, GENERAL REQUIREMENTS FOR

SA-749/SA-749M

[Identical with ASTM Specification A 749/A 749M-97(2002).]

1. Scope

1.1 This specification covers the general requirements for hot-rolled steel strip in coils and cut lengths. It applies to carbon steel and high-strength, low-alloy steel furnished as hot-rolled.

1.2 This specification is not applicable to hot-rolled heavy-thickness carbon sheet and strip coils (ASTM Specification A 635/A 635M), cold-rolled carbon steel strip (ASTM Specification A 109 or A 109M), high-strength, low-alloy coldrolled steel (ASTM Specifications A 606 and A 607) or cold-rolled carbon spring steel (ASTM Specification A 682 or A 682M).

1.3 In case of any conflict in requirements, the requirements of the individual material specification shall prevail over those of this general specification.

1.4 For the purposes of determining conformance with this and the appropriate product specification referenced under 2.1, values shall be rounded to the nearest unit in the right hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

1.5 Annex A1 lists permissible variations in dimensions and mass (Note 1) in S.I. [metric] units. The values listed are not exact conversions of the values listed in the inch-pound tables, but instead are rounded or rationalized values. Conformance to Annex A1 is mandatory when the "M" specification is used.

NOTE 1 — The term "weight" is used when inch-pound units are the standard; however, under S.I., the preferred term is "mass."

1.6 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.7 This specification and the applicable material specifications are expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 109 Specification for Steel, Strip, Carbon, Cold-Rolled
A 109M Specification for Steel, Strip, Carbon, Cold-Rolled (Metric)
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 606 Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance
A 607 Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Columbium or Vanadium, or Both, Hot-Rolled and Cold-Rolled
A 635/A 635M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Carbon, Hot-Rolled
A 682 Specification for Steel, Strip, High-Carbon, Cold-Rolled, Spring Quality, General Requirements For
A 682M Specification for Steel, Strip, High-Carbon, Cold-Rolled, Spring Quality, General Requirements For (Metric)
A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
E 11 Specification for Wire-Cloth Sieves for Testing Purposes
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials

2.2 *Military Standards:*
MIL-STD-129 Marking for Shipment and Storage
MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.3 *Federal Standards:*
Fed. Std. No. 123 Marking for Shipments (Civil Agencies)
Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:* Descriptions of Terms Specific to This Standard:

3.1.1 *Steel Types:*

3.1.2 *carbon steel* — the designation for steel when no minimum content is specified or required for aluminum, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any element added to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40%; or when the maximum content specified for any of the following elements does not exceed the percentages noted; manganese 1.65, silicon 0.60, or copper 0.60.

Discussion — In all carbon steels small quantities of certain residual elements unavoidably retained from raw materials are sometimes found which are not specified or required, such as copper, nickel, molybdenum, chromium, etc. These elements are considered as incidental and are not normally determined or reported.

3.1.3 *high-strength, low-alloy steel* — a specific group of steels in which higher strength, and in some cases additional resistance to atmospheric corrosion, are obtained by moderate amounts of one or more alloying elements.

3.1.4 *Product Types:*

3.1.5 *hot-rolled strip* — manufactured by hot rolling billets or slabs to the required thickness. It may be produced single width or by rolling multiple width and slitting to the desired width. It can be supplied in coils or cut lengths as specified.

Width, in.		Thickness, in.	
Over	Through	Over	Through
. . .	3½	0.044	0.203
3½	6	0.044	0.203
6	12	0.044	0.230 excl

Width, mm		Thickness, mm	
Over	Through	Over	Through
. . .	100	1.2	5.0
100	200	1.2	5.0
200	300	1.2	6.0, excl

Hot-rolled, high-strength, low-alloy strip is commonly available by size as follows:

Width, in.		Thickness, in.		
Over	Through	From	Through	
			Coils & Cut Lengths	Coils Only
. . .	6	0.054	0.203	0.230 excl
6	12	0.054	0.230	0.230 excl

Width, mm		Thickness, mm	
Over	Through	Over	Through
. . .	200	1.8	5.0
200	300	1.8	6.0, excl

4. Materials and Manufacture

4.1 Unless otherwise specified, hot-rolled material shall be furnished hot-rolled, not annealed or pickled.

5. Chemical Composition

5.1 *Limits:*

5.1.1 The chemical composition shall be in accordance with the applicable product specification. However, if other compositions are required for carbon steel, they shall be prepared in accordance with Appendix X1.

5.1.2 Where the material is used for fabrication by welding, care must be exercised in the selection of chemical composition or mechanical properties to ensure compatibility with the welding process and its effect on altering the properties.

5.2 *Cast or Heat (Formerly Ladle) Analysis:*

5.2.1 An analysis of each cast or heat of steel shall be made by the manufacturer to determine the percentage of elements specified or restricted by the applicable specification.

5.2.2 When requested, cast or heat analysis for elements listed or required shall be reported to the purchaser or to his representative.

5.3 *Product, Check, or Verification Analysis:*

5.3.1 Nonkilled steels (such as capped or rimmed) are not technologically suited to product analysis due to the nonuniform character of their chemical composition and therefore, the tolerances in Table 1 do not apply. Product analysis is appropriate on these types of steel only when misapplication is apparent or for copper when copper steel is specified.

5.3.2 For steels other than nonkilled (capped or rimmed), product analysis may be made by the purchaser. The chemical analysis shall not vary from the limits specified by more than the amounts in Table 1. The several determinations of any element in a cast shall not vary both above and below the specified range.

5.4 *Sampling for Product Analysis:*

5.4.1 To indicate adequately the representative composition of a cast by product analysis, it is general practice to select samples to represent the steel, as fairly as possible, from a minimum number of pieces as follows: 3 pieces for lots up to 15 tons inclusive, and 6 pieces for lots over 15 tons [15 Mg].

5.4.2 When the steel is subject to tension test requirements, samples for product analysis may be taken either by drilling entirely through the used tension test specimens themselves or in accordance with 5.4.3.

5.4.3 When the steel is not subject to tension test requirements, the samples for analysis must be taken by milling or drilling entirely through the strip in a sufficient number of places so that the samples are representative of the entire strip. The sampling may be facilitated by folding the strip both ways, so that several samples may be taken at one drilling. Steel subjected to certain heating operations by the purchaser may not give chemical analysis results that properly represent its original composition. Therefore, users must analyze chips taken from the steel in the condition in which it is received from the steel manufacturer.

5.5 *Specimen Preparation* — Drillings or chips must be taken without the application of water, oil, or other lubricant, and must be free of scale, grease, dirt, or other foreign substances. They must not be overheated during cutting to the extent of causing decarburization. Chips must be well mixed, and those too coarse to pass a No. 10 (2.00 mm) sieve or too fine to remain on a No. 30 (600 μm) sieve are not suitable for proper analysis. Sieve size numbers are in accordance with Specification E 11.

5.6 *Test Methods* — In case a referee analysis is required and agreed upon to resolve a dispute concerning the results of a chemical analysis, the procedure for performing the referee analysis must be in accordance with the latest issue of Test Methods, Practices, and Terminology A 751, unless otherwise agreed upon between the manufacturer and the purchaser.

6. Mechanical Properties

6.1 The mechanical property requirements, number of specimens, test locations, and specimen orientation shall be in accordance with the applicable product specification.

6.2 Unless otherwise specified in the applicable product specification, test specimens must be prepared in accordance with Test Methods and Definitions A 370.

6.3 Mechanical tests shall be conducted in accordance with Test Methods and Definitions A 370.

6.4 Bend tests, where required, shall be conducted in compliance with Test Methods E 290.

6.5 To determine conformance with the product specification, a calculated value should be rounded to the nearest 1 ksi [7 MPa] tensile strength and yield point or yield strength, and to the nearest unit in the right hand place of figures used in expressing the limiting value for other values in accordance with the rounding off method given in Practice E 29.

6.6 Structural steels are commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a given steel to cold form over a given radius under shop conditions. These factors include thickness, strength level, degree of restraint, relationship to rolling direction, chemistry, and microstructure. Each of the appropriate product specifications lists in the appendix the suggested minimum inside radius for cold bending. These radii should be used as minima for 90° bends. They presuppose "hard way" bending (bend axis parallel to rolling direction) and reasonably good shop forming practices. Where possible, the use of larger radii or "easy way" bends are recommended for improved performance.

6.7 Fabricators should be aware that cracks may initiate upon bending a sheared or burned edge. This is not considered to be a fault of the steel but is rather a function of the induced cold-work or heat-affected zone.

7. Dimensions, Tolerances, and Allowances

7.1 Dimensions, tolerances, and allowances applicable to products covered by this specification are contained in Table 2 through Table 9 [Annex A1, Tables A1.1 through A1.7]. The appropriate tolerance tables shall be identified in each individual specification.

8. Workmanship

8.1 Cut lengths shall have a workmanlike appearance and shall not have imperfections of a nature or degree for the product, the grade, and the quality ordered that will be detrimental to the fabrication of the finished part.

8.2 Coils may contain some abnormal imperfections that render a portion of the coil unusable since the inspection of coils does not afford the producer the same opportunity to remove portions containing imperfections as in the case with cut lengths.

9. Finish and Condition

9.1 Hot-rolled strip has a surface with an oxide or scale resulting from the hot-rolling operation. The oxide or scale can be removed by pickling or blast cleaning when required for press-work operations or welding. Hot-rolled and hot-rolled descaled strip are not generally used for exposed parts where surface is of prime importance. However, hot-rolled surface might be of importance, as in the case of weathering steels for exposed parts.

9.1.1 Hot-rolled strip can be supplied with mill edges, square edges, or cut (slit) edges as specified.

9.1.1.1 Mill edges are the natural edges resulting from the hot-rolling operation and are generally round and smooth without any definite contour.

9.1.1.2 Square edges are the edges resulting from rolling through vertical edging rolls during the hot-rolling operations. These edges are square and smooth, with the corners slightly rounded.

9.1.1.3 Cut (slit) edges are the normal edges that result from the shearing, slitting, or trimming of mill edges.

9.1.2 The ends of plain hot-rolled mill-edge coils are irregular in shape and are referred to as uncropped ends. Where such ends are not acceptable, the purchaser's order should so specify. Processed coils such as pickled or blast cleaned are supplied with square-cut ends.

9.2 *Oiling:*

9.2.1 Plain hot-rolled strip is customarily furnished not oiled. Oiling must be specified when required

9.2.2 Hot-rolled pickled or descaled strip is customarily furnished oiled. If the product is not to be oiled, it must be so specified since the cleaned surface is prone to rusting.

10. General Requirements for Delivery

10.1 Products covered by this specification are produced to inch-pound or metric decimal thickness only.

10.2 Steel may be produced as ingot-cast or strand-cast. When different grades of strand-cast steel are sequentially cast, identification and separation of the transition material is required.

11. Retests

11.1 If any test specimen shows defective machining or develops flaws, it must be discarded and another specimen substituted.

11.2 If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than [nl]P in. [20 mm] from the center of the gage length of a 2 in. [50 mm] specimen or is outside the middle half of the gage length of an 8 in. [200 mm] specimen, as indicated by scribe scratches marked on the specimen before testing, a retest is allowed.

11.3 If a bend specimen fails, due to conditions of bending more severe than required by the specification, a retest is permitted either on a duplicate specimen or on a remaining portion of the failed specimen.

12. Inspection

12.1 When the purchaser's order stipulates that inspection and test (except product analyses) for acceptance on the steel be made prior to shipment from the mill, the manufacturer shall afford the purchaser's inspector all reasonable facilities to satisfy him that the steel is being produced and furnished in accordance with the specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operation.

13. Rejection and Rehearing

13.1 Unless otherwise specified, any rejection shall be reported to the manufacturer within a reasonable time after receipt of material by the purchaser.

13.2 Material that is reported to be defective subsequent to the acceptance at the purchaser's works shall be set aside, adequately protected, and correctly identified. The manufacturer shall be notified as soon as possible so that an investigation may be initiated.

13.3 Samples that are representative of the rejected material shall be made available to the manufacturer. In the event that the manufacturer is dissatisfied with the rejection, he may request a rehearing.

14. Test Reports and Certification

14.1 When test reports are required by the purchase order or the material specification, the supplier shall report the results of all tests required by the material specification and the order.

14.2 When certification is required by the purchase order, the supplier shall furnish a certification that the material has been manufactured and tested in accordance with the requirements of the material specification.

14.3 A signature is not required on test reports or certifications. However, the document shall clearly identify the organization submitting the document. Notwithstanding the absence of a signature, the organization submitting the document is responsible for the content of the document.

14.4 When test reports are required, copies of the original material manufacturer's test report shall be included with any subsequent test report.

14.5 A material test report, certificate of inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

NOTE 2 — The industry definition as invoked here is: EDI is the computer to computer exchange of business information in an agreed upon standard format such as ANSI ASC X12.

15. Marking

15.1 As a minimum requirement, the material shall be identified by having the manufacturer's name, ASTM designation, weight, purchaser's order number, and material identification legibly stenciled on top of each lift or shown on a tag attached to each coil or shipping unit.

15.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

15.3 For Government procurement by the Defense Supply Agency, strip material shall be continuously marked for identification in accordance with Fed. Std. No. 183.

15.4 Bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the primary metals subcommittee of the AIAG bar code project team.

16. Packaging

16.1 Unless otherwise specified, the strip shall be packaged and loaded in accordance with Practices A 700.

16.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

16.3 When coils are ordered it is customary to specify a minimum or range of inside diameter, maximum outside diameter, and a maximum coil weight, if required. The ability of manufacturers to meet the maximum coil weights depends upon individual mill equipment. When required, minimum coil weights are subject to negotiation.

17. Keywords

17.1 carbon; steel; strip

TABLE 1
TOLERANCES FOR PRODUCT ANALYSIS[A]

Element	Limit, or Maximum of Specified Element, %	Tolerances: Under Minimum Limit	Tolerances: Over Maximum Limit
Carbon	to 0.15, incl	0.02	0.03
	over 0.15 to 0.40, incl	0.03	0.04
	over 0.40 to 0.80, incl	0.03	0.05
	over 0.80	0.03	0.06
Manganese	to 0.60, incl	0.03	0.03
	over 0.60 to 1.15, incl	0.04	0.04
	over 1.15 to 1.65, incl	0.05	0.05
Phosphorus	. . .	. . .	0.01
Sulfur	. . .	. . .	0.01
Silicon	to 0.30, incl	0.02	0.03
	over 0.30 to 0.60, incl	0.05	0.05
Copper	. . .	0.02	. . .

[A] See 6.3.1.

TABLE 2
INDEX OF TABLES FOR DIMENSIONS, TOLERANCES, AND ALLOWANCES

Dimensions	Table No. Inch-Pound Units	SI Units
Camber tolerances	8	A1.6
Crown tolerances	5	A1.3
Flatness tolerances	9	A1.7
Length tolerances	7	A1.5
Thickness tolerances	3, 4	A1.1, A1.2
Width tolerances	6	A1.4

TABLE 3
THICKNESS TOLERANCES OF HOT-ROLLED STRIP[A]
(CARBON AND HIGH-STRENGTH, LOW-ALLOY STEEL) ORDERED
TO NOMINAL THICKNESS
(COILS AND CUT LENGTHS, INCLUDING PICKLED)

Specified Width, in.		Thickness Tolerance, Over and Under, in., for Specified Nominal Thickness, in.				
Over	Through	Through 0.057	Over 0.057 to 0.118, incl	Over 0.118 to 0.187, incl	Over 0.187 to 0.203, incl	Over 0.203 to 0.230, excl
. . .	3½	0.003	0.004	0.005	0.006	. . .
3½	6	0.003	0.005	0.005	0.006	. . .
6	12	0.004	0.005	0.005	0.006	0.006

NOTE 1 — Micrometers used for measurement of thickness shall be constructed with either flat anvils having a minimum diameter of 0.188 in. or rounded anvils having a minimum radius of curvature of 0.100 in. Micrometers with pointed anvils are not suitable for thickness measurement.

[A] Measurements for the above table are taken ⅜ in. from the edge of a strip on 1 in. or wider; and at any place on the strip when narrower than 1 in. The given tolerances do not include crown and therefore the tolerances for crown as shown in Table 5 are in addition to tolerances in Table 3.

TABLE 4
THICKNESS TOLERANCES OF HOT-ROLLED STRIP[A]
(CARBON AND HIGH-STRENGTH, LOW-ALLOY STEEL)
ORDERED TO MINIMUM THICKNESS (COILS AND CUT LENGTHS,
INCLUDING PICKLING)

Specified Width, in.		Thickness Tolerance, Over Only, in., for Specified Nominal Thickness, in.				
Over	Through	Through 0.057	Over 0.057 to 0.118, incl	Over 0.118 to 0.187, incl	Over 0.187 to 0.203, incl	Over 0.203 to 0.230, excl
. . .	3½	0.006	0.008	0.010	0.012	. . .
3½	6	0.006	0.010	0.010	0.012	. . .
6	12	0.008	0.010	0.010	0.012	0.012

NOTE 1 — Micrometers used for measurement of thickness shall be constructed with either flat anvils having a minimum diameter of 0.188 in. or rounded anvils having a minimum radius of curvature of 0.100 in. Micrometers with pointed anvils are not suitable for thickness measurement.

[A] Measurements for the above table are taken ⅜ in. from the edge of a strip on 1 in. or wider; and at any place on the strip when narrower than 1 in. The given tolerances do not include crown and therefore the tolerances for crown as shown in Table 5 are in addition to tolerances in Table 4.

TABLE 5
CROWN TOLERANCES OF HOT-ROLLED STRIP (CARBON AND HIGH-STRENGTH, LOW-ALLOY STEEL) (COILS AND CUT LENGTHS, INCLUDING PICKLED) STRIP MAY BE THICKER AT THE CENTER THAN AT A POINT ⅜ IN. FROM THE EDGE BY THE FOLLOWING AMOUNTS:

Specified Width, in.		Crown Tolerance, Over Only, for Specified Minimum Thickness, in.		
Over	Through	Through 0.118	Over 0.118 to 0.187, incl	Over 0.187 to 0.230, excl
...	3½	0.002	0.002	0.001
3½	6	0.003	0.002	0.002
6	12	0.004	0.003	0.003

TABLE 6
WIDTH TOLERANCES OF HOT-ROLLED STRIP (CARBON AND HIGH-STRENGTH, LOW-ALLOY STEEL) (COILS AND CUT LENGTHS, INCLUDING PICKLED)

Specified Width, in.		Width Tolerance, Over and Under, in.		
			Cut Edge	
Over	Through	Mill Edge and Square Edge Strip	Through 0.109 in.	Over 0.109 in. Through 0.230, excl
...	2	1/32	0.008	0.016
2	5	3/64	0.008	0.016
5	10	1/16	0.010	0.016
10	12	3/32	0.016	0.016

TABLE 7
LENGTH TOLERANCES OF HOT-ROLLED STRIP (CARBON AND HIGH-STRENGTH ALLOY) (CUT LENGTHS, INCLUDING PICKLED)

Specified Widths, in.	Length Tolerances over Specified Length, ft for Widths Given, in., No Tolerance Under					
	To 5 ft, incl	Over 5 to 10 ft, incl	Over 10 to 20 ft, incl	Over 20 to 30 ft, incl	Over 30 to 40 ft, incl	Over 40 ft, incl
To 3, incl	¼	⅜	½	[n1]P	1	1½
Over 3 to 6, incl	⅜	½	⅝	[n1]P	1	1½
Over 6 to 12, incl	½	[n1]P	1	1¼	1½	1[n1]P

TABLE 8
CAMBER TOLERANCES[A] OF HOT-ROLLED STRIP (CARBON AND HIGH-STRENGTH LOW-ALLOY) (COILS AND CUT LENGTHS, INCLUDING PICKLED, APPLICABLE TO MILL EDGE, SQUARE EDGE, AND SLIT OR CUT EDGE)

For strip wider than 1½ in. — ¼ in. in any 8 ft.
For strip 1½ in. and narrower — ½ in. in any 8 ft.

NOTE 1 — Camber is the deviation of a side edge from a straight line. The standard for measuring this deviation is based on any 8 ft length.[B] It is obtained by placing an 8 ft straightedge on the concave side and measuring the maximum distance between the strip edge and the straightedge.

[A] When the camber tolerances shown in the above table are not suitable for a particular purpose, hot-rolled strip is sometimes machine straightened.

[B] For strip less than 8 ft tolerances are to be established in each instance. A formula for calculating camber is as follows:

$$\frac{L^2 \times C_1}{64} = C_2 \text{ in } L$$

where:
C_1 = Camber in 8 ft and
C_2 = Camber in any given length L

TABLE 9
FLATNESS TOLERANCES OF HOT-ROLLED STRIP (CARBON AND HIGH-STRENGTH LOW-ALLOY)

It has not been practicable to formulate flatness tolerances for hot-rolled carbon strip steel because of the wide range of widths and thicknesses, and variety of chemical compositions, mechanical properties and types, produced in coils and cut lengths.

APPENDIX

(Nonmandatory Information)

X1. STANDARD CHEMICAL RANGES AND LIMITS

X1.1 Standard chemical ranges and limits are prescribed for carbon steels in Table X1.1.

TABLE X1.1
STANDARD CHEMICAL RANGES AND LIMITS

	Carbon Steels Only, Cast or Heat Analysis		
Element	Minimum of Specified Element, %	Range	Lowest, max
Carbon (see Note)	to 0.15, incl	0.05	0.08
	over 0.15 to 0.30, incl	0.06	
	over 0.30 to 0.40, incl	0.07	
	over 0.40 to 0.60, incl	0.08	
	over 0.60 to 0.80, incl	0.11	
	over 0.80 to 1.35, incl	0.14	
Manganese	to 0.50, incl	0.20	0.40
	over 0.50 to 1.15, incl	0.30	
	over 1.15 to 1.65, incl	0.35	
Phosphorus	to 0.08, incl	0.03	0.030[A]
	over 0.08 to 0.15, incl	0.05	
Sulfur	to 0.08, incl	0.03	0.035[A]
	over 0.08 to 0.15, incl	0.05	
	over 0.15 to 0.23, incl	0.07	
	over 0.23 to 0.33, incl	0.10	
Silicon	to 0.15, incl	0.08	0.10
	over 0.15 to 0.30, incl	0.15	
	over 0.30 to 0.60, incl	0.30	
Copper	When copper is required 0.20 min is commonly specified.		

NOTE 1 — The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.00%. When the maximum manganese limit exceeds 1.00%, add 0.01 to the carbon ranges shown below.

[A] Certain individual specifications provide for lower standard limits for phosphorus and sulfur.

ANNEX

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS AND MASS IN SI UNITS

A1.1 Listed in Tables A1.1 through A1.7 are permissible variations in dimensions and mass expressed in the International System of Units (SI) terminology.

TABLE A1.1
THICKNESS TOLERANCES OF HOT-ROLLED STRIP[A] (CARBON AND HIGH-STRENGTH, LOW-ALLOY STEEL) ORDERED TO NOMINAL THICKNESS (COILS AND CUT LENGTHS, INCLUDING PICKLED)

Specified Width, mm		Thickness Tolerance, Over and Under, mm, for Specified Nominal Thickness, mm				
Over	Through	Through 1.5	Over 1.5 to 3.0, incl	Over 3.0 to 4.5, incl	Over 4.5 to 5.0, incl	Over 5.0 to 6.0, excl
...	100	0.08	0.10	0.13	0.15	...
100	200	0.08	0.13	0.13	0.15	...
200	300	0.10	0.13	0.13	0.15	0.15

NOTE 1 — Micrometers used for measurement of thickness shall be constructed with either flat anvils having a minimum diameter of 4.80 mm or rounded anvils having a minimum radius of curvature of 2.55 mm. Micrometers with pointed anvils are not suitable for thickness measurement.

[A] Measurements for the above table are taken 10 mm from the edge of a strip on 25 mm or wider; and at any place on the strip when narrower than 25 mm. The given tolerances do not include crown and therefore the tolerances for crown as shown in Table A1.3 are in addition to tolerances in Table A1.1.

TABLE A1.2
THICKNESS TOLERANCES OF HOT-ROLLED STRIP[A] (CARBON AND HIGH-STRENGTH, LOW-ALLOY STEEL) ORDERED TO MINIMUM THICKNESS (COILS AND CUT LENGTHS, INCLUDING PICKLING)

Specified Width, mm		Thickness Tolerance, Over Only, for Specified Minimum Thickness, mm				
Over	Through	Through 1.5	Over 1.5 to 3.0, incl	Over 3.0 to 4.5, incl	Over 4.5 to 5.0, incl	Over 5.0 to 6.0, excl
...	100	0.15	0.20	0.25	0.30	...
100	200	0.15	0.25	0.25	0.30	...
200	300	0.20	0.25	0.25	0.30	0.30

NOTE 1 — Micrometers used for measurement of thickness shall be constructed with either flat anvils having a minimum diameter of 4.80 mm or rounded anvils having a minimum radius of curvature of 2.55 mm. Micrometers with pointed anvils are not suitable for thickness measurement.

[A] Measurements for the above table are taken 10 mm from the edge of a strip on 25 mm or wider; and at any place on the strip when narrower than 25 mm. The given tolerances do not include crown and therefore the tolerances for crown as shown in Table A 1.3 are in addition to tolerances in Table A 1.2.

TABLE A1.3
CROWN TOLERANCES OF HOT-ROLLED STRIP
(CARBON AND HIGH-STRENGTH, LOW-ALLOY STEEL)
(COILS AND CUT LENGTHS, INCLUDING PICKLED)

Specified Width, mm		Crown Tolerance, Over Only, for Specified Minimum Thickness, mm			
Over	Through	Through 3.0	Over 3.0 to 4.5, incl	Over 4.5 to 6.0, incl	Over 6.0 to 9.5, incl
...	100	0.05	0.05	0.03	...
100	200	0.10	0.08	0.05	...
200	300	0.10	0.08	0.08	0.05

TABLE A1.4
WIDTH TOLERANCES OF HOT-ROLLED STRIP
(CARBON AND HIGH-STRENGTH, LOW-ALLOY STEEL)
(COILS AND CUT LENGTHS, INCLUDING PICKLED)

Specified Width, mm		Width Tolerance, Over and Under, mm		
		Mill Edge and Square Edge Strip	Cut Edge	
Over	Through		Through 2.5 mm	Over 2.5 mm
...	50	0.8	0.2	0.4
50	100	1.2	0.2	0.4
100	200	1.6	0.3	0.4
200	300	2.4	0.4	0.4

TABLE A1.5
LENGTH TOLERANCES OF HOT-ROLLED STRIP
(CARBON AND HIGH-STRENGTH, LOW-ALLOY STEEL) (CUT LENGTHS, INCLUDING PICKLED)

Specified Widths, mm		Length Tolerances Over Specified Length, for Widths Given, No Tolerance Under, mm					
Over	Through	Through 1500	Over 1500 to 3000, incl	Over 3000 to 6000, incl	Over 6000 to 9000, incl	Over 9000 to 12 000, incl	Over 12 000
...	100	10	10	15	20	25	40
100	200	10	15	15	20	25	40
200	300	15	20	25	30	40	45

TABLE A1.6
CAMBER TOLERANCES[A] OF HOT-ROLLED STRIP
(CARBON AND HIGH-STRENGTH LOW-ALLOY) (COILS AND CUT LENGTHS, INCLUDING PICKLED, APPLICABLE TO MILL EDGE, SQUARE EDGE, AND SLIT OR CUT EDGE)

For strip wider than 50 mm – 5.0 mm in any 2000 mm
For strip 50 mm and narrower – 10.0 mm in any 2000 mm

NOTE 1 — Camber is the deviation of a side edge from a straight line. The standard for measuring this deviation is based on any 2000 mm length.[B] It is obtained by placing a 2000 mm straightedge on the concave side and measuring the maximum distance between the strip edge and the straightedge.

[A] When the camber tolerances shown in the above table are not suitable for a particular purpose, hot-rolled strip is sometimes machine straightened.

[B] For strip less than 2000 mm tolerances are to be established in each instance.

TABLE A1.7
FLATNESS TOLERANCES OF HOT-ROLLED STRIP
(CARBON AND HIGH-STRENGTH LOW-ALLOY)

It has not been practicable to formulate flatness tolerances for hot-rolled strip because of the wide range of widths and thicknesses, and variety of chemical compositions and qualities, produced in coils and cut lengths.

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TEST METHODS AND PRACTICES FOR CHEMICAL ANALYSIS OF STEEL PRODUCTS

SA-751

(**23**)

(Identical with ASTM Specification A751-21 except for editorial corrections to an element designation in Tables 1 and 2.)

Test Methods and Practices for Chemical Analysis of Steel Products

INTRODUCTION

These test methods and practices were prepared to answer the need for a single document that would include all aspects of obtaining and reporting the chemical analysis of steel, stainless steel, and related alloys. Such subjects as definitions of terms and product (check) analysis variations (tolerances) required clarification. Requirements for sampling, meeting specified limits, and treatment of data usually were not clearly established in product specifications.

It is intended that these test methods and practices will contain all requirements for the determination of chemical composition of steel, stainless steel, or related alloys so that product specifications will need contain only special modifications and exceptions.

1. Scope

1.1 These test methods and practices cover definitions, reference methods, practices, and guides relating to the chemical analysis of steel, stainless steel, and related alloys. They include both wet chemical and instrumental techniques.

1.2 Directions are provided for handling chemical requirements, product analyses, residual elements, and reference standards, and for the treatment and reporting of chemical analysis data.

1.3 These test methods and practices apply only to those product standards which include these test methods and practices, or parts thereof, as a requirement.

1.4 In cases of conflict, the product specification requirements shall take precedence over the requirements of these test methods and practices.

1.5 Attention is directed to ISO/IEC 17025 when there may be a need for information on criteria for evaluation of testing laboratories.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E50 Practices for Apparatus, Reagents, and Safety Considerations for Chemical Analysis of Metals, Ores, and Related Materials

E60 Practice for Analysis of Metals, Ores, and Related Materials by Spectrophotometry

E322 Test Method for Analysis of Low-Alloy Steels and Cast Irons by Wavelength Dispersive X-Ray Fluorescence Spectrometry (Withdrawn 2021)

E350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

E352 Test Methods for Chemical Analysis of Tool Steels and

Other Similar Medium- and High-Alloy Steels
E353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
E354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
E415 Test Method for Analysis of Carbon and Low-Alloy Steel by Spark Atomic Emission Spectrometry
E548 Guide for General Criteria Used for Evaluating Laboratory Competence (Withdrawn 2002)
E572 Test Method for Analysis of Stainless and Alloy Steels by Wavelength Dispersive X-Ray Fluorescence Spectrometry
E743 Guide for Spectrochemical Laboratory Quality Assurance (Withdrawn 1998)
E851 Practice for Evaluation of Spectrochemical Laboratories (Withdrawn 1998)
E882 Guide for Accountability and Quality Control in the Chemical Analysis Laboratory
E1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Inert Gas Fusion Techniques
E1085 Test Method for Analysis of Low-Alloy Steels by Wavelength Dispersive X-Ray Fluorescence Spectrometry
E1086 Test Method for Analysis of Austenitic Stainless Steel by Spark Atomic Emission Spectrometry
E1097 Guide for Determination of Various Elements by Direct Current Plasma Atomic Emission Spectrometry
E1184 Practice for Determination of Elements by Graphite Furnace Atomic Absorption Spectrometry
E1282 Guide for Specifying the Chemical Compositions and Selecting Sampling Practices and Quantitative Analysis Methods for Metals, Ores, and Related Materials
E1329 Practice for Verification and Use of Control Charts in Spectrochemical Analysis (Withdrawn 2019)
E1476 Guide for Metals Identification, Grade Verification, and Sorting
E1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition

2.2 *ISO Standards:*

ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in these test methods and practices, see Terminology A941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *product, check, or verification analysis, n*—a chemical analysis of the semifinished or finished product, usually for the purpose of determining conformance to the specification requirements.

3.2.1.1 *Discussion*—The range of the specified composition applicable to product analysis is normally greater than that applicable to heat analysis in order to take into account deviations associated with analytical reproducibility (Note 1) and the heterogeneity of the steel.

NOTE 1—All of the chemical analysis procedures referenced in these test methods include precision statements with reproducibility data, with the exception of Test Methods E50.

3.2.2 *product analysis tolerances, n*—a permissible variation over the maximum limit or under the minimum limit of a specified element and applicable only to product analyses, not cast or heat analyses (Note 2).

NOTE 2—The term "analysis tolerance" is often misunderstood. It does not apply to cast or heat analyses determined to show conformance to specified chemical limits. It applies only to product analysis and becomes meaningful only when the heat analysis of an element falls close to one of the specified limits. For example, stainless steel UNS 30400 limits for chromium are 18.00 to 20.00 %. A heat that the producer reported as 18.01 % chromium may be found to show 17.80 % chromium by a user performing a product analysis. If the product analysis tolerance for such a chromium level is 0.20 %, the product analysis of 17.80 % chromium would be acceptable. A product analysis of 17.79 % would not be acceptable.

3.2.3 *proprietary analytical method, n*—a non-standard analytical method, not published by ASTM, utilizing reference standards traceable to the National Institute of Standards and Technology (NIST), when available, or other sources referenced in Section 10.

3.2.4 *referee analysis, n*—performed using ASTM test methods listed in 9.1.1, NIST reference standards or methods, and reference standards agreed upon between parties.

3.2.4.1 *Discussion*—The selection of a laboratory to perform the referee analysis shall be a matter of agreement between the supplier and the purchaser.

3.2.5 *certified reference material, n*—a specimen of material specially prepared, analyzed, and certified for chemical content under the jurisdiction of a recognized standardizing agency or group, such as the NIST, for use by analytical laboratories as an accurate basis for comparison.

3.2.5.1 *Discussion*—Reference samples should bear sufficient resemblance to the material to be analyzed so that no significant differences are required in procedures or corrections (for example, for interferences or inter-element effects).

3.2.6 *working reference materials, n*—reference materials used for routine analytical control and traceable to NIST standards and other recognized standards when appropriate standards are available.

4. Concerning Specification of Chemical Composition Requirements

4.1 It is recommended that Guide E1282 be consulted as a guide for specifying the chemical compositions for steels.

4.2 The recommended practice for specifying chemical composition limits is to limit the number of significant figures for each element so that the number of figures to the right of the decimal point conforms to the following:

Chemical Concentration	Maximum Number of Figures to Right of Decimal Point
Up to 0.010 %, incl.	0.XXXX or may be expressed as ppm
Over 0.010 % to 0.10 %, incl	0.XXX
Over 0.10 % to 3.0 %, incl	0.XX
Over 3.0 %	0.X

4.3 For those cases in which the composition range spans either 0.10 or 3.0 %, the number of figures to the right of the decimal is to be determined by that indicated by the upper limit.

4.4 Technical considerations may dictate the employment of less than the number of figures to the right of the decimal as previously recommended.

NOTE 3—The recommendations should be employed to reduce the number of significant figures, such as from 18.00 to 18.0 %, but a significant figure should never be added unless there is a technical reason for so doing.

5. Cast or Heat Analysis

5.1 The producer shall perform analyses for those elements specified in the material specification. The results of such analyses shall conform to the requirements specified in the material specification.

5.1.1 For multiple heats, either individual heat or cast analysis, or an average heat or cast analysis, shall be reported. If significant variations in heat or cast size are involved, a weighted average heat or cast analysis, based on the relative quantity of metal in each heat or cast, shall be reported.

5.1.2 For consumable electrode remelted material, a heat is defined as all the ingots remelted by the same process from a primary heat. The heat analysis shall be obtained from one remelted ingot, or the product of one remelted ingot, from each primary melt. If this heat analysis does not meet the heat analysis requirements of the specification, one sample from the product of each remelted ingot shall be analyzed, and the analyses shall meet the heat analysis requirements.

5.2 If the test samples taken for the heat analysis are lost, inadequate, or not representative of the heat, a product analysis of the semifinished or finished product may be used to establish the heat analysis.

5.2.1 If a product analysis is made to establish the heat analysis, the product analysis shall meet the specified limits for heat analysis and the product analysis tolerances described in Section 6 do not apply.

5.3 Unless otherwise specified, compositions shall be reported in mass fraction percent (wt%).

6. Product Analysis Requirements

6.1 For product analysis, the range of the specified chemical composition is normally greater (designated product analysis tolerances) than that applicable to heat analyses to take into account deviations associated with analytical reproducibility and the heterogeneity of the steel. If several determinations of any element in the heat are made, they may not vary both above and below the specified range.

6.2 Product analysis tolerances may not be used to determine conformance to the specified heat or cast analysis unless permitted by the individual material specification.

6.3 Product analysis tolerances, where available, are given in the individual material specifications or in the general requirement specifications.

7. Unspecified Elements (Note 4)

7.1 Reporting analyses of unspecified elements is permitted.

NOTE 4—All commercial metals contain small amounts of various elements in addition to those which are specified. It is neither practical nor necessary to specify limits for every unspecified element that might be present, despite the fact that the presence of many of these elements is often routinely determined by the producer.

7.2 Analysis limits shall be established for specific elements rather than groups of elements such as "all others," "rare earths," and "balance."

8. Sampling

8.1 *Cast or Heat Analyses:*

8.1.1 Samples shall be taken, insofar as possible, during the casting of a heat, at a time which, in the producer's judgment, best represents the composition of the cast.

8.1.2 In case the heat analysis samples or analyses are lost or inadequate, or when it is evident that the sample does not truly represent the heat, representative samples may be taken from the semifinished or finished product, in which case such samples may be analyzed to satisfy the specified requirements. The analysis shall meet the specified limits for heat analysis.

8.2 *Check, Product, or Verification Analyses*—Unless otherwise specified, the latest revision of Practice E1806 shall be used as a guide for sampling.

9. Test Methods

9.1 This section lists some test methods that have been found acceptable for chemical analysis of steels.

9.1.1 The following ASTM wet chemical test methods have been found acceptable as referee test methods and as a base for standardizing instrumental analysis techniques.

Test Methods	General Description
E350	Basic wet chemical procedure for steels.
E352	Wet chemical procedure for tool steels.
E353	Wet chemical procedure for stainless steels.
E354	Wet chemical procedure for high nickel steels.
E1019	Determination of carbon, sulfur, nitrogen, oxygen, and hydrogen, in steel and in iron, nickel, and cobalt alloys.

9.1.2 The following ASTM instrumental test methods, practices, and guides may be employed for chemical analysis of steels or may be useful as a guide in the calibration and standardization of instrumental equipment for routine sampling and analysis of steels.

Test Methods, Practices, Guides	General Description
E50	Apparatus, reagents, and safety.
E60	Photometric and spectrophotometric work.
	Spectrographic analysis of steels (rod-to-rod technique).
	Spectrographic analysis of acid-soluble aluminum.
E322	X-ray fluorescence for steels
	Spectrometric analysis of stainless steels
E415	Vacuum spectrometric analysis of steels
	Spectrographic determination of silicon and aluminum in high-purity iron.
E572	X-ray emission spectrometric analysis of stainless steels.
	Flame atomic absorption.
E882	Accountability and quality control.
E1019	Determination of carbon, sulfur, nitrogen, oxygen, and hydrogen in steel and in iron, nickel, and cobalt alloys.
E1085	X-ray emission spectrometric analysis of low alloy steels.
E1086	Optical emission vacuum spectrometric analysis of stainless steel.
	By the point-to plane excitation technique.
E1097	Direct current plasma spectroscopy.
E1184	Graphite furnace atomic absorption.
E1282	Selecting sampling practices and analysis methods.
E1329	Verification and use of control charts.
E1806	Sampling.

9.2 The following are some of the commonly accepted techniques employed for routine chemical analysis of steels. These routine analyses are the basis for the producers' quality control/assurance programs. Proprietary methods are permissible provided the results are equivalent to those obtained from standard methods when applicable.

9.2.1 Analysis of stainless steels using x-ray fluorescence spectroscopy (XRF). See Table 1 for normal elements and ranges for stainless steels.

9.2.2 Analysis of stainless steels using spark emission spectroscopy (OES). See Table 2 for normal elements and ranges for stainless steels.

9.2.3 Analysis of solutions using an atomic absorption spectrophotometer.

9.2.4 Analysis of solutions using an inductively coupled plasma emission spectrometer.

9.2.5 Determination of carbon or sulfur, or both, by combustion (in oxygen) and measurement of CO_2 or SO_2, or both, by thermal conductivity or infrared detectors.

Element	Ranges %
C	0.002–5.0
S	0.0005–0.1

9.2.6 Determination of nitrogen and oxygen by fusion (in a helium atmosphere) and measurement of N_2 by thermal conductivity and oxygen by measurement of CO by infrared or thermal conductivity detectors.

Element	Ranges %
N_2	0.0005–0.3
O_2	0.0008–0.02

TABLE 1 Normal Elements and Ranges for Stainless Steels Using X-Ray Fluorescence Spectroscopy

Element	Ranges %	Element	Ranges %
Mn	0.005–15.0	Cu	0.005–4.0
P	0.001–0.15	Cb	0.005–3.0
Si	0.005–5.0	V	0.005–2.0
Cr	0.01–26.0	Ti	0.005–2.5
Ni	0.01–36.0	Co	0.005–4.0
Al	0.002–5.5	Sn	0.002–0.20
Mo	0.005–8.0	W	0.005–3.0

TABLE 2 Normal Elements and Ranges for Stainless Steels Using Spark Emission Spectroscopy

C	0.004–5.0	V	0.005–2.0
S	0.0005–0.1	Ti	0.005–2.5
N_2	0.0020–0.3	Co	0.005–4.0
Mn	0.005–15.0	Sn	0.001–0.20
P	0.001–1.5	W	0.005–3.0
Si	0.005–5.0	Pb	0.002–0.05
Cr	0.01–26.0	B	0.0005–0.05
Ni	0.01–36.0	Ca	0.0002–0.01
Al	0.001–5.5	Mg	0.001–0.01
Mo	0.005–8.0	Ce	0.001–0.2
Cu	0.005–4.0	Zr	0.001–0.1
Cb	0.005–3.0	Ta	0.005–0.5

9.2.7 Analysis of solutions using inductively coupled plasma emission spectroscopy (ICP) or direct plasma emission spectroscopy (DCP). Normal elements and ranges for stainless steels are as follows:

Element	Ranges %
B	0.0002–0.01
Ca	0.0002–0.01
Mg	0.0002–0.01
Ce	0.001–0.2
Zr	0.001–0.1
Ta	0.005–0.5
La	0.001–0.01

9.3 There are additional common techniques often used for chemical analysis of standards for instrument analysis such as: polarographic analysis, ion exchange separations, radioactivation, and mass spectrometry.

10. Reference Materials

10.1 For referee analyses, reference standards of a recognized standardizing agency shall be employed with preference given to NIST standard reference materials when applicable. (NIST does not produce reference standards suitable for all elements or all alloys.)

10.1.1 When standard reference materials for certain alloys are not available from NIST, reference materials may be produced by employing ASTM standard procedures and NIST standard reference materials to the extent that such procedures and reference standards are available. Several independent laboratories should be used for certification of these standards and their results statistically reviewed and merged.

10.1.2 Test methods not published by ASTM, such as a definitive analytical method, may be used when the method is validated by analyzing certified reference materials along with the candidate reference material. Examples of definitive analytical methods include gravimetric, coulometry, titrimetric based on normality, and mass spectrometry.

10.2 Working reference materials may be used for routine analytical control.

11. Significant Numbers

11.1 Laboratories shall report each element to the same number of significant numbers as used in the pertinent material specifications.

11.2 When a chemical determination yields a greater number of significant numbers than is specified for an element, the result shall be rounded in accordance with Section 12.

12. Rounding Procedure

12.1 To determine conformance with the specification requirements, an observed value or calculated value shall be rounded in accordance with Practice E29 to the nearest unit in the last right-hand place of values listed in the table of chemical requirements.

12.2 In the special case of rounding the number "5" when no additional numbers other than "0" follow the "5," rounding shall be done in the direction of the specification analysis limits if following Practice E29 would cause rejection of material.

13. Records

13.1 In addition to the test data requested, the test records shall contain the following information as appropriate:

13.1.1 Description of the material tested, for example, heat number, grade of material, product specification, and

13.1.2 Test method(s) or unambiguous description of the nonstandard method(s) used.

14. Keywords

14.1 cast analysis; chemical analysis; heat analysis; product analysis; reference materials

APPENDIXES

(Nonmandatory Information)

X1. QUALITY ASSURANCE FOR VALIDITY OF ANALYTICAL RESULTS

X1.1 The requirements embodied in Guide E548, ISO/IEC 17025, and Practice E851 provide generic requirements for production of valid chemical-analysis results.

X1.2 Additional pertinent standards for improving the competency of chemical analysis laboratories are included in Guides E743 and E882.

X1.3 Keys to improving validity of chemical analytical results are as follows:

X1.3.1 Replication of sampling and testing to improve the precision of results,

X1.3.2 Use of reference materials is crucial to accurate results,

X1.3.3 Instrumentation that is appropriate and properly maintained, and

X1.3.4 Personnel who are properly trained, ethical chemists or technicians, and who work with properly documented, current standards.

X2. DISCUSSION OF POSITIVE MATERIAL IDENTIFICATION (PMI)

X2.1 PMI is not a true analysis method comparable to the test methods described in the body of this standard and, therefore, is not to be used for reportable analysis of material chemical composition. This appendix is included for reference purposes only and does not allow PMI to be used for the purpose of analysis where these test methods and practices are referenced in other standards.

X2.2 PMI typically utilizes portable instruments to determine material type for the purpose of identification and sorting.

X2.3 PMI can provide accurate non-destructive identification of many material types.

X2.4 PMI is intended for material identification and for sorting by material type.

X2.5 PMI is limited as to the elements reported. Lighter elements may not be reported or, if reported, may have a large uncertainty.

X2.6 The applicable ASTM standard for PMI is Guide E1476. Users are directed to Guide E1476 for additional instruction.

X2.7 In addition to Guide E1476, the user should refer to the instructions from the manufacturer of the specific instrument to determine the operation, capabilities, and limitations of that instrument.

SPECIFICATION FOR CARBON STEEL AND LOW-ALLOY STEEL PRESSURE-VESSEL-COMPONENT FORGINGS WITH MANDATORY TOUGHNESS REQUIREMENTS

SA-765/SA-765M

(Identical with ASTM Specification A765/A765M-07(2017).)

Standard Specification for Carbon Steel and Low-Alloy Steel Pressure-Vessel-Component Forgings with Mandatory Toughness Requirements

1. Scope

1.1 This specification covers heat-treated carbon steel and alloy steel forgings with mandatory toughness requirements. These forgings are intended for pressure vessels, feedwater heaters, and similar uses.

1.2 These forgings include tube sheets, covers, channel barrels, integral forged channels, rings, nozzles, flanges, and similar parts.

1.3 All grades are considered weldable under proper conditions.

1.4 The maximum thickness of forgings produced to this specification is limited only by the capacity of the selected grade to respond to any heat treatment specified and to meet the specified mechanical tests, including impact tests at the specified temperature.

1.5 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

1.6 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, the requirements of this specification shall prevail.

1.7 The values stated in either inch-pound units or SI [metric] units are to be regarded separately as the standard; within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.8 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

A788/A788M Specification for Steel Forgings, General Requirements

E112 Test Methods for Determining Average Grain Size

E165 Practice for Liquid Penetrant Examination for General Industry

2.2 *ASME Standards:*

ASME Boiler and Pressure Vessel Code

3. Ordering Information

3.1 In addition to the ordering information requirements of Specification A788/A788M, a detailed sketch or written description of the forging and the method of selecting the test location (see 6.2) should be supplied to the producer, when appropriate areas of significant in-service loading of the forging need to be designated.

3.2 The required impact test temperature should be supplied if different than the temperature listed in Table 3, otherwise the impact test shall be conducted at the temperature listed in Table 3 for the chosen Grade.

3.3 If a hubbed tube sheet is to be supplied for ASME Boiler and Pressure Code Application Supplementary Requirement S12 of Specification A788/A788M shall be specified.

TABLE 1 Chemical Requirements

	Composition, %				
	Grade I	Grade II	Grade III	Grade IV	Grade V
Carbon, max	0.30	0.30	0.20	0.20	0.30
Manganese	0.60 to 1.35	0.60 to 1.35	0.90 max	1.00–1.60	0.60–1.35
Phosphorus, max	0.020	0.020	0.020	0.020	0.020
Sulfur, max	0.020	0.020	0.020	0.020	0.020
Silicon	0.15 to 0.35	0.15 to 0.35	0.15 to 0.35	0.15–0.50	0.15–0.35
Nickel, max^A	0.50	0.50	3.3 to 3.8	0.50 max	1.0–2.0
Vanadium, max	0.05	0.05	0.05	0.06	0.03
Aluminum, max	0.05	0.05	0.05	0.05	0.05
Chromium,^{A} max	0.40	0.40	0.20	0.40	0.30
Molybdenum,^{A} max	0.10	0.10	0.06	0.10	0.12
Copper, max	0.35	0.35	0.35	0.35	0.35

^{A} Intentional additions of Cr, Mo, and Ni up to the specified maximum are permitted to be made to Grades I, II, and IV by the manufacturer.

3.4 If steel is required to be vacuum degassed, Supplementary Requirement S8 of Specification A788/A788M should be specified.

4. Heat Treatment for Mechanical Properties

4.1 Heat treatment shall consist of one of the following heat treatment options of the manufacturer's choice.

4.1.1 Normalize and temper.

4.1.2 Double normalize, wherein the second austenitizing temperature is at the same or lower temperature than the first, followed by tempering.

4.1.3 Quench and temper, with the option of adding a preliminary normalize before austenitizing for quenching in a suitable liquid medium. The type of cooling medium used shall be reported.

4.1.4 Use of an intercritical heat treatment cycle in accordance with Specification A788/A788M in which cooling from the full and partial austenitization stages may be done by liquid quenching or air cooling. The method of cooling and type of quench medium, if used, shall be reported.

4.1.5 The minimum tempering temperature shall be 1100ºF [590ºC].

5. Chemical Requirements

5.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A788/A788M shall comply with Table 1.

5.2 *Product Analysis*—The purchaser may use the product analysis provision of Specification A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat.

6. Mechanical Requirements

6.1 *General Requirements*—The forgings shall conform to the tension test requirements of Table 2. The forgings shall also conform to the impact test requirements of Table 3. The largest obtainable round tension test specimen as specified in Test Methods and Definitions A370 shall be used. Impact specimens shall be Charpy V-notch, Type A, as in Test Methods and Definitions A370. The usage of subsize impact specimens must have prior purchaser approval.

6.1.1 When agreed upon between the purchaser and the producer and specified on the order, impact tests may be made at temperatures different from those shown in Table 3 provided the test temperature is at least as low as the intended service temperatures and the provided impact energy requirements of Table 3 are met. Such forgings shall be suitably marked in accordance with 9.1 to identify the test temperature.

6.2 *Test Location*—Test coupons shall be taken so that the longitudinal axis and mid-length of tension and impact test specimens shall be positioned in accordance with one of the following methods:

6.2.1 *Method 1*—Forgings with 2 in. [50 mm] maximum thickness. The specimens shall have their longitudinal axis at the midthickness or the center of the cross section and with the midlength of the specimen at least 2 in. [50 mm] from any second surface.

6.2.2 *Method 2*—Grade I and Grade II forgings with thicknesses greater than 2 in. up to 4 in. [50 to 100 mm] inclusive, or Grade III and IV forgings with thicknesses greater than 2 in. up to 6 in. [50 to 150 mm] inclusive. The specimens shall have their longitudinal axis at least ¼ *T* of maximum heat-treated thickness from any surface and with the midlength of the specimen at least one *T* from any second surface. This is normally referred to as ¼ *T* by *T* when *T* is the maximum heat-treated thickness. A thermal buffer may be used to adhere to the condition in 6.3. Unless otherwise agreed upon, the following limitation for heat-treated thickness shall apply:

Grade	in. [mm], min	in. [mm], max
I	2 [50]	4 [100]
II	2 [50]	4 [100]
III	2 [50]	6 [150]
IV	2 [50]	6 [150]
V (Classes 1 and 2)	2 [50]	6 [150]

6.2.3 *Method 3*—For forgings thicker than described in Method 2 (6.2.2):

6.2.3.1 Prior to heat treatment the forging shall be machined to a purchaser supplied or approved drawing that indicates the locations of significant in-service loading in the finished part. The mechanical test specimens shall be located as an integral part of the forging such that the mid-point of the gauge length of the tension test specimen and the area under the notch of the impact specimens are located no closer than the dimension *t* from one heat treated surface and 2*t* from any other heat treated surface where *t* is the dimension from the area of significant loading to the heat treated surface, or ¾ in. [20 mm] whichever is the greater.

6.2.4 *Method 4*—This method shall be limited to forgings with a rough machined weight of not more than 1000 lb [455 kg]. Separate test forging when agreed upon between the purchaser and the supplier. Test coupons representing forgings from one heat and one heat treatment lot may be taken from a separately forged piece under the following conditions:

6.2.4.1 The separate test forging shall be of the same heat of material and shall be subjected to substantially the same reduction and working as the production forging it represents.

TABLE 2 Tensile Requirements

	Grade I	Grade II	Grade III	Grade IV	Grade V	
					Class 1	Class 2
Tensile strength, ksi [MPa]	60 to 85 [415 to 585]	70 to 95 [485 to 655]	70 to 95 [485 to 655]	80–105 [550–725]	60–85 [415– 585]	70–95 [485–655]
Yield strength,[A] in, ksi [MPa]	30 [205]	36 [250]	37.5 [260]	50 [345]	30 [205]	37.5 [260]
Elongation in 2 in. [50 mm], min, %	25	22	22	22	25	22
Reduction of area, min, %	38	30	35	30	38	35

[A] 0.2 % offset or 0.5 % total extension underload method.

TABLE 3 Charpy V-Notch Impact Requirements

	Grade I	Grade II	Grade III	Grade IV	Grade V (Classes 1 and 2)
Minimum average value of set of three specimens, ft-lbf (J)	13 [18]	15 [20]	15 [20]	26 [35][A]	15 [20]
Minimum value of one specimen, ft-lbf (J)	10 [14]	12 [16]	12 [16]	20 [27][A]	12 [16]
Test temperature of,[B] °F [°C]	−20 [−30]	−50 [−45]	−150 [−100]	−20 [−30]	-75 [-60]

[A] Mandatory conformance to the values listed is a matter of agreement between the purchaser and the manufacturer. The energy values above are shown for information as to guarantees that are generally available.
[B] Actual test temperature should be established at time of order. If no temperature is specified, tests will be made at test temperatures shown in this table.

6.2.4.2 The separate test forging shall be heat treated in the same furnace charge and under the same conditions as the production forging.

6.2.4.3 The separate test forging shall be of the same nominal thickness as the production forging.

6.2.4.4 Test coupons for small forgings as described in Method 2 shall be taken so that specimens shall have their longitudinal axes at the region midway between midthickness and the surface and with the midlength of the specimens no nearer any heat-treated edge than a distance equal to the forging thickness except when the thickness-to-length ratio of the production forging does not permit, in which case a production forging shall be used as the test forging and the midlength of the specimens shall be at the midlength of the test forging.

6.2.4.5 Test coupons for larger forgings shall be taken in accordance with Method 3 (6.2.3).

6.3 *Metal Buffers*—The required distances from treated surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at ½ in. [13 mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to assure freedom from cracks unless the welded areas are completely removed by subsequent machining.

6.4 Samples shall be removed from forgings after heat treatments. This sample material shall be subjected to a simulated post-weld heat treatment if Supplementary Requirement S6 is specified.

6.5 *Test Orientation:*

6.5.1 For upset disk forgings such as tube sheets the longitudinal axis of test specimens may be oriented in the radial or tangential direction, or parallel to the axis of the forging, as shown in Supplementary Requirement S12 of Specification A788/A788M.

6.5.2 For all other forgings the longitudinal axis of test specimens may be oriented parallel to the direction of maximum hot working of the forging.

6.6 *Number of Tests:*

6.6.1 *Forgings Under 500 lb [230 kg] As Treated*—For duplicate forgings weighing less than 500 lb as treated, one tension test and one impact test (three specimens) shall be made to represent each heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature control and equipped with recording pyrometers so that complete heat-treatment records are available, a heat-treatment charge shall be considered as any continuous run not exceeding an 8-h duration.

6.6.2 *Forging Weighing 500 to 10 000 lb [230 to 4500 kg] As-Heat Treated*—One tension and one impact test (three specimens) shall be made for each forging.

6.6.3 Each forging weighing over 10 000 lb [4500 kg] shall require two tension tests and two impact tests (three specimens). When the length (excluding prolongs) is equal to or less than 1½ times the diameter, the tests may be taken from one end of the forging with a tension test and one set of impact tests at each of two locations oriented 180° apart. When the length (excluding prolongs) is greater than 1½ times the diameter, one tension test and one set of impact tests must be taken from each location from opposite ends of the forging and the locations on each end should be oriented 180° apart from each other.

7. Repair Welding

7.1 Repair welding, as permitted by the purchaser, shall be performed in accordance with the ASME Boiler and Pressure Vessel Code.

8. Reporting

8.1 The type of quenching medium used for the heat treatment cycle in 4.1.3 shall be reported, or in the case of 4.1.4, whether air cooling or quenching was used and the type of quench medium if applicable. The other certification requirements of Specification A788/A788M also apply.

9. Product Marking

9.1 The test temperature, if different from that given in Table 3, shall be marked on the forging as a suffix to the Grade and Class designation. A prefix of 0 to the test temperature indicates that the temperature was under 0°F, or 0°C if the M designation specification is being used. For example, A765-11-075 would indicate that the impact testing for Grade 11 was done at -75°F instead of -50°F. A marking of A765M-11-10 would indicate that the impact testing was done at 10°F for a Grade 11 forging. For forgings tested under the M designation an example would be A765M-11-060 for a Grade 11 forging tested at -60°C or A765M-11-10 for a Grade 11 forging tested at 10°C.

10. Keywords

10.1 alloy steel forgings; carbon steel forgings; heat-treated; impact tested; intercritical heat treatment; pressure vessel; weldable

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the order. Details of these supplementary requirements shall have been previously negotiated and mutually agreed to between the forging manufacturer and the purchaser.

S1. Product Analysis

S1.1 The manufacturer shall use the product analysis provision of Specification A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat.

S2. Grain Size

S2.1 The forgings, subsequent to the final heat treatment, shall have prior austenitic grain size of 5 or finer as determined by the McQuaid-Ehn Test (Test Methods E112).

S3. Impact Transition Curve

S3.1 Sufficient impact tests shall be made from the forging test material to establish a temperature versus absorbed-energy curve. The test temperature range shall be wide enough to establish the upper and the lower shelf foot-pound-force (or joules) energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S4. Magnetic Particle Examination

S4.1 All accessible surfaces of the finished forging shall be examined by a magnetic particle method. This method shall be in accordance with Test Method A275/A275M.

S4.2 Acceptance criteria shall be specified.

S5. Liquid Penetrant Examination

S5.1 All surfaces shall be examined by a liquid penetrant method. The method shall be in accordance with Test Method E165.

S5.2 Acceptance criteria shall be specified.

S6. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S6.1 All test coupons shall be subjected to single or multiple heat treatments at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, times, and cooling rates.

S7.

Deleted

S8. Ultrasonic Examination

S8.1 Forgings shall be ultrasonically examined in accordance with the procedures of Practice A388/A388M.

S8.2 Acceptance criteria shall be specified.

S9.

Deleted

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SPECIFICATION FOR THROUGH-THICKNESS TENSION TESTING OF STEEL PLATES FOR SPECIAL APPLICATIONS

SA-770/SA-770M

(Identical with ASTM Specification A770/A770M-03(2018) except for editorial correction to Table 2.)

Standard Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications

1. Scope

1.1 This specification covers the procedures and acceptance standards for the determination of reduction of area using a tension test specimen whose axis is perpendicular to the rolled surfaces of steel plates 1 in. [25 mm] and greater in thickness. The principal purpose of the testing is to provide a measure of the resistance of a steel plate to lamellar tearing. (See Appendix X1.)

1.2 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 This specification is expressed in both inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

3. Ordering Information

3.1 The inquiry and order shall include the following, if required:

3.1.1 Supplementary requirements that are available to meet end use requirements (see S1 through S5).

3.1.2 Special requirements agreed upon between the manufacturer and the purchaser.

4. Tension Tests

4.1 *Number of Tests:*

4.1.1 Two tests shall be required from each plate-as-rolled, except for plates subjected to heat treatment by quenching and tempering. Two tests shall be required from each quenched-and-tempered plate. The tests shall be representative of the plate in its final condition.

4.1.2 When plates are furnished by the manufacturer in an unheat-treated condition and qualified by heat-treated specimens (including normalized, normalized and tempered, and quenched and tempered), two tests shall be required from each plate-as-rolled.

NOTE 1—The term "plate-as-rolled'' refers to the unit plate rolled from a slab or directly from an ingot. It does not refer to the condition of the plate.

4.2 *Location of Test Coupons*—Take one test coupon at each end of each plate as defined in 4.1. Take the test coupons from the center of the plate width.

4.3 *Orientation of Test Specimens*—The longitudinal axis of the reduced section of the test specimens shall be perpendicular to the rolled surface of the plate.

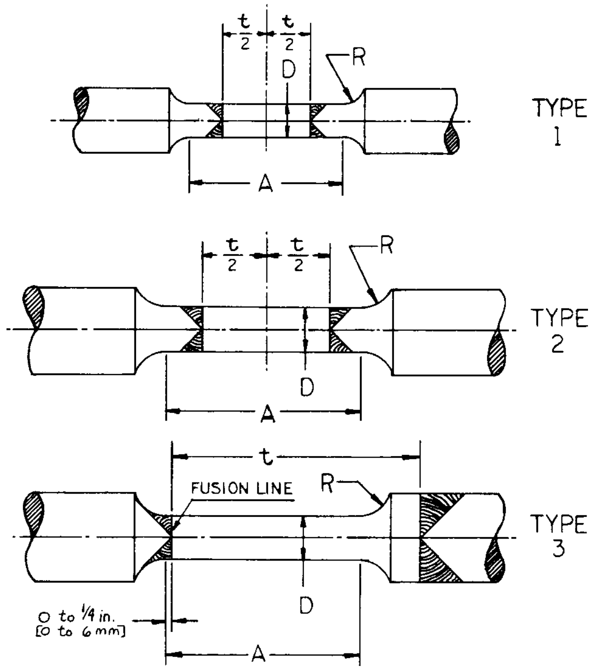
4.4 *Preparation of Test Specimens:*

4.4.1 *Welded Prolongations*—When required, join welded prolongations to the surface(s) of the plate being tested. The joining method used shall be one which results in a minimal heat-affected zone in the portion of the plate to be tested. Shielded metal arc, friction, stud, or electron-beam welding methods have proven to be suitable.

4.4.2 *Standard Test Specimens:*

4.4.2.1 Three types of standard round tension test specimens are shown in Fig. 1 and Table 1. For Types 1 and 2 specimens, locate the center of the length of the reduced section at the approximate mid-point of the plate thickness. For Type 3 specimens, locate the weld fusion line of one plate surface within ¼ in. [6 mm] of one end of the reduced section.

4.4.2.2 For plates from 1 in. [25 mm] to 1¼ in. [32 mm] inclusive in thickness, use either the 0.350-in. [8.75-mm] Type 1 specimen or the 0.500-in. [12.5-mm] Type 2 specimen.



NOTE 1—For Type 3 only one welded prolongation may be needed, depending upon plate thickness.

FIG. 1 Standard Round Tension Test Specimens

TABLE 1 Schedule of Standard Test Specimens, Inches [Millimetres][A]

	Specimen Type		
	1	2	3
Plate thickness (*t*)	1 ≤ *t* ≤ 1¼	1 < *t* ≤ 2	2 < *t*
Diameter (*D*)	0.350 [8.75]	0.500 [12.5]	0.500 [12.5]
Radius, minimum (*R*)	¼ [6]	⅜ [10]	⅜ [10]
Length of reduced section (*A*)	1¾ [45]	2¼ [60]	2¼ [60]

[A] See Test Methods and Definitions A370 (Fig. 5 for further details and Fig. 6 for various types of ends).

4.4.2.3 For plates over 1¼ in. to 2 in. [50 mm] inclusive in thickness, use the 0.500-in. [12.5-mm] Type 2 specimen.

4.4.2.4 For plates greater than 2 in. [50 mm] in thickness, use the Type 3 specimen.

4.4.3 *Alternative Test Specimens*—The alternative test specimens in Fig. 2 and Table 2 may be used in place of the standard specimens in Fig. 1 and Table 1.

4.4.3.1 For plates over 2 in. [50 mm] in thickness, Type A or Type B specimens may be used. The Type A specimen provides a reduced section length greater than the plate thickness. The Type B specimen provides a reduced section length of 2¼ in. [57 mm] with its center at the mid-thickness of the plate. Over a minimum plate thickness determined by the specimen end configuration, no welded prolongations may be needed for the Type B specimen. For plates over 4¼ in. [108 mm] in thickness, the Type C specimen may be used. For plates over 6 in. [150 mm] in thickness, a series of two or more Type A or Type C specimens with reduced sections of 4 in. [100 mm] or less may be used to cover the full thickness of the plate. The number of tests required will depend upon the thickness of the plate being tested and the reduced section length selected.

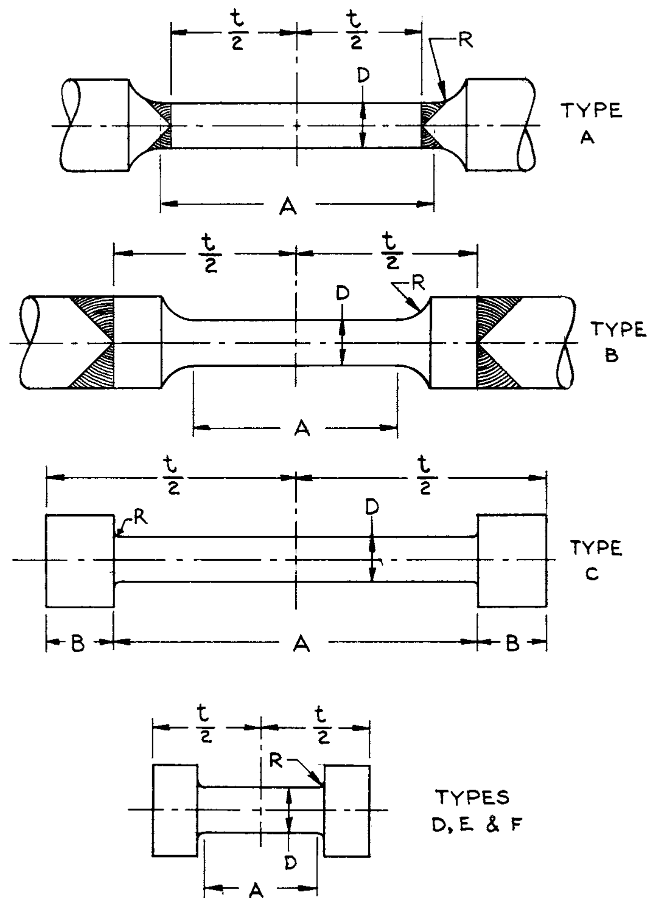


FIG. 2 Alternative Tension Test Specimens

4.4.3.2 For plates over 1 in. [25 mm] in thickness, a series of button-head specimens shown in Fig. 2 and Table 2 may be used. The test specimen type to be used, Type D, Type E, or Type F, is determined by the nominal plate thickness as described in Table 2. A series of two or more Type F specimens may be used to cover the full thickness of the plate. The length of the reduced section (*A*), as shown in Fig. 2 and specified in Table 2, is the length of the reduced section excluding the machined radius (*R*). Within the plate thickness dimension specified for each test specimen type, either the button-head thickness, the reduced section length, or the machined radius may be varied. In all cases, the minimum length of the reduced section must be as specified in Table 2 to maintain a minimum length to diameter ratio (see Appendix X2.2).

5. Acceptance Standards

5.1 Each tension test shall have a minimum reduction of area no less than 20 %. If the reduction of area of both tests is less than 20 %, no retest shall be permitted. If the reduction of area of one of the two tests from a plate is less than 20 %, one retest of two additional specimens taken from a location adjacent to the specimen that failed may be made, and both of these additional specimens shall have a reduction of area of 20 % or more.

TABLE 2 Schedule of Alternative Test Specimens, Inches [Millimetres]

	Specimen Type					
	A[A]	B[A]	C[B]	D	E	F
Plate thickness (t)	2 < t [50 < t]	2 <t [50 < t]	4¼ < t [108 < t]	1 ≤ t ≤ 1 ¾ [25 ≤ t ≤ 45]	1¾ < t ≤ 2½ [45 ≤ t ≤ 64]	2½ < t [64 < t]
Diameter (D)	0.500 [12.5]	0.500 [12.5]	0.500 [12.5]	0.250 [6.25][C] ± 0.005 [0.10]	0.350 [8.75][C] ± 0.007 [0.18]	0.500 [12.5][C] ± 10.010 [0.25]
Radius, min (R)	⅜ [10]	⅜ [10]	1⁄16 [2]	optional	optional	optional
Length of reduced section, min(A)	t + ¼ min [t + 6]	2¼ [60]	t − 1½ [t − 38]	0.625 [16]	0.875 [22]	1.250 [32]

[A] See Test Methods and Definitions A370 (Fig. 5 for further details and Fig. 6 for various types of ends).
[B] See Test Methods and Definitions A370 (Fig. 6, specimen 3 for further details).
[C] The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 % larger in diameter than the center (controlling dimension).

5.2 Failures occurring in the prolongations, the weld, or in the fusion line shall be considered as a "no-test," and an additional specimen shall be tested.

6. Marking

6.1 Plates accepted in accordance with this specification shall be identified by stamping or stenciling ZT adjacent to the marking required by the applicable product specification.

7. Keywords

7.1 lamellar tearing; special steel-making processes; steel plate; through-thickness tension testing

SUPPLEMENTARY REQUIREMENTS

These requirements apply only when specified by the purchaser.

S1. Tensile Strength Requirements

S1.1 Tensile strength shall conform to a minimum value which is subject to agreement between the manufacturer and purchaser.

S2. Yield Strength Requirements

S2.1 Yield strength, for plates 2 in. [50 mm] and over in thickness, shall conform to a minimum value which is subject to agreement between the manufacturer and purchaser.

S3. Reduction of Area Requirements

S3.1 A minimum reduction of area limit higher than that in 5.1 may be specified subject to agreement between the manufacturer and purchaser.

S4. Number of Tests

S4.1 A greater number of tests than indicated in 4.1 may be specified subject to agreement between the manufacturer and purchaser.

S5. Location of Test Coupons

S5.1 Test coupons from locations in addition to those specified in 4.2 may be specified subject to agreement between the manufacturer and purchaser.

APPENDIXES

(Nonmandatory Information)

X1. LAMELLAR TEARING ADJACENT TO WELDS

X1.1 Introduction

X1.1.1 Lamellar tearing is a particular type of cracking that occurs under the weld of a steel plate weldment. It is generally caused by strain induced in the thickness direction resulting from shrinkage of the weld deposit and by the restraint imposed by the components that comprise the weldment. High restraint increases the possibility of lamellar tearing. However, lamellar tearing is not solely confined to highly restrained weldments. Lamellar tearing may also result from loads on the plate surface.

X1.2 Characteristics of Lamellar Tearing

X1.2.1 Lamellar tearing normally occurs in susceptible material underneath the weld, in a direction generally parallel to the plate surface and often slightly outside the heat-affected zone. Lamellar tearing generally has a step-like appearance consisting of "terraces" (cracks running parallel to the plate surface) and "walls" (cracks which connect the individual terraces). The tearing may remain completely subsurface or appear at plate edges or at weld toes.

X1.3 Inclusions

X1.3.1 The step-like cracking characteristic of lamellar tearing is usually considered to result from small elongated nonmetallic inclusions that are normally present in the steel. Strains in the through-thickness direction can cause individual inclusions to fractures or decohere from the surrounding steel matrix, thus initiating a void. Further strain can cause the remaining metallic ligaments to shear or rupture, resulting in the step-like fracture appearance.

X1.3.2 A high or concentrated inclusion content in the steel produces planar regions of poor ductility parallel to the steel surface. On the other hand, a reduction in the magnitude and concentration of these inclusions to a low level tends to preclude any easy fracture path along the low ductility inclusions and the steel exhibits improved ductility in a through-thickness direction.

X1.3.3 The extent of nonmetallic inclusions depends on the type of steel. In silicon semikilled or fully killed steels, these inclusions are primarily oxides (present as silicates) and sulfides (present as manganese sulfides). For aluminum-silicon killed steels, these inclusions are primarily sulfides (manganese sulfides). To improve the through-thickness ductility and thus the resistance of the steel to lamellar tearing, it is necessary to reduce the level of the nonmetallic inclusions. To provide a high resistance to lamellar tearing may require the use of special steel-making processes that can reduce the oxygen and sulfur contents in the steel to very low levels.

X1.4 Steel Manufacturing Processes

X1.4.1 Special steel-making processes are available for improving the through-thickness ductility. The more common processes, used singly or in combination, are: (*1*) low sulfur practices; (*2*) inclusion shape control; (*3*) electroslag or vacuum arc remelting; and (*4*) vacuum degassing. The steel-making processes are not all intended for the same purpose, but will improve the through-thickness ductility to various degrees depending on the process used.

X1.5 Through-Thickness Ductility Requirements

X1.5.1 Susceptibility to lamellar tearing depends on many factors (for example, restraint, welding conditions, etc.) and, consequently a specific through-thickness ductility requirement does not provide a guarantee against lamellar tearing. The most widely accepted method of measuring the material ductility factor of susceptibility to lamellar tearing is the reduction of area of a round tension test specimen oriented perpendicular to the rolled surface of a plate.

X2. TESTING PARAMETERS AFFECTING REDUCTION OF AREA VALUES

X2.1 Variability of Through-Thickness Properties

X2.1.1 Through-thickness tension test results, and in particular the reduction of area determination as provided for in this specification, are subject to substantially greater scatter than would normally be expected from standard tension tests of a plate in the longitudinal or transverse direction. This scatter of test results is due in part to the inherent variability of the distribution of the nonmetallic inclusions discussed in X1.3. For example, those nonmetallic inclusions that form during the solidification phase of the steelmaking process tend to occur with a higher frequency in the area of final solidification.

X2.1.2 Test specimen design may also have an effect on the test results. Some of these factors are discussed in X2.2. Operator technique will also be a factor in increasing scatter, particularly in the measurement of the final diameter of the test specimen. Because of the effect of inclusions on the fracture process, the appearance of the final fracture may be quite different than the classical cup-cone fractures common to longitudinal and transverse tension testing. For those materials with approximately 20 % reduction of area, the final diameter measurement may require a substantial amount of judgment on the part of the test operator.

X2.1.3 In view of the potential variability of the through-thickness reduction of area test results, it is recognized that two tests per plate are not sufficient to fully characterize the through-thickness ductility of that plate. The number of tests and test positions have not been established that would provide a good estimate of both the mean and the variability of through-thickness tensile reduction of values of a plate. Therefore, an average value requirement is not included in this specification. The intent of this specification is to qualify a plate according to the described testing procedures using only a minimum value requirement. The potential variability of the test results also increases the possibility that subsequent testing of a steel plate qualified according to this specification may produce results that do not meet the specified acceptance standard.

X2.2 Effects of Test Specimen Design

X2.2.1 Two main factors considered in the selection of test specimen geometry were the diameter and the slenderness ratio. It is generally accepted that there is a diameter effect on reduction-of-area values such that a smaller diameter specimen generally yields a higher average reduction in area value. It is also accepted that smaller diameter test specimens will tend to give greater variability to the resulting reduction in area values. Because these relationships between the test specimen diameter and the average and variability of the test result have not been satisfactorily quantified at this time, the same minimum requirement has been applied to all test specimen diameters.

X2.2.2 The slenderness ratio (reduced section length/reduced section diameter) is known to affect the reduction in area values when below a minimum value. This minimum value may be from 1.5 to 2.5, depending on the material. Below this minimum value, the reduction at the failure point in the reduced section is restrained by the larger cross section away from the reduced section. A minimum slenderness ratio of 2 was selected for the standard Type 2 specimen to allow a 0.500-in. [12.5-mm] diameter specimen to be used on a 1-in. [25-mm] plate. A minimum slenderness ratio of 2.5 was selected for the collar-button specimens (Types D, E, and F) to ensure that this effect is minimized for these test specimens.

SPECIFICATION FOR CASTINGS, STEEL AND ALLOY, COMMON REQUIREMENTS, FOR GENERAL INDUSTRIAL USE

SA-781/SA-781M

(Identical with ASTM Specification A781/A781M-06.)

SPECIFICATION FOR CASTINGS, STEEL AND ALLOY, COMMON REQUIREMENTS, FOR GENERAL INDUSTRIAL USE

SA-781/SA-781M

(Identical with ASTM Specification A 781/A 781M-06.)

1. Scope

1.1 This specification covers a group of requirements that are mandatory requirements of the following steel casting specifications issued by ASTM. If the product specification specifies different requirements, the product specification shall prevail.

ASTM Designation	Title of Specification
A 27/A 27M	Steel Castings, Carbon, for General Application
A 128/A 128M	Steel Castings, Austenitic Manganese
A 148/A 148M	Steel Castings, High-Strength, for Structural Purposes
A 297/A 297M	Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat-Resistant for General Application
A 447/A 447M	Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service
A 494/A 494M	Castings, Nickel and Nickel Alloy
A 560/A 560M	Castings, Chromium-Nickel Alloy
A 743/A 743M	Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
A 744/A 744M	Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
A 747/A 747M	Steel Castings, Stainless, Precipitation Hardening
A 890/A 890M	Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
A 915/A 915M	Steel Castings, Carbon and Alloy Chemical Requirements Similar to Standard Wrought Grades
A 958	Steel Castings, Carbon and Alloy, with Tensile Requirements, Chemical Requirements Similar to Standard Wrought Grades
A 1002	Castings, Nickel-Aluminum Ordered Alloy

1.2 This specification also covers a group of supplementary requirements that may be applied to the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 The requirements of the individual material specification, and this general specification shall prevail in the sequence named.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 781 and SI units for material ordered to Specification A 781M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 27/A 27M Specification for Steel Castings, Carbon, for General Application

A 128/A 128M Specification for Steel Castings, Austenitic Manganese

A 148/A 148M Specification for Steel Castings, High Strength, for Structural Purposes

A 297/A 297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems

A 447/A 447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service
A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
A 494/A 494M Specification for Castings, Nickel and Nickel Alloy
A 560/A 560M Specification for Castings, Chromium-Nickel Alloy
A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof
A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application.
A 744/A 744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
A 747/A 747M Specification for Steel Castings, Stainless Precipitation Hardening
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 800/A 800M Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof
A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
A 890/A 890M Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
A 915/A 915M Specification for Steel Castings, Carbon, and Alloy, Chemical Requirements Similar to Standard Wrought Grades
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 958 Specification for Steel Castings, Carbon and Alloy, with Tensile Requirements, Chemical Requirements Similar to Standard Wrought Grades
A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts
A 991/A 991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
A 1002 Specification for Castings, Nickel-Aluminum Ordered Alloy
E 94 Guide for Radiographic Examination
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E 165 Test Method for Liquid Penetrant Examination
E 186 Reference Radiographs for Heavy-Walled (2 to 4½ in. [51 to 114 mm]) Steel Castings
E 280 Reference Radiographs for Heavy-Walled (4½ to 12 in. [114 to 305 mm]) Steel Castings
E 340 Test Method for Macroetching Metals and Alloys
E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
E 446 Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness
E 709 Guide for Magnetic Particle Examination

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Test Methods and Definitions A 370, Test Methods, Practices, and Terminology A 751, and Terminology A 941 are applicable to this specification and those listed in 1.1.

3.1.2 *test coupon, n* — the part from which the test specimen will be extracted.

3.1.3 *test specimen, n* — the part that will be acted upon in a test.

4. Materials and Manufacture

4.1 *Melting Process* — The steel shall be made by open-hearth or electric furnace process with or without separate refining, such as argon-oxygen-decarburization (AOD), unless otherwise specified in the individual specification.

4.2 *Heat Treatment:*

4.2.1 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A 991/A 991M.

4.2.2 When castings are heat treated at temperatures above 2000°F [1100°C], then the working zone shall have been established by a survey performed at not more than 25°F [15°C] below nor more than 200°F [110°C] above the minimum heat treatment temperature specified for the grade. If a minimum heat treatment temperature is not specified for the grade, then the survey temperature shall be not more than 50°F [30°C] below nor more than 175°F [100°C] above the furnace set point used.

4.2.3 The maximum variation in measured temperature as determined by the difference between the highest temperature and the lowest temperature shall be as agreed between the purchaser and producer except that during production heat treatment, no portion of the furnace shall be below the minimum specified temperature nor above the maximum specified temperature for the grade being processed.

5. Chemical Composition

5.1 *Chemical Analysis* — Chemical analysis of materials covered by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Heat Analysis* — An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in the individual specification for the grade being poured. The analysis shall be made from a test sample preferably taken during the pouring of the heat. When drillings are used, they shall be taken not less than $\frac{1}{4}$ in. [6.4 mm] beneath the surface. The chemical composition thus determined shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis* — A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis of carbon and alloy steel shall be taken no closer than $\frac{1}{4}$ in. [6 mm] to a cast surface, except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low alloy steel castings may vary from the specified limits by the amounts shown in Table 1. The product analysis tolerances of Table 1 are not applicable as acceptance criteria for heat analysis by the casting manufacturer. When comparing product and heat analysis for other than carbon and low alloy steels, the reproducibility Data R_2, in Test Methods E 353 or E 354, as applicable, shall be taken into consideration.

5.4 *Unspecified Elements* — When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S13 may be specified.

5.4.1 Grade substitution, for stainless steel or nickel base alloy castings, is not permitted. Grade substitution occurs when the material supplied:

(1) contains an element, other than nitrogen, that is not specified in the ordered grade; and,

(2) the amount of that element equals or exceeds the minimum requirement for the element in another grade for which it is specified.

For this requirement, a grade is defined as an alloy described individually in a table of chemical requirements within any specification listed within the scope of A 781/A 781M.

6. Mechanical Test Requirements

6.1 The individual product specifications vary as to whether mechanical tests are required; for this reason, and to determine specific test requirements, the individual product specification should be reviewed.

6.2 Unless otherwise specified by the purchaser, when mechanical properties are required by the product specification, test coupons may be cast integrally with the castings, or as separate blocks, in accordance with Fig. 1, Fig. 2, or Fig. 3, except when Supplementary Requirement S15 is specified. The test coupon in Fig. 3 shall be employed only for austenitic alloy castings with cross sections less than $2\frac{1}{2}$ in. [65 mm].

7. Workmanship, Finish, and Appearance

7.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser, the dimensions of the casting shall be as predicated by the pattern.

8. Quality

8.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

8.2 When additional inspection is desired, Supplementary Requirements S1, S2, S3, S4, or S5 may be specified.

8.3 Rejectable indications shall not be peened, plugged, or impregnated.

9. Repair

9.1 Repair by welding shall be in accordance with the requirements of the individual specification using procedures and welders qualified in accordance with Practice A 488/A 488M.

10. Inspection

10.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.3), shall be made at the place of manufacture unless otherwise agreed.

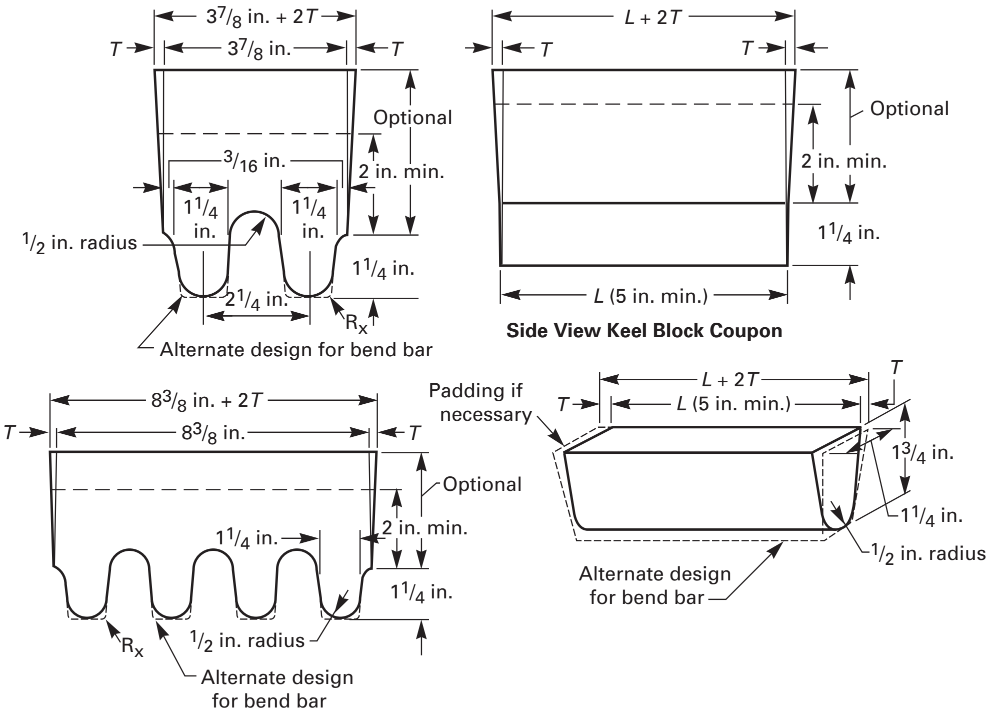
11. Rejection

11.1 Subsequent to acceptance at the manufacturer's works, material that is found to be unacceptable as determined by requirements specified in the order may be rejected by the purchaser. The manufacturer should be notified of such rejection. If the manufacturer is dissatisfied with the results of any tests performed by the purchaser, he may make claim for a rehearing.

12. Keywords

12.1 castings; common requirements; steel and alloy

FIG. 1 TEST COUPONS FOR CASTINGS WITH DETAILS OF DESIGN



GENERAL NOTE: Radius of casting coupon interface at option of foundry.

Metric Equivalents

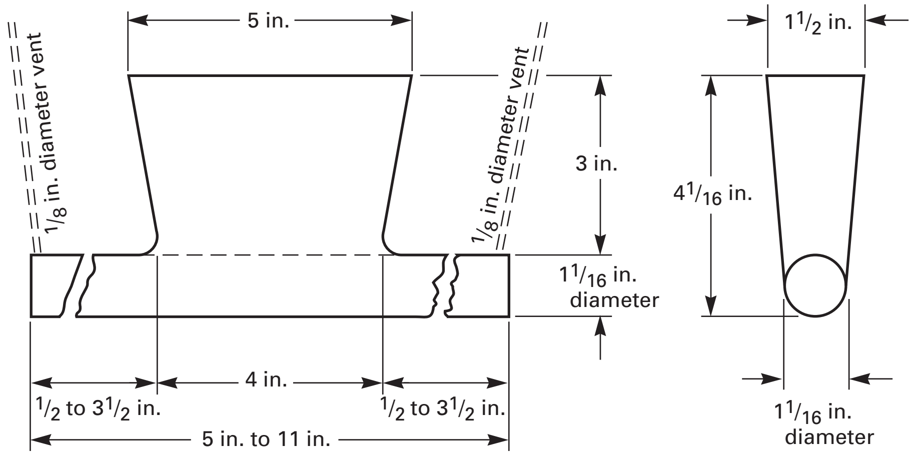
in.	³⁄₁₆	½	1¼	1¾	2	2¼	3⅞	5	8⅜
[mm]	[4.8]	[13]	[32]	[45]	[51]	[57]	[98]	[127]	[213]

	Leg Design [125 mm]		Riser Design
1. *L* (length)	A 5 in. [125 mm] minimum length will be used. This length may be increased at the option of the foundry to accommodate additional test specimens (see Note 1).	1. *L* (length)	The length of the riser at the base will be the same as the top length of the leg. The length of the riser at the top therefore depends on the amount of taper added to the riser.
2. End Taper	Use of and size of end taper is at the option of the foundry.	2. Width	The width of the riser at the base of a multiple-leg coupon shall be *n* (2¼) [57 mm] – ⅝ [16 mm] where *n* equals the number of legs attached to the coupon. The width of the riser at the top is therefore dependent on the amount of taper added to the riser.
3. Height	1¼ in. [32 mm]		
4. Width (at top)	1¼ in. [32 mm] (see Note 1).		
5. Radius (at bottom)	½ in. [13 mm], max		
6. Spacing between legs	A ½ in. [13 mm] radius will be used between the legs.	3. *T* (riser taper) height	Use of and size is at the option of the foundry. The minimum height of the riser shall be 2 in. [51 mm]. The maximum height is at the option of the foundry for the following reasons: (*a*) many risers are cast open. (*b*) different compositions may require variation in risering for soundness. (*c*) different pouring temperatures may require variation in risering for soundness.
7. Location of test specimens	The tensile, bend, and impact specimens will be taken from the lower portion of the leg (see Note 2).		
8. Number of legs	The number of legs is at the option of the foundry providing they are equi-spaced according to item 6.		
9. R_s	Radius from 0 to approximately ¹⁄₁₆ in. [2 mm].		

NOTE 1 — *Test Coupons for Large and Heavy Steel Castings:* The test coupons in Fig. 1 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired.

NOTE 2 — *Bend Specimen:* If a bend specimen is required, an alternate design (as shown by dotted lines in Fig. 1) is indicated.

FIG. 2 TEST COUPON FOR TENSION TEST

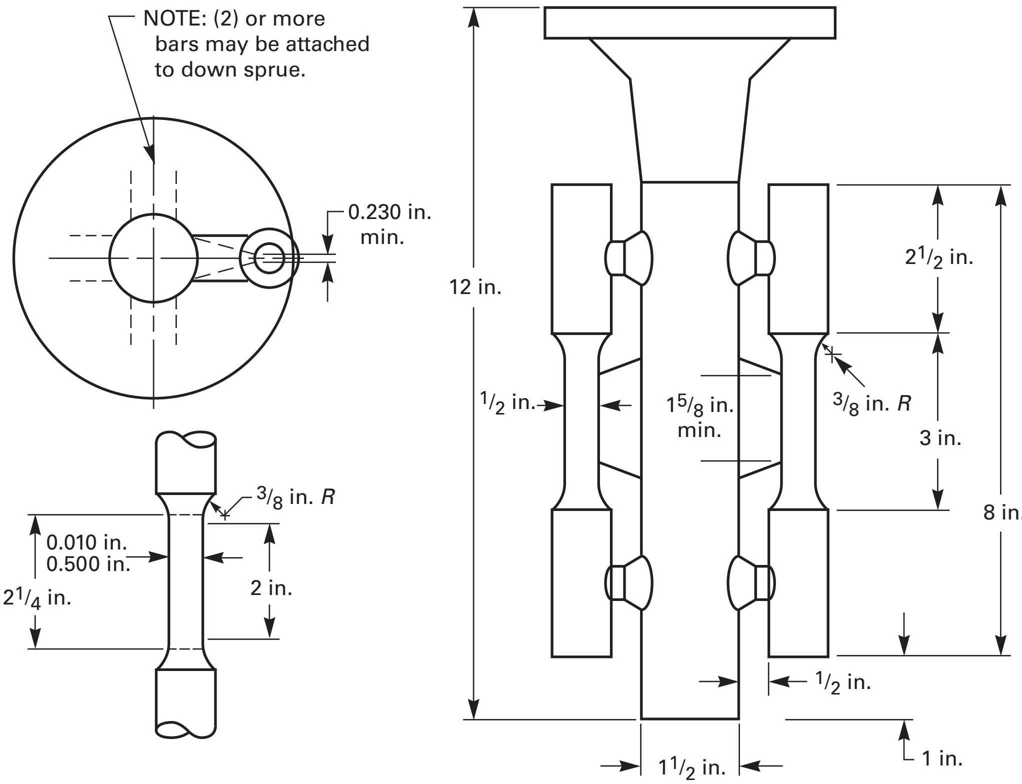


Metric Equivalents

in.	(mm)	in.	(mm)
1/8	(3.2)	3 1/2	(88.9)
1/2	(12.7)	4	(101.6)
1 1/16	(27.0)	4 1/16	(103.2)
1 1/2	(38.1)	5	(127.0)
3	(76.2)	11	(279.4)

GENERAL NOTE: Pour through head; cover molten head with powdered charcoal, coke dust, etc., immediately after pouring, in order to keep head fluid as long as possible.

FIG. 3 CAST-TO-SHAPE TEST COUPON FOR TENSION SPECIMEN



GENERAL NOTE: Coupons produced in this manner are suitable for austenitic alloys only. The mold may be preheated for pouring to produce a sound coupon.

TABLE 1
PRODUCT ANALYSIS TOLERANCES

Element	Range, %[A]	Tolerances[B,C] Over Maximum or Under Minimum Limit, %
C	up to 0.65	$0.03 \times \%\ C_L + 0.02$
	above 0.65	0.04
Mn	up to 1	$0.08 \times \%\ Mn_L + 0.01$
	above 1	0.09
Si	up to 0.60	$0.22 \times \%\ Si_L - 0.01$
	above 0.60	0.15
P	all	$0.13 \times \%\ P_L + 0.005$
S	all	$0.36 \times \%\ S_L + 0.001$
Ni	up to 2	$0.10 \times \%\ Ni_L + 0.03$
	above 2	0.25
Cr	up to 2	$0.07 \times \%\ Cr_L + 0.04$
	above 2	0.18
Mo	up to 0.6	$0.04 \times \%\ Mo_L + 0.03$
	above 0.6	0.06
V	up to 0.25	$0.23 \times \%\ V_L + 0.004$
	above 0.25	0.06
W	up to 0.10	$0.08 \times \%\ W_L + 0.02$
	above 0.10	0.02
Cu	up to 0.15	$0.18 \times \%\ Cu_L + 0.02$
	above 0.15	0.05
Al	up to 0.10	$0.08 \times \%\ Al_L + 0.02$
	above 0.10	0.03

[A] The range denotes the composition limits up to which tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript $_L$ for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit (if applicable), respectively. Examples of computing tolerances are presented in footnote *C*.

[C] To illustrate the computation of the tolerance, consider the manganese maximum of 0.70 for an 0.30 carbon grade 65–35 in Specification A 27/A 27M. The maximum permissible deviation is $(0.08 \times 0.70 + 0.01) = 0.066$. Therefore, the highest acceptable product analysis is 0.766. Similarly, for a 0.20 carbon grade 70–40 in Specification A 27/A 27M, the maximum manganese content is 1.40; thus, the highest acceptable product analysis is $(1.40 + 0.09) = 1.49$.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface and near surface discontinuities by magnetic particle examination. The examination shall be in accordance with Guide E 709. Extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S2. Radiographic Examination

S2.1 Castings shall be examined for internal defects by means of X rays or gamma rays. The procedure shall be in accordance with Guide E 94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 446, E 186, or E 280. Extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Test Method E 165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S4. Ultrasonic Examination

S4.1 Castings shall be examined for internal defects by means of ultrasonic examination. The examination procedure shall be in accordance with Practice A 609/A 609M. Extent of examination, methods of testing, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S5. Examination of Weld Preparation

S5.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the examination method specified for the casting. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125, of Degree 2 in sections up to 2 in. [50.8 mm] thick and of Degree 3 in sections over 2 in. thick shall be acceptable.

S6. Certification

S6.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year date) and was found to meet the requirements.

S6.2 A manufacturer's certification printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility provided it conforms to any existing EDI agreement between the purchaser and the supplier.

S7. Prior Approval of Major Weld Repairs

S7.1 Major weld repairs as defined and agreed upon between the manufacturer and purchaser shall be subject to the prior approval of the purchaser.

S8. Marking

S8.1 The manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings. When further specified, the heat numbers or serial numbers shall be marked on individual castings.

S9. Charpy Impact Test

S9.1 Charpy impact test properties shall be determined by testing a set of three Charpy V-notch specimens made from each heat at a test temperature agreed upon by the manufacturer and purchaser. The material from which the test specimens are prepared shall be cast in accordance with 6.2. The acceptance requirements shall be either energy absorbed, lateral expansion, or percent shear area, or all three, and shall be that agreed upon between the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S9.2 *Absorbed Energy* — Average energy value of three specimens shall be not less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S9.3 *Lateral Expansion* — Lateral expansion value shall be agreed upon between the manufacturer and purchaser.

S9.4 *Percent Shear Area* — Percent shear area shall be agreed upon between the manufacturer and purchaser.

S10. Hardness Test

S10.1 Hardness measurements at specified locations on the castings shall be made in accordance with Test Methods and Definitions A 370 and reported.

S11. Specified Ferrite Content Range

S11.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the chemical composition procedure of Practice A 800/A 800M, shall be in conformance with the specified ferrite content range.

S11.2 The specified ferrite content range shall be as agreed upon between the manufacturer and the purchaser. The minimum specified ferrite content range shall be 10% with the minimum ferrite content being no lower than the percent necessary to achieve the minimum mechanical properties required for the alloy.

S11.3 Should the purchaser wish to have the ferrite content determined by either magnetic response or metallographic methods, the purchaser should impose Supplementary Requirement S1 or S2 of Practice A 800/A 800M.

S12. Test Report

S12.1 The manufacturer shall supply a test report to the purchaser giving the results of all tests performed including chemical analysis.

S13. Unspecified Elements

S13.1 Chemical analysis and limits for elements not specified for the grade ordered shall be as agreed upon between the manufacturer and purchaser.

S14. Tension Test from Castings

S14.1 In addition to the tension test required by the material specification, test material shall be cut from the casting. The mechanical properties and location for the test material shall be agreed upon by the manufacturer and purchaser.

S15. Alternate Mechanical Test Coupons and Specimen Locations for Castings

S15.1 Test coupons may be cast integrally with the castings or separately. Separately cast coupons shall be heat-treated together with the castings they represent.

S15.2 In the following, the casting thickness, *T*, is the maximum thickness of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension, *T*, is for the casting.

S15.3 One of the following shall apply:

S15.3.1 The longitudinal centerline of the test specimen shall be taken at least $\frac{1}{4}$ *T* from the *T* dimension surface and all of the gage length must be at least 1*T* from any other heat treated surface, exclusive of the surface opposite the *T* dimension surface. [See Fig. S15.1(a).] For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least $\frac{1}{4}$ *T* from the outside or inside and all of the gage length must be at least *T* from the as-heat-treated end. [See Fig. S15.1(b).] For ferritic and martensitic castings, partial severing of test coupons prior to final heat treatment is permitted.

S15.3.2 Where separately cast test coupons are used, the dimension shall not be less than 3*T* by 3*T* by *T* and each specimen shall meet the requirements of S15.3.1, except that when *T* exceeds 5 in. [125 mm], the dimension may be 15 by 15 by 5 in. [375 by 375 by 125 mm], by agreement between the manufacturer and the purchaser. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents. Centrifugal castings may be represented by statically cast coupons. (See Fig. S15.2.)

S15.3.3 When agreed upon by the manufacturer and the purchaser, castings that are cast or machined to essentially the finished configuration prior to heat-treatment shall have test specimens removed from a prolongation or other stock on the casting at a location below the nearest heat-treated surface indicated on the order. The specimen location shall be at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high-tensile-stress surface will be from the nearest heat-treated surface and a minimum of twice this distance from a second heat-treated surface, except that the test specimens shall be no nearer than $\frac{3}{4}$ in. [19 mm] to a heat-treated surface and $1\frac{1}{2}$ in. [38 mm] from a second heat-treated surface. (See Fig. S15.3.)

S15.3.4 Where specimens are to be removed from the body of quenched and tempered castings, either the requirements of S15.3.1 shall be met or a steel thermal buffer pad or thermal insulation or other thermal barriers shall be used during heat-treatment. Steel thermal buffer pads shall be a minimum of T by T by $3T$ in length and shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface. Test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of $\frac{1}{2}$ in. [13 mm] from the buffered surface and $\frac{1}{4}$ T from other heat-treated surfaces (see Fig. S15.4). When thermal insulation is used, it shall be applied adjacent to the casting surface where the test specimens are to be removed. The producer shall demonstrate that the cooling rate of the test specimen location is no faster than that of specimens taken by the method described in S15.3.1.

S16. Weld Repair Charts

S16.1 Major weld repairs shall be documented by means of sketches or photographs, or both, showing the location and major dimensions of cavities prepared for welding. Documentation shall be submitted to the purchaser at the completion of the order.

S16.2 A weld repair shall be considered major when it is made to correct leakage on hydrostatic testing, or when the depth of the cavity prepared for welding exceeds 20% of the actual wall thickness or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2].

S17. Macroetch Test

S17.1 Apply Supplementary Requirement S13 for the spectrographic determination and reporting of the total residual aluminum content of all heats of ferritic and martensitic steels subjected to this macroetch test.

S17.2 When the heat analysis indicates a total residual aluminum content in excess of 0.08%, the manufacturer shall etch a cross section of the casting with the heaviest section for which this supplementary requirement is invoked, or a coupon attached to that heaviest section or an area directly under a riser (see Note S17.1). Cross sections from a separately cast test block from the same heat and of a thickness representative of the heaviest section of castings purchased under this supplementary requirement may also be used for macroetch testing. The etching shall be performed on the selected section after its heat treatment, that is, after annealing, normalizing, or quenching and tempering following the initial cooling of the steel below the transformation range.

NOTE S17.1 — High strength martensitic castings, in particular, may be damaged beyond use if the etch is applied directly to the casting.

S17.3 The preparation of the surface and the macroetching procedure with Solution No. 1 (1:1 HCl) of Table 5 in Test Method E 340 shall be followed. The resulting etched surface shall be compared and rated with the reference photographs in Fig. S17.1 depicting ten levels of severity of intergranular network structures indicative of the presence of aluminum nitride or other constituents prone toward precipitating at grain boundaries during solidification and subsequent cooling. Fig. S17.1 relates the severity levels shown in these photographs with specific delineation widths and percent of boundary outlining in the etched structures.

S17.4 Castings represented by etched structures exhibiting a network rating in excess of Severity Level 4 shall be considered unacceptable until further evaluations are completed. The acceptability of individual castings may be determined by etching sections of each casting to ascertain the network severity level. Disposition of unacceptable castings shall be a matter of agreement between the manufacturer and purchaser. Those castings exhibiting etched severity levels greater than four may be evaluated further by any of the following agreed-upon methods:

S17.4.1 Fracture testing to determine the amount of "rock candy" structure.

S17.4.2 Mechanical testing (for example, bend, tensile) to determine the ductility characteristics.

S17.4.3 Weld testing to determine crack susceptibility in the heat-affected zone of a circular groove welded with cellulose-coated electrodes.

S17.5 Alternatively, by agreement, it is permissible to subject castings from an unacceptable heat to a high temperature solution treatment prior to the normal production heat-treatment and subsequently macroetch test each casting.

S17.6 Heavy section castings (see Note S17.2) whose configurations are amenable to the attachment of test coupons representative of the section thickness involved and from which standard 0.505 in. [12.827 mm] diameter tension specimens may be machined are exempt from this macroetch test if the results of the tension test on the coupon after heat-treatment of the casting meet the minimum requirements specified for the grade of steel involved.

NOTE S17.2 — For purposes of this supplementary requirement, a heavy section casting is defined as one having a wall thickness of $1\frac{1}{2}$ in. [37 mm] or greater, in combination with a casting weight of at least 1000 lb [455 kg].

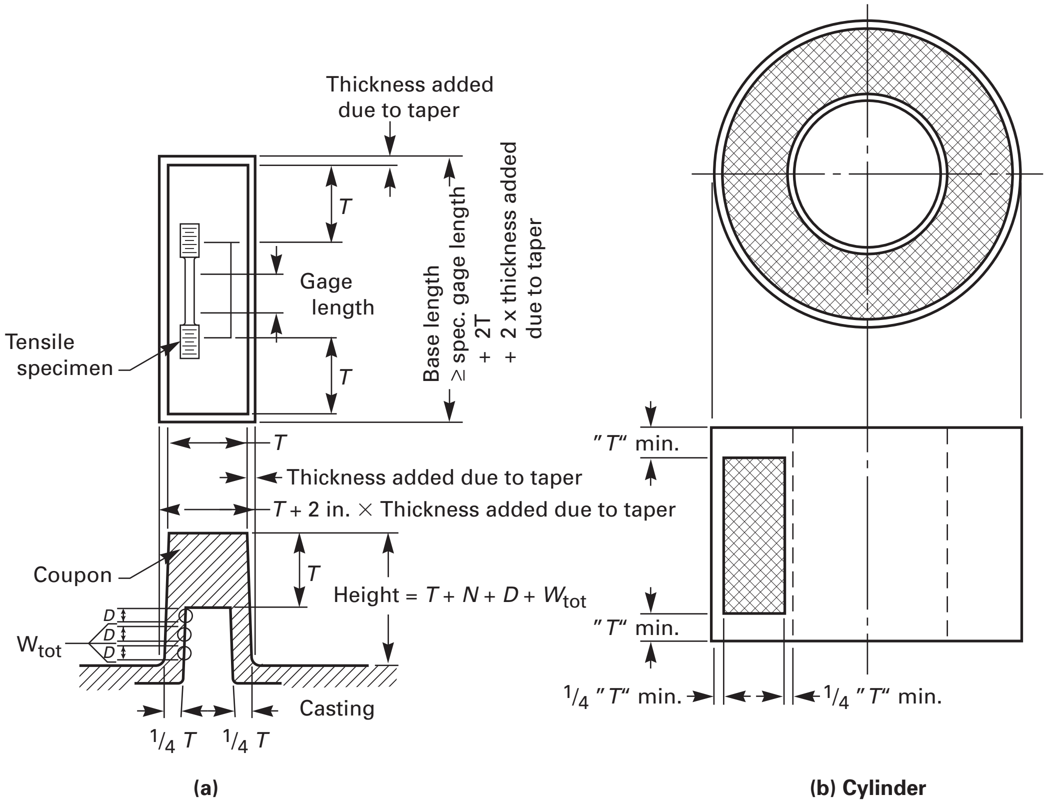
S18. Hot Isostatic Pressing (HIPing)

S18.1 Castings shall be processed by Hot Isostatic Pressing (HIPing). The processing parameters for the HIPing process may be subject to an agreement between the manufacturer and purchaser.

S19. Cleaning of Stainless Steels

S19.1 Final cleaning of the casting surfaces shall be performed in accordance with one of the cleaning methods in Practice A 380 or Specification A 967 as agreed upon between the purchaser and the supplier. Acceptance testing shall be subject to agreement between the purchaser and supplier.

FIG. S15.1 SPECIMEN FROM CASTING



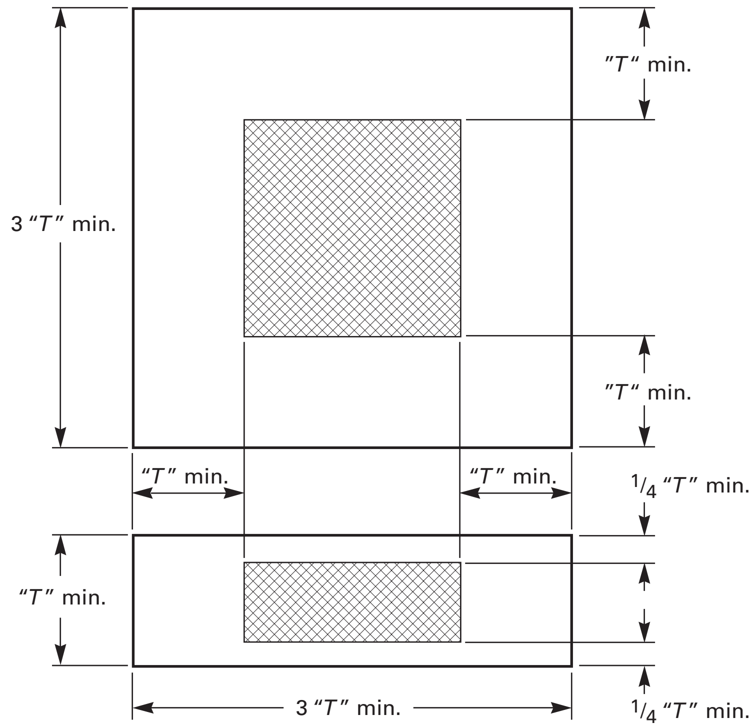
Minimum length of the base—Specimen gage length + 2*x*T + 2*x* the thickness due to the taper.
Minimum width of the base—T + 2*x* the thickness added due to the taper.
Minimum height—$T + N \times D + W_{tot}$
The taper is to be selected by the producer for ease of drawing the pattern from the mold.

where:

N = number of specimens to be cut from one side of the coupon,
D = diameter of the specimens, and
W_{tot} = the total width of metal required to remove the coupon from the casting, and to machine specimens from the coupon.

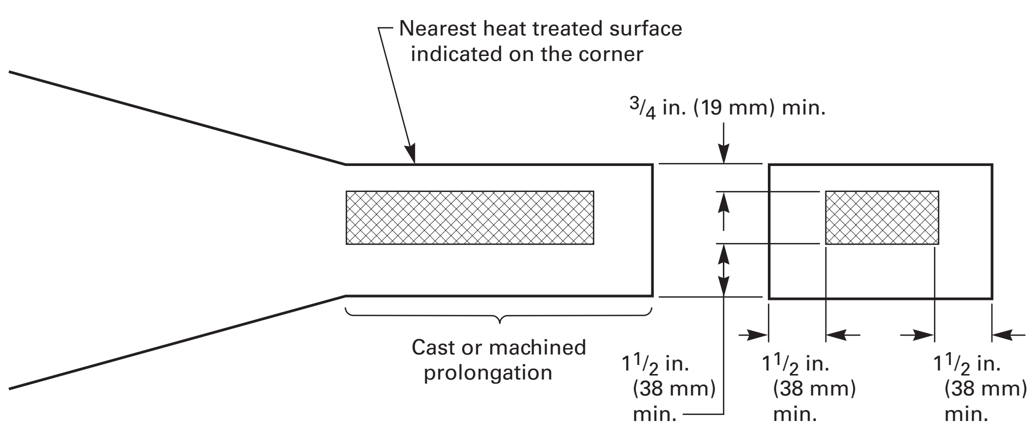
GENERAL NOTE: Longitudinal axis and gage length of test specimen must be within shaded zone.

FIG. S15.2 SEPARATELY CAST BLOCK



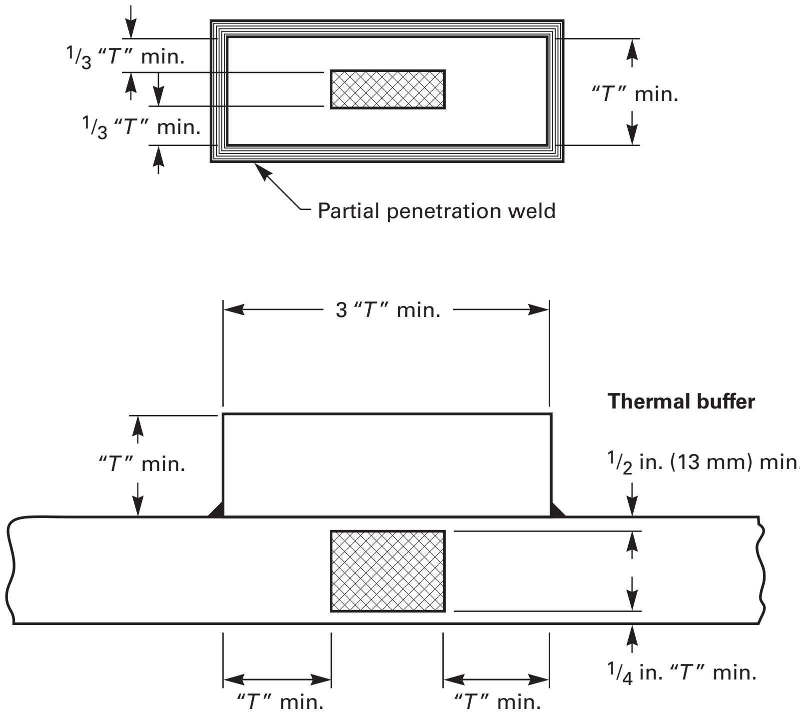
GENERAL NOTE: Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S15.3 PROLONGATION TEST SPECIMEN



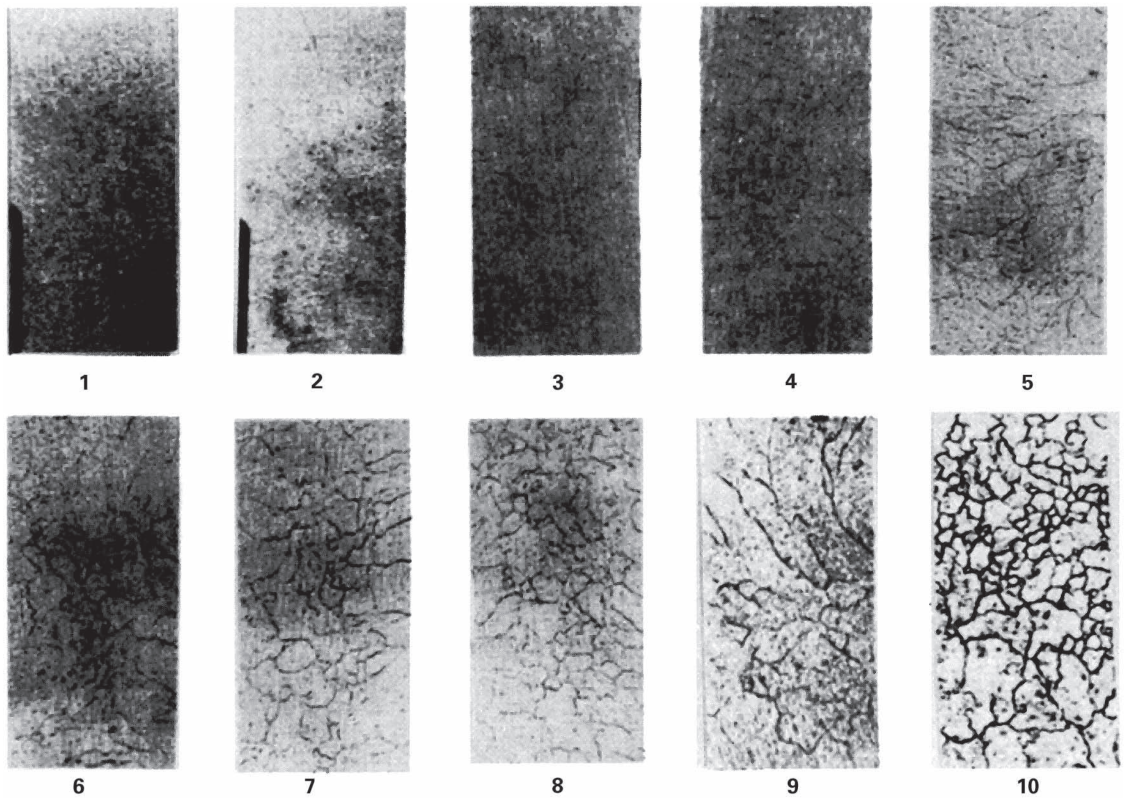
GENERAL NOTE: Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S15.4 THERMAL BUFFER PAD



GENERAL NOTE: Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S17.1 REFERENCE PHOTOGRAPHS OF MACROETCHED CAST STEEL



GENERAL NOTE: The ten levels of severity of intergranular network structures shown are indicative of the presence of aluminum nitride precipitation in the primary austenitic grain boundaries.

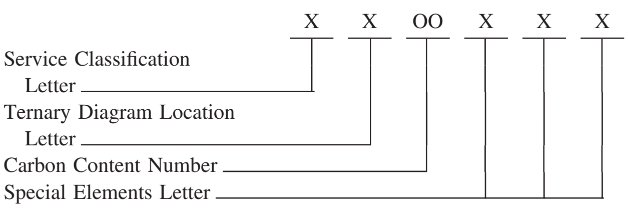
APPENDIXES

(Nonmandatory Information)

X1. ALLOY DESIGNATIONS FOR CAST STAINLESS STEELS

X1.1 Cast stainless steels are usually specified on the basis of composition using the alloy designation system established by the Alloy Casting Institute (ACI). The ACI designations, for example, CF8M, have been adopted by ASTM and are preferred for cast alloys over the designations used by the American Iron and Steel Institute for similar wrought steels.

X1.2 This nomenclature system has served successfully to accommodate changes in old alloys and to designate new ones.



X1.2.1 *Service Classification Letter* — The first letter of the cast stainless steel designation system identifies the intended service application of the alloy. The letter C indicates corrosion-resistant service, and the letter H indicates the heat-resistant service at and above 1200°F [649°C].

X1.2.2 *Ternary Diagram Location Letter* — The second letter indicates the approximate location of the nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram shown in Fig. X1.1.

X1.2.3 *Carbon Content Number* — For C service classifications, this single or dual digit numeral represents the maximum carbon content in units of 0.01%. For H service classifications, this number represents the midpoint of the range of carbon content in terms of 0.01% with a ±0.05% limit.

X1.2.4 *Special Elements Letter* — Additional letters following the numeral represent special chemical elements in the alloy grade, such as M for molybdenum, C for columbium, Cu for copper, W for tungsten. There are two exceptions; the letter A indicates Controlled Ferrite, and the letter F indicates Free Machining.

X1.3 In Fig. X1.1, unlettered Ni-Cr ranges are associated with the nearest lettered location. They may be the result of differences between corrosion and heat-resistant types, or because of the influence of additional elements, for example, the precipitation hardening grade CB-7Cu-1 and CB-7Cu-2.

X2. WROUGHT ALLOYS SIMILAR TO CASTING ALLOYS IN SPECIFICATIONS A 494/A 494M, A 743/A 743M, A 744/A 744M, A 747/A 747M, AND A 890/A 890M

X2.1 Table X2.1 is provided for the user of the above listed specifications as an aid in selecting cast alloys that are similar in chemical composition to wrought alloys. It is not intended to imply that the cast alloy would have the same mechanical, physical or corrosion properties as the indicated wrought alloy.

X3. ADDITION OF NEW GRADES TO PRODUCT SPECIFICATIONS COVERED BY A 781/A 781M

X3.1 Information required for the inclusion of new material grades in product specifications covered by A 781/A 781M:

1. At least one user should support the request.

2. A set of data from ten production heats, this data should include:

X3.1.1 Chemical composition.

X3.1.2 Mechanical properties as applicable to the product specification being cited. These may include but are not limited to the following:

X3.1.2.1 Ultimate tensile strength,

X3.1.2.2 Yield strength,

X3.1.2.3 Reduction in area,

X3.1.2.4 Elongation, and

X3.1.2.5 Impact properties (Charpy V).

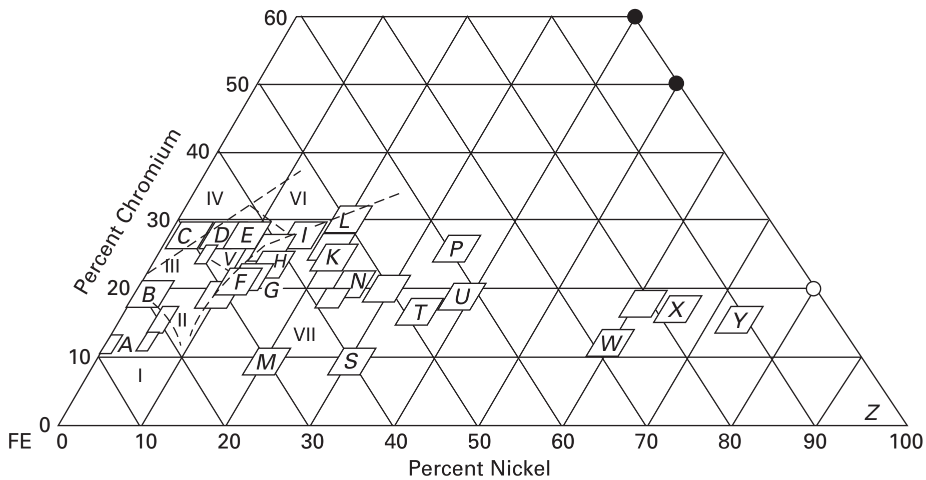
X3.2 The test coupon size from which the test pieces are removed should be stated for each test.

X3.2.1 Heat treatment requirements.

X3.2.2 Weld procedure (welding should be carried out using commercially available consumables).

FIG. X1.1 LETTERS ASSIGNED TO CHROMIUM AND NICKEL RANGES IN ACI DESIGNATION SYSTEM

Location of ACI Alloy Types



GENERAL NOTES:

(a) The approximate areas of microstructures to be expected at room temperature are indicated as follows:

I — Martensite
II — Martensite and untransformed austenite
III — Ferrite plus martensite and untransformed austenite
IV — Ferrite
V — Ferrite plus austenite
VI — Ferrite plus austenite plus sigma
VII — Austenite

(b) Carbides also may be present depending on carbon content and thermal history.

TABLE X2.1
SIMILAR ALLOYS

Nominal Composition	ASTM Casting Specification	Casting Grade Designation	UNS Number	Similar Wrought Alloy	UNS Number
11Cr-7Ni	A 743/A 743M	CA6N	J91650	. . .	. . .
13Cr-4Ni	A 743/A 743M	CA6NM	J91540	F-6NM[A]	S41500
13Cr	A 743/A 743M	CA15	J91150	410[B]	S41000
13Cr	A 743/A 743M	CA40	J91151	. . .	. . .
12Cr-Mo-V-W	A 743/A 743M	CA28MWV	J91422	422[B]	S42200
13Cr-Mo	A 743/A 743M	CA15M	J91153	420[B]	S42000
13Cr-S	A 743/A 743M	CA40F	J91154	420F[B]	S42020
19Cr-1Ni	A 743/A 743M	CB30	J91803	442[B]	S44200
16Cr-4Ni-4Cu	A 747/A 747M	CB7Cu-1	J92180	17-4[C]	S17400
15Cr-5Ni-3Cu	A 747/A 747M	CB7Cu-2	J92110	15-5[C]	S15500
27Cr	A 743/A 743M	CC50	J92615	446[B]	S44600
25Cr-5Ni-3Cu-2Mo	A 890/A 890M	1A & CD4MCu	J93370	255[C]	S32550
25Cr-5Ni-3Cu-2Mo-N	A 890/A 890M	1B & CD4MCuN	J93372	255[C]	S32550
25Cr-6Ni-2Cu-3Mo-N	A 890/A 890M	1C & CD3MCuN	J93373	255[C]	S32550
24Cr-10Ni-3Mo-N	A 890/A 890M	2A & CE8MN	J93345	. . .	. . .
25Cr-5Ni-2Mo-N	A 890/A 890M	3A & CD6MN	J93371	. . .	. . .
22Cr-5Ni-3Mo-N	A 890/A 890M	4A & CD3MN	J92205	2205[C]	S39205
25Cr-7Ni-4Mo-N	A 890/A 890M	5A & CE3MN	J93404	. . .	. . .
25Cr-7Ni-Mo-N	A 890/A 890M	6A & CD3MCuWN	J93380	Zeron 100[D]	S32760
28Cr-9Ni	A 743/A 743M	CE30	J93423	. . .	. . .
18Cr-8Ni	A 743/A 743M, A 744/A 744M	CF3	J92500	304L[B]	S30403
16Cr-12Ni-2Mo	A 743/A 743M, A 744/A 744M	CF3M	J92800	316L[B]	S31603
16Cr-12Ni-2Mo-N	A 743/A 743M	CF3MN	J92804	316LN[B]	S31653
18Cr-8Ni	A 743/A 743M, A 744/A 744M	CF8	J92600	304[B]	S30400
18Cr-10Ni-Cb	A 743/A 743M, A 744/A 744M	CF8C	J92710	347[B]	S34700
16Cr-12Ni-2Mo	A 743/A 743M, A 744/A 744M	CF8M	J92900	316[B]	S31600
18Cr-8Ni-4Si-N	A 743/A 743M	CF10SMnN	J92972	Nitronic[E] 60	S21800
18Cr-8Ni-S	A 743/A 743M	CF16F	J92701	303Se[B]	S30300
18Cr-8Ni	A 743/A 743M	CF20	J92602	302[B]	S30200
22Cr-13Ni-5Mn	A 743/A 743M	CG6MMN	J93790	Nitronic[E] 50	S20910
18Cr-13Ni-3Mo	A 743/A 743M, A 744/A 744M	CG8M	J93000	317[B]	S31700
21Cr-11Ni	A 743/A 743M	CG12	J93001	308[B]	S30800
23Cr-12Ni	A 743/A 743M	CH20	J93402	309[B]	S30900
20Cr-18Ni-6Mo-Cu-N	A 743/A 743M, A 744/A 744M	CK3MCuN	J93254	254 SMO[F]	S31254
25Cr-20Ni	A 743/A 743M	CK20	J94202	310[B]	S31000
24Ni-21Cr-6Mo-N	A 743/A 743M, A 744/A 744M	CN3MN	J94651	AL-6XN[G]	N08367
29Ni-20Cr-3Cu-2Mo	A 743/A 743M, A 744/A 744M	CN7M	N08007	Alloy 20[C]	N08020
24Ni-19Cr-3Mo-2Cu	A 743/A 743M, A 744/A 744M	CN7MS	J94650	. . .	. . .
41Ni-22Cr-3Mo-Fe	A 494/A 494M	CU5MCuC	N08826	825	N28820
61Ni-16Mo-16Cr	A 494/A 494M	CW2M	N26455	C4[C]	N06455
59Ni-18Mo-18Cr	A 494/A 494M	CW6M	N30107	. . .	. . .
60Ni-22Cr-9Mo-3.5Cb	A 494/A 494M	CW6MC	N26625	625[C]	N06625
55Ni-17Mo-16Cr-4W	A 494/A 494M	CW12MW	N30002	C[C]	N10002
57Ni-13Mo-21Cr	A 494/A 494M	CX2MW	N26022	C22[H]	N06022
74Ni-12Cr-4Bi-4Sn	A 494/A 494M	CY5SnBiM	N26055	. . .	. . .
72Ni-15Cr-8Fe	A 494/A 494M	CY40	N06040	600[C]	N06600
95Ni	A 494/A 494M	CZ100	N02100	200[C]	N02200
63Ni-29Cu-4Si	A 494/A 494M	M25S	N24025	. . .	. . .
63Ni-29Cu-2Cb	A 494/A 494M	M30C	N24130	. . .	. . .
63Ni-29Cu-Si	A 494/A 494M	M30H	N24030	. . .	. . .
67Ni-30Cu	A 494/A 494M	M-35-1	N24135	400[C]	N04400
67Ni-30Cu	A 494/A 494M	M-35-2	N04020	400[C]	N04400
65Ni-28Mo-2Fe	A 494/A 494M	N7M	N30007	B2[C]	N10665
62Ni-28Mo-5Fe	A 494/A 494M	N12MV	N30012	B[C]	N10001

[A] ASTM designation.
[B] Common description, formerly used by AISI.
[C] Common name used by two or more producers; not a trademark.
[D] Proprietary trademark: WEIR Materials.
[E] Proprietary trademark: AK Steel Corporation.
[F] Proprietary trademark: Avesta Sheffield AB.
[G] Proprietary trademark: Allegheny Ludlum Corporation.
[H] Proprietary trademark: Haynes International.

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SPECIFICATION FOR STEEL FORGINGS, GENERAL REQUIREMENTS

SA-788/SA-788M

(Identical with ASTM Specification A788/A788M-15.)

Standard Specification for Steel Forgings, General Requirements

1. Scope

1.1 This specification covers a group of common requirements that, unless otherwise specified in the individual product specification, shall apply to steel forgings under any of the following specifications issued by ASTM:

ASTM Designation	Title
A266/A266M	Carbon Steel Forgings for Pressure Vessel Components
A288	Carbon and Alloy Steel Forgings for Magnetic Retaining Rings for Turbine Generators
A289/A289M	Alloy Steel Forgings for Nonmagnetic Retaining Rings for Generators
A290/A290M	Carbon and Alloy Steel Forgings for Rings for Reduction Gears
A291/A291M	Steel Forgings, Carbon and Alloy, for Pinions, Gears, and Shafts for Reduction Gears
A336/A336M	Alloy Steel Forgings for Pressure and High-Temperature Parts
A372/A372M	Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessels
A427/A427M	Wrought Alloy Steel Rolls for Cold and Hot Reduction
A469/A469M	Vacuum-Treated Steel Forgings for Generator Rotors
A470/A470M	Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts
A471/A471M	Vacuum-Treated Alloy Steel Forgings for Turbine Rotor Disks and Wheels
A504/A504M	Wrought Carbon Steel Wheels
A508/A508M	Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels
A521/A521M	Steel, Closed-Impression Die Forgings for General Industrial Use
A541/A541M	Quenched and Tempered Carbon and Alloy Steel Forgings for Pressure Vessel Components
A579/A579M	Superstrength Alloy Steel Forgings
A592/A592M	High-Strength Quenched and Tempered Low-Alloy Steel Forged Fittings and Parts for Pressure Vessels
A646/A646M	Premium Quality Alloy Steel Blooms and Billets for Aircraft and Aerospace Forgings
A649/A649M	Forged Steel Rolls Used for Corrugating Paper Machinery
A668/A668M	Steel Forgings, Carbon and Alloy, for General Industrial Use
A711/A711M	Steel Forging Stock
A723/A723M	Alloy Steel Forgings for High-Strength Pressure Component Application
A729/A729M	Alloy Steel Axles, Heat Treated, for Mass Transit and Electric Railway Service
A765/A765M	Carbon Steel and Low-Alloy Steel Pressure-Vessel-Component Forgings with Mandatory Toughness Requirements
A768/A768M	Vacuum-Treated 12 % Chromium Alloy Steel Forgings for Turbine Rotors and Shafts
A837/A837M	Steel Forgings, Alloy, for Carburizing Applications
A859/A859M	Age-Hardening Alloy Steel Forgings for Pressure Vessel Components
A891/A891M	Precipitation Hardening Iron Base Superalloy Forgings for Turbine Rotor Disks and Wheels
A909/A909M	Steel Forgings, Microalloy, for General Industrial Use
A940/A940M	Vacuum Treated Steel Forgings, Alloy, Differentially Heat Treated, for Turbine Rotors
A965/A965M	Steel Forgings, Austenitic, for Pressure and High Temperature Parts
A982/A982M	Steel Forgings, Stainless, for Compressor and Turbine Airfoils
A983/A983M	Specification for Continous Grain Flow Forged Carbon and Alloy Steel Crankshafts for Medium Speed Diesel Engines
A986/A986M	Magnetic Particle Examination of Continuous Grain Flow Crankshaft Forgings
A1021/A1021M	Martensitic Stainless Steel Forgings and Forging Stock for High-Temperature Service
A1048/A1048M	Pressure Vessel Forgings, Alloy Steel, Higher Strength Chromium-Molybdenum-Tungsten for Elevated Temperature Service
A1049/A1049M	Stainless Steel Forgings, Ferritic/Austenitic (Duplex), for Pressure Vessels and Related Components

1.2 In case of conflict in requirements, the requirements of the individual product specifications shall prevail over those of this specification.

1.3 The purchaser may specify additional requirements (see 4.2.3) that do not negate any of the provisions of either this specification or of the individual product specifications. The acceptance of any such additional requirements shall be dependent on negotiations with the supplier and must be included in the order.

1.4 If, by agreement, forgings are to be supplied in a partially completed condition, that is, all of the provisions of the product specification have not been filled, then the material marking (see Section 17) and certification (see Section 16) shall reflect the extent to which the product specification requirements have been met.

1.5 As noted in the Certification Section (16), the number and year date of this specification, as well as that of the product specification, are required to be included in the product certification.

1.6 When the SI version of a product specification is required by the purchase order, Specification A788/A788M shall be used in conjunction with Test Methods A1058 instead of Test Methods and Definitions A370.

1.7 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A266/A266M Specification for Carbon Steel Forgings for Pressure Vessel Components
A275/A275M Practice for Magnetic Particle Examination of Steel Forgings
A288 Specification for Carbon and Alloy Steel Forgings for Magnetic Retaining Rings for Turbine Generators
A289/A289M Specification for Alloy Steel Forgings for Nonmagnetic Retaining Rings for Generators
A290/A290M Specification for Carbon and Alloy Steel Forgings for Rings for Reduction Gears
A291/A291M Specification for Steel Forgings, Carbon and Alloy, for Pinions, Gears and Shafts for Reduction Gears
A336/A336M Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A372/A372M Specification for Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessels
A388/A388M Practice for Ultrasonic Examination of Steel Forgings
A427/A427M Specification for Wrought Alloy Steel Rolls for Cold and Hot Reduction
A469/A469M Specification for Vacuum-Treated Steel Forgings for Generator Rotors
A470/A470M Specification for Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts
A471/A471M Specification for Vacuum-Treated Alloy Steel Forgings for Turbine Rotor Disks and Wheels
A504/A504M Specification for Wrought Carbon Steel Wheels
A508/A508M Specification for Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels
A521/A521M Specification for Steel, Closed-Impression Die Forgings for General Industrial Use
A541/A541M Specification for Quenched and Tempered Carbon and Alloy Steel Forgings for Pressure Vessel Components
A551/A551M Specification for Carbon Steel Tires for Railway and Rapid Transit Applications
A579/A579M Specification for Superstrength Alloy Steel Forgings
A592/A592M Specification for High-Strength Quenched and Tempered Low-Alloy Steel Forged Parts for Pressure Vessels
A646/A646M Specification for Premium Quality Alloy Steel Blooms and Billets for Aircraft and Aerospace Forgings
A649/A649M Specification for Forged Steel Rolls Used for Corrugating Paper Machinery
A668/A668M Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use
A711/A711M Specification for Steel Forging Stock
A723/A723M Specification for Alloy Steel Forgings for High-Strength Pressure Component Application
A729/A729M Specification for Alloy Steel Axles, Heat-Treated, for Mass Transit and Electric Railway Service
A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A765/A765M Specification for Carbon Steel and Low-Alloy Steel Pressure-Vessel-Component Forgings with Mandatory Toughness Requirements
A768/A768M Specification for Vacuum-Treated 12 % Chromium Alloy Steel Forgings for Turbine Rotors and Shafts
A833 Practice for Indentation Hardness of Metallic Materials by Comparison Hardness Testers
A837/A837M Specification for Steel Forgings, Alloy, for Carburizing Applications
A859/A859M Specification for Age-Hardening Alloy Steel Forgings for Pressure Vessel Components
A891/A891M Specification for Precipitation Hardening Iron Base Superalloy Forgings for Turbine Rotor Disks and Wheels
A909/A909M Specification for Steel Forgings, Microalloy, for General Industrial Use
A939/A939M Practice for Ultrasonic Examination from Bored Surfaces of Cylindrical Forgings

A940/A940M Specification for Vacuum Treated Steel Forgings, Alloy, Differentially Heat Treated, for Turbine Rotors
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A965/A965M Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts
A966/A966M Practice for Magnetic Particle Examination of Steel Forgings Using Alternating Current
A982/A982M Specification for Steel Forgings, Stainless, for Compressor and Turbine Airfoils
A983/A983M Specification for Continuous Grain Flow Forged Carbon and Alloy Steel Crankshafts for Medium Speed Diesel Engines
A986/A986M Specification for Magnetic Particle Examination of Continuous Grain Flow Crankshaft Forgings
A991/A991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
A1021/A1021M Specification for Martensitic Stainless Steel Forgings and Forging Stock for High-Temperature Service
A1048/A1048M Specification for Pressure Vessel Forgings, Alloy Steel, Higher Strength Chromium-Molybdenum-Tungsten for Elevated Temperature Service
A1049/A1049M Specification for Stainless Steel Forgings, Ferritic/Austenitic (Duplex), for Pressure Vessels and Related Components
A1058 Test Methods for Mechanical Testing of Steel Products—Metric
E23 Test Methods for Notched Bar Impact Testing of Metallic Materials
E112 Test Methods for Determining Average Grain Size
E165/E165M Practice for Liquid Penetrant Examination for General Industry
E380 Practice for Use of the International System of Units (SI) (the Modernized Metric System) (Withdrawn 1997)
E399 Test Method for Linear-Elastic Plane-Strain Fracture Toughness K_{Ic} of Metallic Materials
E428 Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing
E1290 Test Method for Crack-Tip Opening Displacement (CTOD) Fracture Toughness Measurement (Withdrawn 2013)
E1820 Test Method for Measurement of Fracture Toughness
E1916 Guide for Identification of Mixed Lots of Metals

2.2 *Other Standards:*

ANSI/ASME B46.1 Surface Texture (Surface Roughness, Waviness and Lay)

ASME Boiler and Pressure Vessel Code

3. Terminology

3.1 Terminology A941 is applicable to this specification. Additional terms and wording more applicable to forgings are as noted in this section.

3.2 *Forging Definitions:*

3.2.1 *steel forging, n*—the product of a substantially compressive plastic working operation that consolidates the material and produces the desired shape. The plastic working may be performed by a hammer, press, forging machine, or ring rolling machine, and must deform the material to produce an essentially wrought structure.

3.2.1.1 *Discussion*—Hot rolling operations may be used to produce blooms or billets for reforging.

3.3 *Forging Geometries:*

3.3.1 *bar forging, n*—forging that has no bore and having an axial length greater than its maximum cross sectional dimension.

3.3.1.1 *Discussion*—More than one cross sectional shape or size may be included. Sometimes referred to as a solid forging.

3.3.2 *disk forging, n*—forging, sometimes referred to as a pancake forging, that has *(a)* an axial length appreciably less than its diameter, *(b)* may be dished on one or both faces, and *(c)* final forging includes upsetting operations to reduce the height of the stock and increase its diameter.

3.3.2.1 *Discussion*—Since much of the hot working is done in axially compressing the stock, the central area may not receive sufficient consolidation. To counter this effect, consideration is usually given to the initial saddening (see 3.3.6) of the ingot or billet.

3.3.3 *hollow forging, n*—forging (also known as a shell forging or a mandrel forging) in which *(a)* the axial length is equal to or greater than the diameter, and *(b)* the forging length and wall thickness are produced by hot working over a mandrel (usually water cooled) such that the bore diameter remains essentially the same as that of the mandrel.

3.3.3.1 *Discussion*—Unless a hollow ingot has been used, the starting slug is hot trepanned or punched after upsetting and the bore diameter adjusted to suit the forging mandrel. The outside diameter may be contoured if required. The workpiece is forged between the upper die and lower dies while the mandrel is supported by cranes or manipulators to facilitate rotation.

3.3.4 *ring forging, n*—type of hollow forging in which *(a)* the axial length is less than the diameter, *(b)* the wall thickness is reduced, and *(c)* the outside diameter is increased by hot working between the top die and a mandrel supported on temporary saddles.

3.3.4.1 *Discussion*—Forging between the top die and the mandrel enables the ring diameter to be increased while reducing the wall thickness, without increasing the axial length.

3.3.5 *ring rolling, n*—involves the use of specialized equipment whereby a hot punched, trepanned, or bored disk is *(a)* hot worked between a powered outer roller and an idling inner roller, such that the wall thickness is reduced and the outside diameter is increased, and *(b)* the axial length of the ring is not intended to increase and may be contained by a radially oriented tapered roller.

3.3.6 *saddening, n*—term used in the open die forging industry to describe the initial hot working of an ingot for surface compaction and flute working surface prior to full working of the ingot cross section.

3.3.6.1 *Discussion*—The term is also extended to initial hot working intended to give consolidation of ingot central areas prior to upsetting when making products such as turbine and generator rotors and tube sheets.

3.3.7 *slab forging, n*—forging, sometimes referred to as a forged plate, that is usually square or rectangular in shape, with a thickness appreciably smaller than the other dimension. The hot working may include upsetting.

3.4 *billets and blooms, n*—interchangeable terms representing hot-worked semi-finished product intended as a starting stock for making forgings.

3.4.1 *Discussion*—No size limitations are assumed for either term. Cast shapes produced by a continuous casting process, without subsequent work, are considered to be ingots for the purposes of this specification, and if supplied as billets or blooms must carry the descriptor *Cast* Billet or *Cast* Bloom.

3.5 *Definitions of Terms Specific to This Standard:*

3.5.1 *bottom pouring, n*—steel from a single heat, or from a multiple heat tapped into a common ladle (see 8.1.1 and 8.1.2), introduced into ingot mold(s) such that they are filled from the bottom up. One or more molds can be set up on an individual plate, and more than one plate may be poured in sequence from a heat.

3.5.2 *ingot, n*—the product obtained when molten steel, upon being cast into a mold, is subsequently capable of being wrought in conformance with 3.1. Open-ended molds, which are usually cooled and used, for example, in the continuous casting of steel, are considered to be included in this definition.

3.5.3 *intercritical heat treatment, n*—use of a multi-stage heat treatment procedure in which the material is first austenitized at a temperature above the upper critical temperature (Ac3) followed by cooling below the lower critical temperature (Ac1). The material is then reheated to a temperature in the intercritical range between the Ac1 and the Ac3 and again cooled below the Ac1, followed by subcritical tempering in the range specified in the material specification.

3.5.3.1 *Discussion*—This procedure is generally applicable to low hardenability carbon and low alloy steels that would usually have a microstructure of ferrite and pearlite in the heat treated section size of the component being heat treated.

3.5.4 *precipitation deoxidation, n*—steelmaking process in which primary deoxidation is achieved by the addition of strong deoxidizing agents, such as aluminum, early in the process, and holding the steel in the molten state for sufficient time for the products of deoxidation to separate from the melt to the slag.

3.5.5 *sequential or continuous strand casting, n*—steel from several heats poured consecutively into a cooled open-ended mold to form a continuous cast product with a change from heat to heat along its length (see 8.1.5).

3.5.6 *strand casting, n*—steel from one heat poured into a cooled open-ended mold to form a continuous strand or strands.

3.5.7 *vacuum carbon deoxidation (VCD), n*—steelmaking process in which primary deoxidation occurs during vacuum treatment as a result of the carbon-oxygen reaction. In order for primary deoxidation to occur during vacuum treatment, deoxidizing agents such as aluminum or silicon are not to be added to the melt in any significant amount prior to the vacuum treatment operation.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for forgings under the applicable product specification. Such requirements to be considered include, but are not restricted to, the following:

4.1.1 Quantity,

4.1.2 Dimensions, including tolerances and surface finishes.

4.1.3 Specification number with type, class, and grade as applicable (including year date), and should include:

4.1.4 Number of copies of the material test report.

4.1.5 Choice of testing track from the options listed in Test Methods A1058 when forgings are ordered to a suffix M product standard. If the choice of test track is not made in the ordering information then the default ASTM track shall be used as noted in Test Methods A1058.

4.2 Additional information including the following may be added by agreement with the supplier:

4.2.1 Type of heat treatment when alternative methods are allowed by the product specification,

4.2.2 Supplementary requirements, if any, and

4.2.3 Additional requirements (see 1.4, 16.1.5, and 16.1.6).

4.2.4 Repair welding NOT permitted.

4.3 For dual format specifications, unless otherwise specified, the inch-pound units shall be used.

5. Melting Process

5.1 Unless otherwise specified in the product specification, the steel shall be produced by any of the following primary processes: electric-furnace, basic oxygen, vacuum-induction (VIM), or open-hearth. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electro slag remelting (ESR) or vacuum arc remelting (VAR).

5.1.1 The steel shall be fully killed.

5.2 The molten steel may be vacuum-treated prior to or during pouring of the ingot.

5.2.1 When vacuum treatment of the molten steel is required by the product specification the following conditions shall apply:

5.2.1.1 When the vacuum stream degassing process is used, the vacuum system must be of sufficient capacity to effect a blank-off pressure low enough (usually less than 1000 μm) to break up the normal tight, rope-like stream of molten metal into a wide-angled conical stream of relatively small droplets.

The capacity of the system must also be sufficiently high to reduce the initial surge pressure at the start of the pour to a low level within 2 min.

5.2.1.2 When the vacuum-lift process is utilized, the molten metal shall be repeatedly drawn into the evacuated vessel to give a recirculation factor (see Annex A1) of at least 2.5 to ensure thorough degassing and mixing of the entire heat. The evacuation system shall be capable of reducing the pressure surges, which occur each time a new portion of steel is admitted to the vessel to increasingly lower levels, until a blank-off pressure (usually less than 1000 μm) is achieved signifying the end of the degassing treatment.

5.2.1.3 When the ladle degassing process is used, the evacuation system shall be capable of reducing the system vacuum pressure to a low level (usually less than 1000 μm). The molten metal shall be adequately stirred for a sufficient length of time to maximize exposure to the evacuated atmosphere.

5.2.1.4 Other methods of vacuum treatment may be used if the supplier can demonstrate adequate degassing and acceptable properties in the finished forging to the satisfaction of the purchaser.

6. Forging

6.1 Forgings shall be made in accordance with 3.2.1.

6.2 Because of differences in manufacture, hot-rolled, or hot-rolled and cold-finished bars (semi-finished or finished), billets, or blooms are not considered to be forgings.

6.3 Cold worked forgings shall be made from material previously hot worked by forging or rolling; however, a hot-cold worked forging may be produced in one continuous operation wherein the material is first hot worked and then cold worked by control of the finishing temperature.

7. Cooling Prior to Heat Treatment

7.1 After forging and before reheating for heat treatment, the forgings shall be allowed to cool in such a manner as to prevent injury and, in the case of ferritic forgings, to permit substantially complete transformation of austenite.

8. Chemical Composition

8.1 *Heat Analysis:*

8.1.1 An analysis of each heat of steel shall be made by the steel producer to determine the percentages of those elements specified in the product specification. This analysis shall be made from a test sample preferably taken during the pouring of the heat and shall conform to the requirements of the product specification.

8.1.2 When multiple heats are tapped into a common ladle, the ladle chemistry shall apply. The chemical composition thus determined shall conform to the requirements of the product specification.

8.1.3 For multiple-heat ingots, either individual heat analyses or a weighted average (see Annex A2) may be taken. The results of the method used shall conform to the requirements of the product specification.

8.1.4 With the exception of the product from multiple heats sequentially cast in strand casting machines (see 8.1.5), if the test sample taken for a heat analysis is lost or declared inadequate for chemical determinations, the steel producer may take alternative samples from appropriate locations near the surface of the ingot or forging as necessary to establish the analysis of the heat in question.

8.1.5 For multiple heats sequentially cast in strand casting machines, the heat analysis shall be determined for each individual heat in accordance with 8.1.1 or 8.1.2 if applicable.

8.1.5.1 If, for multiple heats sequentially strand cast, the test sample is lost or declared inadequate for chemical analysis determination, alternative samples, remote from the transition zones, may be taken by the steel producer from the cast material or product of that heat, as defined in 8.2 or 8.3 as appropriate.

8.1.6 *Heat Analysis for Remelted Ingots:*

8.1.6.1 When consumable remelting processes are used, a chemical analysis shall be taken from a remelted ingot (or the product of a remelted ingot) for the remelt heat analysis.

8.1.6.2 When more than one electrode is prepared from a master or parent heat for remelting in the same facility by the same process, then the heat analysis obtained from one remelted ingot, or the product from that ingot, shall be taken as the heat analysis for all of the remelted ingots from that master heat. For analysis from each remelted ingot, see S27.

8.1.6.3 When electrodes from different master heats are remelted sequentially, an analysis shall be made in each zone of the remelted ingot corresponding to at least one electrode from each master heat. The resultant chemical analysis of each zone shall conform to the requirements of the product specification. The heat analysis of the remelted ingot shall be represented by a weighted average (see Annex A2) of the individual chemical analyses for each zone.

8.1.6.4 Limits on aluminum content in remelt ingots shall be set as required in the product specification.

8.2 *Heat Number Assignment for Sequentially Strand Cast Material*—When heats of the same chemical composition are sequentially strand cast, the heat number assigned to the cast product may remain unchanged until all of the steel in the product is from the following heat, except when Supplementary Requirement S3 is invoked.

8.3 *Identification of Material of Different Chemical Composition Ranges, Sequentially Strand Cast*—Because of intermixing in the tun dish, separation and identification of the resultant transition material is required when steels of different chemical composition ranges are sequentially strand cast. The steel producer shall remove the transition material by any established procedure that positively separates the grades.

8.4 *Product Analysis:*

8.4.1 An analysis may be made by the purchaser from a forging representing each heat or multiple heat (see 8.1). Samples for analysis may be taken from the forging or from a full-size prolongation. The sampling location shall be at any point from the midradius to the outer surface of disk or other solid forgings or midway between the inner and outer surfaces of hollow or bored forgings. The analysis may also be taken from a mechanical test specimen or the mechanical test location as defined in the product specification.

8.4.2 The chemical composition thus determined shall conform to the heat analysis requirements of the forging specification subject to the permissible variations specified in Table 1, for those elements listed in the product specification. Limitations on the application of the allowances in Table 1 may be made in the product specification for specified elements.

TABLE 1 Permissible Variations in Product Analysis for Killed Steel

NOTE 1—This table covers permissible variations in product analysis for most of the elements commonly found in killed steels under the jurisdiction of A01.06. This table is applicable only for those elements for which product analysis variations are permitted by the material specification. The listed variation value is subtracted from the minimum specified limit, or added to the maximum specified limit for the heat analysis in the product specification.

NOTE 2— Product cross-sectional area (taken at right angles to the axis of the original ingot or billet) is defined as either: (*1*) maximum cross-sectional area of rough machined forging (excluding boring), (*2*) maximum cross-sectional area of the unmachined forging, or (*3*) maximum cross-sectional area of the billet bloom or slab.

		Permissible Variation Over the Specified Maximum Limit or Under the Specified Minimum Limit					
Element	Maximum or Specified Range—I	Up to and incl 100 in.^{2} [650 cm^2]^A	Over 100^A to 200 in.^{2} incl [650 to 1300 cm^2]	Over 200 in.^{2} to 400 in.^{2} incl [1300 to 2600 cm^2]	Over 400 in.^{2} to 800 in.^{2} incl [2600 to 5200 cm^2]	Over 800 in.^{2} to 1600 in.^{2} incl [5200 to 10300 cm^2]	Over 1600 in.^{2} [over 10300 cm^2]
Carbon	Up to and incl 0.05	0.005	0.005	0.005	0.01	0.01	0.01
	0.06 to 0.10, incl	0.01	0.01	0.01	0.01	0.01	0.01
	0.11 to 0.25, incl	0.02	0.03	0.03	0.04	0.05	0.05
	0.26 to 0.55, incl	0.03	0.04	0.04	0.05	0.06	0.06
	0.56 and over	0.04	0.05	0.05	0.06	0.07	0.07
Manganese	Up to and incl 0.90	0.03	0.04	0.05	0.06	0.07	0.08
	0.91 and over	0.06	0.06	0.07	0.08	0.08	0.09
Phosphorus	Up to and incl 0.05	0.008	0.008	0.010	0.010	0.015	0.015
Sulfur	Up to and incl 0.030	0.005	0.005	0.005	0.005	0.006	0.006
	0.031 to 0.060 incl	0.008	0.010	0.010	0.010	0.015	0.015
Silicon	Up to and incl 0.35	0.02	0.03	0.04	0.04	0.05	0.06
	0.36 and over	0.05	0.06	0.06	0.07	0.07	0.08
Nickel	Up to and incl 1.00	0.03	0.03	0.03	0.03	0.03	0.03
	1.01 to 2.00, incl	0.05	0.05	0.05	0.05	0.05	0.05
	2.01 to 5.30, incl	0.07	0.07	0.07	0.07	0.07	0.07
	5.31 to 10.00, incl	0.10	0.10	0.10	0.10	0.10	0.10
	10.01 and over	0.15	0.15	0.15	0.15	0.15	0.15
Chromium	Up to and incl 0.90	0.03	0.04	0.04	0.05	0.05	0.06
	0.91 to 2.10, incl	0.05	0.06	0.06	0.07	0.07	0.08
	2.11 to 10.00, incl	0.10	0.10	0.12	0.14	0.15	0.16
	10.01 to 15.00, incl	0.15	0.15	0.15	0.17	0.17	0.19
	15.01 to 20.00, incl	0.20	0.20	0.20	0.22	0.24	0.24
	20.01 and over	0.25	0.25	0.25	0.27	0.27	0.29
Molybdenum	Up to and incl 0.20	0.01	0.02	0.02	0.02	0.03	0.03
	0.21 to 0.40, incl	0.02	0.03	0.03	0.03	0.04	0.04
	0.41 to 1.15, incl	0.03	0.04	0.05	0.06	0.07	0.08
	1.16 to 5.50, incl	0.05	0.06	0.08	0.10	0.12	0.12
Vanadium	Up to and incl 0.10	0.01	0.01	0.01	0.01	0.01	0.01
	0.11 to 0.25, incl	0.02	0.02	0.02	0.02	0.02	0.02
	0.26 to 0.50, incl	0.03	0.03	0.03	0.03	0.03	0.03
	0.51 to 1.25, incl	0.04	0.04	0.04	0.04	0.04	0.04
Columbium (Niobium)	Up to and incl 0.14	0.02	0.02	0.02	0.02	0.03	0.03
	0.15 to 0.50, incl	0.06	0.06	0.06	0.06	0.07	0.08
Titanium	Up to and incl 0.85	0.05	0.05	0.05	0.05	0.05	0.05
Cobalt	Up to and incl 0.25	0.01	0.01	0.01	0.01	0.01	0.01
	0.25 to 5.00, incl	0.07	0.07	0.07	0.08	0.08	0.09
	5.01 to 10.00, incl	0.14	0.14	0.14	0.16	0.16	0.18
Tungsten	Up to and incl 1.00	0.05	0.05	0.05	0.06	0.06	0.07
	1.01 to 4.00, incl	0.09	0.09	0.10	0.12	0.12	0.14
Copper	Up to and incl 1.0	0.03	0.03	0.03	0.03	0.03	0.03
	1.01 to 2.00, incl	0.05	0.05	0.05	0.05	0.05	0.05
	2.01 to 5.00, incl	0.07	0.07	0.07	0.07	0.07	0.07
Aluminum	Up to and incl 0.03	0.01	0.01	0.01	0.01	0.01	0.01
	Over 0.03 to 0.05, incl	0.01	0.01	0.02	0.02	0.03	0.03
	0.06 to 0.15, incl	0.02	0.02	0.02	0.03	0.03	0.03
	0.16 to 0.50, incl	0.05	0.05	0.06	0.07	0.07	0.08
	0.50 to 2.00, incl	0.10	0.10	0.10	0.12	0.12	0.14
Zirconium	Up to and incl 0.15	0.01	0.01	0.01	0.01	0.01	0.01
Nitrogen	Up to 0.02 incl	0.005	0.005	0.005	0.005	0.005	0.005
	Over 0.02 to 0.19, incl	0.01	0.01	0.01	0.01	0.01	0.01
	Over 0.19 to 0.25, incl	0.02	0.02	0.02	0.02	0.02	0.02
	Over 0.25 to 0.35, incl	0.03	0.03	0.03	0.03	0.03	0.03
	Over 0.35 to 0.45, incl	0.04	0.04	0.04	0.04	0.04	0.04

^{A} When the product size range up to 100 in.^{2} [650 cm^2] is deleted, then the 100 to 200-in.^{2} [650 to 1300 cm^2] column shall be changed to read up to and including 200 in.^{2} [1300 cm^2].

8.5 *Residual and Unspecified Elements*—Provisions for the limitation of certain residual and unspecified elements have been made in Supplementary Requirements S1 and S2, respectively.

8.6 Grade substitution is not permitted.

8.7 *Method of Analysis*—Methods included in Test Methods, Practices, and Terminology A751 shall be used for referee purposes.

9. Heat Treatment

9.1 Heat treatment shall be performed as specified in the product specification. Supplementary Requirement S4 concerns a specialized heat treat process (see 3.5.3) whose application will be controlled in the product specification. Unless otherwise specified during a heat treating hold cycle, the recorded furnace temperature shall be within ±25°F [±15°C] of the controlling set point temperature. Material shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A991/A991M provided that the working zone was established using a variation of ±25°F [±15°C] or less from the furnace set point.

10. Mechanical Testing

10.1 *Test Methods*—Except as specified in 4.1.5 or 10.2.1 and 10.2.2, all tests shall be conducted in accordance with Test Methods and Definitions A370. When forgings are ordered to SI requirements (M suffix standard) Test Methods A1058 shall be used (see 4.1.5).

10.1.1 In addition to the hardness testing provisions of Test Methods and Definitions A370 or, when required, Test Methods A1058, comparison hardness testing in accordance with Practice A833 may be used in determining the hardness of forgings.

10.2 *Fracture Appearance Transition Temperature ($FATT_n$)*—For a product specification (including M suffix SI specifications) that requires the determination of the fracture appearance transition temperature ($FATT_n$) where n is the required minimum percentage of shear fracture as measured on the fracture surface of a Charpy V-notch sample by one of the methods described in Test Methods and Definitions A370, the Charpy test specimen location and orientation shall be as specified in the product standard.

10.2.1 When the actual fracture appearance transition temperature is required, break at least four specimens that have been taken from a comparable location. Test each specimen at a different temperature such that the percentage of shear fracture will be both above and below the value of n, but within a range of ±0.60 times that of the specified value of n. It is desirable that two of the specimens will have values of cleavage fracture above the value of n, and two will have values below this level. Plot the percentage shear fracture against test temperature and determine the transition temperature by interpolation (extrapolation is not permitted).

10.2.2 When rather than calling for an actual $FATT_n$ as described in 10.2.1, the product specification requires a minimum $FATT_n$ at a given temperature then, unless otherwise specified, a single test run at the required temperature satisfies the requirement provided that the fracture appearance value is at least n. For example, a single test run at 100°F [38°C] with a fracture appearance of 55 % shear fracture satisfies a requirement of $FATT_{50}$ at 100°F [38°C].

10.3 *Retests*—If the results of the tests do not conform to the requirements specified, retests are permitted as outlined in Test Methods and Definitions A370 or as follows:

10.3.1 If the percentage of elongation or reduction of area of any tension test specimen is less than specified because a flaw becomes evident in the test specimen during testing, a retest shall be allowed provided that the defect was not attributable to ruptures, cracks, or flakes in the steel.

10.3.2 If the average impact energy value meets the specification requirements, but the energy value for one specimen is below the specified minimum value for individual specimens prescribed in the material specification, a retest is permitted. This shall consist of two impact specimens from a location adjacent to and on either side of the specimen that failed. Each of the retested specimens must exhibit an energy value equal to or greater than the minimum average value required by the product specification.

11. Reheat Treatment

11.1 If the results of the initial mechanical tests do not conform to the specified requirements, the forgings may be heat treated (if initially tested in the as-forged condition) or reheat treated (if heat treated prior to initial testing).

12. Repair Welding

12.1 Repair welding of forgings is not permitted unless specifically allowed by the product specification (see also 4.2.4).

13. Dimensions and Finish

13.1 The forgings shall conform to the dimensions, tolerances, and finishes required by the ordering information (4.1.2). Supplementary Requirements S5 or S6, concerning straightening of forgings, may be used.

13.2 When surface finish, roughness, or texture is specified in a steel forging product standard, unless otherwise required by the purchaser, the roughness average (Ra), as defined in ANSI/ASME B46.1, shall be used (see 4.1.2).

14. Inspection

14.1 The manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products comply with all requirements of the contract. The manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed.

14.2 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with the material specification.

14.3 Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

15. Rejection

15.1 Any rejection based on the presence of an injurious defect found subsequent to acceptance at the manufacturer's works or based on the results of a product analysis made in accordance with 8.4 shall be reported to the manufacturer.

15.2 Disposition of forgings rejected by the purchaser under 15.1 shall be as agreed upon between manufacturer and the purchaser.

16. Certification

16.1 The manufacturer shall furnish to the purchaser the number of copies of the material test report specified in the ordering information (4.1.4). The following items shall be reported:

16.1.1 Purchase order number,

16.1.2 Forging identification number,

16.1.3 The product specification number, including the year date and revision letter if any, as well as the appropriate class, type, and grade,

16.1.3.1 Reference to Specification A788/A788M including the year date together with the applicable revision letter, if any, of the revision used shall be a part of the certification.

16.1.4 Heat number and analysis,

16.1.5 Results of the required acceptance tests for mechanical properties,

16.1.6 Results of any required nondestructive examinations,

16.1.7 Final heat treatment cycle including austenitizing and tempering temperatures and holding times and cooling methods if required by the product specification or 4.2.3,

16.1.8 Extent to which the forging is incomplete with respect to the product specification (see 1.4 and 16.1.7), and

16.1.9 Results of any supplementary and additional test requirements that were specified.

16.1.10 The material test report may be sent to the purchaser in electronic form from an electronic data interchange (EDI) transmission, and this shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

17. Packaging and Package Marking

17.1 Each forging shall be legibly identified as required by the product specification and instructions from the purchaser. When not otherwise defined, each forging shall be identified by the manufacturer as follows:

17.1.1 Manufacturer's name or symbol.

17.1.2 Manufacturer's identification or heat number.

17.1.3 Product specification number.

17.1.4 The class, grade, and type identification as appropriate.

17.1.5 Purchaser's identification (4.2.3).

17.1.6 Location of stamping (4.2.3).

17.1.7 Incomplete forging (1.4). The marking shall include the suffix Y immediately following the ASTM number, and preceding any other suffix. This suffix shall not be removed until the material specification requirements have been completed and the material test report supplemented.

17.2 Marking shall be done by impression stamping or other acceptable means specified in the product specification or order. Bar coding is an acceptable supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of published industry standards for bar coding.

17.3 The specification year date, and revision letter are not required to be marked on the forgings.

18. Keywords

18.1 general delivery requirements; steel forgings—alloy; steel forgings—carbon

SUPPLEMENTARY REQUIREMENTS

(GENERAL)

The following supplementary general requirements are common to the forging specifications listed in this specification. These and other limitations or tests may be performed by agreement between the supplier and purchaser. The additional requirements shall be specified in the order, and shall be completed by the supplier before the shipment of the forgings.

S1. Residual Elements

S1.1 Small quantities of certain unspecified elements may be present in carbon and low alloy steel forgings. These elements are considered as incidental and may be present to the following maximum amounts:

Copper	0.35 %
Nickel	0.30 %
Chromium	0.25 %
Molybdenum	0.10 %
Vanadium[A]	0.03 %

[A] Unless Supplementary Requirement S2 is required.

S2. Unspecified Elements

S2.1 Vanadium used for grain refinement or deoxidation shall not exceed 0.08 %.

S3. Sequential or Continuous Strand Casting

S3.1 When multiple heats of the same chemical composition range are sequentially strand cast, the heats shall be separated by an established procedure such that intermix material will not be supplied.

S4. Intercritical Heat Treatment

S4.1 The austenitizing stage in the heat treatment of ferritic forgings is intended to be done at suitable temperatures above the upper critical temperature (Ac_3) for the heat of steel involved, that is, full austenitization. However, when multiple austenitizing stages are used the temperature for the last may be set between the upper (Ac_3) and lower (Ac_1) critical temperature for partial austenitizing. Such cycles shall be followed by tempering within the temperature limits required by the material specification.

S5. Straightening of Forgings

S5.1 Unless otherwise specified by Supplementary Requirement S6, straightening of forgings after heat treatment for properties shall be performed at a temperature which is not more than 100°F [55°C] below the final tempering temperature. Following straightening, forgings shall be stress relieved at a temperature of 50 to 100°F [30 to 55°C] below the final tempering temperature and shall be reported on the material test report. Any straightening performed before heat treatment for properties does not require an intermediate stress-relief heat treatment.

S6. Post-Heat Treatment Straightening of Forgings

S6.1 Straightening after heat treatment for specified properties is not permitted without prior approval by the purchaser.

S7. Fracture Toughness Test

S7.1 The purchaser shall specify one or more of the following test methods for fracture toughness determination. Required information including test temperature, conditioning, environment, and acceptance criteria shall be provided as necessary.

S7.2 Determination of the plane strain fracture toughness in accordance with Test Method E399.

S7.3 Fracture toughness determination in accordance with Test Method E1820.

S7.4 Crack-tip opening displacement determination in accordance with Test Method E1290.

S8. Vacuum Degassing

S8.1 The vacuum degassing requirements of 5.2 shall apply.

S9. Vacuum Carbon Deoxidation

S9.1 The molten steel shall be vacuum carbon deoxidized (VCD) during processing, in which case the silicon content shall be 0.10 % maximum.

S10. Restricted Phosphorus and Sulfur, Levels A or B

S10.1 For level A, the phosphorus and sulfur levels shall be limited as follows:

		Heat	Product
Level A	P	0.015 % maximum	0.018 % maximum
	S	0.018 % maximum	0.021 % maximum

S10.2 For level B, the phosphorus and sulfur levels shall be limited to the following:

		Heat	Product
Level B	P	0.012 % maximum	0.015% maximum
	S	0.015% maximum	0.018 % maximum

S11. Restricted Copper, Levels A or B

S11.1 For level A, the heat and product analyses limits for copper shall be 0.15 % maximum.

S11.2 For level B, the heat and product analyses limits for copper shall be 0.10 % maximum.

S12. Tension Specimens for Hubbed Flat Heads and Tube Sheets

S12.1 For hubbed tube sheets and flat heads to be used in ASME Boiler and Pressure Vessel Code construction, an axial tension specimen shall be taken as close as possible to the hub and either inboard or outboard of it, using a sub size specimen if necessary. The longitudinal axis of the specimen shall be parallel to the length of the hub, as shown in Fig. S12.1.

S12.2 By agreement with the purchaser, this test orientation may replace a specified tension test specimen, provided that other location criteria are met.

S13. Charpy Impact Tests

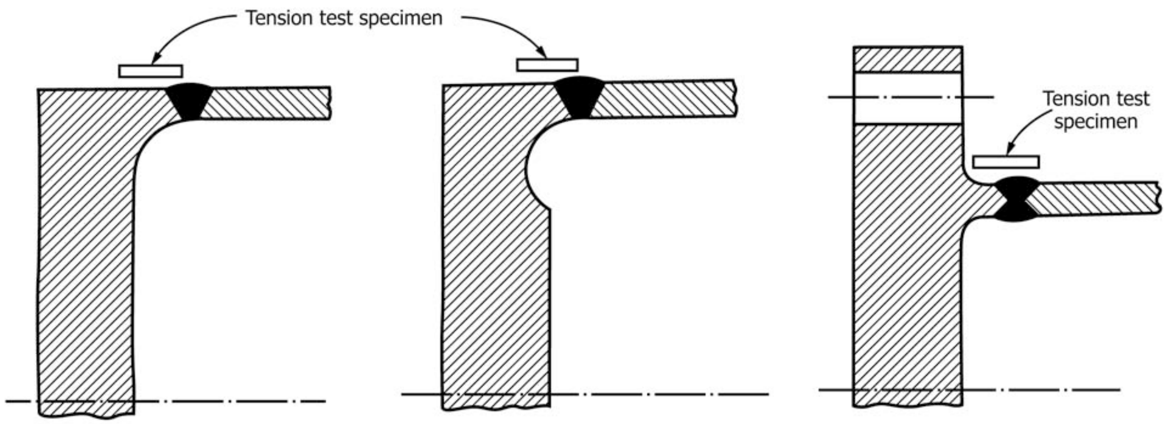
S13.1 Charpy impact tests shall be made. The number, orientation and location of the tests shall be specified along with the test temperature and the applicable acceptance criteria for absorbed energy, fracture appearance, lateral expansion, or both.

S13.2 The specimens shall be machined and tested in accordance with Test Methods and Definitions A370 or Test Methods A1058 in accordance with the purchase order.

S14. Charpy V Notch Impact Transition Curve

S14.1 Sufficient impact tests shall be made from the forging material to establish a transition temperature curve based upon one or several of the following criteria:

S14.1.1 Absorbed energy (ft·lbf [J]) (See Test Methods E23 or, if required by the purchase order, Test Methods A1058),



NOTE 1—Tension test specimens also may be located inboard of the hub.

FIG. S12.1 Tension Test Specimens

S14.1.2 Fracture appearance (see Supplement 5 of Test Methods and Definitions A370), or

S14.1.3 Lateral expansion.

S14.1.4 The test temperature range shall be wide enough to establish the upper and lower shelf energies, with sufficient testing at intermediate temperatures to permit a smooth curve to be plotted. A minimum test temperature may be set by agreement instead of establishing the lower shelf temperature. The upper shelf energy level is defined as having at least 95 % fibrous fracture and the lower shelf level is defined as showing 5 % or less fibrous fracture.

S14.2 The purchaser shall furnish the manufacturer with details of sample location, number of specimens, heat treatments, and information to be derived from the test.

S15. Grain Size

S15.1 When a grain size range is required, it shall be specified in the ordering information as heat treated or austenitic, and shall be determined by an agreed-upon method from Test Methods E112.

S15.2 Samples for grain size estimation from heat treated products shall be taken from the tension test specimen location.

S16. Rough Machining and Boring

S16.1 The position of the rough machining and boring in the manufacturing sequence shall be specified by the purchaser, particularly with regard to heat treatment for mechanical properties.

S17. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S17.1 All test coupons shall be subjected to single or multiple heat treatments at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, times, and cooling rates.

S18. Magnetic Particle Examination

S18.1 All accessible surfaces of the finished forging shall be subject to magnetic particle examination in accordance with Practice A275/A275M.

S18.2 Unless otherwise agreed upon between the manufacturer and the purchaser the wet continuous method shall be used.

S18.2.1 The following conditions are subject to rejection or removal:

S18.2.1.1 Indications with major dimension exceeding 3⁄16 in. [5 mm].

S18.2.1.2 Four or more indications exceeding 1⁄16 in. [1.5 mm] in major dimensions that are aligned and separated by 1⁄16 in. [1.5 mm] or less end to end.

S18.2.1.3 Ten or more indications exceeding 1⁄16 in. [1.5 mm] in major dimensions contained in any 6 in.^{2} [40 cm^2] of surface, with the major dimension of this area not to exceed 6 in. [150 mm]. The area shall be taken in the most unfavorable location relative to the indications being evaluated.

S19. Liquid Penetrant Examination

S19.1 All accessible surfaces of the finished forging shall be subject to liquid penetrant examination in accordance with Practice E165/E165M. The penetrant system to be used shall be agreed upon between the manufacturer and purchaser.

S19.2 The following conditions are subject to rejection or removal:

S19.2.1 Indications with major dimensions exceeding 3⁄16 in. [5 mm].

S19.2.2 Four or more indications exceeding 1⁄16 in. [1.5 mm] in major dimensions that are aligned and separated by 1⁄16 in. [1.5 mm] or less end to end.

S19.2.3 Ten or more indications exceeding 1⁄16 in. [1.5 mm] in major dimensions contained in any 6 in.^{2} [40 cm^2] of surface, with the major dimension in this area not to exceed 6 in. [150 mm]. The area shall be taken in the most unfavorable location relative to the indications being evaluated.

S20. Ultrasonic Examination

S20.1 Ultrasonic examination of forgings shall be carried out in accordance with Practice A388/A388M.

S20.2 Unless otherwise agreed upon between the manufacturer and the purchaser, acceptance levels BR or DA shall be specified for the longitudinal wave examination and level S for shear wave examination.

Level BR—Longitudinal Wave

S20.2.1 The back reflection method of tuning shall be used in accordance with Practice A388/A388M.

S20.2.2 In addition to the reportable conditions of the Recording Section of Practice A388/A388M, indications exceeding the resultant back reflection shall be recorded.

S20.2.3 The following conditions are subject to rejection, or repair if applicable.

S20.2.3.1 Complete loss of back reflection accompanied by an indication of a discontinuity. For this purpose, a back reflection less than 5 % of full screen height shall be considered complete loss of back reflection.

S20.2.3.2 An indication equal in amplitude to that of the back reflection established in an indication-free portion of the forging.

Level DA—Longitudinal Wave

S20.2.4 Reference blocks of acoustically similar metal shall be used for calibration. Blocks shall meet one of the following requirements:

S20.2.4.1 A comparison of the back reflections between equivalent thicknesses of the reference block material and the actual forging to be tested, without change in instrument setting shall not show a variation in excess of 25 %.

S20.2.4.2 The reference blocks shall be manufactured from steel that is similar in chemistry and processing history to the production forging being tested. The reference blocks shall be fabricated in accordance with the procedures of Practice E428.

S20.2.4.3 For test sections up to and including 12 in. [300 mm] thick, the reference blocks shall contain a ¼ in. [6 mm] diameter flat-bottom hole; for over 12 in. [300 mm] up to and including 18 in. [300 to 450 mm], the hole diameter shall be ⅜ in. [10 mm]; and for over 18 in. [450 mm], it shall be ½ in. [13 mm].

S20.2.4.4 A distance-amplitude correction curve shall be established for the proper grade of steel and specified hole size.

S20.2.4.5 A forging containing one or more indications equal in amplitude to that of the applicable reference hole, when properly corrected for distance, is subject to rejection, or repair if applicable.

Level S–Shear Wave

S20.2.5 Calibration notches, calibration reference, and method of scanning shall be in accordance with Practice A388/A388M. Unless otherwise agreed upon, a 60° V-notch shall be used.

S20.2.6 A forging containing a discontinuity that results in an indication exceeding the amplitude of the reference line is subject to rejection.

S20.2.7 The report of the ultrasonic examination shall be in compliance with Practice A388/A388M.

S20.2.8 Additional nondestructive examination or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious conditions that will not be removed in final machining.

S21. Additional Test Coupon Heat Treatment

S21.1 When subcritical heat treatment, applied to a completed forging during subsequent fabrication, may affect the mechanical properties of the forging, then coupons for the mechanical testing required by the product specification shall be given a laboratory heat treatment, which simulates the anticipated subcritical heat treatment.

S21.2 The purchaser shall specify the required heat treatment temperature range, minimum time at temperature, and the rates of heating and cooling.

S21.3 The required number of test coupons shall be taken from the forging location described in the product specification.

S21.4 The test specimens shall meet the minimum mechanical test requirements of the product specification, as well as those of any additional tests agreed upon between producer and purchaser, after completion of the test coupon heat treatment.

S21.5 The forgings supplied in accordance with this supplementary requirement shall be marked in accordance with 17.1.7.

S21.6 The material test reports shall include the heat treatment of the as-delivered material and the results of the mechanical tests from the test coupons subjected to the purchaser specified heat treatments that represent fabrication.

S22. Ultrasonic Examination from Bore Surface

S22.1 Bored cylindrical forgings shall be examined from the bored surface in accordance with Practice A939/A939M. The acceptance criteria shall be agreed upon between the purchaser and the producer.

S23. Magnetic Particle Examination Using AC Current

S23.1 The designated surfaces of ferromagnetic steel forgings shall be examined at the stage in machining specified by the purchaser in accordance with Practice A966/A966M. The acceptance criteria for the examination shall be specified by the purchaser.

S24. J_{factor}

S24.1 The J_{factor}, calculated by means of the following equation, shall be established for each heat of steel used in forging manufacture:

$$J_{factor} = (Mn + Si)\,(P + Sn) \times 10^4$$

Has been found to be effective in reducing temper embrittlement effects.

S24.2 The purchaser shall specify the required maximum value of J_{factor} in both the inquiry and ordering documents.

S24.3 The determination of the tin content of the steel is necessary for the application of this supplementary requirement even if there is no chemical analysis requirement for tin in the product specification.

Note—In Dr. Paul Bates's paper,[1] it was noted that the Fracture Appearance Transition Temperature (FATT) fell steadily from J_{factor} 120 to 60, but below 20, the drop in FATT was much less apparent.

S25. Positive Material Identification

S25.1 Forgings shall receive positive material identification to ensure that forgings are of the ordered material grade prior to shipment.

S25.2 Forgings shall receive a positive material identification in accordance with Guide E1916.

S25.3 The entire ordered quantity of forgings shall be examined.

S25.4 Forgings not conforming to the ordered grade shall be rejected.

S25.5 Following this material identification examination, acceptable forgings shall be marked as agreed between the purchaser and producer.

S26. Pressure Equipment Directive—Mechanical Testing

S26.1 Charpy impact testing shall be done at the lowest scheduled operating temperature, but not higher than 68°F [20°C].

S26.2 The frequency of Charpy impact testing shall be the same as that specified in the product specification for the tension test, with one Charpy test (3 specimens) for each required tension test.

S26.3 The minimum individual absorbed energy for the Charpy impact test shall be 20 ft·lbf [27 J].

S26.4 The minimum elongation in the tension test shall be measured on a gauge length of five times the diameter of the test specimen (5D), and shall be not less than 14 %.

S26.5 The results of the impact and tension tests shall be included in the product certification.

S27. Heat Analysis for Remelted Ingots

S27.1 Instead of the heat analysis provisions in 8.1.6.2 of Specification A788/A788M for consumable electrode remelting processes, a heat analysis shall be obtained from each remelted ingot (or the product from it) from single master or parent heat.

S27.2 The product analysis provisions of Specification A788/A788M shall not apply.

[1] Bates, P., "The Production of Safety Critical Forgings for Pressure Vessel Applications," *International Forgemasters Conference*, Wiesbaden, Germany, September 2000.

ANNEXES

(Mandatory Information)

A1. RECIRCULATION FACTOR

A1.1 The recirculation factor for the vacuum lift process is obtained as follows:

$$\frac{\text{Tons (kg) of Steel Lifted per Cycle} \times \text{Number of Cycles}}{\text{Heat Weight in Tons [kg]}}$$

A2. EXPLANATORY NOTE FOR WEIGHTED AVERAGE ANALYSIS

A2.1 A weighted average analysis is mandatory whenever an ingot is poured from the combination of two or more heats wherein the resultant chemistry of the ingot assumes an identity attributable to each heat involved in the combination. It is necessary to make this determination to ensure that each element in the official chemistry is represented by proportion to its amount in each individual furnace heat. An example of the determination of a weighted average analysis for an ingot made from a three-heat combination pour with varying weights and chemistry involved in each heat is shown below:

Furnace	Heat[A] Weight, tons	Individual Heat Chemistry, %								
		C	Mn	P	S	Si	Ni	Cr	Mo	V
A	25	0.20	0.50	0.010	0.020	0.34	0.92	0.32	0.12	0.03
B	50	0.25	0.50	0.013	0.015	0.38	0.98	0.32	0.12	0.02
C	50	0.25	0.50	0.015	0.018	0.38	0.94	0.34	0.13	0.02
	125[B]									

[A] This is individual heat contribution to the total ingot weight.
[B] Total ingot weight.

Step # 1—Determine furnace factor (FF) for each heat based on weight.

Furnace A = 25/125 = 20 %
Furnace B = 50/125 = 40 %
Furnace C = 50/125 = 40 %

$$\mathrm{FF} = \frac{(\text{Individual Fnce Ht. Wt})}{(\text{Combined Heat Weight})} \times 100\,\%$$

Step # 2—Calculate the weighted average for each element. Examples for several elements shown below:

$$\text{Weighted avg} = \text{sum of } (\%\ \text{element in each furnace heat} \times \mathrm{FF})$$

° Weighted avg of Carbon (weighted avg):
Furnace A—0.20 % × 20 % = 0.04 %
Furnace B—0.25 % × 40 % = 0.10 %
Furnace C—0.25 % × 40 % = 0.10 %
Add to get weighted avg of 0.24 %

° Weighted avg of manganese:
Furnace A—0.50 % × 20 % = 0.10 %
Furnace B—0.50 % × 40 % = 0.20 %
Furnace C—0.50 % × 40 % = 0.20 %
Add to get weighted avg of 0.50 %

° Weighted avg of phosphorus:
Furnace A—0.010 % × 20 % = 0.002 %
Furnace B—0.013 % × 40 % = 0.0052 %
Furnace C—0.015 % × 40 % = 0.006 %
Add to get weighted avg of 0.013 %[A]

[A] (Round to significant figures in accordance with Practice E380.)
° The same procedure is used for all of the other elements.

A3. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A3.1 New materials may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A3.1.1 Application for the addition of a new grade to a specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A3.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A3.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A3.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A3.1.5 The application shall state whether or not the new grade is covered by patent.

A4. REQUIREMENTS FOR THE INTRODUCTION OF MATERIALS FROM OTHER A01 OR B02.07 SPECIFICATIONS

A4.1 Wrought materials that are already covered by another A01 or B02.07 specification may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A4.1.1 Application for the addition of a grade that is already covered in another A01 or B02.07 specification shall be made to the chair of the subcommittee that has jurisdiction over the specification to which the addition is being proposed.

A4.1.2 The chemical requirements, the specified mechanical properties, and the heat treatment requirements of the grade being added shall be the same as those for the grade in the A01 or B02.07 specification in which the grade is presently covered.

A4.1.3 The application shall provide recommendations for all requirements appearing in the applicable specification.

A4.1.4 The application shall state whether or not the grade is covered by patent.

SPECIFICATION FOR SEAMLESS AND WELDED FERRITIC/AUSTENITIC STAINLESS STEEL TUBING FOR GENERAL SERVICE

SA-789/SA-789M

(Identical with ASTM Specification A789/A789M-18.)

Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service

1. Scope

1.1 This specification covers grades of average wall thickness, or, if specified on the order, minimum wall thickness, of stainless steel tubing for services requiring general corrosion resistance, with particular emphasis on resistance to stress corrosion cracking. These steels are susceptible to embrittlement if used for prolonged periods at elevated temperatures.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Within the text, the SI units are shown in brackets. The inch-pound units shall apply unless the *M* designation of this specification is specified in the order.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *SAE Standard:*

SAE J 1086 Practice for Numbering Metals and Alloys (UNS)

3. Ordering Information

3.1 Orders for product under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of product (seamless or welded tubes),

3.1.3 Grade (see Table 1),

3.1.4 Size (outside diameter and average wall thickness, unless minimum wall thickness is specified),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (for product analysis, see Section 8; for hydrostatic or nondestructive electric test, see Section 10),

3.1.7 Test report required (see the Inspection section of Specification A1016/A1016M),

3.1.8 Specification designation, and

3.1.9 Special requirements.

4. General Requirements

4.1 Product furnished under this specification shall conform to the applicable requirements of Specification A1016/A1016M, unless otherwise provided herein.

5. Manufacture

5.1 The tubes shall be made by the seamless or welded process with no filler metal added.

6. Heat Treatment

6.1 All tubes shall be furnished in the heat-treated condition in accordance with the procedures shown in Table 2. For seamless tubes, as an alternate to final heat treatment in a continuous furnace or batch-type furnace, immediately following hot forming while the temperature of the tubes is not less

TABLE 1 Chemical Requirements[A]

UNS Designation[B]	C	Mn	P	S	Si	Ni	Cr	Mo	N	Cu	Others
S31200	0.030	2.00	0.045	0.030	1.00	5.5–6.5	24.0–26.0	1.20–2.00	0.14–0.20	. . .	. . .
S31260	0.030	1.00	0.030	0.030	0.75	5.5–7.5	24.0–26.0	2.5–3.5	0.10–0.30	0.20–0.80	W 0.10–0.50
S31500	0.030	1.20–2.00	0.030	0.030	1.40–2.00	4.3–5.2	18.0–19.0	2.50–3.00	0.05–0.1	. . .	. . .
S31803	0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5	0.08–0.20	. . .	. . .
S32001	0.030	4.00–6.00	0.040	0.030	1.00	1.0–3.0	19.5–21.5	0.60	0.05–0.17	1.00	. . .
S32003	0.030	2.00	0.030	0.020	1.00	3.0-4.0	19.5-22.5	1.50-2.00	0.14-0.20	. . .	. . .
S32101	0.040	4.0-6.0	0.040	0.030	1.00	1.35-1.70	21.0-22.0	0.10-0.80	0.20-0.25	0.10-0.80	. . .
S32202	0.030	2.00	0.040	0.010	1.00	1.00–2.80	21.5–24.0	0.45	0.18–0.26	. . .	. . .
S32205	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	0.14–0.20	. . .	. . .
S32304	0.030	2.50	0.040	0.040	1.00	3.0–5.5	21.5–24.5	0.05–0.60	0.05–0.20	0.05–0.60	. . .
S32506	0.030	1.00	0.040	0.015	0.90	5.5–7.2	24.0–26.0	3.0–3.5	0.08–0.20	. . .	W 0.05–0.30
S32520	0.030	1.50	0.035	0.020	0.80	5.5–8.0	23.0–25.0	3.–5.	0.20–0.35	0.50–3.00	. . .
S32550	0.04	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9	0.10–0.25	1.50–2.50	. . .
S32707	0.030	1.50	0.035	0.010	0.50	5.5–9.5	26.0–29.0	4.0–5.0	0.30–0.50	1.0 max	Co 0.5–2.0
S32750[C]	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0–5.0	0.24–0.32	0.50	. . .
S32760[D]	0.030	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0	0.20–0.30	0.50–1.00	W 0.50–1.00
S32808	0.030	1.10	0.030	0.010	0.50	7.0–8.2	27.0–27.9	0.80–1.20	0.30–0.40	. . .	W 2.10–2.50
S32900	0.08	1.00	0.040	0.030	0.75	2.5–5.0	23.0–28.0	1.00–2.00	. . .	. . .	. . .
S32906	0.030	0.80–1.50	0.030	0.030	0.80	5.8–7.5	28.0 –30.0	1.50–2.60	0.30–0.40	0.80	. . .
S32950	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	0.15–0.35	. . .	. . .
S33207	0.030	1.50	0.035	0.010	0.80	6.0–9.0	29.0–33.0	3.0–5.0	0.40–0.60	1.0	. . .
S39274	0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5	0.24–0.32	0.20–0.80	W 1.50–2.50
S39277	0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.00–4.00	0.23–0.33	1.20–2.00	W 0.80–1.21
S82011	0.030	2.0–3.0	0.040	0.020	1.00	1.00–2.00	20.5–23.5	0.10–1.00	0.15–0.27	0.50	. . .
S82031	0.05	2.50	0.040	0.005	0.80	2.0–4.0	19.0–22.0	0.60–1.40	0.14–0.24	1.00	. . .
S82441	0.030	2.50–4.00	0.035	0.005	0.70	3.0–4.5	23.0–25.0	1.00–2.00	0.20–0.30	0.10–0.80	. . .
S83071	0.030	0.50–1.50	0.030	0.020	0.50	6.0–8.0	29.0–31.0	3.0–4.0	0.28–0.40	0.80	. . .

[A] Maximum, unless a range or minimum is indicated. Where ellipses (...) appear in this table, there is no minimum and analysis for the element need not be determined or reported.
[B] Designation established in accordance with Practice E527 and SAE J1086.
[C] % Cr + 3.3 × % Mo + 16 × % N ≥ 41.
[D] % Cr + 3.3 × % Mo + 16 × % N ≥ 40.

than the specified minimum solution treatment temperature, tubes may be individually quenched in water or rapidly cooled by other means.

7. Chemical Composition

7.1 The steel shall conform to the chemical requirements prescribed in Table 1.

8. Product Analysis

8.1 An analysis of either one billet or one length of flat-rolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 A product analysis tolerance (see the annex table on Chemical Requirements (Product Analysis Tolerances) in Specification A480/A480M) shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04 % or less.

8.3 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests for the elements in question shall meet the requirements of this specification; otherwise, all remaining material in the heat shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock, or tubes that do not meet the requirements of this specification shall be rejected.

NOTE 1—For flange and flaring requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, or when heat treated condition is obtained directly by quenching after hot forming, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 3.

NOTE 2—For tension and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, or when heat treated condition is obtained directly by quenching after hot forming, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed, or all tubes of the same size and heat, hot formed and quenched in the same production run.

9. Mechanical Tests Required

9.1 *Tension Tests*—One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (see Note 2).

9.2 *Flaring Test (for Seamless Tubes)*—One test shall be made on specimens from one end of one tube from each lot (see Note 1) of finished tubes. The minimum expansion of the inside diameter shall be 10 %.

9.3 *Flange Test (for Welded Tubes)*—One test shall be made on specimens from one end of one tube from each lot (see Note 1) of finished tubes.

TABLE 2 Heat Treatment

UNS Designation	Temperature °F [°C]	Quench
S31200	1920–2010 [1050–1100]	rapid cooling in water
S31260	1870–2010 [1020–1100]	rapid cooling in air or water
S31500	1800–1900 [980–1040]	rapid cooling in air or water
S31803	1870–2010 [1020–1100]	rapid cooling in air or water
S32001	1800–1950 [982–1066]	rapid cooling in air or water
S32003	1850–2050 [1010–1120]	rapid cooling in air or water
S32101	1870 [1020] min	quenched in water or rapidly cooled by other means
S32202	1870–1975 [1020–1080]	rapid cooling in air or water
S32205	1870–2010 [1020–1100]	rapid cooling in air or water
S32304	1700–1920 [925–1050]	rapid cooling in air or water
S32506	1870–2050 [1020–1120]	rapid cooling in air or water
S32520	1975–2050 [1080–1120]	rapid cooling in air or water
S32550	1900 [1040] min	rapid cooling in air or water
S32707	1975–2050 [1080–1120]	rapid cooling in air or water
S32750	1880–2060 [1025–1125]	rapid cooling in air or water
S32760	1960–2085 [1070–1140]	rapid cooling in air or water
S32808	1920–2100 [1050–1150]	rapid cooling in air or water
S32900	1700–1750 [925–955]	rapid cooling in air or water
S32906	1870–2100 [1020–1150]	rapid cooling in air or water
S32950	1820–1880 [990–1025]	air cool
S33207	1905–2085 [1040–1140]	rapid cooling in water or by other means
S39274	1920–2060 [1025–1125]	rapid cooling in air or water
S39277	1975–2155 [1080–1180]	rapid cooling in air or water
S82011	1850–2050 [1010–1120]	rapid cooling in air or water
S82031	1830 [1000] min	rapid cooling in water or by other means
S82441	1830 [1000] min	rapid cooling in air or water
S83071	1830–2100 [1000–1150]	rapid cooling in water or by other means

TABLE 3 Number of Tubes in a Lot Heat Treated by the Continuous Process or by Direct Quench after Hot Forming

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

9.4 *Hardness Test:*

9.4.1 Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (see Note 2).

9.4.2 For tubing less than 0.354 in. [9.00 mm] in inside diameter and for tubing less than 0.065 in. [1.65 mm] in wall thickness, it is permissible to use the Vickers hardness test in lieu of the Brinell or Rockwell methods.

9.5 When more than one heat is involved, the tension, flaring, flanging, and hardness test requirements shall apply to each heat.

9.6 *Reverse Flattening Test*—For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

10. Hydrostatic or Nondestructive Electric Test

10.1 Each tube shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

10.2 The hydrostatic test shall be in accordance with Specification A1016/A1016M, except that in the calculation of the hydrostatic test pressure *64000(441.2)* shall be substituted for *32000(220.6)*.

11. Tensile and Hardness Properties

11.1 The material shall conform to the tensile and hardness properties prescribed in Table 4.

12. Permissible Variations in Dimensions

12.1 Variations in outside diameter, wall thickness, and length from those specified shall not exceed the amounts prescribed in Table 5.

12.2 The permissible variations in outside diameter given in Table 5 are not sufficient to provide for ovality in thin-walled tubes, as defined in the table. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than twice the permissible variation in outside diameter given in Table 5; however, the mean diameter at that cross section must still be within the given permissible variation.

13. Surface Condition

13.1 All tubes shall be free of excessive mill scale, suitable for inspection. A slight amount of oxidation will not be considered as scale. Any special finish requirements shall be subject to agreement between the manufacturer and the purchaser.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A1016/A1016M, the marking shall indicate whether the tubing is seamless or welded and the wall designation (average wall or minimum wall).

15. Keywords

15.1 duplex stainless steel; ferritic/austenitic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

TABLE 4 Tensile and Hardness Requirements[A]

UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Hardness, max		
				Brinell HBW	Rockwell HRC	Vickers[C] HV
S31200	100 [690]	65 [450]	25	280	29	280
S31260	100 [690]	65 [450]	25	290	30	290
S31500	92 [630]	64 [440]	30	290	30	290
S31803	90 [620]	65 [450]	25	290	30	290
S32001	90 [620]	65 [450]	25	290	30	290
S32003[B]						290
Wall 0.187 in. [5.00 mm] and under	100 [690]	70 [485]	25	290	30	290
Wall above 0.187 in. [5.00 mm]	95 [655]	65 [450]	25	290	30	290
S32101						
Wall 0.187 in. [5.00 mm] and under	101 [700]	77 [530]	30	290	30	290
Wall above 0.187 in. [5.00 mm]	94 [650]	65 [450]	30	290	30	290
S32202	94 [650]	65 [450]	30	290	30	290
S32205	95 [655]	70 [485]	25	290	30	290
S32304						
OD 1 in. [25 mm] and under	100 [690]	65 [450]	25	. . .	. . .	290
OD above 1 in. [25 mm]	87 [600]	58 [400]	25	290	30	290
S32506	90 [620]	65 [450]	18	302	32	300
S32520	112 [770]	80 [550]	25	310	32	310
S32550	110 [760]	80 [550]	15	297	31	295
S32707	133 [920]	101 [700]	25	318	34	315
S32750	116 [800]	80 [550]	15	300	32	300
S32760	109 [750]	80 [550]	25	310	32	310
S32808	116 [800]	80 [550]	15	310	32	310
S32900	90 [620]	70 [485]	20	271	28	275
S32906						
Wall under 0.40 in. [10 mm]	116 [800]	94 [650]	25	300	32	300
Wall 0.40 in. [10 mm] and above	109 [750]	80 [550]	25	300	32	300
S32950	100 [690]	70 [480]	20	290	30	290
S33207						
Wall under 0.157 in. [4 mm]	138 [950]	112 [770]	15	336	36	330
Wall 0.157 in. [4 mm] and above	123 [850]	101 [700]	15	336	36	330
S39274	116 [800]	80 [550]	15	310	32	310
S39277	120 [825]	90 [620]	25	290	30	290
S82011						
Wall 0.187 in. [5.00 mm] and under	101 [700]	75 [515]	30	293	31	295
Wall above 0.187 in. [5.00 mm]	95 [655]	65 [450]	30	293	31	295
S82031						
Wall 0.187 in. [5.00 mm] and under	102 [700]	73 [500]	35	293	31	295
Wall above 0.187 in. [5.00 mm]	94 [650]	58 [400]	35	290	30	290
S82441						
Wall under 0.40 in. [10 mm]	107 [740]	78 [540]	25	290	30	290
Wall 0.40 in. [10 mm] and above	99 [680]	70 [480]	25	290	30	290
S83071	120 [830]	98 [680]	25	300	32	300

[A] For tubing smaller than ½ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 4 shall apply. Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in outside diameter or with walls thinner than 0.015 in. [0.4 mm].
[B] Prior to A789/A789M–04, the values for S32003 were 90 ksi tensile strength and 65 ksi yield strength.
[C] See 9.4.2 for when Vickers hardness testing is permitted.

TABLE 5 Permissible Variations in Dimensions

Group	Size, Outside Diameter, in. [mm]	Permissible Variations in Outside Diameter, in. [mm]	Average Wall[D] Permissible Variations in Wall Thickness,[A] %	Minimum Wall[E] Permissible Variations in Wall Thickness,[A] %		Permissible Variations in Cut Length, in.[B] [mm]		Thin Walled Tubes[C]
				Over	Under	Over	Under	
1	Up to ½ [12.7], excl	±0.005 [0.13]	±15	30	0	⅛ [3]	0	. . .
2	½ to 1½ [12.7 to 38.1], excl	±0.005 [0.13]	±10	20	0	⅛ [3]	0	less than 0.065 in. [1.6 mm] specified
3	1½ to 3½ [38.1 to 88.9], excl	±0.010 [0.25]	±10	20	0	3⁄16 [5]	0	less than 0.095 in. [2.4 mm] specified
4	3½ to 5½ [88.9 to 139.7], excl	±0.015 [0.38]	±10	20	0	3⁄16 [5]	0	less than 0.150 in. [3.8 mm] specified
5	5½ to 8 [139.7 to 203.2], incl	±0.030 [0.76]	±10	20	0	3⁄16 [5]	0	less than 0.150 in. [3.8 mm] specified

[A] When tubes as ordered require wall thicknesses ¾ in. [19 mm] or over, or an inside diameter 60 % or less of the outside diameter, a wider variation in wall thickness is required. On such sizes a variation in average wall thickness of 12.5 % over or under, or a variation in minimum wall thickness of 25.0 % over and 0 % under, shall be permitted.

For tubes less than ½ in. [12.7 mm] in inside diameter that cannot be successfully drawn over a mandrel, the average wall thickness may vary ±15 % from that specified or the minimum wall thickness may vary by +30 %, –0 % from that specified.

[B] These tolerances apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over-tolerances shall be increased by ⅛ in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or ½ in. [13 mm], whichever is the lesser.

[C] Ovality provisions of 12.2 apply.

[D] Applicable to tubing specified as average wall (see 3.1.4).

[E] Applicable to tubing specified as minimum wall (see 3.1.4).

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Pneumatic Test

S1.1 The tubing shall be examined by a pneumatic test (either air underwater or pneumatic leak test) in accordance with Specification A1016/A1016M.

SPECIFICATION FOR SEAMLESS AND WELDED FERRITIC/AUSTENITIC STAINLESS STEEL PIPE

SA-790/SA-790M

(Identical with ASTM Specification A790/A790M-19.)

Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe

1. Scope

1.1 This specification covers seamless and straight-seam welded ferritic/austenitic steel pipe intended for general corrosive service, with particular emphasis on resistance to stress corrosion cracking. These steels are susceptible to embrittlement if used for prolonged periods at elevated temperatures.

1.2 Optional supplementary requirements are provided for pipe when a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.3 Appendix X1 of this specification lists the dimensions of welded and seamless stainless steel pipe as shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the *M* designation of this specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as nominal diameter, size, and nominal size.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E309 Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E426 Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ANSI Standards:*

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *SAE Standard:*

SAE J 1086

2.4 *Other Standard:*

SNT-TC-1A Personal Qualification and Certification in Nondestructive Testing

2.5 *AWS Standard:*

A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Electrodes

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification refer to Terminology A941.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, [metres], or number of lengths),

4.1.2 Name of material (ferritic/austenitic steel pipe),

4.1.3 Process (seamless or welded),

4.1.4 Grade (see Table 1),

4.1.5 Size (NPS designator or outside diameter and schedule number of average wall thickness),

4.1.6 Length (specific or random) (see Section 11),

TABLE 1 Heat Treatment

UNS Designation	Type[A]	Temperature °F [°C]	Quench
S31200		1920–2010 [1050–1100]	Rapid cooling in water
S31260		1870–2010 [1020–1100]	Rapid cooling in air or water
S31500		1800–1900 [980–1040]	Rapid cooling in air or water
S31803		1870–2010 [1020–1100]	Rapid cooling in air or water
S32003		1850–2050 [1010–1120]	Rapid cooling in air or water
S32101		1870 [1020]	Quenched in water or rapidly cooled by other means
S32202		1870–1975 [1020–1080]	Rapid cooling in air or water
S32205	2205	1870–2010 [1020–1100]	Rapid cooling in air or water
S32304	2304	1700–1920 [925–1050]	Rapid cooling in air or water
S32506		1870–2050 [1020–1120]	Rapid cooling in air or water
S32520		1975–2050 [1080–1120]	Rapid cooling in air or water
S32550	255	1900 [1040] min	Rapid cooling in air or water
S32707		1975–2050 [1080–1120]	Rapid cooling in air or water
S32750	2507	1880–2060 [1025–1125]	Rapid cooling in air or water
S32760		1960–2085 [1070–1140]	Rapid cooling in air or water
S32808		1920–2100 [1050–1150]	Rapid cooling in air or water
S32900	329	1700–1750 [925–955]	Rapid cooling in air or water
S32906		1870–2100 [1020–1150]	Rapid cooling in air or water
S32950		1820–1880 [990–1025]	Air cool
S33207		1905–2085 [1040–1140]	Rapid cooling in water or by other means
S39274		1920–2060 [1025–1125]	Rapid cooling in air or water
S39277		1975–2155 [1080–1180]	Rapid cooling in air or water
S81921		1760–2010 [960–1100]	Rapid cooling in air or water
S82011		1850–2050 [1010–1120]	Rapid cooling in air or water
S82121		1830–2010 [1000–1100]	Rapid cooling in air or water
S82441		1870 [1020]	Rapid cooling in air or water
S83071	. . .	1830–2100 [1000–1150]	Rapid cooling in water or by other means

[A] Common name, not a trademark, widely used, not associated with any one producer. 329 is an AISI number.

4.1.7 End finish (section on ends of Specification A999/A999M),

4.1.8 Optional requirements (product analysis, Section 9; hydrostatic test or nondestructive electric test, Section 14),

4.1.9 Test report required (section on certification of Specification A999/A999M),

4.1.10 Specification designation, and

4.1.11 Special requirements and any supplementary requirements selected.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 *Manufacture:*

6.1.1 The pipe shall be made by the seamless or an automatic welding process, with no addition of filler metal in the welding operation.

6.1.2 At the manufacturer's option, pipe may be either hot-finished or cold-finished.

6.1.3 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

6.2 *Discard*—A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

6.3 Unless otherwise stated in the order, all pipe shall be furnished in the heat-treated condition as shown in Table 1.

6.3.1 For seamless pipe, as an alternate to final heat treatment in a continuous furnace or batch-type furnace, immediately following hot forming while the temperature of the pipes is not less than the specified minimum solution treatment temperature, pipes shall be individually quenched in water or rapidly cooled by other means, except for UNS S32950, which shall be air cooled.

6.3.2 If the purchaser desires pipe without heat treatment subsequent to welding, the purchase order shall specify the following condition:

6.3.2.1 No final heat treatment of pipe fabricated from plate that has been heat treated as required by Table 1 for the particular grade is required, *provided a sample of that heat of finished pipe or material representative of that heat of pipe as a prolongation of the weld passes the Test Methods A923 Method B or C (See Note 2*), including base metal, weld metal, and heat affected zone per heat. Each pipe supplied under this requirement shall be stenciled with the suffix "HT-O."

6.3.2.2 For materials not listed in Table 3 of Test Methods A923, the HT-O provision does not apply.

NOTE 2—The Test Methods A923 test method (B or C) is at the manufacturer's option, unless otherwise specified by the purchaser.

7. Chemical Composition

7.1 The steel shall conform to the chemical requirements as prescribed in Table 2.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified.

9. Product Analysis

9.1 At the request of the purchaser's inspector, an analysis of one billet or one length of flat-rolled stock from each heat, or two pipes from each lot, shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5, incl	200 or fraction thereof
6 and over	100 or fraction thereof

9.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.3 If the analysis of one of the tests specified in 8.1 or 9.1 does not conform to the requirements specified in Section 7, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

10. Tensile and Hardness Properties

10.1 The material shall conform to the tensile and hardness properties prescribed in Table 3.

11. Lengths

11.1 Pipe lengths shall be in accordance with the following regular practice:

11.1.1 Unless otherwise agreed upon, all sizes from NPS ⅛ to and including NPS 8 are available in a length up to 24 ft (see Note 3) with the permissible range of 15 to 24 ft (see Note 3). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 3—This value applies when the inch-pound designation of this specification is the basis of purchase. When the *M* designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

11.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be less than the specified length and no more than ¼ in. [6 mm] over it.

11.1.3 No jointers are permitted unless otherwise specified.

12. Workmanship, Finish, and Appearance

12.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted, in the Permissible Variations in Wall Thickness Section of Specification A999/A999M.

13. Mechanical Tests Required

13.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100

TABLE 2 Chemical Requirements[A]

UNS Designation[B]	Type[C]	C	Mn	P	S	Si	Ni	Cr	Mo	N	Cu	Others
S31200		0.030	2.00	0.045	0.030	1.00	5.5–6.5	24.0–26.0	1.20–2.00	0.14–0.20	. . .	. . .
S31260		0.030	1.00	0.030	0.030	0.75	5.5–7.5	24.0–26.0	2.5–3.5	0.10–0.30	0.20–0.80	W 0.10–0.50
S31500		0.030	1.20–2.00	0.030	0.030	1.40–2.00	4.2–5.2	18.0–19.0	2.50–3.00	0.05–0.10	. . .	. . .
S31803		0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5	0.08–0.20	. . .	. . .
S32003		0.030	2.00	0.030	0.020	1.00	3.0–4.0	19.5–22.5	1.50–2.00	0.14–0.20	. . .	. . .
S32101		0.040	4.0–6.0	0.040	0.030	1.00	1.35–1.70	21.0–22.0	0.10–0.80	0.20–0.25	0.10–0.80	. . .
S32202		0.030	2.00	0.040	0.010	1.00	1.00–2.80	21.5–24.0	0.45	0.18–0.26	. . .	. . .
S32205	2205	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	0.14–0.20	. . .	. . .
S32304	2304	0.030	2.50	0.040	0.040	1.00	3.0–5.5	21.5–24.5	0.05–0.60	0.05–0.20	0.05–0.60	. . .
S32506		0.030	1.00	0.040	0.015	0.90	5.5–7.2	24.0–26.0	3.0–3.5	0.08–0.20	. . .	W 0.05–0.30
S32520		0.030	1.5	0.035	0.020	0.80	5.5–8.0	24.0–26.0	3.0–5.0	0.20–0.35	0.5–3.00	. . .
S32550	255	0.04	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9	0.10–0.25	1.50–2.50	. . .
S32707		0.030	1.50	0.035	0.010	0.50	5.5–9.5	26.0–29.0	4.0–5.0	0.30–0.50	1.0	Co 0.5–2.0
S32750[D]	2507	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0–5.0	0.24–0.32	0.5	. . .
S32760[E]		0.030	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0	0.20–0.30	0.50–1.00	W 0.50–1.00
S32808		0.030	1.10	0.030	0.010	0.50	7.0–8.2	27.0–27.9	0.80–1.20	0.30–0.40	. . .	W 2.10–2.50
S32900	329	0.08	1.00	0.040	0.030	0.75	2.5–5.0	23.0–28.0	1.00–2.00	. . .	. . .	. . .
S32906		0.030	0.80–1.50	0.030	0.030	0.80	5.8–7.5	28.0–30.0	1.50–2.60	0.30–0.40	0.80	. . .
S32950		0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	0.15–0.35	. . .	. . .
S33207		0.030	1.50	0.035	0.010	0.80	6.0–9.0	29.0–33.0	3.0–5.0	0.40–0.60	1.0	
S39274		0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5	0.24–0.32	0.20–0.80	W 1.50–2.50
S39277		0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.0–4.0	0.23–0.33	1.20–2.00	W 0.8–1.2
S81921		0.030	2.00–4.00	0.040	0.030	1.00	2.00–4.00	19.0–22.0	1.00–2.00	0.14–0.20	. . .	. . .
S82011		0.030	2.0–3.0	0.040	0.020	1.00	1.00–2.00	20.5–23.5	0.10–1.00	0.15–0.27	0.50	. . .
S82121	. . .	0.035	1.00–2.50	0.040	0.010	1.00	2.00–4.00	21.0–23.0	0.30–1.30	0.15–0.25	0.20–1.20	. . .
S82441		0.030	2.5–4.0	0.035	0.005	0.70	3.0–4.5	23.0–25.0	1.00–2.00	0.20–0.30	0.10–0.80	
S83071	. . .	0.030	0.50–1.50	0.030	0.020	0.50	6.0–8.0	29.0–31.0	3.0–4.0	0.28–0.40	0.80	. . .

[A] Maximum, unless a range or minimum is indicated. Where ellipses (...) appear in this table, there is no minimum and analysis for the element need not be determined or reported.
[B] New designation established in accordance with Practice E527 and SAE J 1086.
[C] Common name, not a trademark, widely used, not associated with any one producer. 329 is an AISI number.
[D] % Cr + 3.3 × % Mo + 16 × % N ≥ 41.
[E] % Cr + 3.3 × (% Mo + 0.5 %W) + 16 × % N ≥ 41.

pipes. Tension tests shall be made on specimens from 2 pipes for lots of more than 100 pipes.

13.2 *Mechanical Testing Lot Definition*—The term *lot* for mechanical tests applies to all pipe of the same nominal size and wall thickness (or schedule) that is produced from the same heat of steel and subjected to the same finishing treatment as defined as follows:

13.2.1 Where the heat treated condition is obtained, consistent with the requirements of 6.3, in a continuous heat treatment furnace or by directly obtaining the heat treated condition by quenching after hot forming, the lot shall include all pipe of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed or all pipe of the same size and heat, hot formed and quenched in the same production run.

13.2.2 Where final heat treatment is obtained, consistent with the requirements of 6.3, in a batch-type heat-treatment furnace equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or smaller range, the lot shall be the larger of (*a*) each 200 ft [60 m] or fraction thereof or (*b*) that pipe heat treated in the same batch furnace charge.

13.2.3 Where the final heat treatment is obtained, consistent with the requirements of 6.3, in a batch-type heat-treatment furnace not equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or smaller range, the term *lot* for mechanical tests applies to the pipe heat treated in the same batch furnace charge, provided that such pipe is of the same nominal size and wall thickness (or schedule) and is produced from the same heat of steel.

13.3 *Flattening Test*—For pipe heat treated in a batch-type furnace, flattening tests shall be made on 5 % of the pipe from each heat-treated lot. For pipe heat treated by the continuous process, or by direct quenching after hot forming, this test shall

TABLE 3 Tensile and Hardness Requirements

UNS Designation	Type[A]	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Hardness, max	
					HBW	HRC
S31200		100 [690]	65 [450]	25	280	. . .
S31260		100 [690]	65 [450]	25	. . .	. . .
S31500		92 [630]	64 [440]	30	290	30
S31803		90 [620]	65 [450]	25	290	30
S32003						
t ≤ 0.187 in. [5.00 mm]		100 [690]	70 [485]	25	290	30
t > 0.187 in. [5.00 mm]		95 [655]	65 [450]	25	290	30
S32101						
t ≤ 0.187 in. [5.00 mm]		101 [700]	77 [530]	30	290	. . .
t > 0.187 in. [5.00 mm]		94 [650]	65 [450]	30	290	. . .
S32202		94 [650]	65 [450]	30	290	30
S32205	2205	95 [655]	65 [450]	25	290	30
S32304	2304	87 [600]	58 [400]	25	290	30
S32506		90 [620]	65 [450]	18	302	32
S32520		112 [770]	80 [550]	25	310	. . .
S32550	255	110 [760]	80 [550]	15	297	31
S32707		133 [920]	101 [700]	25	318	34
S32750	2507	116 [800]	80 [550]	15	300	32
S32760[B]		109 [750]	80 [550]	25	310	32
S32808						
t < 0.40 in. [10 mm]		116 [800]	80 [550]	15	310	32
t ≥ 0.40 in. [10 mm]		101 [700]	72 [500]	15	310	32
S32900	329	90 [620]	70 [485]	20	271	28
S32906						
t < 0.40 in. [10 mm]		116 [800]	94 [650]	25	300	32
t ≥ 0.40 in. [10 mm]		109 [750]	80 [550]	25	300	32
S32950		100 [690]	70 [480]	20	290	30
S33207						
t < 0.157 in. [4 mm]		138 [950]	112 [770]	15	336	36
t ≥ 0.157 in. [4 mm]		123 [850]	101 [700]	15	336	36
S39274		116 [800]	80 [550]	15	310	32
S39277		120 [825]	90 [620]	25	290	30
S81921		90 [620]	65 [450]	25	290	30
S82011						
t < 0.187 in. [5.00 mm]		101 [700]	75 [515]	30	293	31
t ≥ 0.187 in. [5.00 mm]		95 [655]	65 [450]	30	293	31
S82121	. . .	94 [650]	65 [450]	25	286	30
S82441						
t < 0.4 in. [10 mm]		107 [740]	78 [540]	25	290	. . .
t ≥ 0.4 in. [10 mm]		99 [680]	70 [480]	25	290	. . .
S83071	. . .	120 [830]	98 [680]	25	300	32

[A] Common name, not a trademark, widely used, not associated with any one producer. 329 is an AISI number.
[B] Prior to A790/A790M – 04, the tensile strength value for UNS 32760 was 109–130 ksi [750–895 MPa].

be made on a sufficient number of pipes to constitute 5 % of the lot, but in no case less than two lengths of pipe.

13.3.1 For welded pipe with a diameter equal to or exceeding NPS 10, a transverse guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipes or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

13.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two pipes from each lot (see 13.2).

14. Hydrostatic or Nondestructive Electric Test

14.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

14.2 The hydrostatic test shall be in accordance with Specification A999/A999M, except that the value for S to be used in the calculation of the hydrostatic test pressure shall be equal to 50 % of the specified minimum yield strength of the pipe.

14.3 *Nondestructive Electric Test*—Nondestructive electric tests shall be in accordance with Practices E213 or E309.

14.3.1 As an alternative to the hydrostatic test, and when specified by the purchaser, each pipe shall be examined with a nondestructive test in accordance with Practices E213 or E309. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

14.3.1.1 The following information is for the benefit of the user of this specification:

14.3.1.2 The reference standards defined in 14.3.1.3 – 14.3.1.5 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

14.3.1.3 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

14.3.1.4 The eddy-current testing (ET) referenced in this specification (see Practice E426) has the capability of detecting significant discontinuities, especially the short abrupt type.

14.3.1.5 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

14.4 *Time of Examination*—Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

14.5 *Surface Condition:*

14.5.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

14.5.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

14.6 *Extent of Examination:*

14.6.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 14.6.2.

14.6.2 The existence of end effects is recognized and the extent of such effects shall be determined by the manufacturer and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

14.7 *Operator Qualifications*—The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

14.8 *Test Conditions:*

14.8.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

14.8.2 The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in.—100 KHz max
On specified walls up to 0.150 in.—50 KHz max
On specified walls over 0.150 in.—10 KHz max

14.8.3 *Ultrasonic*—For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in. If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

14.9 *Reference Standards*—Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish and heat treatment condition as the pipe to be examined.

14.9.1 *For Ultrasonic Testing,* the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E213, at the option of the manufacturer. The depth of each notch shall not exceed 12 ½ % of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

14.9.2 *For Eddy-Current Testing,* the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

14.9.2.1 *Drilled Hole*—The reference standard shall contain three or more holes equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
	0.039 in. [1 mm]
above ½ to 1¼	0.055 in. [1.4 mm]
above 1¼ to 2	0.071 in. [1.8 mm]
above 2 to 5	0.087 in. [2.2 mm]
above 5	0.106 in. [2.7 mm]

14.9.2.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. [6.4-mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12 ½ % of the specified nominal wall thickness of the pipe or 0.004 in. [0.102 mm], whichever is greater.

14.9.2.3 *Longitudinal Notch*—A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe to have a depth not exceeding 12 ½ % of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

14.10 *Standardization Procedure:*

14.10.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness, grade, and heat treatment condition), and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

14.10.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, process shutdown, or when a problem is suspected.

14.10.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

14.10.4 The signal-to-noise ratio for the reference standard shall be 2½ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, and so forth shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50 % of full scale of the readout display.

14.10.5 If upon any standardization, the rejection amplitude has decreased by 29 % (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed or the transducer(s), coil(s), or sensor(s) adjusted and the unit restandardized. But all pipe tested since the last acceptable standardization must be retested for acceptance.

14.11 *Evaluation of Imperfections:*

14.11.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

14.11.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by cracks or crack-like imperfections. These pipes may be repaired per Sections 12 and 13. To be accepted, a repaired pipe must pass the same non-destructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

14.11.3 If the test signals were produced by visual imperfections such as: (*1*) scratches, (*2*) surface roughness, (*3*) dings, (*4*) straightener marks, (*5*) cutting chips, (*6*) steel die stamps, (*7*) stop marks, or (*8*) pipe reducer ripple. The pipe may be accepted based on visual examination, provided the imperfection is less than 0.004 in. [0.1 mm] or 12 ½ % of the specified wall thickness (whichever is greater).

14.11.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

14.11.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

15. Repair by Welding

15.1 For welded pipe of size NPS 6 or larger with a specified wall thickness of 0.188 in. [4.8 mm] or more, weld repairs made with the addition of compatible filler metal may be made to the weld seam with the same procedures specified for plate defects in the section on Repair by Welding of Specification A999/A999M.

15.2 Weld repairs of the weld seam shall not exceed 20 % of the seam length.

15.3 Except as allowed by 15.3.1, weld repairs shall be made only with the gas tungsten-arc welding process using the same classification of bare filter rod qualified to the most current AWS Specification A5.9 as the grade of pipe being repaired as given in Table 4.

15.3.1 Subject to approval by the purchaser, it shall be permissible for weld repairs to be made with the gas tungsten-arc welding process using a filler metal more highly alloyed than the base metal, if needed for corrosion resistance or other properties.

15.4 Pipes that have had weld seam repairs with filler metal shall be identified with the symbol "WR" and shall be so stated

TABLE 4 Pipe and Filler Metal Specification

Pipe	Filler Metal	
UNS Designation	AWS A5.9 Class	UNS Designation
S31803	ER2209	S39209
S32205	ER2209	S39209
S31200	ER2553	S39553
S82441	ER2209	S39209

and identified on the certificate of tests. If filler metal other than that listed in Table 4 is used, the filler metal shall be identified on the certificate of tests.

15.5 Weld repairs shall be completed prior to any heat treatment.

16. Product Marking

16.1 In addition to the marking prescribed in Specification A999/A999M, the marking shall include the manufacturer's private identifying mark and whether the pipe is seamless or welded. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

17. Keywords

17.1 duplex stainless steel; ferritic/austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

SUPPLEMENTARY REQUIREMENTS

FOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe over NPS 5 there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 7 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe over NPS 8.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A999/A999M shall be made on a specimen from one end or both ends of each pipe. Crops ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

APPENDIX

(Nonmandatory Information)

X1. Table X1.1 IS BASED ON TABLE 1 OF THE AMERICAN NATIONAL STANDARD FOR STAINLESS STEEL PIPE (ANSI B36.19-1965)

TABLE X1.1 Dimensions of Welded and Seamless Stainless Steel Pipe

NOTE 1—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1/8	0.405	10.29	...	...	0.049[B]	1.24	0.068	1.73	0.095	2.41
1/4	0.540	13.72	...	...	0.065[B]	1.65	0.088	2.24	0.119	3.02
3/8	0.675	17.15	...	...	0.065[B]	1.65	0.091	2.31	0.126	3.20
1/2	0.840	21.34	0.065[B]	1.65	0.083[B]	2.11	0.109	2.77	0.147	3.73
3/4	1.050	26.67	0.065[B]	1.65	0.083[B]	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065[B]	1.65	0.109[B]	2.77	0.133	3.38	0.179	4.55
1 1/4	1.660	42.16	0.065[B]	1.65	0.109[B]	2.77	0.140	3.56	0.191	4.85
1 1/2	1.900	48.26	0.065[B]	1.65	0.109[B]	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065[B]	1.65	0.109[B]	2.77	0.154	3.91	0.218	5.54
2 1/2	2.875	73.03	0.083	2.11	0.120[B]	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120[B]	3.05	0.216	5.49	0.300	7.62
3 1/2	4.000	101.60	0.083	2.11	0.120[B]	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120[B]	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109[B]	2.77	0.134[B]	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134[B]	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109[B]	2.77	0.148[B]	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134[B]	3.40	0.165[B]	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156[B]	3.96	0.180[B]	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156[B]	3.96	0.188	4.78	...	...	...	...
16	16.000	406.40	0.165[B]	4.19	0.188	4.78	...	...	...	...
18	18.000	457.20	0.165[B]	4.19	0.188	4.78	...	...	...	...
20	20.000	508.00	0.188[B]	4.78	0.218[B]	5.54	...	...	...	...
22	22.000	558.80	0.188[B]	4.78	0.218[B]	5.54	...	...	...	...
24	24.000	609.60	0.218[B]	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
[B] These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10-1979).

SPECIFICATION FOR SEAMLESS AND WELDED FERRITIC STAINLESS STEEL FEEDWATER HEATER TUBES

SA-803/SA-803M

(Identical with ASTM Specification A803/A803M-16.)

Standard Specification for Seamless and Welded Ferritic Stainless Steel Feedwater Heater Tubes

1. Scope

1.1 This specification covers seamless and welded ferritic stainless steel feedwater heater tubes including those bent, if specified, into the form of U-tubes for application in tubular feedwater heaters.

1.2 The tubing sizes covered shall be ⅝ to 1 in. [15.9 to 25.4 mm] inclusive outside diameter, and average or minimum wall thicknesses of 0.028 in. [0.7 mm] and heavier.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A941.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (length or number of pieces),

4.1.2 Material description (seamless or welded),

4.1.3 Dimensions (outside diameter, wall thickness (minimum or average wall), and length),

4.1.4 Grade (chemical composition) (Table 1), and

4.1.5 U-bend requirements, if order specifies bending, U-bend schedules or drawings shall accompany the order.

4.2 *Optional Requirements*—Purchaser shall specify whether annealing of the U-bends is required or whether tubes are to be hydrotested or air-tested (see 10.6).

4.3 *Supplementary Requirements*—Purchaser shall specify on this purchase order if material is to be eddy-current tested in accordance with Supplementary Requirement S1 or S2, and if special test reports are required, under Supplementary Requirement S3, and,

4.4 Any additional special requirements.

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the latest published edition of Specification A1016/A1016M unless otherwise provided herein.

6. Materials and Manufacture

6.1 The tubing shall be manufactured by either the seamless or welded process.

6.2 *Seamless Tubing:*

6.2.1 Seamless tubing shall be supplied from a cold finish process. Hot finishing as the final sizing process is not allowed.

6.3 *Welded Tubing:*

6.3.1 The tube shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

6.4 Surface contaminants may have detrimental effects on high temperature properties or corrosion resistance of tubing. Contamination by copper, lead, mercury, zinc, chlorides, or

TABLE 1 Chemical Requirements

Grade	UNS S 40900 TP409	UNS S 43035 TP439	UNS S 44627 TP XM-27	UNS S 44626 TP XM-33	UNS S 44635 25-4-4	UNS S 44660 26-3-3	UNS S 44700 29-4	UNS S 44800 29-4-2	UNS S 44400 18-2	UNS S 44735 29-4C
Element	Composition, %									
C, max	0.08	0.07	0.01[A]	0.06	0.025	0.030	0.010	0.010	0.025	0.030
Mn, max	1.00	1.00	0.40	0.75	1.00	1.00	0.30	0.30	1.00	1.00
P, max	0.045	0.040	0.02	0.040	0.040	0.040	0.025	0.025	0.040	0.040
S, max	0.030	0.030	0.02	0.020	0.030	0.030	0.020	0.020	0.030	0.030
Si, max	1.00	1.00	0.40	0.75	0.75	1.00	0.20	0.20	1.00	1.00
Ni	0.50 max	0.50 max	0.5[B] max	0.50 max	3.5–4.5	1.0–3.5	0.15 max	2.0–2.5	1.00 max	1.00 max
Cr	10.5–11.7	17.0–19.0	25.0–27.5	25.0–27.0	24.5–26.0	25.0–28.0	28.0–30.0	28.0–30.0	17.5–19.5	28.0–30.0
Mo	. . .	. . .	0.75–1.50	0.75–1.50	3.5–4.5	3.0–4.0	3.5–4.2	3.5–4.2	1.75–2.50	3.6–4.2
Al	. . .	0.15 max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Cu	. . .	. . .	0.20 max	0.20 max	. . .	. . .	0.15 max	0.15 max	. . .	. . .
N	. . .	0.04 max	0.015 max	0.040 max	0.035	0.040 max	0.020 max[C]	0.020 max[C]	0.035 max	0.045 max
Ti	6 × C min; 0.75 max	0.20 + 4 (C + N) min; 1.10 max	. . .	7 × (C + N) but no less than 0.20 min; 1.00 max	(Ti + Nb[D]) = 0.2 + 4 (C + N) min; 0.80 max	Ti + Nb[D] = 6 × (C + N) but no less than 0.20 min; 1.00 max			(Ti + Nb[D]) = 0.20 + 4 (C + N) min; 0.80 max	Ti + Nb[D] = 6 × (C + N) but no less than 0.20 min; 1.00 max
Nb[D]	. . .	. . .	0.05–0.20	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] For small diameter or thin walls, or both, tubing, where many drawing passes are required, a carbon maximum of 0.015 % is necessary. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.040 in. [1 mm] in minimum wall thickness).
[B] Nickel + copper.
[C] Carbon + nitrogen = 0.025 max.
[D] The term Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

sulfur may be detrimental to stainless steels. The manufacturer shall employ techniques which minimize surface contamination by these elements.

7. Cleaning Before Annealing

7.1 All lubricants or coatings used in the manufacture of straight-length tube or in the bending shall be removed from all surfaces prior to any annealing treatments. U-bends on which a lubricant had been applied to the inside surface during bending shall have the cleanness of their inside surface confirmed by blowing close-fitting acetone-soaked felt plugs through 10 % of the tubes of each bend radius. Dry, oil-free air or inert gas shall be used to blow the plugs through the tubes. If the plugs blown through any tube show more than a light gray discoloration, all tubes that have had a lubricant applied to the inside surface during bending shall be recleaned. After recleaning 10 % of the tubes of each bend radius whose inside surface had been subjected to bending, lubricants shall be retested.

8. Heat Treatment

8.1 All finished straight tubing or straight tubing ready for U-bending shall be furnished in the solution-annealed condition. The annealing procedure shall consist of heating the material to a temperature of 1200°F [650°C] or higher and cooling (as appropriate for the grade) to meet the requirements of this specification.

8.2 If heat treatment of U-bends is specified, it shall satisfy the annealing procedure described in 8.1 and shall be done as follows:

8.2.1 The heat treatment shall be applied to the U-bend area plus approximately 6 in. [150 mm] of each leg beyond the tangent point of the U-bend.

8.2.2 If the heat treatment specified in 8.2 is accomplished by resistance-heating methods wherein electrodes are clamped to the tubes, the clamped areas shall be visually examined for arc burns. Burn indications shall be cause for rejection unless they can be removed by local polishing without encroaching upon minimum wall thickness.

8.2.3 Temperature control shall be accomplished through the use of optical or emission pyrometers, or both. No temperature-indicating crayons, lacquers, or pellets shall be used.

8.2.4 The inside of the tube shall be purged with a protective or an inert gas atmosphere during heating and cooling to below 700°F [370°C] to prevent scaling of the inside surface. The atmosphere should be noncarburizing.

9. Chemical Composition

9.1 *Product Analysis:*

9.1.1 The steel shall conform to the chemical composition in Table 1.

9.1.2 When specified on the purchase order, a product analysis shall be supplied from one tube or coil of steel per heat. The product analysis tolerance of Specification A480/A480M shall apply.

9.1.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of this specification; otherwise all remaining material in the heat or lot shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of this specification shall be rejected.

10. Mechanical Requirements

10.1 *Tensile Properties:*

10.1.1 The material shall conform to the tensile properties shown in Table 2.

10.1.2 One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes.

10.1.3 Table 3 gives the computed minimum elongation values for each 1⁄32 in. [0.8 mm] decrease in wall thickness.

10.2 *Hardness:*

10.2.1 The tubes shall have a hardness number not to exceed those prescribed in Table 4. This hardness requirement is not to apply to the bend area of U-bend tubes which are not heat treated after bending.

10.2.2 Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot.

10.3 *Reverse Flattening Test (for Welded Product)*—One reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

10.4 *Flange Test (for Welded Product)*—Flange tests shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot.

10.5 *Flaring Test (for Seamless Tubes)*—One test shall be made on specimens from one end of one tube from each lot of finished tubes. The minimum expansion of the inside diameter shall be 10 %.

10.6 *Pressure Test*—Each straight tube, or each U-tube after completion of the bending and post-bending heat treatment, shall be pressure-tested in accordance with one of the following paragraphs as specified by the purchaser:

10.6.1 *Hydrostatic Test*—Each tube shall be given an internal hydrostatic test in accordance with Specification A1016/A1016M.

TABLE 2 Tensile Requirements

Grade	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation[A] in 2 in. or 50 mm, min, %
TP 409	55 [380]	30 [205]	20
TP 439	60 [415]	30 [205]	20
TP XM-27	65 [450]	40 [275]	20
TP XM-33	68 [470]	45 [310]	20
25-4-4	90 [620]	75 [515]	20
26-3-3	85 [585]	65 [450]	20
29-4	80 [550]	60 [415]	20
29-4-2	80 [550]	60 [415]	20
18-2	60 [415]	35 [240]	20
29-4C	75 [515]	60 [415]	18

[A] For longitudinal strip tests, a deduction of 0.90 % for 29-4C and 1 % for all other grades shall be made from the basic minimum elongation for each 1⁄32 in. [0.8 mm] decrease in wall thickness below 5⁄16 in. [8 mm]. Table 3 gives the computed minimum values.

TABLE 3 Minimum Elongation Values[A]

Wall Thickness[B]		Elongation in 2 in. or 50 mm, min, %	
in.	mm	29-4C	All Other
5⁄16 (0.312)	8	18	20
9⁄32 (0.281)	7.2	17	19
1⁄4 (0.250)	6.4	16	18
7⁄32 (0.219)	5.6	15	17
3⁄16 (0.188)	4.8	14	16
5⁄32 (0.156)	4	13	15
1⁄8 (0.125)	3.2	13	14
3⁄32 (0.094)	2.4	12	13
1⁄16 (0.062)	1.6	11	12
0.062 to 0.035, excl	1.6 to 0.9	10	12
0.035 to 0.022, excl	0.9 to 0.6	10	11
0.022 to 0.015, excl	0.6 to 0.4	10	11

[A] Calculation elongation shall be rounded to the nearest whole number.
[B] Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation
29-4C	$E = 28.8t + 9.00$
	$[E = 1.13t + 9.00]$
All other	$E = 32t + 10.00$
	$[E = 1.25t + 10.00]$

where:

E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in. [mm].

TABLE 4 Hardness Requirements

Grade	Brinell Hardness, max	Rockwell Hardness, B Scale, max
TP 409	207	95
TP 439	207	95
P XM-27	241	100
TP XM-33	241	100
25-4-4	270	27[A]
26-3-3	265	25[A]
29-4	241	100
29-4-2	241	100
18-2	217	95
29-4C	241	100

[A] Rockwell Hardness, C scale.

10.6.2 *Pneumatic Test*—Each tube shall be examined by a pneumatic test (either air underwater or pneumatic leak test) in accordance with Specification A1016/A1016M.

10.7 *Lot Definitions:*

10.7.1 For flange and flaring test requirements, the term “lot” applies to 125 tube groupings, prior to cutting to length, of the same nominal size and wall thickness, produced from the same heat of steel and annealed in a continuous furnace.

10.7.2 For tension and hardness requirements, the term “lot” applies to all tubes, prior to cutting to length, of the same nominal diameter and wall thickness, produced from the same heat of steel and annealed in a continuous furnace at the same temperature, time at temperature, and furnace speed.

11. Corrosion Resisting Properties

11.1 One full section sample 1 in. [25 mm] long from the center of a sample tube of the smallest radius bend that is heat treated shall be tested in the heat treated condition in accordance with the appropriate practice in Practices A763 for the specified grade, or as agreed upon for TP409.

11.2 One full-section sample 1 in. [25 mm] long from each lot of straight tubes shall be tested in the finished condition in accordance with the appropriate practice in Practices A763 for the specified grade, or as agreed upon for TP409.

11.3 The appearance of any fissures or cracks in the test specimen, when evaluated in accordance with the Evaluation Sections of Practices A763 indicating the presence of intergranular attack, shall be cause for rejection of that lot.

11.4 For corrosion test requirements, the term "lot" applies to all tubes, prior to cutting to length, of the same nominal diameter and wall thickness, produced from the same heat of steel and annealed in a continuous furnace at the same temperature, time at temperature, and furnace speed.

12. Permissible Variations in Dimensions (Fig. 1)

12.1 Permissible variations from the specified outside diameter shall be in accordance with Specification A1016/A1016M. Those tolerances do not apply to the bent portion of the U-tubes. At the bent portion of a U-tube for $R = 2 \times D$ or greater, neither the major nor minor diameter of the tube shall deviate from the nominal diameter prior to bending by more than 10 %. If less than $2 \times D$ is specified, tolerances could be greater.

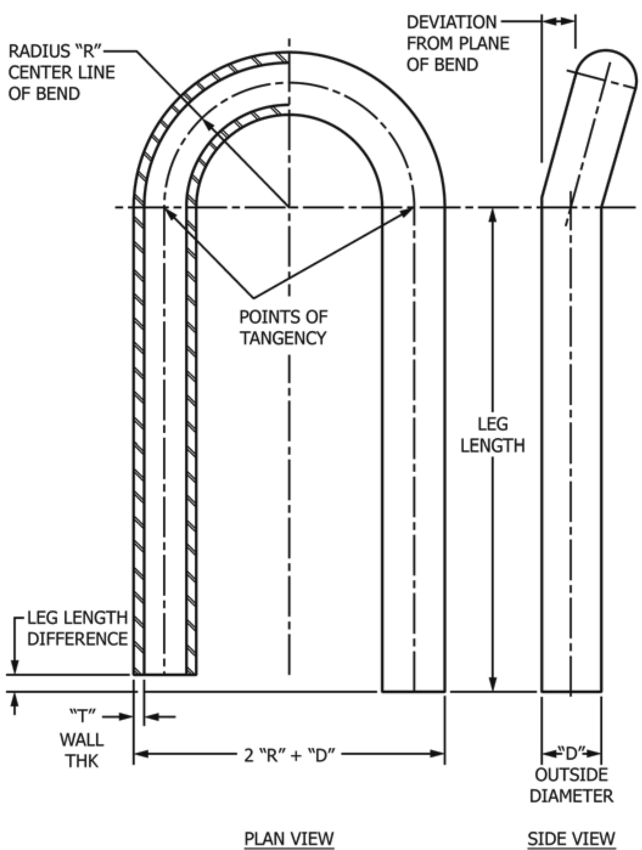


FIG. 1 Plane Bend for U-Tube

12.2 *Permissible Variations from the Specified Wall Thickness:*

12.2.1 Permissible variations from the specified minimum wall thickness shall not exceed +20 – 0 %.

12.2.2 Permissible variations from the specified average wall thickness are ±10 % of the nominal wall thickness.

12.2.3 The wall thickness of the tube in the U-bent section shall not be less than value determined by the equation:

$$t_f = \frac{4RT}{4R + D}$$

where:

t_f = wall thickness after bending, in. [mm],
T = specified minimum tube wall thickness, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

12.3 *Permissible Variations from the Specified Length:*

12.3.1 *Straight Lengths*—The maximum permissible variations for lengths 24 ft [7.3 m] and shorter shall be +1⁄8 in. [+3 mm], –0; for lengths longer than 24 ft [7.3 m], an additional over tolerance of +1⁄8 in. [+3 mm] for each 10 ft [3 m], or fraction thereof, shall be permitted up to a maximum of +1⁄2 in. [+13 mm].

12.3.2 *U-Bends*—In the case of U-tubes, the length of the tube legs, as measured from the point of tangency of the bend and the tube leg to the end of the tube leg, shall not be less than specified, but may exceed the specified values by the amount given in Table 5. The difference in lengths of the tube legs shall not be greater than 1⁄8 in. [3 mm] unless otherwise specified.

12.4 The end of any tube may depart from square by not more than the amount given in Table 6.

12.5 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value (2*R*-specified tube outside diameter) by more than 1⁄16 in. [1.5 mm] where *R* is the center-line bend radius.

12.6 The bent portion of the U-tube shall be substantially uniform in curvature, and not to exceed ±1⁄16 in. [±1.5 mm] of the nominal center-line radius.

12.7 Permissible deviation from the plane of bend (see Fig. 1) shall not exceed 1⁄16 in. [1.5 mm] as measured from the points of tangency.

13. Workmanship, Finish, and Appearance

13.1 Tubing purchased to this specification is intended for use in heat exchangers and will be inserted through close-fitting holes in baffles or support plates, or both, spaced along the tube length. The tube ends will also be inserted into very close-fitting holes in a tubesheet and expanded and may be welded therein. The tubes shall be able to stand roll expanding (See Note 1) and bending without showing cracks and flaws, and shall be finished reasonably straight and suitable for the

TABLE 5 Tube Leg Length Tolerance

Leg Length, ft [m]	Plus Tolerance, in. [mm]
Up to 20 [6], incl	1⁄8 [3.2]
Over 20 to 30 [6 to 9], incl	5⁄32 [4.0]
Over 30 to 40 [9 to 12], incl	3⁄16 [4.8]

TABLE 6 Squareness of Ends Tolerance

Tube OD, in. [mm]	Tolerance, in. [mm]
Up to ⅝ [15.9], incl	0.010 [0.25]
Over ⅝ to 1 in. [15.9 to 25.4], incl	0.016 [0.41]

intended purpose. Surface defects that violate minimum wall requirements shall be cause for rejection.

NOTE 1—Ferritic stainless steels may be expanded by other methods but the user should exercise precautions when using methods other than roll expansion as these grades have a higher ductile-brittle transition temperature, are more strain rate sensitive, and have lower ductility than austenitic grades.

13.2 The residual chloride salt contamination of the inside and outside surface of the tubing at the time of packing for shipment from the mill shall not exceed a concentration of 1 mg/ft^2 [10.7 mg/m^2] of tube surface. One tube in each 500 pieces shall be checked immediately prior to packing for shipment for chloride salt contamination by a procedure agreed to between the manufacturer and purchaser.

14. Surface Condition

14.1 The straight tubes, after final annealing, shall be pickled using a solution of nitric and hydrofluoric acids followed by flushing and rinsing in water. If bright-annealing is performed, this requirement does not apply.

14.1.1 All tubes shall be free of excessive mill scale, suitable for inspection. A slight amount of oxidation will not be considered as scale. Any special finish requirements shall be subject to agreement between the manufacturer and the purchaser.

14.2 A light oxide scale on the outside surface of U-bend area shall be permitted for tubes that have been electric-resistance heat treated after bending.

15. Nondestructive Test (Electric Test)

15.1 Each straight tube shall be tested after the finish heat treatment by passing it through a nondestructive tester capable of detecting defects on the entire cross section of the tube in accordance with Specification A1016/A1016M.

16. Inspection

16.1 The inspector representing the purchaser shall have entry, at all times, to those areas where inspection and testing is being performed on the purchaser's ordered material. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All required tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

17. Rejection

17.1 Each length of tubing received from the manufacturer may be inspected by the purchaser, and, if it does not meet the requirements of the specification based on the inspection and test method outlined in the specification, the tubing may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

17.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective, shall be set aside, and the manufacturer shall be notified. Disposition of such material shall be a matter for agreement between the manufacturer and the purchaser.

18. Certification

18.1 A test report, signed by an authorized employee or representative of the manufacturer, shall be furnished to the purchaser to indicate the specification and grade, seamless or welded, the results of the heat analysis, hardness, and tensile properties. Product analysis will be reported only when requested on the purchase order as provided in 9.1.1.

19. Product Marking

19.1 All tubes shall be marked with the heat number.

19.2 Containers and packages shall be marked or tagged to show the purchaser's order number, the manufacturer's order number, specification, seamless or welded, grade, size and wall thickness, minimum or average, number of pieces contained in the package, and item number (if appropriate).

20. Packaging

20.1 All tubing shall be packaged and blocked in such a manner as to prevent damage in ordinary handling and transportation. The boxes shall be constructed in such a manner that no nails, staples, screws, or similar fasteners are required to close and secure the box after the tubes have been placed in the box. The box shall be lined with plastic sheet or vapor barrier materials so as to prevent chloride contamination of the tube during handling, transportation, and storage.

20.2 The U-bent tubes shall be arranged in boxes so that the smaller radius bends may be removed without disturbing larger radius bends. Tubes for an item number shall be boxed together.

21. Keywords

21.1 feedwater heater tubes; ferritic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which event the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

S1. Nondestructive Eddy-Current Test

S1.1 Each tube in the finished condition, except for bending if that is required, shall be tested by passing it through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation shall be used to clearly distinguish the artificial defects. The outside and inside surfaces of the tubes shall be free of loose scale, metallic particles, or other material that would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding it longitudinally through an inspection coil or coils with a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from the appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed that the inspection of the tubing is performed.

S1.2 The factors listed in S1.3 shall be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions, for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portions of the tube.

S1.3 The following as well as other factors involved shall not be used in such a manner that they detract from the overall ability of the instrument to detect defects: test frequency, direct-current saturation level, filter networks, phase-analysis circuits, coil diameter, and instrument gain.

S1.4 The reference standard shall consist of a defect-free sample of the same size, alloy, and condition (temper) as that being tested, and shall contain longitudinal and circumferential notches on the outside diameter establishing the rejection level of the tubing to be tested. Inside diameter notches, both longitudinal and transverse, shall also be a part of the reference standard. These inside notches may be larger than the outside notches, and are intended for use only to assure instrument phase settings capable of yielding optimum inside surface sensitivity.

S1.4.1 All notches shall be produced by EDM methods. The outside diameter notches shall be of the dimensions shown in Table S1.1. See also Fig. S1.1.

S1.5 All tubing shall meet this specification. The instrument calibration shall be verified at the start of testing, after any shut down of the test equipment, after any test equipment adjustment, or at least every ½ h of continuous production testing, or both. Tubes generating a signal above the outside-diameter calibration standard sensitivity level shall be rejected.

S1.6 Tubes may be reconditioned and retested provided reconditioning does not adversely effect the minimum wall thickness or other properties of the tube specification requirements. Upon agreement between purchaser and manufacturer, the referee method, employing ultrasonic testing, may be employed for retesting tubes rejected by the eddy-current test. The calibration standard for this test shall be identical to that required for the eddy-current test.

TABLE S1.1 Notch Depth[A]

OD, in. [mm]	Wall, in. [mm]	Depth, max in. [mm]	Length, max, in. [mm]	Width, max
⅝ to 1 [15.9 to 25.4] incl	0.028 [0.71] and heavier	0.005 [0.12] or 10.8 % of specified average wall (when average wall is ordered), or 11.8 % of specified minimum wall (when minimum wall is ordered), whichever is greater	0.375 [9.52]	wall thickness, but not greater than 0.062 in. [1.6 mm]

[A] The tolerance of notch depth shall be ± 8 % or ± 0.0005 in. [0.01 mm], whichever is greater. Refer to Fig. S1.1 for notch location orientation and length of calibration standard.

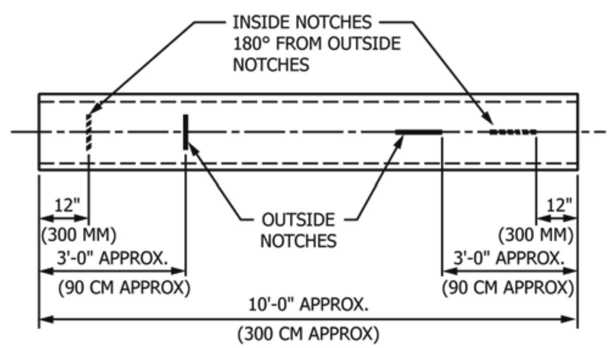


FIG. S1.1 Eddy-Current Test Standard

S2. Nondestructive Eddy-Current Testing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch standards, which shall be as indicated in Table S2.1.

S3. Report

S3.1 A report shall be furnished by the manufacturer to include a record of all tests performed to qualify material to this specification. This record shall include numbers of tests performed and qualitative or quantitative results as are applicable.

TABLE S2.1 Notch Depth for Select Commercial Grade[A]

OD, in. [mm]	Wall, in. [mm]	Depth, max in. [mm]	Length, max, in. [mm]	Width, max
⅝ to 1 [15.9 to 25.4], incl	0.035 [0.9 mm] and heavier	0.005 [0.12] or 10.8 % of specified average wall (when average wall is ordered), or 11.8 % of specified minimum wall (when minimum wall is ordered), whichever is greater	0.375 [9.5]	3 times notch depth
⅝ to 1 [15.9 to 25.4], incl	less than 0.035 [0.9 mm]		0.375 [9.5]	wall thickness

[A]The tolerance of notch depth shall be ± 8 % or ± 0.0005 in. [0.01 mm], whichever is greater. Refer to Fig. S1.1 for notch location orientation and length of calibration standard.

SPECIFICATION FOR SINGLE- OR DOUBLE-WELDED AUSTENITIC STAINLESS STEEL PIPE

SA-813/SA-813M

(**23**)

(Identical with ASTM Specification A813/A813M-14(2019) except for the addition of grain size requirements for H grades and S30815, the addition of E112 to section 2, the deletion of heat treat omitted options, and adding a minimum heat treat temperature for S30815.)

Specification for Single- or Double-Welded Austenitic Stainless Steel Pipe

1. Scope

1.1 This specification covers two classes of fit-up and alignment quality straight-seam single- or double-welded austenitic steel pipe intended for high-temperature and general corrosive service.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft·lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades 304, 304L, and 347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3 for service at temperatures as low as −425 °F [−250 °C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325 °F [−200 °C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50 °F [−45 °C]

1.2 Grades TP304H, TP304N, TP316H, TP316N, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Two classes of pipe are covered as follows:

1.3.1 *Class SW*—Pipe, single-welded with no addition of filler metal and

1.3.2 *Class DW*—Pipe, double-welded with no addition of filler metal.

1.4 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.5 Table 1 lists the dimensions of welded stainless steel pipe as shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E112 Test Methods for Determining Average Grain Size

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E426 Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

TABLE 1 Dimensions of Welded and Seamless Stainless Steel Pipe[A]

NOTE 1—Table 1 is based on Table number 1 of the American National Standard for Stainless Steel Pipe (ANSI B36.19-1965).

NOTE 2—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[B]		Schedule 10S[B]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	. . .	. . .	0.049[C]	1.24	0.068	1.73	0.095	2.41
¼	0.540	13.72	. . .	. . .	0.065[C]	1.65	0.088	2.24	0.119	3.02
⅜	0.675	17.15	. . .	. . .	0.065[C]	1.65	0.091	2.31	0.126	3.20
½	0.840	21.34	0.065[C]	1.65	0.083[C]	2.11	0.109	2.77	0.147	3.73
¾	1.050	26.67	0.065[C]	1.65	0.083[C]	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065[C]	1.65	0.109[C]	2.77	0.133	3.38	0.179	4.55
1¼	1.660	42.16	0.065[C]	1.65	0.109[C]	2.77	0.140	3.56	0.191	4.85
1½	1.900	48.26	0.065[C]	1.65	0.109[C]	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065[C]	1.65	0.109[C]	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120[C]	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120[C]	3.05	0.216	5.49	0.300	7.62
3½	4.000	101.60	0.083	2.11	0.120[C]	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120[C]	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109[C]	2.77	0.134[C]	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134[C]	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109[C]	2.77	0.148[C]	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134[C]	3.40	0.165[C]	4.19	0.365	9.27	0.500[C]	12.70[C]
12	12.750	323.85	0.156[C]	3.96	0.180[C]	4.57	0.375[C]	9.52[C]	0.500[C]	12.70[C]
14	14.000	355.60	0.156[C]	3.96	0.188	4.78	. . .	. . .	. . .	. . .
16	16.000	406.40	0.165[C]	4.19	0.188	4.78	. . .	. . .	. . .	. . .
18	18.000	457.20	0.165[C]	4.19	0.188	4.78	. . .	. . .	. . .	. . .
20	20.000	508.00	0.188[C]	4.78	0.218[C]	5.54	. . .	. . .	. . .	. . .
22	22.000	558.80	0.188[C]	4.78	0.218[C]	5.54	. . .	. . .	. . .	. . .
24	24.000	609.60	0.218[C]	5.54	0.250	6.35	. . .	. . .	. . .	. . .
30	30.000	762.00	0.250	6.35	0.312	7.92	. . .	. . .	. . .	. . .

[A]For pipe sizes not listed, the dimensions and tolerances shall be by agreement between the purchaser and producer.
[B]Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
[C]These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10-1979).

2.2 *ANSI Standards:*

B1.20.1 Pipe Threads, General Purpose
B31.3 Chemical Plant and Refinery Piping Code
B36.10 Welded and Seamless Wrought Steel Pipe
B36.19 Stainless Steel Pipe

2.3 *ASME Boiler and Pressure Vessel Code:*

Section VIII Division 1, Pressure Vessels

2.4 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)
SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

3. Ordering Information

3.1 Orders for material under this specification should include the following as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (austenitic steel pipe),

3.1.3 Class (1.3). If not specified by the purchaser, the producer shall have the option to furnish either single-welded (SW) or double-welded (DW) pipe,

3.1.4 Grade (Table 2),

3.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

3.1.6 Length (specific or random), (Section 9),

3.1.7 End finish (section on Ends of Specification A999/A999M),

3.1.8 Optional requirements (hydrostatic or nondestructive electric test, Section 13,) (Supplementary Requirements S1 to S6),

3.1.9 Test report required (Section on Certification of Specification A999/A999M),

3.1.10 Specification number, and

3.1.11 Special requirements or exceptions to the specification.

4. Materials and Manufacture

4.1 *Manufacture:*

4.1.1 The pipe shall be made by a machine-welding or an automatic-welding process, welding from one or both sides and producing full penetration welds with no addition of filler metal in the welding operation.

4.1.2 Weld repairs, with the addition of compatible filler metal, may be made to the weld joint in accordance with the requirements of the section on Repair by Welding of Specification A999/A999M.

TABLE 2 Chemical Requirements

Grade	UNS Desig- nation[A]	Composition, %															
		Carbon, max[B]	Manga- nese, max[B]	Phos- phorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molyb- denum	Titanium	Colum- bium	Tanta- lum, max	Nitrogen[C]	Vanadium	Copper	Cerium	Cobalt
TP201[D]	S20100	0.15	5.5–7.5	0.060	0.030	1.00	3.5–5.5	16.0–18.0	. . .	. . .	. . .	. . .	0.25	. . .	. . .	. . .	. . .
TP201LN[D]	S20153	0.03	6.4–7.5	0.045	0.015	0.75	4.0–5.0	16.0–17.5	. . .	. . .	. . .	. . .	0.10–0.25	. . .	1.00	. . .	. . .
TP304	S30400	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP304L	S30403	0.030[E]	2.00	0.045	0.030	1.00 max	8.0–12.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP304N	S30451	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .	. . .
TP304LN	S30453	0.030	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .	. . .
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00 max	12.0–16.0	22.0–24.0	. . .	. . .	10 × C min, 1.10 max	. . .	. . .	. . .	. . .	. . .	. . .
TP309S	S30908	0.08	2.00	0.045	0.030	1.00 max	12.0–15.0	22.0–24.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	. . .	. . .	10 × C min, 1.10 max	. . .	. . .	. . .	. . .	. . .	. . .
TP310S	S31008	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316	S31600	0.08	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316L	S31603	0.030[E]	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316N	S31651	0.08	2.00	0.045	0.030	1.00 max	10.0–15.0	16.0–18.0	2.00–3.00				0.10–0.16	. . .	. . .	. . .	. . .
TP316LN	S31653	0.030[E]	2.00	0.045	0.030	1.00 max	10.0–13.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .	. . .
TP317	S31700	0.08	2.00	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP317L	S31703	0.030	2.00	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S31727	0.030	1.00	0.030	0.030	1.00 max	14.5–16.5	17.5–19.0	3.8–4.5	. . .	. . .	. . .	0.15–0.21	. . .	2.8–4.0	. . .	. . .
. . .	S32053	0.030	1.00	0.030	0.010	1.00 max	24.0–26.0	22.0–24.0	5.0–6.0	. . .	. . .	. . .	0.17–0.22	. . .	. . .	. . .	. . .
TP321	S32100	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	F	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	G	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP347	S34700	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	. . .	H	. . .	. . .	. . .	. . .	. . .	. . .
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	. . .	I	. . .	. . .	. . .	. . .	. . .	. . .
TP348	S34800	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	. . .	H	0.10	. . .	. . .	. . .	. . .	0.20 max
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	. . .	I	0.10	. . .	. . .	. . .	. . .	0.20 max
TPXM-10	S21900	0.08	8.0–10.0	0.045	0.030	1.00 max	5.5–7.5	19.0–21.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .	. . .
TPXM-11	S21903	0.04	8.0–10.0	0.045	0.030	1.00 max	5.5–7.5	19.0–21.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .	. . .
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.5–18.5	17.0–19.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TPXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00 max	11.5–13.5	20.5–23.5	1.50–3.00	. . .	0.10–0.30	. . .	0.20–0.40	0.10–0.30	. . .	. . .	. . .
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00 max	2.3–3.7	17.0–19.0	. . .	. . .	. . .	. . .	0.20–0.40	. . .	. . .	. . .	. . .
. . .	S31254	0.020	1.00	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.0–6.5	. . .	. . .	. . .	0.18–0.22	. . .	0.50–1.00	. . .	. . .
. . .	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	. . .	. . .	. . .	. . .	0.14–0.20	. . .	. . .	0.03–0.08	. . .
. . .	N08367	0.030	2.00	0.040	0.030	1.00 max	23.5–25.5	20.0–22.0	6.0–7.0	. . .	. . .	. . .	0.18–0.25	. . .	0.75 max	. . .	. . .
. . .	S31266[J]	0.030	2.00–4.00	0.035	0.020	1.00 max	21.0–24.0	23.0–25.0	5.2–6.2	. . .	. . .	. . .	0.35–0.60	. . .	1.00–2.50	. . .	. . .

[A] New designation established in accordance with ASTM E527 and SAE J1086 Practice for Numbering Metals and Alloys (UNS).
[B] Maximum, unless otherwise indicated.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
[D] DELETED
[E] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1 mm] in minimum wall thickness).
[F] The titanium content shall be not less than five times the carbon content and not more than 0.70 %.
[G] The titanium content shall be not less than four times the carbon content and not more than 0.70 %.
[H] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.0 %.
[I] The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.10 %.
[J] For S31266, W = 1.50–2.50.

4.1.3 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

4.1.4 H grades and S30815 shall have a grain size of 7 or coarser when determined in accordance with ASME E112. Grain size determinations shall be made on each heat treatment lot, as defined in Section 12, for the same number of pipes as prescribed for the flattening test in 12.2.

4.2 *Heat Treatment:*

4.2.1 All pipe shall be furnished in the heat-treated condition. The heat-treatment procedure, except for H grades, N08367, and S31254, shall consist of heating the pipe to a minimum temperature of 1900 °F [1040 °C] and quenching in water or rapidly cooling by other means.

4.2.2 All H grades and S30815 shall be furnished in the solution-treated condtion. If cold working is involved in processing, the minimum solution treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000 °F [1100 °C] and for Grades TP304H and TP316H, 1900 °F [1040 °C]. If the H Grade is hot rolled, the minimum solution treating temperatures for Grades TP321H, TP347H, and TP348H shall be 1925 °F [1050 °C], and for Grades TP304H and TP316H, 1900 °F [1040 °C]. The mimum temperature for S30815 shall be 1920 °F [1050 °C].

4.2.3 The heat-treatment procedure for S31254 shall consist of heating the pipe to a minimum temperature of 2100 °F [1150 °C] and quenching in water or rapidly cooling by other means.

4.2.4 S31727 and S32053 shall be heat treated 1975 to 2155 °F [1080 to 1180 °C] followed by quenching in water or rapidly cooling by other means.

4.2.5 UNS N08367 should be solution annealed from 2025 °F [1107 °C] minimum followed by rapid quenching.

4.2.6 DELETED

4.2.7 DELETED

4.2.8 DELETED

5. Chemical Composition

5.1 The steel shall conform to the chemical composition in Table 2.

5.2 When specified on the purchase order, a product analysis shall be supplied from one tube or coil of steel per heat. The product analysis tolerance of Specification A480/A480M shall apply.

6. Product Analysis

6.1 At the request of the purchaser, an analysis of one length of flat-rolled stock from each heat, or one pipe from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel.

NPS Number	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5 inclusive	200 or fraction thereof
6 and over	100 or fraction thereof

6.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

6.3 If the analysis of one of the tests specified in 6.1 does not conform to the requirements specified in Section 5, an analysis of each length of flat-rolled stock from each heat or pipe from the same heat or lot may be made, and all pipe conforming to the requirements shall be accepted.

6.4 For referee purposes, Test Methods, Practices, and Terminology A751 shall be used.

7. Tensile Requirements

7.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

8. Permissible Variations in Dimensions

8.1 Permissible variations in dimensions shall not exceed the following at any point in each length of pipe.

TABLE 3 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP201	S20100	75 [515]	38 [260]
TP201LN	S20153	95 [665]	45 [310]
TP304L	S30403	70 [485]	25 [170]
TP316L	S31603	70 [485]	25 [170]
TP304	S30400	75 [515]	30 [205]
TP304H	S30409	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316H	S31609	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
. . .	S31727	80 [550]	36 [245]
. . .	S32053	93 [640]	43 [295]
TP321	S32100	75 [515]	30 [205]
TP321H	S32109	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21903	90 [620]	50 [345]
TPXM-15	S38100	75 [515]	30 [205]
TPXM-29	S24000	100 [690]	55 [380]
TPXM-19	S20910	100 [690]	55 [380]
TP304N	S30451	80 [550]	35 [240]
TP316N	S31651	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
TP316LN	S31653	75 [515]	30 [205]
. . .	S31254	94 [650]	44 [300]
. . .	S30815	87 [600]	45 [310]
. . .	N08367		
	$t \leq 0.187$	100 [690]	45 [310]
	$t > 0.187$	95 [655]	45 [310]
. . .	S31266	109 [750]	61 [420]

8.1.1 *Specified Diameter*—The outside diameter shall be based on circumferential measurement and shall not exceed the tolerances stated as follows:

8.1.1.1 For sizes up to and including NPS 1¼, ±0.010 in. [±0.25 mm],

8.1.1.2 For sizes NPS 1½ up to and including NPS 6, ±0.020 in. [±0.5 mm],

8.1.1.3 For sizes NPS 8 up to and including NPS 18, ±0.030 in. [±0.75 mm],

8.1.1.4 For sizes NPS 20 up to and including NPS 24, ±0.040 in. [±1 mm], and

8.1.1.5 For sizes NPS 30, ±0.050 in. [±1.25 mm].

8.1.1.6 Outside diameter tolerances closer than shown above may be obtained by agreement between the pipe manufacturer and purchaser.

8.1.2 *Out-of-Roundness*—The difference between the major and the minor outside diameter shall not be more than 1.5 % of the specified outside diameter.

8.1.3 *Alignment (Camber)*—Using a 10-ft [3.0-m] straightedge placed so that both ends are in contact with the pipe, the camber shall not be more than 3⁄16 in. [4.8 mm].

8.1.4 *Thickness*—The wall thickness at any point in the pipe excluding the weld, shall not be more than 12 % under or over the nominal thickness for wall thickness less than 0.188 in. [4.8 mm] and not more than 0.030 in. [0.8 mm] under or over the nominal thickness for wall thickness 0.188 in. [4.8 mm] and greater. Weld reinforcement not to exceed 20 % of the wall thickness is permitted on each of the inside and outside surfaces of the pipe.

9. Lengths

9.1 Pipe lengths shall be in accordance with the following regular practice:

9.1.1 Unless otherwise agreed upon, all sizes up to and including NPS 8 are available in a length up to 24 ft (Note 2) with the permissible range of 15 to 24 ft (Note 2). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 2—The value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

9.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than ¼ in. [6 mm] over that specified.

10. Workmanship, Finish, and Appearance

10.1 The finished pipes shall be free of injurious imperfections and shall have a workmanlike finish. Minor imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 8.

11. Examination of Double-Welded Pipe

11.1 Both ends of each double-welded (Class DW) pipe shall be visually examined to determine that complete fusion was attained between the two welds. In lieu of examining the ends of the pipe, this examination may be performed on cropped ends removed from both ends of each double welded pipe.

12. Mechanical Tests Required

12.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes. Pipe size greater than NPS 6 shall be tested using the transverse tension test with the weld centered in the gauge length of the test specimen. Test specimens shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as prolongation of the pipe longitudinal weld seam.

NOTE 3—The term lot, for mechanical tests, applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment: (*1*) in a continuous heat-treatment furnace, or (*2*) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] range, the larger of: (*a*) each 200 ft [60 m] or fraction thereof or (*b*) that pipe heat treated in the same batch furnace charge.

12.2 *Flattening Test*—For material heat treated in a batch-type furnace, flattening tests shall be made on 5 % of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than two lengths of pipe.

12.2.1 For pipe where the diameter equals or exceeds NPS 10, a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

13. Hydrostatic or Nondestructive Electric Test

13.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

13.2 The hydrostatic test shall be in accordance with Specification A999/A999M.

13.3 *Nondestructive Examination*—Each pipe shall be examined with a nondestructive test in accordance with Practice E213, or E426. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

13.3.1 The following information is for the benefit of the user of this specification:

13.3.1.1 The reference standards defined in 13.9.1 – 13.9.4 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

13.3.1.2 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

13.3.1.3 The eddy-current testing (ET) referenced in this specification, (Practice E426), has the capability of detecting significant discontinuities, especially the short abrupt type.

13.3.1.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

13.4 *Time of Examination:*

13.4.1 Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

13.5 *Surface Condition:*

13.5.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

13.5.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

13.6 *Extent of Examination:*

13.6.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 13.5.2.

13.6.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

13.7 *Operator Qualifications:*

13.7.1 The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

13.8 *Test Conditions:*

13.8.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

13.8.2 The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in.—100 KHz max

On specified walls up to 0.150 in.—50 KHz max

On specified walls above 0.150 in.—10 KHz max

13.8.3 *Ultrasonic*—For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in.

(1) If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

13.9 *Reference Standards:*

13.9.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish and heat treatment condition as the pipe to be examined.

13.9.2 *For Ultrasonic Testing,* the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E213, at the option of the manufacturer. The depth of each notch shall not exceed 12½ % of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

13.9.3 *For Eddy-Current Testing,* the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

(1) Drilled Hole—The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
½	0.039 in. [1 mm]
above ½ to 1¼	0.055 in. [1.4 mm]
above 1¼ to 2	0.071 in. [1.8 mm]
above 2 to 5	0.087 in. [2.2 mm]
above 5	0.106 in. [2.7 mm]

(2) Transverse Tangential Notch—Using a round tool or file with a ¼ in. [6.4 mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12½ % of the specified nominal wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

(3) Longitudinal Notch—A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

13.9.4 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

13.10 *Standardization Procedure:*

13.10.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), Grade and heat treatment condition, and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

13.10.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, process shutdown or when a problem is suspected.

13.10.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

13.10.4 The signal-to-noise ratio for the reference standard shall be 2½ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, etc., shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50 % of full scale of the readout display.

13.10.5 If upon any standardization, the rejection amplitude has decreased by 29 % (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested for acceptance.

13.11 *Evaluation of Imperfections:*

13.11.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

13.11.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by cracks or crack-like imperfections. These pipes may be repaired per Sections 4 and 10. To be accepted, a repaired pipe must pass the same non-destructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

13.11.3 If the test signals were produced by visual imperfections such as:

(1) Scratches,
(2) Surface roughness,
(3) Dings,
(4) Straightener marks,
(5) Cutting chips,
(6) Steel die stamps,
(7) Stop marks, or
(8) Pipe reducer ripple.

The pipe may be accepted based on visual examination provided the imperfection is less than 0.004 in. [0.1 mm] or 12½ % of the specified wall thickness (whichever is greater).

13.11.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

13.11.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

14. Product Marking

14.1 In addition to that specified in Specification A999/A999M, the marking shall include the manufacturer's private identifying mark and identified as either single welded (SW) or double welded (DW) as applicable. For Grades TP304H, TP316H, TP321H, TP347H, and TP348H, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weights.

14.2 DELETED

14.3 When a hydrostatic test of the pipe is not performed, the pipe shall be marked NH.

15. General Requirements

15.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M unless otherwise provided herein.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipes NPS 5 and larger in nominal size, there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5, there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 5 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger in nominal size.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A999/A999M shall be made on a specimen from one or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be tested, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound welds and reasonably uniform material free of injurious laminations, cracks, and similar objectionable imperfections. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable imperfections, the length shall be rejected subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Radiographic Examination

S5.1 Weld soundness shall be determined through radiographic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S6. Corrosion Requirements

S6.1 *Boiling Nitric Acid Test*—Except for Grade TP 321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50 % and less molybdenum) shall meet the requirements of Practice C of Practices A262. The condition of the test specimens and the corrosion rates are as follows: Types 304L, 304LN, 347, and 348 shall be tested in the sensitized condition (heated for 1 h at 1240 °F [670 °C]) and the rate of penetration when the solution is tested in accordance with Practice C shall not exceed 0.0020 in. [0.05 mm] per month. All other nonmolybdenum-bearing types, except for Grade TP 321, shown in Table 2, shall be tested in the annealed and unsensitized condition and the rate of penetration shall not exceed 0.0015 in. [0.038 mm] per month.

S6.2 *Acidified Copper Sulfate Test*—Coupons representing finished pipe made of molybdenum-bearing material (over 0.50 % molybdenum) and Type 321 shall meet the requirements of Practice E of Practices A262. The condition of the test specimen is as follows: Types 316L, 316LN, 317L, and 321 shall be tested in the sensitized condition (heated for 1 h at 1240 °F [670 °C]). All molybdenum-bearing types shown in Table 2 shall be tested in the annealed and unsensitized condition. All specimens shall meet the requirements of the prescribed bend tests.

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SPECIFICATION FOR COLD-WORKED WELDED AUSTENITIC STAINLESS STEEL PIPE

SA-814/SA-814M

(23)

(Identical with ASTM Specification A814/A814M-15(2019).)

Specification for Cold-Worked Welded Austenitic Stainless Steel Pipe

1. Scope

1.1 This specification covers two classes of flanged and cold-bending quality cold-worked straight-seam single or double welded austenitic steel pipe intended for high-temperature and general corrosive services.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft·lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades 304, 304L, and 347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3 for service at temperatures as low as −425 °F [−250 °C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325 °F [−200 °C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50 °F [−45 °C].

1.2 Grades TP304H, TP304N, TP316H, TP316N, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Two classes of pipe are covered as follows:

1.3.1 *Class SW*—Pipe, single-welded with no addition of filler metal and

1.3.2 *Class DW*—Pipe, double-welded with no addition of filler metal.

1.4 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.5 Table 1 lists the dimensions of cold-worked single- or double-welded stainless steel pipe. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E112 Test Methods for Determining Average Grain Size

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ANSI Standards:*

B31.3 Process Piping

TABLE 1 Pipe Dimensions[A]

NPS No.	Outside Diameter	Outside Diameter Tolerance	Schedule	Wall	
	in. [mm]	in. [mm]		Thickness in. [mm]	Tolerance in. [mm]
e ⅛	0.405 [10.29]	+0.004 [0.10]	10	0.049 [1.24]	±0.004 [0.10]
		−0.002 [0.05]	40	0.068 [1.72]	±0.005 [0.12]
			80	0.095 [2.41]	±0.006 [0.15]
¼	0.540 [13.72]	+0.005 [0.12]	10	0.065 [1.65]	±0.005 [0.12]
		−0.003 [0.08]	40	0.088 [2.24]	±0.006 [0.15]
			80	0.119 [3.02]	±0.009 [0.23]
⅜	0.675 [17.15]	+0.006 [0.15]	10	0.065 [1.65]	±0.005 [0.12]
		−0.004 [0.10]	40	0.091 [2.31]	±0.006 [0.15]
			80	0.126 [3.20]	±0.010 [0.25]
½	0.840 [21.34]	+0.007 [0.18]	5	0.065 [1.65]	±0.005 [0.12]
		−0.005 [0.12]	10	0.083 [2.11]	±0.006 [0.15]
			40	0.109 [2.77]	±0.009 [0.23]
			80	0.147 [3.73]	±0.011 [0.28]
¾	1.050 [26.67]	+0.010 [0.25]	5	0.065 [1.65]	±0.005 [0.12]
		−0.007 [0.18]	10	0.083 [2.11]	±0.006 [0.15]
			40	0.113 [2.87]	±0.009 [0.23]
			80	0.154 [3.91]	±0.011 [0.28]
1	1.315 [33.40]	+0.010 [0.25]	5	0.065 [1.65]	±0.005 [0.12]
		−0.007 [0.18]	10	0.109 [2.77]	±0.009 [0.23]
			40	0.133 [3.38]	±0.011 [0.28]
			80	0.179 [4.55]	±0.014 [0.36]
1¼	1.660 [42.16]	+0.012 [0.30]	5	0.065 [1.65]	±0.005 [0.12]
		−0.008 [0.20]	10	0.109 [2.77]	±0.009 [0.23]
			40	0.140 [3.56]	±0.011 [0.28]
			80	0.191 [4.85]	±0.014 [0.36]
1½	1.900 [48.26]	+0.015 [0.38]	5	0.065 [1.65]	±0.005 [0.12]
		−0.008 [0.20]	10	0.109 [2.77]	±0.009 [0.23]
			40	0.145 [3.68]	±0.011 [0.28]
			80	0.200 [5.08]	±0.015 [0.38]
2	2.375 [60.33]	+0.018 [0.46]	5	0.065 [1.65]	±0.005 [0.12]
		−0.008 [0.20]	10	0.109 [2.77]	±0.009 [0.23]
			40	0.154 [3.91]	±0.011 [0.28]
			80	0.218 [5.54]	±0.015 [0.38]
2½	2.875 [73.03]	+0.020 [0.51]	5	0.065 [1.65]	±0.005 [0.12]
		−0.009 [0.23]	10	0.120 [3.05]	±0.010 [0.25]
			40	0.203 [5.16]	±0.015 [0.38]
			80	0.276 [7.01]	±0.020 [0.51]
3	3.500 [88.90]	+0.025 [0.63]	5	0.083 [2.11]	±0.006 [0.15]
		−0.010 [0.25]	10	0.120 [3.05]	±0.010 [0.25]
			40	0.216 [5.49]	±0.015 [0.38]
			80	0.300 [7.62]	±0.020 [0.51]
3½	4.000 [101.6]	+0.025 [0.63]	5	0.083 [2.11]	±0.006 [0.15]
		−0.010 [0.25]	10	0.120 [3.05]	±0.010 [0.25]
			40	0.226 [5.74]	±0.018 [0.46]
			80	0.318 [8.08]	±0.020 [0.51]
4	4.500 [114.3]	+0.025 [0.63]	5	0.083 [2.11]	±0.006 [0.15]
		−0.010 [0.25]	10	0.120 [3.05]	±0.010 [0.25]
			40	0.237 [6.02]	±0.019 [0.48]
			80	0.337 [8.56]	±0.020 [0.51]

[A] All dimensions in inches.

2.3 *ASME Boiler and Pressure Vessel Code:*

Section VIII Division 1, Pressure Vessels

2.4 *SAE Standard:*

SAE J 1086 Practice for Numbering Metals and Alloys (UNS)

3. Ordering Information

3.1 Orders for material under this specification should include the following as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (austenitic steel pipe),

3.1.3 Class (1.3). If not specified by the purchaser, the producer shall have the option to furnish either single-welded (SW) or double-welded (DW) pipe,

3.1.4 Grade (Table 2),

3.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

3.1.6 Length (specific or random) (Section 10),

3.1.7 End finish (Section on Ends of Specification A999/A999M),

3.1.8 Optional requirements (Section 9), (Supplementary Requirements S1 to S8),

3.1.9 Test report required (Section on Certification of Specification A999/A999M),

TABLE 2 Chemical Requirements

Grade	UNS Designation[A]	Composition, %														
		Carbon, max[B]	Manganese, max[B]	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium plus Tantalum	Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium
TP 201	S20100	0.15	5.5–7.5	0.060	0.030	1.00	3.5–5.5	16.0–18.0	. . .	. . .	. . .	. . .	0.25	. . .	. . .	. . .
TP 201LN	S20153	0.03	6.4–7.5	0.045	0.015	0.75	4.0–5.0	16.0–17.5	. . .	. . .	. . .	. . .	0.10–0.25	. . .	1.00	. . .
TP 304	S30400	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 304L	S30403	0.030[D]	2.00	0.045	0.030	1.00 max	8.0–13.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 304N	S30451	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .
TP 304LN	S30453	0.030	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .
TP 309Cb	S30940	0.08	2.00	0.045	0.030	1.00 max	12.0–16.0	22.0–24.0	. . .	. . .	10 × C min, 1.10 max	. . .	. . .	. . .	. . .	. . .
TP309S	S30908	0.08	2.00	0.045	0.030	1.00 max	12.0–15.0	22.0–24.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 310Cb	S31040	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	. . .	. . .	10 × C min, 1.10 max	. . .	. . .	. . .	. . .	. . .
TP 310S	S31008	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	0.75 max	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 316	S31600	0.08	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 316L	S31603	0.030[D]	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 316N	S31651	0.08	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00				0.10–0.16	. . .	. . .	. . .
TP 316LN	S31653	0.030	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .
TP 317	S31700	0.08	2.00	0.045	0.030	1.00 max	11.0–14.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 317L	S31703	0.030	2.00	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S31727	0.030	1.00	0.030	0.030	1.00	14.5–16.5	17.5–19.0	3.8–4.5	. . .	. . .	. . .	0.15–0.21	. . .	2.8–4.0	. . .
. . .	S32053	0.030	1.00	0.030	0.010	1.00	24.0–26.0	22.0–24.0	5.0–6.0	. . .	. . .	. . .	0.17–0.22	. . .	. . .	. . .
TP 321	S32100	0.08	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	[E]	. . .	. . .	. . .	. . .	. . .	. . .
TP 321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	[F]	. . .	. . .	. . .	. . .	. . .	. . .
TP 347	S34700	0.08	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	. . .	[G]	. . .	. . .	. . .	. . .	. . .
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	. . .	[H]	. . .	. . .	. . .	. . .	. . .
TP 348	S34800	0.08	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	. . .	[G]	0.10	. . .	. . .	. . .	
TP 348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	. . .	[H]	0.10	. . .	. . .	. . .	. . .
TP XM-10	S21900	0.08	8.0–10.0	0.045	0.030	1.00 max	5.5–7.5	19.0–21.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .
TP XM-11	S21903	0.04	8.0–10.0	0.045	0.030	1.00 max	5.5–7.5	19.0–21.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .
TP XM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.5–18.5	17.0–19.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP XM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00 max	11.5–13.5	20.5–23.5	1.50–3.00	. . .	0.10–0.30	. . .	0.20–0.40	0.10–0.30	. . .	. . .
TP XM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00 max	2.3–3.7	17.0–19.0	. . .	. . .	. . .	. . .	0.20–0.40	. . .	. . .	. . .
. . .	S31254	0.020	1.00	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.0–6.5	. . .	. . .	. . .	0.18–0.22	. . .	0.50–1.00	. . .
. . .	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	. . .	. . .	. . .	. . .	0.14–0.20	. . .	. . .	0.03–0.08
	N08367	0.030	2.00	0.040	0.030	1.00 max	23.5-25.5	20.0-22.0	6.0-7.0	. . .	. . .	. . .	0.18-0.25	. . .	0.75 max	. . .

[A]New designation established in accordance with Practice E527 and SAE J 1086.
[B]Maximum, unless otherwise indicated.
[C]The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
[D]For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1 mm] in minimum wall thickness).
[E]The titanium content shall be not less than five times the carbon content and not more than 0.70 %.
[F]The titanium content shall be not less than four times the carbon content and not more than 0.70 %.
[G]The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.10 %.
[H]The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.10 %.

3.1.10 Specification designation, and

3.1.11 Special requirements or exceptions to the specification.

4. Materials and Manufacture

4.1 *Manufacture:*

4.1.1 The pipe shall be made by a machine-welding or an automatic-welding process, welding from one or both sides and producing full penetration welds with no addition of filler metal in the welding operation.

4.1.2 Weld repairs, with the addition of compatible filler metal, may be made to the weld joint in accordance with the requirements of the section on Repair by Welding of Specification A999/A999M.

4.1.3 Prior to final heat treatment of the pipe, the weld bead must be cold-worked by methods such as forging, planishing, drawing, swaging or bead rolling so as to obtain a flush condition on the inside and outside of the pipe. Undercuts shall be limited to shallow rounded depressions of less than 0.005 in. [0.127 mm] deep on either the inside or outside surface of the pipe with no encroachment of the minimum permitted wall thickness.

4.1.4 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

4.2 *Heat Treatment:*

4.2.1 All pipe shall be furnished in the heat-treated condition. The heat-treatment procedure, except for H grades, S30815, N08367 and S31254, shall consist of heating the pipe to a minimum temperature of 1900 °F [1040 °C] and quenching in water or rapidly cooling by other means.

4.2.2 All H grades and S30815 shall be furnished in the solution-treated condition. The minimum solution treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000 °F [1100 °C] and for Grades TP304H and TP316H, 1900 °F [1040 °C]. The minimum temperature for S30815 shall be 1920 °F [1050 °C].

4.2.3 The heat-treatment procedure for S31254 shall consist of heating the pipe to a minimum temperature of 2100 °F [1150 °C] and quenching in water or rapidly cooling by other means.

4.2.4 The heat-treatment procedure for S31727 and S32053 shall consist of heating the pipe to a minimum temperature of 1975 to 2155 °F [1080 to 1180 °C] and quenching in water or rapidly cooling by other means.

4.2.5 UNS N08367 shall be solution annealed from 2025 °F [1110 °C] minimum followed by rapid quenching.

4.3 H grades and S30815 shall have a minimum grain size of 7 or coarser when measured in accordance with Test Methods E112.

5. Chemical Composition

5.1 The steel shall conform to the chemical composition prescribed in Table 2.

5.2 When specified on the purchase order, a product analysis shall be supplied from one tube or coil of steel per heat. The product analysis tolerance of Specification A480/A480M shall apply.

6. Tensile Requirements

6.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

7. Permissible Variations in Dimensions

7.1 *Specified Diameter*—The diameter at any point in each length of pipe shall be within the tolerance specified in Table 1.

TABLE 3 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP201	S20100	75 [515]	38 [260]
TP201LN	S20153	95 [665]	45 [310]
TP304L	S30403	70 [485]	25 [170]
TP316L	S31603	70 [485]	25 [170]
TP304	S30400	75 [515]	30 [205]
TP304H	S30409	75 [515]	30 [205]
TP309CB	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316H	S31609	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
TP321	S32100	75 [515]	30 [205]
TP321H	S32109	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21903	90 [620]	50 [345]
TPXM-15	S38100	75 [515]	30 [205]
TPXM-29	S24000	100 [690]	55 [380]
TPXM-19	S20910	100 [690]	55 [380]
TP304N	S30451	80 [550]	35 [240]
TP316N	S31651	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
TP316LN	S31653	75 [515]	30 [205]
. . .	S31254	94 [650]	44 [300]
. . .	S31727	80 [550]	36 [245]
. . .	S32053	93 [640]	43 [295]
. . .	S30815	87 [600]	45 [310]
. . .	N08367		
	t≤0.187	100 [690]	45 [310]
	t>0.187	95 [655]	45 [310]

7.2 *Alignment (Camber)*—Using a 3-ft [1.0-m] straightedge placed so that both ends are in contact with the pipe, the camber shall not be more than 0.030-in. [0.8-mm].

7.3 *Thickness*—The wall thickness at any point in the pipe shall be within the thickness tolerance specified in Table 1, except that for pipe in which the wall thickness exceeds 0.188-in. [4.8-mm] a weld reinforcement of up to 0.015-in. [0.38-mm] is permitted on the inside of the pipe.

8. Lengths

8.1 Pipe lengths shall be in accordance with the following regular practice.

8.1.1 Unless otherwise agreed upon, all sizes up to and including NPS 4 are available in a length up to 24 ft (Note 2) with the permissible range of 15 to 24 ft (Note 2).

NOTE 2—The value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

8.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than ¼ in. [6 mm] over that specified.

8.1.3 No jointers are permitted unless otherwise specified.

9. Workmanship, Finish, and Appearance

9.1 The finished pipes shall be free of injurious imperfections and shall have a workmanlike finish. Minor imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 7.

10. General Requirements

10.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M unless otherwise provided herein.

11. Examination of Double-Welded Pipe

11.1 Both ends of each double-welded (Class DW) pipe shall be visually examined to determine that complete fusion was attained between the two welds. In lieu of examining the ends of the pipe, this examination may be performed on cropped ends removed from both ends of each double welded pipe.

12. Mechanical Tests Required

12.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

NOTE 3—The term "lot," for mechanical tests, applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment (*1*) in a continuous heat-treatment furnace, or (*2*) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] range, the larger of (*a*) Each 200 ft [60 m] or fraction thereof or, (*b*) That pipe heat treated in the same batch furnace charge.

12.2 *Flattening Test*—For material heat treated in a batch-type furnace, flattening tests shall be made of 5 % of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than two lengths of pipe.

12.2.1 For pipe where the diameter equals or exceeds NPS 10, a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

12.3 *Hydrostatic Test*—Each length of pipe shall be subjected to the hydrostatic test in accordance with Specification A999/A999M.

13. Product Marking

13.1 In addition to the marking specified in Specification A999/A999M, the marking shall include the manufacturer's identifying mark and double-welded pipe shall be identified with the mark (DW). For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

14. Keywords

14.1 austenitic stainless steel pipe; cold-worked pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger in nominal size, there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 in nominal size there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 6 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger in nominal size.

S2.2 If a specimen from any length fails to conform to the tensile properties specified, that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A999/A999M shall be made on a specimen from one or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound welds and reasonably uniform material free of injurious laminations, cracks, and similar objectionable imperfections. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable imperfections, the length shall be rejected subject to the removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Eddy Current Examination

S5.1 Pipe soundness shall be determined through eddy-current examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S6. Ultrasonic Examination

S6.1 Pipe soundness shall be determined through ultrasonic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S7. Corrosion Requirements

S7.1 *Boiling Nitric Acid Test*—Except for Grade TP 321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50 % and less molybdenum) shall meet the requirements Practice C of Practices A262. The condition of the test specimens and the corrosion rates are as follows: Types 304L, 304LN, 347, and Type 348 shall be tested in the sensitized condition (heated for 1 h at 1240 °F [670 °C]) and the rate of penetration shall not exceed 0.0020 in. [0.05 mm]/month. All other nonmolybdenum-bearing types, except for Grade TP 321, shown in Table 2 shall be tested in the annealed and unsensitized condition and the rate of penetration when solution tested in accordance with Practice C shall not exceed 0.0015 in./month [0.038 mm/month].

S7.2 *Acidified Copper Sulfate Test*—Coupons representing finished pipe made of molybdenum-bearing material (over 0.50 % molybdenum) and Type 321 shall meet the requirements of Practice E of Practices A262. The condition of the test specimen is as follows: Types 316L, 316LN, 317L and 321 shall be tested in the sensitized condition (heated for 1 h at 1240 °F [670 °C]). All molybdenum-bearing types shown in Table 2 shall be tested in the annealed and unsensitized condition. All specimens shall meet the requirements of the prescribed bend tests.

S8. Flange Test

S8.1 A section of pipe shall be capable of having a flange turned over at a right angle to the body of the pipe without cracking. The width of the flange shall be not less than 15 % of the oustide diameter of the pipe.

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SPECIFICATION FOR WROUGHT FERRITIC, FERRITIC/ AUSTENITIC, AND MARTENSITIC STAINLESS STEEL PIPING FITTINGS

SA-815/SA-815M

(Identical with ASTM Specification A815/A815M-10a except for the deletion of 5.9, 5.14 (Class CR Fittings) and 5.15.4.)

Standard Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings

1. Scope

1.1 This specification covers two general classes, WP and CR, of wrought ferritic, ferritic/austenitic, and martensitic stainless steel fittings of seamless and welded construction covered by the latest revision of Specification A960/A960M. Fittings differing from these standards may be furnished in accordance with Supplementary Requirement S58 of Specification A960/A960M.

1.1.1 Class WP fittings are subdivided into four subclasses: Classes WP-S, WP-W, WP-WX, and WP-WU. They are manufactured to the requirements of Specification A960/A960M, and they shall have pressure ratings compatible with 12.2. Class WP-S fittings are those manufactured from seamless product by a seamless method of manufacture (marked with class symbol WP-S); Class WP-W fittings are those which contain welds where the fitting fabrication or construction welds have been radiographed (marked with class symbol WP-W); and Class WP-WX fittings are those which contain welds where all welds have been radiographed (marked with class symbol WP-WX); and Class WP-WU fittings are those which contain welds where all welds have been ultrasonically tested (marked with class symbol WP-WU).

1.1.2 Class CR fittings are those manufactured to the requirements of MSS SP-43, and they shall have pressure ratings compatible with 12.3.

1.2 This specification does not apply to cast fittings.

1.3 Optional supplementary requirements are provided. When desired, one or more of these may be specified in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation [SI units], the material shall be furnished to inch-pound units.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels

A960/A960M Specification for Common Requirements for Wrought Steel Piping Fittings

E165 Practice for Liquid Penetrant Examination for General Industry

2.2 *ASME Standards:*

B16.9 Factory-Made Wrought Butt-Welding Fittings

B16.11 Forged Fittings, Socket-Welding and Threaded

2.3 *MSS Standards:*

MSS SP-43 Standard Practice for Light Weight Stainless Steel Butt-Welding Fittings

MSS SP-79 Socket-Welding Reducer Inserts

MSS SP-83 Steel Pipe Unions, Socket-Welding and Threaded

MSS SP-95 Swage(d) Nipples and Bull Plugs
MSS SP-97 Integrally Reinforced Forged Branch Outlet Fittings—Socket Welding, Threaded and Buttwelding Ends

2.4 *ASME Boiler and Pressure Vessel Codes:*
Section VIII Division I, Pressure Vessels
Section IX, Welding and Brazing Qualifications

2.5 *ASNT Standard:*
SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Common Requirements and Ordering Information

3.1 Material furnished to this specification shall conform to the requirements of Specification A960/A960M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the common requirements of Specification A960/A960M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A960/A960M, this specification shall prevail.

3.2 Specification A960/A960M identifies the ordering information that should be complied with when purchasing material to this specification.

4. Materials

4.1 The material for fittings shall consist of forgings, bars, plates, or seamless or welded tubular products that conform to the chemical requirements in Table 1.

4.2 The steel shall be melted by one of the following processes:

4.2.1 Electric furnace (with separate degassing and refining optional),

4.2.2 Vacuum furnace, or

4.2.3 Electric furnace followed by vacuum or electroslag-consumable remelting.

4.3 If secondary melting is employed, the heat shall be defined as all ingots remelted from a primary heat.

5. Manufacture

5.1 *Forming*—Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining or by combination of two or more of these operations. The forming procedure shall be so applied that it will not produce surface discontinuities deeper than 5 % of the specified nominal thickness of the fitting.

5.2 All classes of fittings shall be heat treated in accordance with Section 6.

5.3 Fittings ordered as Class WP-S shall be of seamless construction and shall meet all requirements of Specification A960/A960M.

5.4 Fittings ordered as Class WP-W shall meet the requirements of Specification A960/A960M and (*1*) shall have all welds made by the fitting manufacturer and all pipe welds made with the addition of filler metal radiographically examined throughout the entire length in accordance with Paragraph UW-51 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code; and (*2*) shall not require radiography of the starting pipe weld if the pipe was welded without the addition of filler metal. In place of radiographic examination, welds made by the fitting manufacturer may be ultrasonically examined in accordance with the code requirements stated in 5.6.

5.5 Fittings ordered as Class WP-WX shall meet the requirements of Specification A960/A960M and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, radiographically examined throughout their entire length in accordance with Paragraph UW-51 of Section VIII, Division I of the ASME Boiler and Pressure Vessel Code. The radiography of welds for this class of fittings can be done either prior to or after forming at the option of the manufacturer.

5.6 Fittings ordered as Class WP-WU shall meet the requirements of Specification A960/A960M and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, ultrasonically examined throughout their entire length in accordance with Appendix 12 of Section VIII, Division 1 of ASME Boiler and Pressure Vessel Code.

5.7 The radiography or ultrasonic examination for this class of fittings may be done at the option of the manufacturer, either prior to or after forming.

5.8 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

5.9 Deleted

5.10 All classes of fittings shall have the welders, welding operators, and welding procedures qualified under the provisions of Section IX of the ASME Boiler and Pressure Vessel Code except that starting pipe welds made without the addition of filler metal do not require such qualification.

5.11 All joints welded with filler metal shall be finished in accordance with the requirements of Paragraph UW-35 (a) of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code.

5.12 Fittings machined from bar shall be restricted to NPS 4 or smaller.

5.12.1 All caps machined from bar shall be examined by liquid penetrant in accordance with Practice E165.

5.13 Weld buildup is permitted to dimensionally correct unfilled areas produced during cold forming of stub ends. Radiographic examination of the weld buildup shall not be required provided that all of the following steps are adhered to:

5.13.1 The weld procedure and welders or welding operators meet the requirements of 5.10,

5.13.2 Heat-treatment is performed after welding and prior to machining,

TABLE 1 Chemical Requirements

NOTE 1—Where an ellipsis (. . .) appears in this table, there is no requirement.

Grade[A]			Composition, %											
Grade WP	Grade CR	UNS	C, max	Mn[B]	P, max	S, max	Si, max	Ni[B]	Cr	Mo	Cu[B]	N[B]	Ti	Other
Ferritic Steels														
WP27	CR27	S44627	0.010	0.75	0.020	0.020	0.40	0.50	25.0–27.5	0.75–1.50	0.20	0.015	. . .	Cb 0.05–0.20
WP33	CR33	S44626	0.06	0.75	0.040	0.020	0.75	0.50	25.0–27.0	0.75–1.50	0.20	0.040	0.20–1.00 (7×(C+N)) min	. . .
WP429	CR429	S42900	0.12	1.0	0.040	0.030	0.75	0.50	14.0–16.0	. . .	. . .	. . .	. . .	. . .
WP430	CR430	S43000	0.12	1.00	0.040	0.030	1.00	0.50	16.0–18.0	. . .	. . .	. . .	. . .	. . .
WP430TI	CR430Ti	S43036	0.10	1.00	0.040	0.030	1.00	0.75	16.0–19.5	. . .	. . .	. . .	(5×C) min 0.75 max	. . .
WP446	CR446	S44600	0.20	1.50	0.040	0.030	0.75	0.50	23.0–27.0	. . .	. . .	0.25	. . .	. . .
Ferritic/Austenitic Steels														
WPS31803	CRS31803	S31803	0.030	2.00	0.030	0.020	1.0	4.5–6.5	21.0–23.0	2.5–3.5	. . .	0.08–0.20	. . .	. . .
WPS32101	CRS32101	S32101	0.040	4.0–6.0	0.040	0.030	1.00	1.35–1.70	21.0–22.0	0.10–0.80	0.10–0.80	0.20–0.25	. . .	. . .
WPS32202	CRS32202	S32202	0.030	2.00	0.040	0.010	1.00	1.00–2.80	21.5–24.0	0.45	. . .	0.18–0.26	. . .	. . .
WPS32750	CRS32750	S32750	0.030	1.20	0.035	0.020	0.8	6.0–8.0	24.0–26.0	3.0–5.0	0.5	0.24–0.32	. . .	. . .
WPS32950	CRS32950	S32950	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	. . .	0.15–0.35	. . .	. . .
WPS32760	CRS32760	S32760	0.030	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0[C]	3.0–4.0[C]	0.50–1.00	0.20–0.30[C]	. . .	W 0.50–1.00
WPS39274	CRS39724	S32974	0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.50–3.50[C]	0.20–0.80	0.24–0.32	. . .	W 1.50–2.50
WPS32550	CRS32550	S32550	0.04	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9	1.50–2.50	0.10–0.25	. . .	. . .
WPS32205	CRS32205	S32205	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	. . .	0.14–0.20	. . .	. . .
Martensitic Steels														
WP410	CR410	S41000	0.15	1.00	0.040	0.030	1.00	0.50 max	11.5–13.5	. . .	. . .	. . .	. . .	. . .
WPS41008	CRS41008	S41008	0.08	1.00	0.040	0.030	1.00	0.60	11.5–13.5	. . .	. . .	. . .	. . .	. . .
WPS41500	CRS41500	S41500	0.05	0.50–1.00	0.030	0.030	0.60	3.5–5.5	11.5–14.0	0.50–1.00	. . .	. . .	. . .	W 0.50–1.00

[A] Naming system developed and applied by ASTM International.
[B] Maximum unless otherwise indicated.
[C] % Cr + 3.3 × % Mo + 16 × % N = 40 min.

5.13.3 All weld surfaces are liquid penetrant examined in accordance with Appendix 8 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, and

5.13.4 Repair of areas in the weld is permitted, but 5.13.1, 5.13.2, and 5.13.3 must be repeated.

5.14 Deleted

5.15 Stub ends may be produced with the entire lap added by the welding of a ring, made from plate or bar of the same alloy grade and composition, to the outside of a straight section of pipe, provided the weld is double welded, is a full penetration joint, satisfies the requirements of 5.10 for qualifications and Section 6 for post weld heat treatment.

5.15.1 *Class WP-W*—Radiographic inspection of all welds, made with the addition of filler metal is required (see 5.4).

5.15.2 *Class WP-WX*—Radiographic inspection of all welds, made with or without the addition of filler metal, is required (see 5.5).

5.15.3 *Class WP-WU*—Ultrasonic inspection of all welds, made with or without the addition of filler metal, is required (see 5.6).

5.15.4 Deleted

6. Heat Treatment

6.1 Unless otherwise stated herein, heat treatment shall be performed after welding and in accordance with the requirements of Table 2.

6.1.1 No final heat treatment of welded fittings (HT-O) fabricated from ferritic/austenitic plate that has been heat treated as required by Table 2 for the particular grade, is required, provided material representative of the fittings, including base metal, weld metal, and heat affected zone, passes a Test Methods A923 Method B or C (See Note 1) corrosion evaluation per heat. Each fitting supplied under this requirement shall be stenciled with the suffix HT-O.

6.1.2 For materials not listed in Table 3 of Test Methods A923, the HT-O provision does not apply.

NOTE 1—The Test Methods A923 test method (B or C) is at the manufacturer's option, unless otherwise specified by the purchaser.

6.2 All fittings machined directly from forgings or bars (see 5.12), previously heat treated in accordance with the requirements specified in Table 2, need not be reheat treated.

7. Chemical Composition

7.1 The chemical composition of each cast or heat shall be determined and shall conform to the requirements of the chemical composition for the respective grades of materials listed in Table 1. Methods and practices relating to chemical analyses required by this specification shall be in accordance with Methods, Practices, and Definitions A751. Product analysis tolerances in accordance with Specification A960/A960M are applicable.

7.2 Except as listed below, in fittings of welded construction, the composition of the deposited weld shall conform to the same requirements as the base metal.

7.2.1 Welds on S32950 base metal shall be made with nominal 26 % Cr, 8 % Ni, 2 % Mo weld metal.

7.2.2 Welds on S31803 base metal shall conform to the same requirements as the base metal or shall be made with nominal 22 % Cr, 9 % Ni, 3 % Mo weld metal.

7.2.3 Welds on S32202 base metal shall be made with nominal 22 % Cr, 9 % Ni, 3 % Mo weld metal.

8. Tensile Requirements

8.1 The tensile properties of the fitting material shall conform to the requirements of Table 3. The testing and reporting shall be performed in accordance with Specification A960/A960M.

8.2 The fittings manufacturer shall perform a tensile test on material representative of the finished fitting. Records of the

TABLE 2 Heat Treatment

Stainless Steel	All WP and CR Grades	Temperature	Cooling	Tempering Temperature
Ferritic	All	≥ 1200 °F [650 °C]	As appropriate for grade	Not specified
Ferritic/Austenitic	S31803	1870–2010 °F [1020–1100 °C]	Water quench or rapidly cooled by other means	Not required
	S32101	1870 °F [1020 °C] min	Water quench or rapidly cooled by other means	Not required
	S32202	1870–1975 °F [1020–1080 °C]	Water quench or rapidly cooled by other means	Not required
	S32205	1870–2010 °F [1020–1100 °C]	Water quench	Not required
	S32750	1920–2060 °F [1025–1125 °C]	Water quench or rapidly cooled by other means	Not required
	S32760	2010–2085 °F [1100–1140 °C]	Water quench or rapidly cooled by other means	Not required
	S39274	1920–2060 °F [1025–1125 °C]	Water quench or rapidly cooled by other means	Not required
	S32550	1950–1975 °F [1065–1080 °C]	Water quench	Not required
	S32950	Not specified	Not specified	Not required
Martensitic	S41000	≥ 1200°F [650°C]	Not specified	Not specified
	S41008	>1200°F [650°C]	In still air as appropriate for grade	Not specified
	S41500	≥ 1750 °F [955 °C]	Air cool to ≤ 200 °F [95 °C] prior to any optional intermediate temper and prior to final temper.	1050–1150 °F [565–620 °C]

TABLE 3 Tensile and Hardness Requirements

All WP and CR Grades	Yield Strength, min, ksi [MPa]	Tensile Strength,[A] ksi [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	HBW max
Ferritic Steels:				
S44627	40 [275]	65 [450]–90 [620]	20.0	190
S44626	45 [310]	68 [470]–93 [640]	20.0	241
S42900	35 [240]	60 [415]–85 [585]	20.0	190
S43000	35 [240]	65 [450]–90 [620]	20.0	190
S43036	35 [240]	60 [415]–85 [585]	20.0	190
S44600	40 [275]	70 [485]–95 [655]	18.0	207
Ferritic/Austenitic Steels:				
S31803	65 [450]	90 [620]	20.0	290
S32101	65 [450]	94 [650]	30.0	290
S32202	65 [450]	94 [650]	30.0	290
S32205	65 [450]	95 [655]	20.0	290
S32750	80 [550]	116 [800]–140 [965]	15.0	310
S32760	80 [550]	109 [750]–130 [895]	25.0	270
S32950	70 [485]	100 [690]	15.0	290
S39274	80 [550]	116 [800]	15.0	310
S32550	80 [550]	110 [760]	15.0	302
Martensitic Steels:				
S41000	30 [205]	70 [485]–95 [655]	20.0	207
S41008	30[205]	60[415]	22.0	183
S41500	90 [620]	110 [760]–135 [930]	15.0	295

[A]Minimum unless otherwise indicated.

tensile test made on the starting material may be certification that the material of hot-finished fittings meets the tensile requirements of this specification provided the heat treatments are the same. For purposes of tensile, yield and elongation requirements listed in Table 3, the tensile specimen shall consist of base metal only. If the purchaser requires results, involving the weld, in addition to the base metal only results, then the S2 supplemental requirement of this specification shall be specified on the purchase order. When S2 is specified, the weld metal must meet only the minimum ultimate tensile strength of Table 3.

9. Hardness Requirements

9.1 Fittings shall not exceed the maximum hardness shown in Table 3.

10. Dimensions

10.1 The sizes, shapes, and dimensions of the fittings covered by ASME B16.9, ASME B16.11, MSS SP-43, MSS SP-79, MSS SP-83, MSS SP-95, or MSS SP-97 shall be as specified in those standards.

10.2 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification, may be furnished in accordance with Supplementary Requirement S58 of Specification A960/A960M.

11. Workmanship, Finish, and Appearance

11.1 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. The fittings shall be free from surface discontinuities that penetrate more than 5 % of the specified nominal wall thickness, except as defined in 11.3 and 11.4, and shall have a workmanlike finish.

11.2 Surface discontinuities deeper than 5 % of the specified nominal wall thickness, except as defined in 11.3 and 11.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall be well faired. The wall thickness at all points shall be at least 87½ % of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

11.3 Surface checks (fish scale) deeper than 1⁄64 in. [0.4 mm] shall be removed.

11.4 Mechanical marks deeper than 1⁄16 in. [1.6 mm] shall be removed.

11.5 When the removal of a surface discontinuity reduces the wall thickness below 87½ % of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in 11.6.

11.6 *Repair by Welding:*

11.6.1 Repair welding, of the base metal by the manufacturer, is permissible for fittings made to the dimensional standards listed in 10.1 or for other standard fittings made for stock. Prior approval of the purchaser is required to repair special fittings made to the purchaser's requirements. Repair by welding shall neither exceed 10 % of the outside surface area of the fitting nor 33⅓ % of the nominal wall thickness.

11.6.2 The welding procedure and welders shall be qualified in accordance with Specification A960/A960M.

11.6.3 The alloy content (carbon, chromium, nickel, molybdenum, columbium, and titanium) of the deposited weld metal shall be within the same percentage range as permitted for the base metal. (**Warning—**When selecting the filler metal and welding procedure, consideration should be given to their effect on corrosion resistance in service.)

11.6.4 Surface discontinuities deeper than 5 % of the specified nominal wall thickness shall be removed by mechanical means or thermal cutting or gouging methods. Cavities prepared for welding shall be examined by the liquid penetrant method of Practice E165. No cracks shall be permitted in the prepared cavities.

11.6.5 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Specification A960/A960M.

11.6.6 Weld repair area(s) shall be blended uniformly to the base metal and shall be examined by liquid penetrant in accordance with Practice E165. No cracks shall be permitted in the weld or surrounding ½ in. [13 mm] of base metal.

11.6.7 After weld repair, material shall be heat treated in accordance with Section 6.

11.7 The fittings shall be cleaned free of scale.

12. Hydrostatic Tests

12.1 Hydrostatic testing is not required by this specification.

12.2 Each fitting of Class WP shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure equal to that prescribed for the specified matching pipe or equivalent material.

12.3 Each fitting of Class CR, except tees covered in 12.3.1, shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure based on the ratings in MSS SP-43.

12.3.1 Class CR tees fabricated using intersection welds shall be capable of passing a hydrostatic test based on 70 % of the ratings in MSS SP-43.

13. Rejection

13.1 Unless otherwise specified, any rejection based on tests by the purchaser shall be reported to the manufacturer within 30 working days from the receipt of samples or test reports by the purchaser.

13.2 Each fitting that develops surface discontinuities deeper than 5 % of the specified nominal wall thickness in shop working or application operations may be rejected and the manufacturer so notified.

14. Rehearing

14.1 Test samples that represent fittings rejected by the purchaser shall be preserved for four weeks from the date of the rejection report. In case of dissatisfaction with the test results, the manufacturer may make claim for a rehearing within the period that the samples are preserved.

15. Test Reports

15.1 Test reports are required for all fittings covered by this specification. Each test report shall include the following information:

15.1.1 The year-date of the specification to which the fitting was furnished,

15.1.2 Heat number or serial number traceable to a heat number,

15.1.3 Chemical analysis for all starting materials,

15.1.4 Starting material; plate, bar, pipe (specify welded or seamless), forging,

15.1.5 Mechanical test results (Section 8),

15.1.6 Seamless or welded construction,

15.1.7 For construction with filler metal added, weld metal specification number,

15.1.8 For welded fittings, construction method, weld process, and procedure specification number,

15.1.9 Heat treatment type,

15.1.10 Results of all nondestructive examinations,

15.1.11 Results of all tests required by Supplementary Requirements and the order, and

15.1.12 Statement that the fitting was manufactured, sampled, tested, and inspected in accordance with the specification and was found to meet the requirements.

16. Product Marking

16.1 All fittings shall have the prescribed information stamped or otherwise suitably marked on each fitting in accordance with Section 19 of Specification A960/A960M.

16.2 Marking paint or ink shall not contain harmful amounts of chlorides, metals, or metallic salt, such as zinc or copper, that cause corrosive attack on heating. On wall thicknesses thinner than 0.083 in. [2.1 mm], no metal impression stamps shall be used. Vibrating pencil marking is acceptable.

16.3 The prescribed information for butt-welding fittings shall be: the manufacturer's name or trademark (see Note 2), schedule number or nominal wall thickness designation, size, grade, class, and the heat number or manufacturer's heat identification.

16.4 The prescribed information for threaded or socket-welding fittings shall be: the manufacturer's name or trademark (see Note 2), pressure class or schedule number, grade and class, and heat number or manufacturer's heat identification. The class S marking need not be added to the material grade for threaded or socket-welded fittings.

NOTE 2—For purposes of identification marking, the manufacturer is considered the organization that certifies that the piping component complies with this specification.

16.5 *Bar Coding*—In addition to the requirements in 16.1-16.4, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

17. Keywords

17.1 corrosive service applications; ferritic/austenitic stainless steel; ferritic stainless steel; martensitic stainless steel; pipe fittings-steel; piping applications; pressure containing parts; stainless steel fittings

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below may be included in the purchaser's inquiry or in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier.

S1. Product Analysis (Note S1.1)

S1.1 A product analysis shall be made for each heat of base metal and, if of welded construction, from each lot number of welding material of the fittings offered for delivery and shall conform to the requirements specified in Section 7.

NOTE S1.1—If the results of any of the tests specified in Supplementary Requirements S1, S2, or S3 do not conform to requirements, retests may be made at the manufacturer's expense on additional fittings or representative test pieces of double the original number from the same heat or lot as defined in Supplementary Requirements S1, S2, or S3, each of which shall conform to the requirements specified.

S2. Tension Test (Note S1.1)

S2.1 One tension test shall be made on one fitting or representative test piece (Note S2.1) per lot (Note S2.2) of fittings. If the fittings are of welded construction, the tension specimen shall include the weld and be prepared so that the weld is at the midlength of the specimen.

NOTE S2.1—Where the test specimen for the tension or intergranular corrosion bend test cannot be taken from a fitting due to size limitations, a representative test piece shall be obtained. The test piece shall be from the same lot it represents and shall have approximately the same amount of working. In addition, these pieces representing fittings manufactured from bars, plate, or forgings shall have a cross section equal to the greatest cross section of the fitting, and test pieces representing fittings manufactured from tubular products shall have a cross section approximately the same as that of the finished product. The test piece for fittings of welded construction shall be prepared to the same weld procedures and from the same heats of materials as the fittings it represents.

NOTE S2.2—A lot shall consist of all fittings of the same type, size, and wall thickness, manufactured from one heat of material (and, if fabrication welding is performed using one lot number of electrode or one heat of weld wire), and heat treated using the same heat treat cycle in either a continuous or batch-type furnace controlled within a range of 50 °F [28 °C] and equipped with recording pyrometers so that complete records of heat treatment are available.

S3. Intergranular Corrosion Bend Test (Note S1.1)

S3.1 An intergranular corrosion bend test shall be made on one fitting or representative test piece (Note S2.1) per lot (Note S2.2) of fittings. If the fittings are of welded construction, the bend specimen shall include the weld and be prepared so that the weld is at the midlength location of the specimen. Specimens containing a weld shall be bent so that the location of weld is at the point of maximum bend. The method of testing shall be in accordance with Practices A262 or Practices A763, as applicable.

S4. Ultrasonic Test

S4.1 Each fitting or the raw material from which each fitting is made shall be ultrasonically tested to determine its soundness. The method, where applicable, shall be in accordance with Practice A388/A388M. Acceptance limits shall be specified by the purchaser.

S5. Photomicrographs

S5.1 Photomicrographs at 100 diameters shall be made for information only of the actual base metal structure from one fitting as furnished in each lot. The photomicrographs shall be identified as to fitting size, wall thickness, lot identification, and heat. The definition of "lot" shall be as specified by the purchaser.

S6. Surface Finish

S6.1 Machined surfaces shall have a maximum roughness of 250 RMS (root-mean-square) or 6.3 µin. AA (arithmetical average). All other surfaces shall be suitable for ultrasonic testing.

S7. Liquid Penetrant Test

S7.1 All surfaces shall be liquid penetrant tested. The method shall be in accordance with Practice E165.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, CHROMIUM-MOLYBDENUM-VANADIUM

SA-832/SA-832M

(Identical with ASTM Specification A832/A832M-17.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium

1. Scope

1.1 This specification covers chromium-molybdenum-vanadium alloy steel plates intended primarily for the fabrication of welded pressure vessels.

1.2 The plates furnished under this specification are required to be normalized-and-tempered. Specification A542/A542M includes coverage of the material in the quenched-and-tempered condition.

1.3 The maximum thickness of plates furnished to this specification is limited only by the capacity of the composition to meet the specified property requirements.

1.4 The material is intended to be suitable for fusion welding. Welding technique is of fundamental importance and it is presupposed that welding procedures will be in accordance with approved methods.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A542/A542M Specification for Pressure Vessel Plates, Alloy Steel, Quenched-and-Tempered, Chromium-Molybdenum, and Chromium-Molybdenum-Vanadium

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Process*—The steel shall be made by one of the processes permitted in Specification A20/A20M.

TABLE 1 Tensile Requirements

Tensile strength, ksi, [MPa]	85–110 [585–760]
Yield strength, min, ksi, [MPa]	60 [415]
Elongation in 2 in. [50 mm], min, %[A]	18
Reduction of area, min, %	45[B] 40[C]

[A] See Specification A20/A20M for elongation adjustments.
[B] Measured on round specimen.
[C] Measured on flat specimen.

4.2 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 All plates shall be normalized and tempered except as allowed by 5.2. The minimum normalizing temperature for Grade 22V shall be 1650°F [900°C]. The minimum normalizing temperature for Grade 23V shall be 1850°F [1010°C]. The minimum tempering temperature shall be 1250°F [675°C].

5.2 Plates ordered without the heat treatment required by 5.1 shall be furnished in either the stress-relieved or the annealed condition. Heat treatment of plates so ordered, to conform to 5.1 and to Table 1, shall be the responsibility of the purchaser.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition shown in Table 2.

7. Mechanical Properties

7.1 *Tension Test Requirements:*

7.1.1 The material as represented by the tension test specimens shall conform to the requirements of Table 1.

7.2 *Notch Toughness Requirements:*

7.2.1 A transverse Charpy V-notch test from each plate as heat-treated shall have a minimum energy absorption value of 40 ft·lbf [54 J] average of three specimens and 35 ft·lbf [48 J] for one specimen only in the set.

7.2.2 The notch toughness test temperature shall be 0°F [−18°C].

8. Keywords

8.1 alloy steel plates; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

TABLE 2 Chemical Requirements

NOTE 1—Where "..." appears there is no requirement.

Element	Composition, %		
	Grade 21V	Grade 22V	Grade 23V
Carbon			
Heat analysis	0.10–0.15	0.11–0.15	0.10–0.15
Product analysis	0.08–0.18	0.09–0.18	0.08–0.18
Manganese			
Heat analysis	0.30–0.60	0.30–0.60	0.30–0.60
Product analysis	0.25–0.66	0.25–0.66	0.25–0.66
Phosphorus, max	0.025[A]		0.025[A]
Heat analysis	...	0.015	...
Product analysis	...	0.020	...
Sulfur, max	0.025[A]		0.010[A]
Heat analysis	...	0.010	...
Product analysis	...	0.015	...
Silicon, max			
Heat analysis	0.10	0.10	0.10
Product analysis	0.13	0.13	0.13
Chromium			
Heat analysis	2.75–3.25	2.00–2.50	2.75–3.25
Product analysis	2.63–3.37	1.88–2.62	2.63–3.37
Molybdenum			
Heat analysis	0.90–1.10	0.90–1.10	0.90–1.10
Product analysis	0.85–1.15	0.85–1.15	0.85–1.15
Vanadium			
Heat analysis	0.20–0.30	0.25–0.35	0.20–0.30
Product analysis	0.18–0.33	0.23–0.37	0.18–0.33
Titanium			
Heat analysis	0.015–0.035	0.030, max	...
Product analysis	0.005–0.045	0.035, max	...
Boron			
Heat analysis	0.001–0.003	0.0020, max	...
Product analysis	NA[B]	NA[B]	...
Copper, max			
Heat analysis	...	0.20	...
Product analysis	...	0.23	...
Nickel, max			
Heat analysis	...	0.25	...
Product analysis	...	0.28	...
Columbium (Niobium),[C] max			
Heat analysis	...	0.07	0.015–0.070
Product analysis	...	0.08	0.010–0.075
Calcium, max[D]			
Heat analysis	...	0.015	0.0005–0.0150
Product analysis	...	0.020	NA[B]

[A] Applies to both heat analysis and product analysis.
[B] NA = Not Applicable.
[C] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.
[D] Rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case, the total amount of REM shall be determined and reported.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Some of those considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,
S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S4. Additional Tension Test,
S6. Drop-Weight Test (for Material 0.625 in. [16 mm] and Over in Thickness),
S7. High-Temperature Tension Test,
S8. Ultrasonic Examination in accordance with Specification A435/A435M,
S9. Magnetic Particle Examination,
S11. Ultrasonic Examination in accordance with Specification A577/A577M,
S12. Ultrasonic Examination in accordance with Specification A578/A578M, and
S19. Restricted Chemical Requirements.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

HIGH TEMPERATURE HYDROGEN SERVICE

In addition, the following supplementary requirements are suitable for this application.

S62. Temper Embrittlement Factor

S62.1 The composition of the steel, based on heat analysis, shall be restricted in accordance with the following equations:

$$J = (\mathrm{Si}+\mathrm{Mn}) \times (\mathrm{P}+\mathrm{Sn}) \times 10^4 \leq 150 \qquad (\text{Si, Mn, P and Sn in wt \%})$$
$$\mathrm{Cu} \leq 0.20\,\%$$
$$\mathrm{Ni} \leq 0.30\,\%$$

S62.1.1 Lower values of J, Cu, and Ni can be specified by agreement between purchaser and the supplier.

S62.1.2 When so specified by the purchaser, the maximum value of J shall not exceed 100.

S62.1.3 The values of J shall be reported.

S62.1.4 If the plates are repaired by welding, the composition of the weld deposit shall be restricted in accordance with the following equations:

$$\mathrm{X} = (10\mathrm{P}+5\mathrm{Sb}+4\mathrm{Sn}+\mathrm{As})/100 \leq 15 \qquad (\text{P, Sb, Sn and As in ppm})$$
$$\mathrm{Cu} \leq 0.20\,\%$$
$$\mathrm{Ni} \leq 0.30\,\%$$

S62.1.5 The values of X shall be reported.

S63. Impact Properties After Step Cooling

S63.1 The Charpy V-notch impact properties shall be determined as follows:

S63.1.1 A sufficient amount of Charpy V-notch test specimens shall be taken from the same location from a plate from each heat of steel to construct two transition temperature curves.

S63.1.2 The test specimens for one transition temperature curve shall be given the minimum post-weld heat treatment (PWHT) cycle specified by the purchaser.

S63.2 The test specimens for the other transition temperature curve shall be given the PWHT cycle specified in S63.1.2 plus the following step cooling heat treatment:

Hold at 1100°F (593°C) for 1 h, then cool at 10°F (5.6°C)/h to 1000°F (538°C).

Hold at 1000°F (538°C) for 15 h, then cool at 10°F (5.6°C)/h to 975°F (524°C).

Hold at 975°F (524°C) for 24 h, then cool at 10°F (5.6°C)/h to 925°F (496°C).

Hold at 925°F (496°C) for 60 h, then cool at 5°F (2.8°C)/h to 875°F (468°C).

Hold at 875°F (468°C) for 100 h, then cool at 50°F (27.8°C)/h to 600°F (315°C).

Cool in still air.

S63.3 Test the Charpy V-notch test specimens in accordance with Test Methods and Definitions A370 to determine the 40-ft-lbs (55 J) transition temperature from each transition temperature curve using a set of three test specimens at each test temperature. The test temperatures shall include tests on the upper and lower shelves and a minimum of four intermediate temperatures.

S63.4 The following requirements shall be met:

$$\mathrm{vTr40}+2.5\,\Delta\mathrm{vTr40} \leq 50°F$$
$$\mathrm{vTr55}+2.5\,\Delta\mathrm{vTr55} \leq 10°C$$

where:

vTr40 (vTR55) = the 40-ft-lbs (55 J) transition temperature of the material subjected to the minimum PWHT specified by the purchaser.

ΔvTr40 (ΔvTr55) = the shift of the 40-ft-lbs (55 J) transition temperature the of the step cooled material. (The 40-ft-lbs (55 J) transition temperature the of the step cooled material minus that of the material subjected to the minimum PWHT only).

S63.5 The 40-ft-lbs (55 J) transition temperatures for the two material conditions shall be reported. (Fig. S1.1)

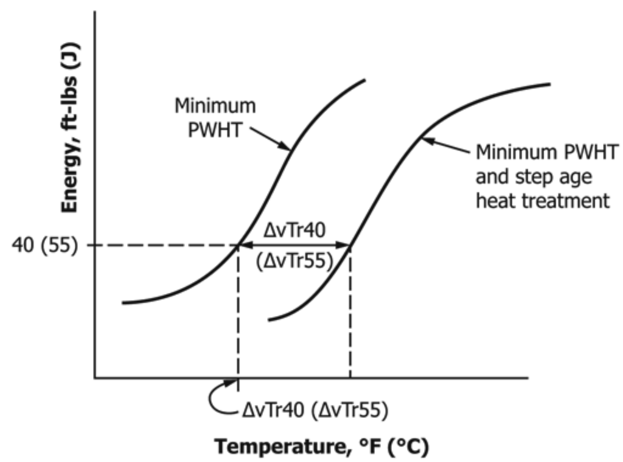

FIG. S1.1 Transition Temperature Curves Before and After Step Cool Heat Treatment

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SPECIFICATION FOR COMMON REQUIREMENTS FOR IRON CASTINGS FOR GENERAL INDUSTRIAL USE

SA-834

(Identical with ASTM Specification A834-95(2015).)

Standard Specification for Common Requirements for Iron Castings for General Industrial Use

1. Scope

1.1 This specification covers a group of requirements that are mandatory requirements when used in conjunction with the following iron casting specifications issued by ASTM:

ASTM Specification
A47/A47M
A48/A48M
A197/A197M
A220/A220M
A278/A278M
A319
A395/A395M
A436
A439
A518/A518M
A532/A532M
A536
A571/A571M
A823
A842
A874/A874M
A897/A897M

1.2 This specification also covers a group of supplementary requirements which may be applied to the above specifications as indicated herein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 The requirements of the individual material specification, and this general specification shall prevail in the sequence named.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A47/A47M Specification for Ferritic Malleable Iron Castings

A48/A48M Specification for Gray Iron Castings

A197/A197M Specification for Cupola Malleable Iron

A220/A220M Specification for Pearlitic Malleable Iron

A247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings

A278/A278M Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (350°C)

A319 Specification for Gray Iron Castings for Elevated Temperatures for Non-Pressure Containing Parts

A395/A395M Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures

A436 Specification for Austenitic Gray Iron Castings

A439 Specification for Austenitic Ductile Iron Castings

A518/A518M Specification for Corrosion-Resistant High-Silicon Iron Castings

A532/A532M Specification for Abrasion-Resistant Cast Irons

A536 Specification for Ductile Iron Castings

A571/A571M Specification for Austenitic Ductile Iron Castings for Pressure-Containing Parts Suitable for Low-Temperature Service

A644 Terminology Relating to Iron Castings

A802/A802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination

A823 Specification for Statically Cast Permanent Mold Gray Iron Castings

A842 Specification for Compacted Graphite Iron Castings

A874/A874M Specification for Ferritic Ductile Iron Castings Suitable for Low-Temperature Service

A897/A897M Specification for Austempered Ductile Iron Castings
A919 Terminology Relating to Heat Treatment of Metals (Withdrawn 1999)
E8 Test Methods for Tension Testing of Metallic Materials
E10 Test Method for Brinell Hardness of Metallic Materials
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron (Withdrawn 1995)
E59 Practice for Sampling Steel and Iron for Determination of Chemical Composition (Withdrawn 1996)
E94 Guide for Radiographic Examination
E165 Practice for Liquid Penetrant Examination for General Industry
E351 Test Methods for Chemical Analysis of Cast Iron—All Types
E689 Reference Radiographs for Ductile Iron Castings
E709 Guide for Magnetic Particle Testing
E802 Reference Radiographs for Gray Iron Castings Up to 4½ in. (114 mm) in Thickness

2.2 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage

2.3 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

3. Terminology

3.1 *Definitions:*
3.1.1 Definitions for many terms common to iron castings and their heat treatment are found in Terminology A919 and Terminology A644. A classification of graphite structure is found in Test Method A247.

4. Ordering Information

4.1 The purchase order for castings ordered under this specification shall stipulate the applicable material specification(s), grade of iron, and any options or additions to the basic requirements, including the supplementary requirements included in this specification.

5. Tensile Requirements

5.1 The individual product specifications vary as to whether tension tests are required. For this reason, and to determine specific test requirements, the individual product specification shall be reviewed. When required, tension tests shall be determined in accordance with Test Methods E8.

6. Chemical Requirements

6.1 The individual product specifications vary as to whether chemical analysis is required. To determine specific requirements, the individual product specification should be reviewed.

6.2 Sampling shall be conducted in accordance with Test Method E59. Spectrographic or other methods such as those in Test Methods E30 and E351 may be used for chemical analysis. In the event of a dispute regarding chemical composition, Test Methods E351 and E30 shall be used for referee purposes.

6.3 The chemical analysis for total carbon shall be made on chilled pencil-type specimens or from thin wafers approximately 1⁄32 in. (0.8 mm) thick cut from test coupons. Drillings are not reliable because of a probable loss of graphite.

6.4 Chemical analysis results shall be rounded, in accordance with Practice E29, to the nearest unit in the last right-hand place of values in the table of chemical requirements.

6.5 A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis shall be taken no closer than ¼ in. to a cast surface, and shall follow the practice in 5.3, except where the size or shape of the casting does not permit such sampling. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved.

7. Workmanship, Finish, and Appearance

7.1 All castings shall be made in a workman-like manner and shall conform to the dimensions on drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser, the dimensions of the casting shall be as predicted by the pattern.

8. Sampling

8.1 A lot shall consist of one of the following:
8.1.1 All the metal from a single heating in a batch–type melting furnace.
8.1.2 All the metal poured from two or more batch–type melting furnaces into a single ladle or a single casting.
8.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry, or 4 h, whichever is the shorter period.
8.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

9. Inspection

9.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

9.2 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

9.3 When agreed upon between manufacturer and purchaser, test specimens or unbroken test bars from the same lot shall be saved for a period of 3 months after date of the test report.

9.4 When unbroken test bars are reprocessed with castings for rehearing, test specimens from these bars shall be saved, as described in 9.3.

9.5 The purchaser reserves the right to perform any inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to the prescribed requirements.

10. Repair

10.1 Any repair shall be made in accordance with the requirements of the individual specification using procedures qualified by the manufacturer for the type of repair involved.

11. Rejection and Rehearing

11.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

12. Packaging and Package Marking

12.1 Unless otherwise specified in the contract or purchase order, cleaning, preservation, and packaging of castings shall be in accordance with the manufacturer's commercial practice. Packing and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

12.2 *Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military activities.

13. Quality Assurance

13.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Practice A802/A802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

13.2 When additional inspection is desired, Supplementary Requirements S1, S2, or S3 may be specified.

14. Keywords

14.1 chemical composition; common requirements; general industry; inspection; iron castings; ordering information; packaging; quality assurance; repair; sampling; tensile requirements; terminology; workmanship

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface discontinuities by magnetic particle examination. The examination shall be in accordance with Practice E709. The extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S2. Radiographic Examination

S2.1 Castings shall be examined for internal defects by means of X-rays or gamma rays. The procedure shall be in accordance with Guide E94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E689 and E802. The extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Practice E165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S4. Certification

S4.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification, including the year date, and was found to meet the requirements. Additionally, the certification shall include for each lot the results of all tests required by the material specification and any supplementary or additional requirements imposed by the purchase order.

S4.2 A signature is not required on the certification or test report. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

S4.3 The test report shall be furnished within 5 working days of shipment of the castings.

S5. Prior Approval of Major Repairs

S5.1 Major repairs as defined and agreed upon between the manufacturer and purchaser shall be subject to the prior approval of the purchaser.

S6. Marking

S6.1 The manufacturer's name or identification mark and the part identification number shall be cast or stamped on all castings. When further specified, lot numbers shall be marked on individual castings.

S6.2 When the castings are of such size that individual marking is impracticable, they shall be grouped by part identification or lot number and placed in a container. The container shall be marked with the required identification.

S7. Hardness Test

S7.1 Hardness measurements at specified locations on the castings shall be made in accordance with Test Method E10 and reported.

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SPECIFICATION FOR TITANIUM-STABILIZED CARBON STEEL FORGINGS FOR GLASS-LINED PIPING AND PRESSURE VESSEL SERVICE

SA-836/SA-836M (23)

(Identical with ASTM Specification A836/A836M-14(2020).)

Specification for Titanium-Stabilized Carbon Steel Forgings for Glass-Lined Piping and Pressure Vessel Service

1. Scope

1.1 This specification covers nonstandard as-forged fittings, valve components, and parts for glass-lined piping and pressure vessel service. Mechanical properties are certified on the basis of test material subjected to heat treatments to simulate glass-coating operations.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A788/A788M Specification for Steel Forgings, General Requirements

A961/A961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

3. Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A961/A961M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A961/A961M constitutes non-conformance with this specification.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the ordering information in Specification A961/A961M and the following:

3.2.1 Supplementary requirements, and

3.2.2 Additional requirements (see 11.1, 13.1, and 13.2).

3.3 If the requirements of this specification are in conflict with the requirements of Specification A961/A961M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 The material shall be forged by hammering, pressing, rolling, extruding, or upsetting, such that the finished product will be a forging as defined in the Terminology Section of Specification A788/A788M.

4.2 When specified in the order, the manufacturer shall submit for approval by the purchaser a sketch showing the shape of the rough forging before machining.

4.3 Forgings shall be protected against sudden or too rapid cooling from the rolling or forging while passing through the critical range.

4.4 Heat treatment of forgings is neither required nor prohibited. However, the test material for qualifying the forging or the welding procedure shall be heat treated to simulate glass-coating operations.

5. Chemical Composition

5.1 An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The chemical composition thus determined shall conform to the requirements in Table 1.

6. Mechanical Properties

6.1 The test material shall conform to the requirements as to tensile properties prescribed in Table 2.

TABLE 1 Chemical Requirements

Element	Composition, %
Carbon, max	0.20
Manganese, max	0.90
Phosphorus, max	0.05
Silicon, max	0.35
Sulfur, max	0.05
Titanium, min	4× carbon content
Titanium, max.	1.00

TABLE 2 Tensile Requirements

	Class I
Tensile strength, min, ksi [MPa]	55 [380]
Yield strength,[A] min, ksi [MPa]	25 [175]
Elongation in 2 in. or 50 mm, min, %	22
Reduction of area, min, %	35

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

7. Number of Tests and Retests

7.1 One tension test shall be made from each heat.

7.2 If any test specimen is defectively machined, it may be discarded and another specimen substituted.

8. Retests

8.1 When one or more representative test specimens do not conform to specification requirements for the tested characteristic, only a single retest for each nonconforming characteristic may be performed to establish product acceptability. Retests shall be performed on twice the number of representative specimens that were originally nonconforming. When any retest specimen does not conform to specification requirements for the characteristic in question, the lot represented by that specimen shall be rejected, or the test material shall be heat treated or reheat-treated in accordance with 4.4, and tested in accordance with Sections 6 and 7.

9. Test Specimens

9.1 The test material to be used for qualifying the forgings shall be heat treated with the forgings represented by the test material, if the forgings are heat treated, then, the test material shall be normalized three times from a minimum temperature of 1550 °F [845 °C] prior to testing. This heat treatment simulates glass-coating operations.

10. Surface Finish, Appearance, and Corrosion Protection

10.1 The requirements of Specification A961/A961M apply to forgings and finished parts.

11. Repair by Welding

11.1 Approval by the purchaser shall be required prior to weld repair.

11.2 The welded test plate used to qualify the procedure shall be normalized three times at 1550 °F [845 °C] prior to testing to simulate glass-coating operations.

11.3 The composition of the weld deposits shall be similar to the base metal and in accordance with the procedure qualification for the applicable material. Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short-circuit gas metal arc welding is permissible only with the approval of the purchaser.

12. Rejection and Rehearing

12.1 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon by the manufacturer and the purchaser.

13. Certification

13.1 See Specification A961/A961M.

13.2 A test report of the test results for chemistry (Section 5 and Table 1) and tensile properties (Section 6 and Table 2) shall be furnished.

14. Product Marking

14.1 In addition to marking requirements of Specification A961/A961M, the following additional marking requirements shall apply:

14.1.1 Forgings repaired by welding shall be marked with the letter "W" following this specification number.

14.2 *Bar Coding*—In addition to the requirements in 14.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

15. Keywords

15.1 carbon; pipe fittings; piping applications; pressure containing parts; pressure vessel service; steel; steel flanges; steel forgings; steel valves

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SPECIFICATION FOR STEEL PLATES FOR PRESSURE VESSELS, PRODUCED BY THERMO-MECHANICAL CONTROL PROCESS (TMCP)

SA-841/SA-841M

(Identical with ASTM Specification A841/A841M-17.)

Standard Specification for
Steel Plates for Pressure Vessels, Produced by Thermo-Mechanical Control Process (TMCP)

1. Scope

1.1 This specification covers steel plates produced by the thermo-mechanical control process (TMCP). The plates are intended primarily for use in welded pressure vessels. A description of the TMCP method is given in Appendix X1.

1.2 Due to the inherent characteristics of the TMCP method, the plates cannot be formed at elevated temperatures without sustaining significant losses in strength and toughness. Except for Grade G, the plates may be formed and post-weld heat-treated at temperatures not exceeding 1200°F [650°C], providing the requirements of 6.1 are met. Grade G plates may be formed at temperatures not exceeding 985°F [530°C] provided the requirements of 6.1 are met.

1.3 The maximum permitted nominal thickness of plates furnished to this specification is 4 in. [100 mm] for Grades A, B, and C; 1.5 in. [40 mm] for Grades D, E, and F; and 2 in. [50 mm] for Grade G.

1.4 Grade G is susceptible to magnetization. Use of magnets in handling after heat treatment should be avoided if residual magnetism would be detrimental to subsequent fabrication or service.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A20/A20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions, quality and repair of defects, marking, loading, etc.

3.2 Specification A20/A20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.2.1 If the plates are to be subjected to warm forming or post-weld heat treatment, the order must indicate the temperatures and times-at-temperature that will be utilized in such operations. (See 6.1 and Specification A20/A20M, Supplementary Requirement S3.)

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Additional or special impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

4.2 The plates shall be produced by the thermo-mechanical control process.

5. Chemical Composition

5.1 The chemical composition on heat analysis shall conform to the requirements given in Table 1, except as otherwise provided in Supplementary Requirement S17 of Specification A20/A20M when that requirement is involved.

5.2 If a product analysis is made on a sample taken from the standard location (see Specification A20/A20M), the results of the analysis shall not deviate from the limits for the heat analysis by more than the values given in Table 2.

6. Mechanical Requirements

6.1 If the plates are to be subjected to warm forming or post-weld heat treatment, the test coupons shall be subjected to heat treatment to simulate such fabrication operations. (See 3.2.1 and Specification A20/A20M, Supplementary Requirement S3.)

6.2 *Tension Test Requirements*—The plates as represented by the tension-test specimens shall conform to the requirements given in Table 3.

6.2.1 *Number and Location of Test Coupons*—Two tension tests shall be made from each plate-as-rolled. One test coupon shall be taken from a corner of the plate on each end.

6.3 *Notch Toughness Test Requirements:*

6.3.1 Except for Grade G, longitudinal Charpy V-notch tests shall be made in accordance with Specification A20/A20M.

6.3.2 For Grades A, B and C, unless the test temperature and absorbed energy requirements are specified in the purchase order, the tests shall be conducted at –40°F [–40°C] and the average absorbed energy for each set of three full size specimens shall be 15 ft·lb [20J] or more.

6.3.3 For Grade D, unless the test temperature and the lateral expansion requirements are specified in the purchase order, the tests shall be conducted at –40°F [–40°C] and the lateral expansion for each specimen shall be 0.015 in. [0.4 mm] or more.

6.3.4 For Grades E and F, unless the test temperature and absorbed energy requirements are specified in the purchase order, the tests shall be conducted at –40°F [–40°C] and the average absorbed energy for each set of three full size specimens shall be 20 ft·lb [27 J] or more.

6.3.5 For Grade G, transverse Charpy V-notch tests shall be made in accordance with Specification A20/A20M. Unless the test temperature is specified in the purchase order, the tests shall be conducted at –320°F [–195°C]. Each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm], up to a plate thickness of 1.25 in. [31.75 mm] inclusive; and 0.019 in. [0.48 mm] at a plate thickness of 2.0 in. [50 mm]. Values of lateral expansion for plate thicknesses between 1.25 in. [31.75 mm] and 2.0 in. [50 mm] shall be determined by linear interpolation.

7. Marking

7.1 In addition to the marking required in Specification A20/A20M, each plate shall be legibly stamped with the letters "TMC" following the stamped specification designation.

8. Keywords

8.1 pressure containing parts; pressure vessel steel; steel plates; steel plates for pressure vessel applications

TABLE 1 Chemical Requirements[A]

Element	Composition, %						
	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G
Carbon	0.20	0.15	0.10	0.09	0.07	0.10[B]	0.13
Manganese							
$t \leq 1.5$ in. [40 mm]	0.70–1.35[C]	0.70–1.35[C]	0.70–1.60	1.00–2.00	0.70–1.60	1.10–1.70[B]	0.60–1.20
$t > 1.5$ in. [40 mm]	1.00–1.60	1.00–1.60	1.00–1.60	[D]	[D]	[D]	0.60–1.20
Phosphorus	0.030	0.030	0.030	0.010	0.015	0.020	0.015
Sulfur	0.030	0.025	0.015	0.005	0.005	0.008	0.015
Silicon	0.15–0.50	0.15–0.50	0.15–0.50	0.05–0.25	0.05–0.30	0.10–0.45	0.04–0.15[E]
Copper	0.35	0.35	0.35	0.50	0.35	0.40	. . .
Nickel	0.25	0.60	0.25	1.0–5.0	0.60	0.85	6.0–7.5
Chromium	0.25	0.25	0.25	0.30	0.30	0.30	0.30–1.00
Molybdenum	0.08	0.30	0.08	0.40	0.30	0.50	0.30
Columbium (Niobium)[F]	0.03	0.03	0.06	0.05	0.08	0.10	. . .
Vanadium	0.06	0.06	0.06	0.02	0.06	0.09	. . .
Titanium	[G]	[G]	0.006–0.02	0.006–0.03	[G]	[H]	. . .
Boron	...	...	...	0.0005–0.002	0.0007	0.0007	. . .
Aluminum, min	0.020 total or 0.015 acid soluble[G]	0.020 total or 0.015 acid soluble[G]	...	...	0.020 total or 0.015 acid soluble[G]	0.020 total or 0.015 acid soluble[H]	[E] 0.008 acid soluble

[A] Values are maximums unless a minimum or a range is indicated. Where ellipses appear in this table, there is no requirement.
[B] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage points above the specified maximum for manganese is permitted, up to a maximum of 1.85 %.
[C] Manganese may exceed 1.35 % on heat analysis, up to a maximum of 1.60 %, provided that the carbon equivalent on heat analysis does not exceed 0.47 %, or the value specified in Supplementary Requirement S77 when that requirement is invoked, when based on the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15\ \%$$

When this option is exercised, the manganese content on product analysis shall not exceed the heat analysis content by more than 0.12 percentage points.
[D] Not applicable.
[E] Silicon may be less than 0.04 %, provided that total aluminum is 0.030 % or over, or provided acid soluble aluminum is 0.025 % or over.
[F] Columbium and niobium are interchangeable names for the same element and both names are acceptable in A01 specifications.
[G] By agreement, the steel may be produced with titanium, in which case the minimum aluminum content shall not apply. When this option is exercised, the titanium content, by heat analysis, shall be 0.006 % to 0.02 %, and the actual titanium content shall be reported on the test report.
[H] By agreement, the steel may be produced with titanium, in which case the minimum aluminum content shall not apply. When this option is exercised, the titanium content, by heat analysis, shall be 0.006 % to 0.03 %, and the actual titanium content shall be reported on the test report.

TABLE 2 Product Analysis Tolerances

Element	Specified Limit, %	Tolerances, % Under Minimum Limit	Tolerances, % Over Maximum Limit
Carbon	to 0.15, incl	0.02	0.03
	over 0.15	0.03	0.04
Manganese	to 0.60, incl	0.05	0.06
	over 0.60 to 0.90, incl	0.06	0.08
	over 0.90 to 1.20, incl	0.08	0.10
	over 1.20 to 1.35, incl	0.09	0.11
	over 1.35 to 1.65, incl	0.09	0.12
	over 1.65	0.11	0.14
Phosphorus	to 0.020, incl	...	0.005
	over 0.020	...	0.010
Sulfur	to 0.020, incl	...	0.005
	over 0.020	...	0.010
Silicon	to 0.30, incl	0.02	0.03
	over 0.30 to 0.40, incl	0.05	0.05
	over 0.40	0.06	0.06
Nickel	to 1.00, incl	0.03	0.03
	over 1.0 to 2.0, incl	0.05	0.05
	over 2.0 to 3.8, incl	0.07	0.07
	over 3.8	0.08	0.08
Chromium	to 0.90, incl	0.04	0.04
Molybdenum	to 0.20, incl	0.01	0.01
	over 0.20	0.03	0.03
Copper	to 1.00, incl	0.03	0.03
Vanadium	to 0.10, incl	0.01	0.01
Columbium (Niobium)[A]	to 0.10, incl	0.01	0.01
Aluminum	to 0.15, incl	0.005	0.01
Titanium	to 0.010, incl	0.002	0.01
	over 0.010	0.01	0.01
Boron	any	[B]	[B]

[A] Columbium and niobium are interchangeable names for the same element and both names are acceptable in A01 specifications.
[B] Product analysis is not applicable for this element.

TABLE 3 Tensile Requirements

	Grades A, B, and C		Grade D	Grade E		Grade F			Grade G	
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10
Yield strength, min, ksi [MPa]										
to 1.5 in. [40 mm] incl	50 [345]	60 [415]	100 [690]	70 [485]	75 [515]	70 [485]	75 [515]	80 [550]	85 [585]	90 [620]
over 1.5 in. [40 mm] to 2.0 in. [50 mm]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	85 [585]	90 [620]
over 1.5 in. [40 mm] to 2.5 in. [to 65 mm]	50 [345]	60 [415]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]
over 2.5 in. [over 65 mm]	45 [310]	55 [380]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]
Tensile strength, ksi [MPa]										
to 1.5 in. [40 mm] incl	70–90 [485–620]	80–100 [550–690]	145–170 [1000–1170]	84–104 [580–715]	88–108 [605–745]	82–102 [565–705]	86–106 [590–730]	90–110 [620–760]	100–120 [690–825]	109–129 [750–885]
over 1.5 in. [40 mm] to 2.0 in. [50 mm]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	100–120 [690–825]	109–129 [750–885]
over 1.5 in. [40 mm] to 2.5 in. [to 65 mm]	70–90 [485–620]	80–100 [550–690]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]
over 2.5 in. [over 65 mm]	65–85 [450–585]	75–95 [515–655]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]
Elongation in 2 in. [50 mm], min, %[B]										
to 1.5 in. [40 mm] incl	22	22	13	20	19	20	19	18	20	20
over 1.5 in. [40 mm] to 2.0 in. [50 mm]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	20	20
over 1.5 in. [40 mm] to 2.5 in. [to 65 mm]	22	22	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]
over 2.5 in. [over 65 mm]	22	22	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]
Elongation in 8 in. [200 mm], min, %[B]										
to 1.5 in. [40 mm] incl	18	...	...	16	15	16	15	14	[A]	[A]
over 1.5 in. [40 mm] to 2.5 in. [to 65 mm]	18	....	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]
over 2.5 in. [over 65 mm]	18	...	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]

[A] Not applicable.
[B] See Specification A20/A20M for elongation requirement adjustments.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those that are considered suitable for use with this specification are listed in this section by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and Over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S10. Charpy V-Notch Test Curve,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M,

S13. NDT Temperature Determination,

S17. Vacuum Carbon-Deoxidized Steel,

S18. Unspecified Elements, and

S19. Restricted Chemical Requirements.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed are additional supplementary requirements suitable for use with this specification.

S55. Longitudinal Charpy Impact Energy Absorption Requirement

S55.1 Longitudinal Charpy V-notch tests shall be made in accordance with Specification A20/A20M. Unless the test temperature is specified in the purchase order, the tests shall be conducted at –320°F [–195°C] and the average absorbed energy for each set of three full size specimens shall be 25 ft-lb [34 J] or more, and the individual test value of not more than one specimen may be below 25 ft-lb [34 J], but in no case below 20 ft-lb [27 J].

S56. Transverse Charpy Impact Energy Absorption Requirement

S56.1 Transverse Charpy V-notch tests shall be made in accordance with Specification A20/A20M. Unless the test temperature is specified in the purchase order, the tests shall be conducted at –320°F [–195°C] and the average absorbed energy for each set of three full size specimens shall be 20 ft-lb [27 J] or more, and the individual test value of not more than one specimen may be below 20 ft-lb [27 J], but in no case below 15 ft-lb [20 J].

S64. Heat Treatment Parameters for Grad G

S64.1 Except for the TMR-I-T process, the plates shall be cooled directly after rolling without being allowed to cool below 1025°F [550°C]. Quenching hardening shall be initiated from a temperature within the range from 1025 to 1490°F [550 to 810°C].

S64.2 Subsequent to quenching, the plates shall be tempered within the range from 1030 to 1155°F [555 to 625°C], holding at that temperature for a minimum of 30 min/in. [1.2 min/mm] of thickness but for not less than 15 min, and then cooling at a rate of not less than 300°F/h [165°C/h], either in air or by quenching in water, to ambient temperature.

S64.3 Prior to the tempering treatment, the plates may be subjected to an intermediate heat treatment (Note S64.1) consisting of heating to a temperature in the range from 1185 to 1310°F [640 to 710°C], holding at that temperature for a minimum of 1 hr/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and then water-quenching to below 300°F [150°C] in the case of plate thicknesses of more than ⅝ in. [16 mm]; or cooling in air or water-quenching in the case of plate thickness of ⅝ in. [16 mm] and under.

NOTE S64.1—The intermediate heat treatment is for the purpose of enhancing elongation and notch-toughness and for reducing susceptibility to strain-aging embrittlement and temper embrittlement. It may be performed at the option of the material manufacturer or may be specified by the purchaser.

S64.4 Heat treatment temperatures and times shall be reported in accordance with Section 19 of Specification A20/A20M.

S77. Carbon Equivalent Limit

S77.1 The carbon equivalent, on heat analysis, shall not exceed the limits listed in this section when based on the following equation:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Cu + Ni)/15\,\%$$

[Grade A]	
t = 2 in. [50 mm] and under in thickness	0.40 %
t > 2 in. [50 mm] in thickness	0.45 %
[Grade B]	
t = 2 in. [50 mm] and under in thickness	0.45 %
t > 2 in. [50 mm] in thickness	0.50 %

S78. Low Sulfur Treatment

S78.1 Restricted sulfur content shall be specified on the order. In the absence of such a specification the maximum sulfur furnished under this supplementary requirement shall be 0.003 % on heat analysis.

NOTE S78.1—The low sulfur treatment is for the purpose of enhancing the HIC (Hydrogen Induced Cracking) and SSC (Sulfide Stress Cracking) resistance.

S79. Carbon Equivalent Limit

S79.1 The carbon equivalent, on heat analysis, shall not exceed 0.27 %, or a lower value as specified in the purchase order, when based on the following equation:

$$P_{CM} = C + \frac{Si}{30} + \frac{Mn + Cu + Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B\,\%$$

APPENDIX

(Nonmandatory Information)

X1. THERMO-MECHANICAL CONTROLLED PROCESSING (TMCP)

X1.1 *Introduction*—The Thermo-Mechanical Controlled Processing, commonly referred to as "TMCP," has evolved from the "controlled rolling" (CR) processes, which have been known and used for a number of years. TMCP produces fine-grained steel by a combination of chemical composition and integrated controls of manufacturing processes from slab reheating to post-rolling cooling, thereby achieving the specified mechanical properties in the required plate thicknesses. TMCP requires accurate control of both the steel temperature and rolling reductions, and does not involve coiling after the post- cooling.

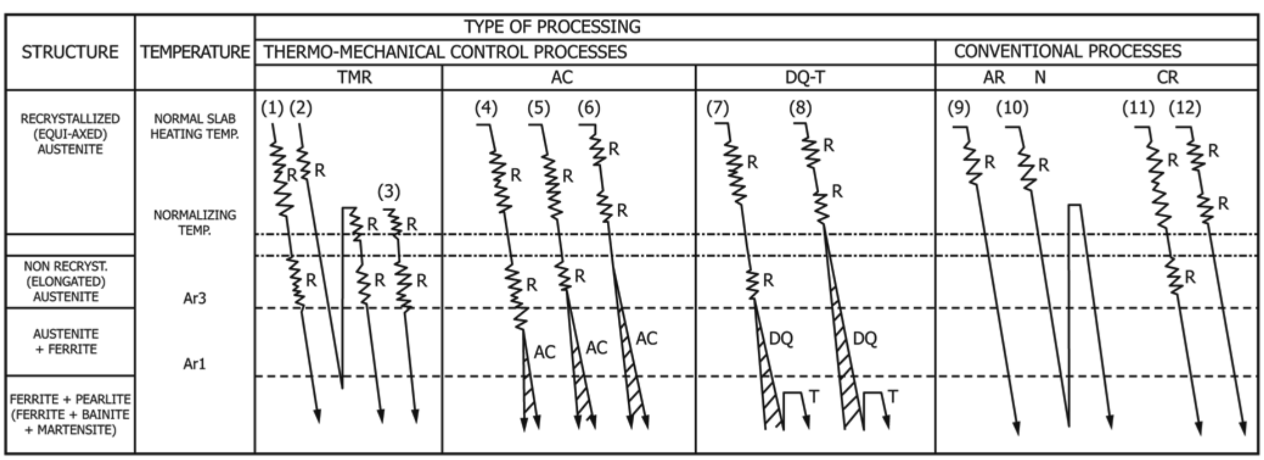
X1.2 *Outline of TMCP As May Be applied to Grades A through F*—As shown in Fig. X1.1, TMCP for those grades may incorporate three processes, as follows:

X1.2.1 *Thermo-Mechanical Rolling (TMR)*—Steels of fine grain size are produced by rolling in the recrystallization and the nonrecrystallization regions of austenite, and sometimes in the dual-phase temperature region of austenite and ferrite. Generally, a high proportion of the rolling reduction is performed close to, or below, the temperature at which austenite begins to transform to ferrite during cooling (Ar3) and may involve rolling in the lower portion of the temperature range of the intercritical dual-phase region.

X1.2.2 *Accelerated Cooling (AC)*—Steels meeting the specified requirements are produced by controlled cooling (accelerated cooling and air cooling) through the dual-phase temperature region immediately after final controlled rolling (CR) or TMR operation.

X1.2.3 *Direct Quenched and Tempered (DQT)*—Steels meeting the specified requirements are produced by promoting grain refinement and increasing hardness through direct quenching immediately after final controlled rolling (CR) or TMR operations. Subsequent to direct quenching the plates are tempered.

X1.2.4 The selection, from the above, of the method to be used is made by the plate producer depending upon the chemical composition, the plate thickness, and the required properties.



NOTE:
TMR: THERMO-MECHANICAL ROLLING
AC: ACCELERATED COOLING PROCESS
AR: AS ROLLED
N: NORMALIZED
CR: CONTROLLED ROLLING
R: REDUCTION
DQ: DIRECT QUENCHING
T: TEMPERED

FIG. X1.1 Schematic Diagrams of Thermo-Mechanical Control and Conventional Process of Steel Plate as may be Applied to Grades A through F

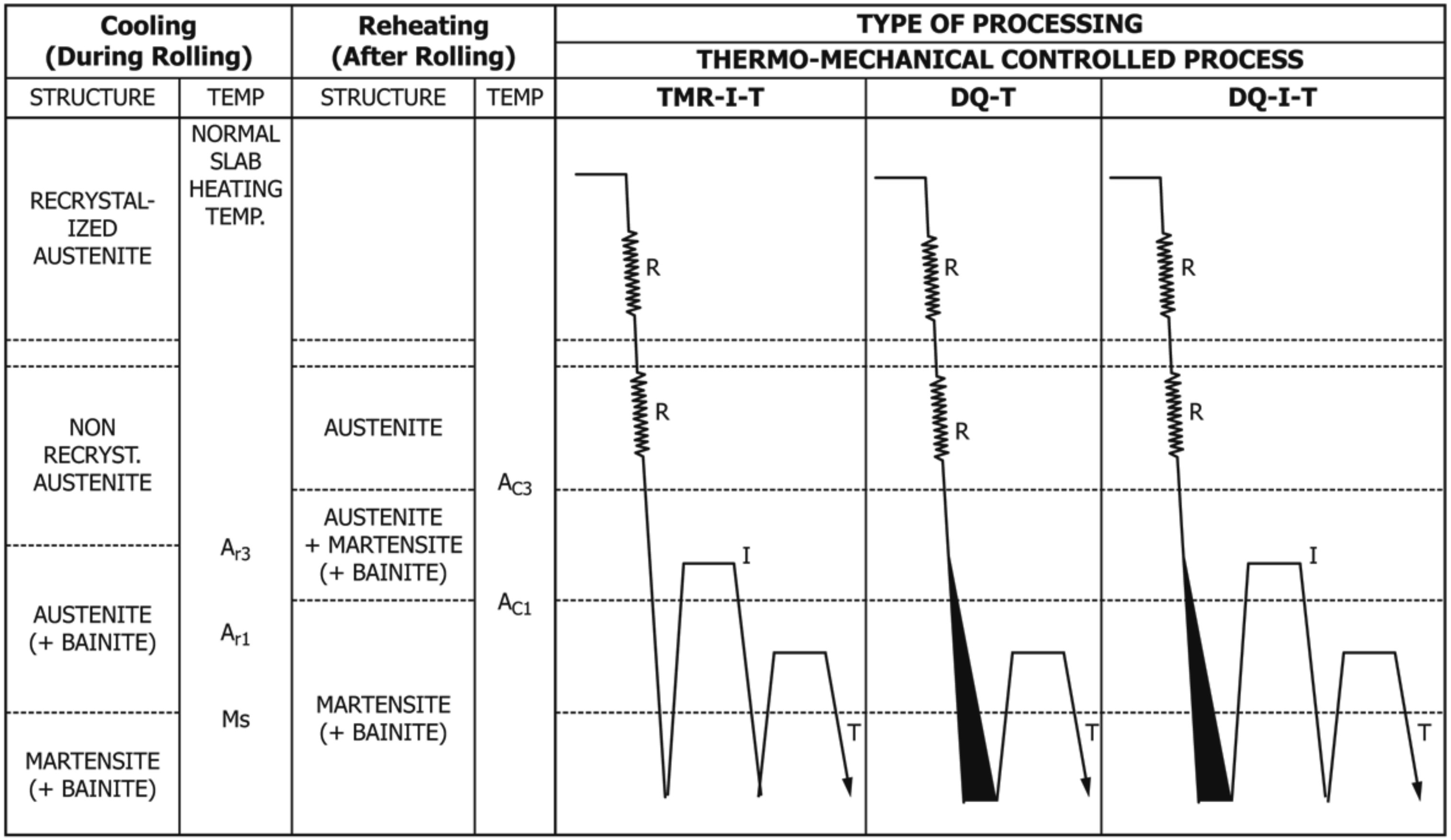
X1.3 *Outline of TMCP As May Be Applied to Grade G*—As shown in Fig. X1.2, TMCP for this grade may incorporate three processes, as follows:

X1.3.1 *Thermo-Mechanical Rolling and Intermediately Heat Treated and Tempered (TMR-I-T)*—Subsequent to TMR as described in X1.2.1, the plate may be tempered, except that prior to tempering after TMR, the plate may be subjected to an intermediate heat treatment consisting of heating to a temperature in the range from A_{C1} to A_{C3}.

X1.3.2 *Direct Quenched and Tempered (DQ-T)*—As described in X1.2.3.

X1.3.3 *Direct Quenched and Intermediately Heat Treated and Tempered (DQ-I-T)*—Similar to DQT, as described in X1.2.3, except that prior to the tempering treatment and after DQ, the plate may be subjected to an intermediate heat treatment consisting of heating to a temperature in the range from A_{C1} to A_{C3}.

X1.3.4 The selection, from the above, of the method to be used is made by the plate producer depending upon the chemical composition, the plate thickness, and the required properties.



NOTE:
TMR: THERMO-MECHANICAL ROLLING DQ: DIRECT QUENCHING
I: INTERMEDIATE HEAT TREATMENT T: TEMPERING
R: REDUCTION

FIG. X1.2 Schematic Diagrams of Thermo-Mechanical Control Processes of Steel Plate as may be Applied to Grade G

SPECIFICATION FOR FERRITIC DUCTILE IRON CASTINGS SUITABLE FOR LOW-TEMPERATURE SERVICE

SA-874/SA-874M

(Identical with ASTM Specification A874/A874M-98(2018)$^{\varepsilon 1}$.)

Standard Specification for
Ferritic Ductile Iron Castings Suitable for Low-Temperature Service

1. Scope

1.1 This specification covers ductile iron castings suitable for service at temperatures of −40°F [–40°C] and above.

1.2 The values stated in either inch-pound or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 The following precautionary statement pertains only to the test methods portion, Section 11, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings
E 8 Test Methods for Tension Testing of Metallic Materials
E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron
E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition
E 94 Guide for Radiographic Examination
E 165 Test Method for Liquid Penetrant Examination
E 351 Test Methods for Chemical Analysis of Cast Iron—All Types
E 562 Test Method for Determining Volume Fraction by Systematic Manual Point Count
E 689 Reference Radiographs for Ductile Iron Castings
E 709 Guide for Magnetic Particle Examination

3. Ordering Information

3.1 Orders for material under this specification shall include the following applicable information:

3.1.1 Drawing, catalog number, or part identification,
3.1.2 Quantity (weight or number of pieces),
3.1.3 ASTM designation and year of issue,
3.1.4 Marking instructions (see Section 15),
3.1.5 Place of inspection (see 13.1),
3.1.6 Limits on residual elements (see 5.2),
3.1.7 Visual and dimensional acceptance standard (see 7.1),
3.1.8 Sampling plan (see Section 9), and
3.1.9 Supplementary requirements.

4. Materials and Manufacture

4.1 Castings may be supplied either as cast or heat treated and shall have essentially a ferritic structure that contains no massive carbides.

5. Chemical Composition

5.1 The iron shall conform to the requirements for chemical composition shown in Table 1.

5.2 By agreement between the manufacturer and purchaser, analysis may be required and limits established for elements not specified in Table 1.

6. Mechanical and Microstructural Properties

6.1 *Tensile Properties*—The iron shall conform to the requirements for tensile properties shown in Table 2.

6.2 *Microstructure*—Graphite contained in the microstructure shall be evaluated in accordance with Test Method A 247. The percent of each graphite type shall be estimated, and the total of all estimates shall equal 100 %. The total percent of Types 1 and 2 graphite shall be a minimum of 90 %.

7. Workmanship, Finish, and Appearance

7.1 The surface of the casting shall be examined visually and shall be free from adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet visual and dimensional acceptance standards specified in the order.

TABLE 1 Chemical Composition

Element	Minimum, %	Maximum, %
Total carbon	3.0	3.7
Carbon equivalent (carbon + ⅓ silicon)	. . .	4.5
Silicon	1.2	2.3
Phosphorous	. . .	0.03
Magnesium	. . .	0.07
Manganese	. . .	0.25
Copper	. . .	0.1
Nickel	. . .	1.0
Chromium	. . .	0.07

TABLE 2 Tensile Properties

Tensile Strength, min, psi [MPa]	Yield Strength, min, psi [MPa]	Elongation in 2 in. [50 mm], min, %
45 000 [300]	30 000 [200]	12 [12]

7.2 Conditioning of castings is permitted to the extent that the removal of metal does not extend into the envelope of the finished container and does not alter the properties of the metal remaining in the finished container.

8. Repair

8.1 Castings shall not be repaired by plugging, welding, brazing, impregnation, or any other means.

9. Sampling

9.1 Test coupons will be obtained from the casting. The location in the casting from which the test coupons are obtained and the number obtained from each location shall be agreed upon between the manufacturer and purchaser.

9.2 Metallographic samples shall be obtained from the same location as the mechanical test coupons.

9.3 Nondestructive examination methods for estimating microstructure may be used to supplement the destructive examination sampling plan.

9.4 Sampling for chemical analysis shall be in accordance with Practice E 59.

9.4.1 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or thin wafers approximately ¹⁄₃₂ in. [0.8 mm] thick cut from test coupons.

10. Number of Tests and Retests

10.1 The number of tension tests and the number of microstructural examinations shall be agreed upon between the manufacturer and purchaser.

10.2 If any tension test specimen shows obvious defects, it may be discarded and another from the same coupon may be tested.

11. Test Methods

11.1 Conduct the tension test in accordance with Test Methods E 8.

11.2 Determine the yield strength using one of the following methods:

11.2.1 The 0.2 % offset method, or

11.2.2 Extension under load method where the yield strength may be determined as the stress producing an elongation under load of 0.330 %, that is, 0.0066 in. [0.165 mm] in a gage length of 2 in. [50 mm].

11.3 Determine the percent of each graphite nodule type by manual coating, semi-automatic, or automatic image analysis methods. The manual count method shall prevail when the results of other methods differ. Magnification shall be at 100 ×.

11.4 Spectrometric methods may be used for chemical analysis. Should a dispute arise concerning chemical composition, use Test Methods E 351 and E 30 for referee methods.

12. Records

12.1 Records of the chemical composition, mechanical properties, and the metallographic examination shall be systematically made and maintained.

13. Inspection

13.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall perform all of the tests and inspections required by the specification.

13.2 All tests and inspections shall be made at the place of manufacture or a mutually agreed upon location.

13.3 The inspector representing the purchaser shall have entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with these specifications. The inspector representing the purchaser shall not interfere unnecessarily with the operation of the works.

14. Certification

14.1 The manufacturer's certification shall be furnished to the purchaser stating the material was manufactured, sampled, tested, and inspected in accordance with this specification (including the year of issue) and was found to meet the requirement(s). In addition, a test report shall be included with the certification giving the results of all tests performed including chemical analysis.

15. Product Marking

15.1 The casting shall be identified and shall be marked in accordance with instructions issued by the purchaser.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface discontinuities by magnetic particle examination. The examination shall be in accordance with Guide E 709. The extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S2. Ultrasonic Examination

S2.1 Castings shall be examined for internal defects by ultrasonic examination. The examination procedures and acceptance criteria shall be agreed upon between the manufacturer and purchaser.

S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Test Method E 165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S4. Radiographic Examination

S4.1 Castings shall be examined for internal defects by means of X rays or gamma rays. The procedure shall be in accordance with Guide E 94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 689. The extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S5. Fracture Toughness

S5.1 Fracture toughness testing shall be performed on samples removed from the casting. The method of fracture toughness testing, the location from which the samples are removed, the number of tests performed, and the acceptance requirements shall be agreed upon between the manufacturer and purchaser.

S6. Nodule Count

S6.1 The nodule count per unit area shall be determined by examining 100 × micrographs [see Note (1)]. The samples for the micrographs shall be removed from the casting at locations agreed upon. The inspection method and the acceptance requirements shall be agreed upon between the manufacturer and purchaser. Test Method E 562 may be used for guidance.

NOTE 1:_ Electric Power Research Institute Project 2813-1, "Relationships Between Ductile Iron Fracture Toughness and Microstructure," December 1986, provides background information.

SPECIFICATION FOR STEEL WIRE, PRESSURE VESSEL WINDING

SA-905

(Identical with ASTM Specification A905-93.)

SPECIFICATION FOR STEEL WIRE, PRESSURE VESSEL WINDING

SA-905

(Identical with ASTM Specification A 905-93.)

1. Scope

1.1 This specification covers requirements for a high strength drawn and cold rolled steel wire in two strength classes, with rectangular cross section, and round mill edge. This wire is intended for prestressed vessel and press frame windings.

1.2 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards. Within the text and tables, the SI units are shown in parentheses. The values stated in each system are not exact equivalents. Therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 510 Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel

A 510M Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel [Metric]

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

E 30 Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron and Wrought Iron

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

2.2 *Military Standard:*

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.4 *AIAG Standard:*

AIAG B-502.00 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 510 or A 510M.

3.2 Orders for material under this specification shall include the following information for each ordered item.

3.2.1 Quantity (mass),

3.2.2 Name of material,

3.2.3 Dimensions (see Section 7),

3.2.4 Finish (see Section 8),

3.2.5 Packaging (see Section 11),

3.2.6 Heat analysis report (see 5.2),

3.2.7 Number of certification and test reports required,

3.2.8 ASTM designation and year of issue, and

3.2.9 Supplementary requirements, if any.

4. Material and Manufacture

4.1 The steel shall be produced by any of the following primary processes: (1) basic oxygen, and (2) electric furnace or vacuum induction (VIM). The primary melting may incorporate separate degassing or refining and may be followed by secondary melting by the electrode slag process (ESR) or the vacuum arc remelting process (VAR).

4.1.1 The steel may be ingot cast or continuously cast.

4.2 The finished wire shall be free from detrimental pipe and undue segregation.

4.3 The wire shall be cold drawn or cold rolled, or both, to produce the desired mechanical properties and dimensions after subjecting it to the patenting treatment.

4.4 The width to thickness ratio of the wire cross section shall not exceed 8.

5. Chemical Composition

5.1 The steel shall conform to the requirements for chemical composition prescribed in Table 1.

5.2 *Heat Analysis* — Each heat of steel shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 1. This analysis shall be made from a test specimen preferably taken during the pouring of the heat. When requested, this shall be reported to the purchaser and shall conform to the requirements of Table 1.

5.3 *Heat Number Assignment for Sequentially Strand Cast Material* — When heats of the same chemical composition are sequentially strand cast, the heat number assigned to the cast product may remain unchanged until all of the steel in the product is from the following heat.

5.4 *Product Analysis* — An analysis may be made by the purchaser from finished wire representing each heat of steel. The chemical composition thus determined, as to elements required or restricted, shall conform to the product analysis requirements specified in Table 10 of Specification A 510 or A 510M.

5.5 For referee purposes, Methods E 30 shall be used.

6. Mechanical Requirements

6.1 *Tension Test:*

6.1.1 *Requirements*— The material as represented by tension test specimens shall conform to the requirements prescribed in Table 2.

6.1.2 *Number of Tests* — One test specimen shall be taken from each end of every coil.

6.1.3 *Test Method* — The tension test shall be made in accordance with Test Methods A 370, except that the length L for evaluation of the elongation shall be calculated from the following formula:

$$L = 11.3\sqrt{W \cdot T}$$

where:

W = width of the wire, and
T = thickness of the wire.

The length L shall be used to calculate the permanent elongation. The distance between the gage marks shall be measured to the nearest 0.004 in. (0.1 mm). Determine tensile properties and permanent elongation as described in Test Methods A 370.

6.1.4 *Retest* — If any test specimen exhibits obvious discontinuity, it may be discarded and another specimen substituted.

7. Dimensions and Permissible Variations

7.1 The permissible variations in dimensions of the wire shall be as specified in Table 3, unless otherwise specified in the ordering information.

8. Workmanship, Finish, and Appearance

8.1 The wire shall be free of detrimental surface imperfections, tangles and sharp kinks.

8.2 The wire shall conform to the dimensions, tolerances, and finish specified on the order or drawing. Welds are not permitted.

8.3 When required, non-destructive examination shall be carried out in accordance with Supplementary Requirement S1.

8.4 The wire as received shall be smooth and substantially free from rust. No detrimental die marks or scratches may be present.

9. Inspection

9.1 All tests and inspections shall be made at the place of manufacture unless otherwise agreed upon, and shall not interfere unnecessarily with the manufacturer's operations. The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification.

10. Certification and Reports

10.1 The manufacturer shall furnish the required number, from the purchase order, of test reports to the purchaser. The following items shall be reported.

10.1.1 Heat number,

10.1.2 Heat chemical analysis,

10.1.3 Result of test of tensile properties,

10.1.4 Reports of non-destructive tests, if required (S.1), and

10.1.5 ASTM specification number, year of issue and revision letter, if any.

11. Packaging, Marking, and Loading for Shipment

11.1 The coil, reel or spool mass, dimensions, and the method of packaging shall be agreed upon between the manufacturer and purchaser.

11.2 The size of the wire, purchaser's order number, ASTM specification number, and name or mark of the manufacturer shall be marked on a tag securely attached to each coil, reel, or spool of wire.

11.3 Unless otherwise specified in the purchaser's order, packaging, marking, and loading for shipments shall be in accordance with those procedures recommended by Practices A 700.

11.4 *For Government Procurement* — Packaging, packing, and marking of material for military procurement shall be in accordance with the requirements of MIL-STD-163, Level A, Level C, or commercial as specified in the contract or purchase order. Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

11.5 *Bar Coding* — In addition to the previously-stated identification requirements, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard 02.00, Primary Metals Identification Tag Application. The bar code may be applied to a substantially affixed tag.

12. Keywords

12.1 pressure vessel; winding; wire

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition %
Carbon	0.80–0.95
Manganese	0.30–0.60
Phosphorus	0.025
Sulphur, max	0.020
Silicon	0.10–0.30

TABLE 2
TENSILE REQUIREMENTS

Thickness[A] in. (mm)	Tensile Strength min, ksi (MPa) Class 1	Tensile Strength min, ksi (MPa) Class 2	Yield Strength min, ksi (MPa) Class 1	Yield Strength min, ksi (MPa) Class 2	Elongation min, % Class 1	Elongation min, % Class 2
0.020 (051)	296 (2045)	268 (1850)	260 (1795)	232 (1600)	4.0	5.0
0.030 (0.76)	290 (2000)	262 (1810)	255 (1760)	226 (1560)	4.0	5.0
0.040 (1.02)	285 (1965)	256 (1770)	250 (1725)	221 (1525)	4.0	5.0
0.051 (1.30)	280 (1930)	250 (1725)	243 (1680)	214 (1480)	4.0	5.0
0.059 (1.50)	275 (1900)	246 (1700)	239 (1650)	210 (1450)	4.0	5.0

[A] Tensile requirement values for intermediate thickness may be interpolated.

TABLE 3
PERMISSIBLE VARIATIONS IN DIMENSIONS

Thickness in. (mm)	Permissible Variation, ± in. (mm)
0.02 to 0.03 (0.51 to 0.76), incl	0.0004 (0.01)
Over 0.03 to 0.04 (0.76 to 1.02), incl	0.0008 (0.02)
Over 0.04 to 0.06 (1.02 to 1.52), incl	0.0012 (0.03)
Width in. (mm)	**Permissible Variation, ± in. (mm)**
0.08 to 0.16 (2.03 to 4.06), incl	0.0016 (0.04)
Over 0.16 to 0.24 (4.06 to 6.10), incl	0.0024 (0.06)
Over 0.24 to 0.48 (6.10 to 12.2), incl	0.0040 (0.10)

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements to this specification shall only apply to a product specification when specified by the purchaser in his inquiry, contract or order. Details of the supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser.

S1. Surface Examination

S1.1 The surface of the wire shall be examined by the eddy current method in accordance with Practice E 309. The acceptance criteria shall be mutually agreed upon by the purchaser and manufacturer.

TERMINOLOGY RELATING TO STEEL, STAINLESS STEEL, RELATED ALLOYS, AND FERROALLOYS

SA-941

(23)

(Identical with ASTM Specification A941-22a.)

Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

1. Scope

1.1 This standard is a compilation of definitions of terms related to steel, stainless steel, related alloys, and ferroalloys.

1.2 When a term is used in an ASTM document for which Committee A01 is responsible, it is included herein only when judged, after review by Subcommittee A01.92, to be a generally usable term.

1.3 Some definitions include a discussion section, which is a mandatory part of the definition and contains additional information that is relevant to the meaning of the defined term.

1.4 Definitions of terms specific to a particular standard will appear in that standard and will supersede any definitions of identical terms in this standard.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*
E112 Test Methods for Determining Average Grain Size

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

Ac_{cm}, Ac_1, Ac_3, Ac_4—See **transformation temperature**.

Ae_{cm}, Ae_1, Ae_3, Ae_4—See **transformation temperature**.

age hardening, *n*—hardening by **aging**, usually after rapid cooling or **cold working**.

age hardening, *n*—see **precipitation hardening**.

aging, *n*—a change in the properties of certain **steels** that occurs at ambient or moderately elevated temperatures after hot working or a heat treatment (**quench aging, natural aging,** or **artificial aging**) or after a cold-working operation (**strain aging**).

Discussion—The change in properties is often, but not always, due to **precipitation hardening**, but never involves a change in the chemical composition of the **steel**.

alloy steel, *n*—a **steel**, other than a **stainless steel**, that conforms to a specification that requires one or more of the following elements, by mass percent, to have a minimum content equal to or greater than: 0.30 for aluminum; 0.0008 for boron; 0.30 for chromium; 0.30 for cobalt; 0.40 for copper; 0.40 for lead; 1.65 for manganese; 0.08 for molybdenum; 0.30 for nickel; 0.06 for niobium (columbium); 0.60 for silicon; 0.05 for titanium; 0.30 for tungsten (wolfram); 0.10 for vanadium; 0.05 for zirconium; or 0.10 for any other alloying element, except sulphur, phosphorus, carbon, and nitrogen.

annealing, *n*—a generic term covering any of several **heat treatments**.

Discussion—This treatment is used for purposes such as reducing hardness, improving machinability, facilitating **cold working**, producing a desired microstructure, or obtaining desired mechanical, physical, or other properties. Where applicable, it is preferred that the following more specific terms be used: **box annealing, bright annealing, full annealing, intermediate annealing, isothermal annealing, process annealing, spheroidizing**, and **subcritical annealing**. The term "**annealing**," without qualification, implies **full annealing**. Any process of **annealing** will usually reduce stresses; however, if the treatment is applied for the sole purpose of stress reduction, it should be designated **stress relieving**.

Ar_{cm}, Ar_1, Ar_3, Ar_4—See **transformation temperature**.

artificial aging, *n*—**aging** above room temperature.

atmospheric corrosion resistance, *n*—the ability to resist degradation or alteration of material through chemical reaction with the surrounding atmosphere.

Discussion—This term generally pertains to carbon steel, low alloy steel, or micro-alloyed steel.

austempering, *n*—**heat treatment** involving **quenching** a steel object from a temperature above the **transformation range** in a medium maintained at a temperature above the **martensite range** sufficiently fast to avoid the formation of high temperature transformation products, and then holding it at that temperature until transformation is complete.

austenitizing, *n*—forming austenite by heating a steel object above the **transformation range**.

baking, *n*—heating to a low temperature in order to remove gases.

batch furnace, *n*—a heating device within which steel objects are held stationary or oscillated during the thermal processing cycle.

blank carburizing, *n*—simulating the **carburizing** operation without introducing carbon.

Discussion—This is usually accomplished by using an inert material in place of the carburizing agent, or by applying a suitable protective coating on the object being heat treated.

blank nitriding, *n*—simulating the nitriding operation without introducing nitrogen.

Discussion—This is usually accomplished by using an inert material in place of the nitriding agent, or by applying a suitable protective coating on the object being heat treated.

bluing, *n*—subjecting the scale-free surface of a steel object to the action of air, steam, or other agents at a suitable temperature, thereby forming a thin blue film of oxide and improving the object's appearance and corrosion resistance.

Discussion—This term is ordinarily applied to sheet, strip, or finished parts. It is used also to denote the heating of springs after fabrication in order to improve their properties.

box annealing, *n*—**annealing** in a sealed container under conditions that minimize oxidation.

Discussion—The charge is usually heated slowly to a temperature below the **transformation range**, but sometimes above or within it, and is then cooled slowly.

bright annealing, *n*—**annealing** in a protective medium to prevent discoloration of the bright surface.

capped steel, *n*—a **rimmed steel** in which, during ingot solidification, the rimming action was limited by mechanical or chemical means.

carbon potential, *n*—the carbon content at the surface of a specimen of pure iron in equilibrium with the carburizing medium considered, and under the conditions specified.

carbon restoration, *n*—replacing the carbon lost from the surface layer in previous processing by carburizing this layer to substantially the original carbon level.

carbon steel, *n*—a **steel** that conforms to a specification that prescribes a maximum limit, by **heat analysis** in mass percent, of not more than: 2.00 for carbon and 1.65 for manganese, but does not prescribe a minimum limit for chromium, cobalt, molybdenum, nickel, niobium (columbium), tungsten (wolfram), vanadium, or zirconium.

Discussion—Except as required above, it is permissible for carbon steel specifications to prescribe limits (minimum or maximum, or both) for each specified alloying element, subject to the following restrictions for the heat analysis limits in mass percent:
(a) for wrought carbon steel products, the specified maximum limit is not to exceed: 0.10 for aluminum, 0.60 for silicon, and 0.050 for titanium;
(b) for carbon steel castings, the specified maximum limit is not to exceed: 0.10 for aluminum, 1.00 for silicon, and 0.050 for titanium.
(c) for **carbon steels** that are required to be rephosphorized, the specified minimum limit for phosphorus is not to be less than 0.040;
(d) for **carbon steels** that are required to be resulfurized, the specified minimum limit for sulfur is not to be less than 0.060;
(e) for **carbon steels** that are not required to be rephosphorized or resulfurized, the specified maximum limit is not to exceed: 0.60 for copper, 0.050 for phosphorus, and 0.060 for sulfur; and
(f) for **carbon steels** that are required to contain boron, copper, or lead, the specified minimum limit is not to exceed: 0.0005 for boron, 0.35 for copper, and 0.25 for lead.

carbonitriding, *n*—**case hardening** in which a suitable steel object is heated above Ac_1 in a gaseous atmosphere of such composition as to cause simultaneous absorption of carbon and nitrogen by the surface and, by diffusion, to create a concentration gradient.

carburizing, *n*—a process in which an austenitized steel object is brought into contact with a carbonaceous environment of sufficient carbon potential to cause absorption of carbon at the surface and, by diffusion, to create a concentration gradient.

case, *n*—*in case hardening*, the outer portion that has been made harder than the **core** as a result of altered composition or microstructure, or both, from treatments such as **carburizing, nitriding**, and **induction hardening**.

case hardening, *n*—a generic term covering any of several processes applicable to **steel** that change the chemical composition or microstructure, or both, of the surface layer.

Discussion—The processes commonly used are: **carburizing** and **quench hardening**; **nitriding**; and **carbonitriding**. It is preferred that the applicable specific process name be used.

cast analysis—Deprecated term. Use the preferred term **heat analysis**.

cementation, *n*—the introduction of one or more elements into the outer portion of a steel object by means of diffusion at high temperature.

certificate of compliance, *n*—*in manufactured products*, a document that states that the product was manufactured, sampled, tested, and inspected in accordance with the requirements of the specification (including year of issue) and any other requirements specified in the purchase order or contract, and has been found to meet such requirements.

Discussion—A single document, containing test report information and certificate of compliance information, may be used.

certifying organization, *n*—*in product specifications*, the entity responsible for the conformance and certification of the product to the specification requirements.

check analysis—Deprecated term. Use the preferred term **product analysis**.

coarse grain practice, *n*—a steelmaking practice for other than **stainless steel** that is intended to produce a **killed steel** in which aluminum, niobium (columbium), titanium, and vanadium are **residual elements**.

cold working, *n*—mechanical deformation of a metal at temperatures below its **recrystallization temperature**.

cold treatment, *n*—exposing a steel object to temperatures below room temperature for the purpose of obtaining desired conditions or properties, such as dimensional or structural stability.

conditioning heat treatment, *n*—a preliminary **heat treatment** used to prepare a steel object for a desired reaction to a subsequent **heat treatment**.

continuous-conveyance furnace, *n*—a heating device through which steel objects are intentionally moved at a constant rate during the thermal processing cycle.

controlled cooling, *n*—cooling a steel object from an elevated temperature in a predetermined manner to avoid hardening, cracking, or internal damage, or to produce a desired microstructure or mechanical properties.

controlling cross section thickness (Tc), *n*—diameter of the largest theoretical sphere that can be inscribed within the volume of the component.

Discussion—The controlling cross section thickness (Tc) is used to determine the size of prolongations, test blocks, or representative test pieces. It is calculated based on the dimensions of the component at the time of heat treatment. Where components are heat treated with internal diameters the calculation is made based on the wall thickness.

core, *n—in case hardening,* the interior portion of unaltered composition or microstructure, or both, of a case hardened steel object.

core, *n—in clad products,* the central portion of a multilayer composite metallic material.

critical cooling rate, *n*—the slowest rate of continuous cooling at which austenite can be cooled from above the **transformation range** to prevent its transformation above M_s.

cycle annealing, *n*—**annealing** employing a predetermined and closely controlled time-temperature cycle to produce specific properties or a specific microstructure.

decarburization, *n*—the loss of carbon from the surface of a steel object as a result of its being heated in a medium that reacts with the carbon.

defect, *n*—an imperfection of sufficient magnitude to warrant rejection based on the specified requirements.

differential heating, *n*—heating that intentionally produces a temperature gradient within a steel object such that, after cooling, a desired stress distribution or variation in properties is present within the object.

diffusion coating, *n*—any process whereby a base metal is either coated with another metal and heated to a sufficient temperature in a suitable environment, or exposed to a gaseous or liquid medium containing the other metal, thereby causing diffusion of the coating or other metal into the base metal, with a resultant change in the composition and properties of its surface.

direct quenching, *n—in thermochemical processing*, **quenching** immediately following the thermochemical treatment.

direct quenching, *n—in thermomechanical processing*, **quenching** immediately following the final hot deformation.

document, *n*—a written, printed, or electronic record that provides information, evidence, or official statements.

double aging, *n*—employment of two different aging treatments, in sequence, to control the type of precipitate formed from a supersaturated alloy matrix in order to obtain the desired properties.

Discussion—The first aging treatment, sometimes referred to as intermediate or stabilizing, is usually carried out at a higher temperature than the second.

double tempering, *n*—a treatment in which a quench-hardened steel object is given two complete tempering cycles at substantially the same temperature for the purpose of ensuring completion of the tempering reaction and promoting stability of the resultant microstructure.

electronic data interchange, *n*—the computer to computer exchange of business information in a standardized format.

ellipsis, *n—in a tabular entry*, three periods (...) that indicate that there is no requirement.

ferritizing anneal, *n*—a **heat treatment** that produces a predominantly ferritic matrix in a steel object.

ferroalloy, *n*—an alloy of iron and one or more other metals, for use as an addition to the molten metal during the manufacture of **steels**, nickel alloys, or cobalt alloys.

ferrous material, *n*—metals and alloys that contain iron as the principal component.

Discussion—The iron content is not always stated in the specification and is not always determined by chemical analysis. The iron content may be taken to be 100 % minus the sum of the mean values permitted by the specification for all other elements having a specified range or a specified maximum. For conformance purposes, the mean value for iron, whether specified or calculated, is compared on an individual basis to the mean values permitted by the specification for each of the other elements having a specified range or a specified maximum. If an element other than iron is not specified, but is listed as remainder or balance, then, for conformance purposes the mean value for iron is compared to the calculated value for that other element.

fine grain practice, *n*—a steelmaking practice for other than **stainless steel** that is intended to produce a **killed steel** that is capable of meeting the requirements specified for fine austenitic grain size when and if the as-rolled or as-forged product is reheated to a temperature at or above the transformation temperature, Ac_3.

Discussion—When stated as a requirement, **fine grain practice** normally involves the addition of one or more austenitic grain refining elements in amounts that have been established by the steel producer as being sufficient. Austenitic grain refining elements include, but are not limited to, aluminum, niobium (columbium), titanium, and vanadium. A **fine grain practice** requirement *(1)* does not specify a minimum austenitic grain refining element addition; *(2)* does not require prior austenite grain size testing or measurement, or both; *(3)* if tested, does not require meeting any prior austenite grain size requirement; and *(4)* does not apply to, nor in any way control, the prior austenite grain size or the ferrite grain size of the steel in the as-rolled or as-forged condition. The prior austenitic grain size and the ferritic grain size of as-rolled or as-forged steel products are controlled by the manufacturing process and may be assisted by suitable chemistry. The appropriate manufacturing process controls needed to meet the mechanical property requirements of the specification in the asrolled or as-forged condition are neither defined nor implied by the inclusion of a **fine grain practice** requirement.

flame annealing, *n*—**annealing** in which the heat is applied directly by a flame.

flame hardening, *n*—a process in which only the surface layer of a suitable steel object is heated by flame to above Ac_3 or Ac_{cm}, and then the object is **quenched**.

fog quenching, *n*—**quenching** in a mist.

full annealing, *n*—**annealing** a steel object by **austenitizing** it and then cooling it slowly through the **transformation range**.

Discussion—The austenitizing temperature is usually above Ac_3 for hypoeutectoid steels and between Ac_1 and Ac_{cm} for hypereutectoid steels.

grain growth, *n*—an increase in the grain size of a steel object, usually as a result of exposure to elevated temperatures.

grain size, *n*—the dimensions of the grains or crystals in a polycrystalline metal, exclusive of twinned regions and subgrains when present.

Discussion—**Grain size** is usually estimated or measured on the cross section of an aggregate of grains, and designated by an ASTM grain size number. (See Test Methods E112.)

graphitization annealing, *n*—**annealing** a steel object in such a way that some or all of the carbon is precipitated as graphite.

hardenability, *n*—the property that determines the depth and distribution of hardness induced by **quenching** a steel object.

hardening, *n*—increasing the hardness by suitable treatment, usually involving heating and cooling.

Discussion—Where applicable, it is preferred that the following more specific terms be used: **age hardening**, **case hardening**, **flame hardening**, **induction hardening**, **precipitation hardening**, and **quench hardening**.

heat, *n*—a generic term denoting a specific **lot** of **steel**, based upon steelmaking and casting considerations.

Discussion—Where it is necessary to be more definitive, the following more specific terms are used: **primary heat**, **multiple heat**, and **remelted heat**. In product specifications, the term **heat** generally is used, without qualification, to mean the **primary**, **multiple**, or **remelted heat**, whichever is applicable.

heat analysis, *n*—the chemical analysis determined by the steel producer as being representative of a specific **heat** of **steel**.

Discussion—Where the analysis reported by the steel producer is not sufficiently complete for conformance with the heat analysis requirements of the applicable product specification to be fully assessed, the **manufacturer** may complete the assessment of conformance with such heat analysis requirements by using a product analysis for the **specified elements** that were not reported by the steel producer, provided that product analysis tolerances are not applied and the **heat analysis** is not altered.

heat number, *n*—the alpha, numeric, or alphanumeric designator used to identify a specific **heat** of **steel**.

heat treatment, *n*—heating and cooling a steel object in such a way as to obtain desired conditions or properties.

Discussion—Heating for the sole purpose of hot working is excluded from the meaning of this definition.

high-strength low-alloy steel, *n*—a **steel**, other than a **carbon steel** or an **interstitial-free steel**, that conforms to a specification that requires the minimum content for each specified alloying element to be lower than the applicable limit in the definition for **alloy steel**, and the yield point or yield strength of the product to be at least 36 ksi or 250 MPa.

homogeneous carburizing, *n*—a process that converts a low-carbon steel to one of substantially uniform and higher carbon content throughout the section, so that a specific response to **hardening** may be obtained.

homogenizing, *n*—holding a steel object at high temperature to eliminate or decrease chemical segregation by diffusion.

hot-cold working, *n*—the mechanical deformation of austenitic and precipitation hardening steels at a temperature just below the **recrystallization temperature** to increase the yield strength and hardness by plastic deformation or precipitation hardening effects induced by plastic deformation, or both.

hot-finished, *n*—the condition of a product that has been cooled directly after the last **hot-working** operation, without **cold-working** (except for straightening or flattening), and independent of the temperature at which hot-working was completed.

Discussion—The tolerances and surface finish of hot-finished product can be different from those of cold-finished, cold-drawn, or cold-rolled product.

hot quenching, *n*—an imprecise term used to cover a variety of quenching procedures in which the quenching medium is maintained at a prescribed temperature above 160 °F or 70 °C.

hot working, *n*—mechanical deformation of a metal at temperatures above its **recrystallization temperature**.

imperfection, *n*—a material discontinuity or irregularity that is detectable by **inspection**.

inclusion shape control, *n*—the addition of elements during steel making in order to affect the inclusion morphology.

induction hardening, *n*—*in surface hardening*, a process in which only the surface layer of a suitable steel object is heated by electrical induction to above Ac_3 or Ac_{cm}, and then the object is **quenched**.

induction hardening, *n*—*in through hardening*, a process in which a suitable steel object is heated by electrical induction to above Ac_3 or Ac_{cm} throughout its section, and then the object is **quenched**.

induction heating, *n*—heating by electrical induction.

inspection, *n*—the process of measuring, examining, testing, gaging, or otherwise comparing the unit of product with the applicable requirements.

intermediate annealing, *n*—**annealing** wrought steel objects at one or more stages during manufacture prior to final thermal treatment.

interrupted aging, *n*—**aging** at two or more temperatures, by steps, and cooling to room temperature after each step.

interrupted quenching, *n*—**quenching** in which the object being quenched is removed from the quenching medium while the object is at a temperature substantially higher than that of the quenching medium.

interstitial-free steel, *n*—a **steel** that has essentially all of its carbon and nitrogen chemically combined with stabilization elements rather than being present interstitially.

Discussion—The heat analysis limits (minimum or maximum, or both) that are permitted to be prescribed in interstitial-free steel specifications are as given in the definition for **carbon steel**, except that the 0.050 % maximum limit for titanium does not apply.

isothermal annealing, *n*—**austenitizing** a steel object and then cooling it to, and holding it at, a temperature at which austenite transforms to a ferrite-carbide aggregate.

isothermal transformation, *n*—a change in phase at any constant temperature.

killed steel, *n*—a **steel** deoxidized to such a level that essentially no reaction occurred between carbon and oxygen during solidification.

laser beam welding, *n*—a welding process that uses a laser beam as the heat source.

lot, *n*—a definite quantity of product manufactured under conditions that are considered uniform.

low-alloy steel, *n*—a **steel**, other than a **carbon steel** or an **interstitial-free steel**, that conforms to a specification that requires the minimum content for each specified alloying element to be lower than the applicable limit in the definition for **alloy steel**.

M_f, M_s—See **transformation temperature**.

manufacturer, *n*—the organization responsible for the conversion of materials into products meeting the requirements of a product specification.

maraging, *n*—a precipitation hardening treatment applied to a special group of **alloy steels** to precipitate one or more intermetallic compounds in a matrix of essentially carbon-free martensite.

martempering, *n*—**quenching** an austenitized steel object in a medium at a temperature in the upper part of, or slightly above, the **martensite range**, holding it in the medium until its temperature is substantially uniform throughout, and then cooling it in air through the **martensite range**.

martensite range, *n*—the temperature interval between M_s and M_f.

microalloyed steel, *n*—a **low-alloy steel** that conforms to a specification that requires the presence of one or more carbide-, nitride-, or carbonitride-forming elements, generally in individual concentrations less than 0.15 mass percent, to enhance strength.

Discussion—The most common microalloying elements are niobium (columbium), titanium, and vanadium.

multiple heat, *n*—two or more molten **primary heats**, in whole or in part, combined in a common ladle or in a common non-oscillating mold.

Discussion—A **multiple heat** is identified by a single **heat number** representative of the **multiple heat**, or by the individual **heat numbers** of the **primary heats** contained in the **multiple heat**. The **heat analysis** of a **multiple heat** identified by a single **heat number** is the weighted average analysis of the individual **primary heats** contained in the **multiple heat**. Two or more molten **primary heats** sequentially strand cast (poured into an oscillating mold) constitute a series of individual **heats**, not a **multiple heat**.

natural aging, *n*—spontaneous aging of a super-saturated solid solution at room temperature.

nickel alloy, *n*—a material that conforms to a specification that requires by mass percent more nickel than any other element.

Discussion—In castings, the nickel content requirement is not normally stated in the specification and is not normally determined by chemical analysis, but is taken to be 100 % minus the sum of the mean values permitted by the specification for all other elements having a specified range or a specified maximum.

nitriding, *n*—introducing nitrogen into a solid steel object by holding it at a suitable temperature in contact with a nitrogenous environment.

nonferrous material, *n*—metals and alloys that do not contain iron as the principal component.

Discussion—The iron content is not always stated in the specification and is not always determined by chemical analysis. The iron content may be taken to be 100 % minus the sum of the mean values permitted by the specification for all other elements having a specified range or a specified maximum. For conformance purposes, the mean value for iron, whether specified or calculated, is compared on an individual basis to the mean values permitted by the specification for each of the other elements having a specified range or a specified maximum. If an element other than iron is not specified, but is listed as remainder or balance, then, for conformance purposes, the mean value for iron is compared to the calculated value for that other element.

normalizing, *v*—reheating a steel object to a temperature above the **transformation range** and then cooling it in air to a temperature substantially below the transformation range to achieve both grain refinement and improved homogenization.

overaging, *n*—**aging** under conditions of time and temperature greater than those required to obtain maximum change in a certain property, so that the property is altered away from the maximum.

overheating, *n*—heating a steel object to such a high temperature that excessive grain growth occurs.

Discussion—Unlike burning, it may be possible to restore the original properties/microstructure by further heat treatment or mechanical working, or a combination thereof.

patenting, *n—in wire making,* **heat treatment** of a medium-carbon or high-carbon steel wire or wire rod that includes heating to a temperature above Ac_3 but below normal **hot working** temperatures, followed directly without **hot working** by **controlled cooling** to achieve a uniform microstructure suitable for **cold working** and typically characterized by pearlite having a fine interlamellar spacing.

Discussion—The method used for controlled cooling is often used to describe the type of patenting. Examples include but are not limited to, air patenting, salt patenting, fluidized bed patenting, and lead patenting. Furthermore, double lead patenting describes a patenting process in which molten lead is used not only for the controlled cooling, but also for the heating to a temperature above Ac_3.

plate-as-rolled, *n*—the quantity of plate product rolled at one time, either from an individual slab or directly from an ingot.

Discussion—This term does not refer to the surface condition or the heat-treatment state of the material; a **plate-as-rolled** may be in the as-rolled condition, or may have received one or more surface treatments or **heat treatments**, or both.

post-weld heat treatment, *n*—heating weldments immediately after welding, to provide **tempering**, **stress relieving**, or a controlled rate of cooling to prevent formation of a hard or brittle microstructure.

precipitation hardening, *n*—**hardening** caused by the precipitation of a constituent from a supersaturated solid solution.

precipitation heat treatment, *n*—**artificial aging** in which a constituent precipitates from a supersaturated solid solution.

preheating, *n*—heating before welding, a mechanical treatment, or some further thermal treatment.

preheating, *n—for tool steels*, heating to an intermediate temperature immediately before final **austenitizing**.

primary heat, *n*—the product of a single cycle of a batch melting process.

Discussion—In the investment casting industry, the term *master heat* is used.

process annealing, *n—in the sheet and wire industries*, heating a steel object to a temperature close to, but below, Ac_1 and then cooling it, in order to soften it for further cold working.

product analysis, *n*—a chemical analysis of a specimen taken from the semi-finished product or the finished product.

progressive aging, *n*—**aging** by increasing the temperature in steps, or continuously, during the aging cycle.

quench aging, *n*—**aging** associated with **quenching** after **solution heat treatment**.

quench hardening, *n*—**hardening** a steel object by **austenitizing** it, and then cooling it rapidly enough that some or all of the austenite transforms to martensite.

Discussion—The austenitizing temperature is usually above Ac_3 for hypoeutectoid steels and between Ac_1 and Ac_{cm} for hypereutectoid steels.

quenching, *n*—rapid cooling in a fluid at a rate sufficient to preserve or produce desired material characteristics.

Discussion—Where applicable, it is preferred that the following more specific terms be used: **fog quenching, hot quenching, interrupted quenching, selective quenching, spray quenching,** and **time quenching**. Quenching is often used in solution heat treatment of austenitic steels to retain certain constituents in solution. Quenching is also used for ferritic steels to develop desired characteristics (such as microstructure or toughness) in thicker sections that can otherwise only be achieved in thinner sections. Liquids and gasses are both fluids.

recrystallization, *n*—the formation of a new grain structure through a nucleation and growth process.

Discussion—This is commonly produced by subjecting a steel object, which may be strained, to suitable conditions of time and temperature.

recrystallization annealing, *n*—**annealing** a cold-worked steel object to produce a new grain structure without a change in phase.

recrystallization temperature, *n*—the approximate minimum temperature at which recrystallization of a cold-worked steel object occurs within a specified time.

remelted heat, *n*—the product of the remelting of a **primary heat**, in whole or in part.

Discussion—In the investment casting industry, the term *sub-heat* is used.

residual element, *n—in **steel***, a specified or unspecified element, not intentionally added, originating in the raw materials, refractories, or surrounding atmospheres used in steel making.

rimmed steel, *n*—a **steel** that contained sufficient oxygen to generate carbon monoxide at the boundary between the solid metal and the remaining molten metal during solidification, resulting in an outer layer low in carbon.

secondary hardening, *n*—the hardening phenomenon that occurs during high-temperature **tempering** of certain **steels** containing one or more carbide-forming alloying elements.

selective heating, *n*—intentionally heating only certain portions of a steel object.

selective quenching, *n*—**quenching** only certain portions of a steel object.

semicontinuous-conveyance furnace, *n*—a heating device through which steel objects are intentionally moved in accordance with a predetermined start-stop-start pattern during the thermal processing cycle.

semikilled steel, *n*—an incompletely deoxidized **steel** that contained sufficient oxygen to form enough entrapped carbon monoxide during solidification to offset solidification shrinkage.

shell hardening, *n*—a surface hardening process in which a suitable steel object, when heated through and quench hardened, develops a martensitic layer or shell that closely follows the contour of the piece and surrounds a **core** of essentially pearlitic transformation product.

DISCUSSION—This result is accomplished by a proper balance between section size, **hardenability**, and severity of quench.

slack quenching, *n*—the incomplete **hardening** of a steel object due to **quenching** from the austenitizing temperature at a rate slower than the **critical cooling rate** for the particular steel composition, resulting in the formation of one or more transformation products in addition to martensite.

snap temper, *n*—a precautionary interim stress-relieving treatment applied to a high-hardenability steel immediately after **quenching** to prevent cracking because of delay in **tempering** it at the prescribed higher temperature.

soaking, *n*—prolonged holding at a selected temperature.

solution heat treatment, *n*—heating a steel object to a suitable temperature, holding it at that temperature long enough to cause one or more constituents to enter into solid solution, and then cooling it rapidly enough to hold such constituents in solution.

specified element, *n—in **steel***, an element controlled to a specified minimum, maximum, or range, in accordance with the requirements of the applicable product specification.

spheroidizing, *n*—heating and cooling a steel object to produce a spheroidal or globular form of carbide in its microstructure.

DISCUSSION—Spheroidizing methods commonly used are the following: (1) prolonged holding at a temperature just below Ae_1; (2) heating and cooling alternately between temperatures that are just above, and just below, Ae_1; (3) heating to a temperature above Ae_1 or Ae_3 and then cooling very slowly in the furnace or holding at a temperature just below Ae_1; (4) cooling, from the minimum temperature at which all carbide is dissolved, at a rate suitable to prevent the reformation of a carbide network, and then reheating in accordance with Method (1) or (2) above. (Applicable to hypereutectoid steels containing a carbide network.)

spray quenching, *n*—**quenching** in a spray of liquid.

stabilized stainless steel, *n*—a **stainless steel** that conforms to a specification that prescribes limits (minimum or range) for niobium (columbium), tantalum, titanium, or a combination thereof.

DISCUSSION—Such limits are sometimes expressed as a function of the carbon and nitrogen contents. In an appropriately annealed condition, a **stabilized stainless steel** will resist sensitization to intergranular corrosion associated with the precipitation of chromium carbide at grain boundaries as a result of thermal exposure, such as **annealing, stress relieving**, welding, or high temperature service. Resistance to sensitization to intergranular corrosion is dependent upon the corrosivity of the environment. The condition of being stabilized with respect to sensitization is frequently demonstrated by passing one or more standard corrosion tests for sensitization.

stabilizing treatment, *n*—any treatment intended to stabilize the microstructure or dimensions of a steel object.

stainless steel, *n*—a **steel** that conforms to a specification that requires, by mass percent, a minimum chromium content of 10.5 or more, and a maximum carbon content of less than 1.20.

steel, *n*—a material that conforms to a specification that requires, by mass percent, more iron than any other element and a maximum carbon content of generally less than 2.

DISCUSSION—The iron content requirement is not normally stated in the specification and is not normally determined by chemical analysis, but is taken to be 100 % minus the sum of the mean values permitted by the specification for all other elements having a specified range or a specified maximum. For conformance purposes, this calculated value for iron is compared on an individual basis to the mean values permitted by the specification for each of the other elements having a specified range or a specified maximum. Some chromium-containing steels may contain more than 2 % carbon; however, 2 % carbon is generally considered to be the demarcation between **steel** and cast iron.

strain aging, *n*—**aging** induced by cold working.

strain hardening, *n*—an increase in hardness and strength of a metal caused by plastic deformation at temperatures below its **recrystallization temperature**. (Syn. *work hardening*)

stress relieving, *n*—heating a steel object to a suitable temperature, holding it long enough to reduce residual stresses, and then cooling it slowly enough to minimize the development of new residual stresses.

subcritical annealing, *n*—**annealing** at a temperature slightly below Ac_1.

surface hardening, *n*—a generic term covering any of several processes that, by **quench hardening** only, produce in a steel object a surface layer that is harder or more wear resistant than the **core**.

DISCUSSION—There is no significant alteration of the chemical composition of the surface layer. Where applicable, it is preferred that the following more specific terms be used: **induction hardening, flame hardening**, and **shell hardening**.

temper brittleness, *n*—brittleness that results when certain **steels** are held within, or are cooled slowly through, a certain range of temperature below the **transformation range**.

tempering, *n*—reheating a quench hardened or normalized steel object to a temperature below Ac_1, and then cooling it at any desired rate.

test record, *n*—a document or electronic record that contains the observations and derived data obtained by applying a given test method.

test report, *n*—a document that presents the applicable qualitative or quantitative results obtained by applying one or more given test methods.

DISCUSSION—A single document, containing test report information and certificate of compliance information, may be used.

Thermal-Mechanical Control Process (TMCP), *n*—a rolling process that produces a fine-grained ferritic steel by a particular combination of controls on the manufacturing process, from slab reheating to post-rolling cooling, thereby achieving enhanced mechanical properties.

DISCUSSION—(TMCP) requires appropriate selection of chemical composition and accurate control of steel temperature and rolling reduction.

thermochemical treatment, *n*—a **heat treatment** carried out in a medium suitably chosen to produce a change in the chemical composition of the steel object by exchange with the medium.

time quenching, *n*—interrupted **quenching** in which the duration of holding in the quenching medium is controlled.

transformation ranges, *n*—those ranges of temperature within which austenite forms during heating and transforms during cooling.

Discussion—The two ranges are distinct, sometimes overlapping but never coinciding. The limiting temperatures of the ranges are dependent upon the steel composition and the rate of change of temperature, particularly during cooling.

transformation temperature, *n*—the temperature at which a change in phase occurs, with the limiting temperatures of the **transformation ranges** designated using the following symbols:

Ac_{cm}—the temperature at which the solution of cementite in austenite is completed during heating.

Ac_1—the temperature at which austenite begins to form during heating.

Ac_3—the temperature at which transformation of ferrite to austenite is completed during heating.

Ac_4—the temperature at which austenite transforms to delta ferrite during heating.

Ae_1, Ae_3, Ae_{cm}, Ae_4—the temperatures of phase change at equilibrium.

Ar_{cm}—the temperature at which precipitation of cementite starts during cooling.

Ar_1—the temperature at which transformation of austenite to ferrite or to ferrite plus cementite is completed during cooling.

Ar_3—the temperature at which austenite begins to transform to ferrite during cooling.

Ar_4—the temperature at which delta ferrite transforms to austenite during cooling.

M_f—the temperature at which transformation of austenite to martensite is substantially completed during cooling.

M_s—the temperature at which transformation of austenite to martensite starts during cooling.

Discussion—All of the above changes, except the formation of martensite, occur at lower temperatures during cooling than during heating, and are dependent upon the rate of change of temperature.

unspecified element, *n—in* ***steel***, an element not controlled to a specified minimum, maximum, or range, in accordance with the requirements of the applicable product specification.

wrought product, *n*—item of steel which has been subject to deformation by rolling, drawing, forging, or some other method, for example, a bar, plate, strip, tube, or wire.

Discussion—The extent of deformation needed to transform an as-cast material to one that exhibits the microstructure and properties expected for wrought products is impractical to define because it may vary among different deformation practices and product application.

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SPECIFICATION FOR COMMON REQUIREMENTS FOR WROUGHT STEEL PIPING FITTINGS

SA-960/SA-960M

(23)

(Identical with ASTM Specification A960/A960M-20.)

Specification for
Common Requirements for Wrought Steel Piping Fittings

1. Scope

1.1 This specification covers a group of common requirements that shall apply to wrought steel piping fittings covered in any of the following individual product specifications or any other ASTM specification that invokes this specification or portions thereof:

Title of Specification	ASTM Designation
Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service	A234/A234M
Specification for Wrought Austenitic Stainless Steel Piping Fittings	A403/A403M
Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service	A420/A420M
Specification for Wrought-Carbon Steel Butt-Welding Piping Fittings with Improved Notch Toughness	A758/A758M
Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures	A774/A774M
Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings	A815/A815M
Specification for Heat-Treated Carbon Steel Fittings for Low-Temperature and Corrosive Service	A858/A858M
Specification for Wrought High-Strength Ferritic Steel Butt-Welding Fittings	A860/A860M

1.2 In case of conflict between a requirement of the individual product specification and a requirement of this general requirement specification, the requirements of the individual product specification shall prevail over those of this specification.

1.3 By mutual agreement between the purchaser and the supplier, additional requirements may be specified (See 4.1.8). The acceptance of any such additional requirements shall be dependent on negotiations with the supplier and must be included in the order as agreed upon by the purchaser and supplier.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text and the tables, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the specification. The inch-pound units shall apply unless the "M" designation [SI] of the product specification is specified in the order.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A29/A29M Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought

A234/A234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

A403/A403M Specification for Wrought Austenitic Stainless Steel Piping Fittings

A420/A420M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service

A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A758/A758M Specification for Wrought-Carbon Steel Butt-Welding Piping Fittings with Improved Notch Toughness

A763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A774/A774M Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures
A815/A815M Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings
A858/A858M Specification for Heat-Treated Carbon Steel Fittings for Low-Temperature and Corrosive Service
A860/A860M Specification for Wrought High-Strength Ferritic Steel Butt-Welding Fittings
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A967/A967M Specification for Chemical Passivation Treatments for Stainless Steel Parts
A1058 Test Methods for Mechanical Testing of Steel Products—Metric
E165/E165M Practice for Liquid Penetrant Testing for General Industry
E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing
E709 Guide for Magnetic Particle Testing
E1916 Guide for Identification of Mixed Lots of Metals

2.2 *Manufacturer's Standardization Society Standards:*
MSS-SP-25 The Standard Marking System of Valves, Fittings, Flanges and Unions
MSS-SP-43 Standard Practice for Light Weight Stainless Steel Butt-Welding Fittings
MSS-SP-75 Specification for High Test Wrought Butt-Welding Fittings
MSS-SP-79 Socket Welding Reducer Inserts
MSS-SP-83 Class 3000 Steel Pipe Unions, Socket Welding and Threaded
MSS-SP-95 Swage(d) Nipples and Bull Plugs
MSS-SP-97 Integrally Reinforced Forged Branch Outlet Fittings—Socket Welding, Threaded and Buttwelding Ends

2.3 *American Society of Nondestructive Testing:*
SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

2.4 *ASME Standards:*
B16.9 Steel Butt-Welding Fittings
B16.11 Forged Steel Fittings, Socket Welding and Threaded
Boiler and Pressure Vessel Code Section IX

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bar*—a solid section that is long in relationship to its cross sectional dimensions, with a relatively constant cross section throughout its length. (See Specification A29/A29M for definitions relating to the production of hot wrought and cold finished bars.)

3.1.2 *certifying organization*—the company or association responsible for the conformance of, the marking of, and the certification of the product to the specification requirements.

3.1.3 *fitting*—a component for non-bolted joints used in piping systems and pressure vessels.

3.1.4 *flange*—a component for bolted joints used in piping systems and pressure vessels.

3.1.5 *forging*—the product of a substantially compressive hot or cold plastic working operation that consolidates the material and produces the required shape.

3.1.6 *Discussion*—The plastic working must be performed by a forging machine, such as a hammer, press, or ring rolling machine and must deform the material to produce an essentially wrought structure throughout the material cross section.

3.2 *Definitions*—For definitions of other terms used in this specification, refer to Terminology A941.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

4.1.1 Quantity,

4.1.2 Description of fitting and nominal dimensions (standard or special),

4.1.3 Steel composition by grade and class designation,

4.1.4 Construction, seamless or welded (unless seamless or welded construction is specified by the purchaser, either may be furnished at the option of the supplier),

4.1.5 Specification number (including the year/date of issue),

4.1.6 Choice of testing track from the options listed in Test Methods A1058 when material is ordered to an M suffix (SI units) product standard. If the choice of test track is not specified in the order, then the default ASTM track shall be used as noted in Test Methods A1058.

4.1.7 Supplementary requirements, and

4.1.8 Additional requirements.

5. Material

5.1 The material for fittings shall consist of forgings, bars, plates and seamless or welded tubular products.

5.2 The steel shall conform to the chemical requirements of the individual product specification and may be made from any process.

5.3 Ferritic steels shall be fully killed.

5.4 If secondary melting is employed, the heat shall be defined as all ingots remelted from a primary heat.

6. Manufacture

6.1 Forging or shaping operations may be performed by any of the methods included in the individual product specification.

6.2 Cylindrically shaped parts up to and including NPS 4 may be machined from bar or seamless tubular material provided the axial length of the part is approximately parallel to the axial length of the fitting. Elbows, return bends, tees and header tees shall not be machined directly from bar stock.

6.3 Fittings, after forming at an elevated temperature, shall be cooled to a temperature below the critical range under suitable conditions to prevent injury by cooling too rapidly.

6.4 All classes of fittings shall have the welders, welding operators, and welding procedures qualified under the provision of Section IX of the ASME Boiler and Pressure Vessel Code except that welds from the original pipe manufacturer made without the addition of filler metal do not require such qualification.

7. Heat Treatment

7.1 Fittings requiring heat treatment shall be treated as specified in the individual product specification using the following procedures:

7.1.1 *Annealing*—Fittings shall be uniformly reheated to a temperature above the transformation range and, after holding for a sufficient time at this temperature, cooled slowly to a temperature below the transformation range.

7.1.2 *Solution Annealing (or Solution Treat or Treatment)*—Fittings shall be heated to a temperature that causes the carbides to go into solution and then quenched in water or rapidly cooled by other means to prevent reprecipitation.

7.1.3 *Isothermal Annealing*—Isothermal annealing shall consist of austenitizing a ferrous alloy and then cooling to and holding within the range of temperature at which the austenite transforms to a relatively soft ferrite-carbide aggregate.

7.1.4 *Normalizing*—Fittings shall be uniformly reheated to a temperature above the transformation range and subsequently cooled in air at room temperature.

7.1.5 *Tempering and Post-Weld Heat Treatment*—Fittings shall be reheated to the prescribed temperature below the transformation range, held at temperature for the greater of ½ h or 1 h/in. [25.4 mm] of thickness at the thickest section and cooled in still air.

7.1.6 *Stress Relieving*—Fittings shall be uniformly heated to the selected stress relieving temperature, held long enough to reduce stresses and then cooled at a rate that will result in the properties required for the material grade and minimize the development of new residual stresses. The temperature shall not vary from the selected temperature by more than ± 25 °F [± 14 °C].

7.1.7 *Quench and Temper*—Fittings shall be fully austenitized and immediately quenched in a suitable liquid medium. The quenched fittings shall be reheated to a minimum temperature of 1100 °F [590 °C] and cooled in still air.

8. Chemical Requirements

8.1 *Chemical Analysis*—Samples for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices and Terminology A751 for Chemical Analysis of Steel Products.

8.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of those elements specified in the individual product specification. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot of each primary melt. The chemical analysis thus determined shall conform to the requirements of the individual product specification. Note that the product analysis (check analysis) tolerances are not to be applied to the heat analysis requirements.

8.2.1 For steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element, other than nitrogen for stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS or grade designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification.

8.3 *Product Analysis*—If a product analysis is performed it shall be in accordance with Test Methods, Practices, and Terminology A751. The chemical composition thus determined shall conform to limits of the product specification, within the permissible variations of Table 1 of this specification.

8.3.1 Limits on formula calculations involving elemental contents shall apply only to the heat analysis, unless agreed upon between supplier and purchaser. Where limits on formula calculations involving elemental contents apply to product analysis by such agreement, permissible variations in the formula calculation results beyond the limits for the heat analysis shall also be agreed upon between supplier and purchaser. Examples of such formula calculations include, but are not limited to, the following: carbon equivalent $CE = C + Mn/6 + (Cr + Mo + V) / 5 + (Ni + Cu) / 15$; J factor $= (Mn + Si) \times (P + Sn) \times 10^4$; or requirements for specific elemental balance or sufficiency, typically related to Ti, Nb, or Al and interstitials C and N, such as $Nb = 5 \times C$ minimum.

9. Mechanical Requirements

9.1 *Method of Mechanical Test*—All tests shall be conducted in accordance with Test Methods and Definitions A370 if the inch-pound units are specified or Test Methods A1058 if the M suffix (SI Units) standard is specified.

9.2 The test specimen shall represent all material from the same heat and heat treatment load whose maximum thicknesses do not exceed the thickness of the test specimen or blank by more than ¼ in. [6 mm].

9.3 One tension test at room temperature shall be made in accordance with 9.2 from each heat in each heat treatment load.

9.3.1 If heat treatment is performed in either a continuous or batch type furnace controlled within ± 25 °F [± 14 °C] of the required heat treatment temperature and equipped with recording pyrometers so that complete records of heat treatment are available, and if the same heat treating cycles are used on the material represented by the tension test, then one tension test from each heat shall be required, instead of one tension test from each heat in each heat treatment load in accordance with 9.2.

9.4 *Retest*—When a retest is permitted by the product specification, it shall be performed on twice the number of representative specimens that were originally nonconforming.

TABLE 1 Product Analysis Tolerances[A]

Element	Limit or Maximum of Specified Range, Wt %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	to 0.010, incl	0.002
	over 0.010 to 0.030, incl	0.005
	over 0.030 to 0.20, icl	0.01
	over 0.20 to 0.80, incl	0.02
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00, incl	0.05
	over 6.00 to 10.00, incl	0.06
Phosphorous	to 0.040, incl	0.005
	over 0.040 to 0.20, incl	0.010
Sulfur	to 0.040, incl	0.005
	over 0.040 to 0.20, incl	0.010
	over 0.20 to 0.50, incl	0.020
Silicon	to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.10
	over 3.00 to 7.00, incl	0.15
Chromium	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.05
	over 2.10 to 4.00, incl	0.07
	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	over 20.00 to 30.00, incl	0.25
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 30.00, incl	0.20
	over 30.00 to 40.00, incl	0.25
Molybdenum	to 0.20, incl	0.01
	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 7.00, incl	0.10
Titanium	to 1.15, incl	0.05
Niobium (Columbium)	to 0.14, incl	0.02
	over 0.14 to 5.50	0.05
Tantalum	to 0.10 incl	0.02
Copper	to 0.50, incl	0.03
	over 0.50 to 1.00, incl	0.05
	over 1.00 to 5.00, incl	0.10
Cobalt	0.05 to 0.25, incl	0.01[B]
	0.25 to 5.00, incl	0.07
Nitrogen	to 0.02, incl	0.005
	over 0.02 to 0.19, incl	0.01
	over 0.19 to 0.25	0.02
	over 0.25 to 0.35	0.03
	over 0.35 to 0.45	0.04
	over 0.45	0.05
Aluminum	to 0.15, incl	–0.005 +0.01
	over 0.15 to 0.50, incl	0.05
	over 0.50 to 0.80, incl	0.07
Vanadium	to 0.10 incl	0.01
	over 0.10 to 0.25, incl	0.02
	over 0.25 to 0.50, incl	0.03
	minimum value specified, under minimum limit only	0.01
Cerium	to 0.20, incl	0.01
Selenium	to 0.35, incl	0.001
Tungsten	to 0.50, incl	0.02
	over 0.50 to 1.00, incl	0.03
	over 1.00 to 2.00, incl	0.05
	over 2.00 to 4.00, incl	0.06
Lead	to 0.35, incl	0.03
Zirconium	to 0.01, incl	0.005
Boron	to 0.015 incl	0.0005
Tin	to 0.010, incl	[C]
Arsenic	to 0.010, incl	[C]
Antimony	to 0.003, incl	[C]

[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05 % have not been established and the producer should be consulted for those limits.
[C] No over tolerance allowed.

When any retest specimen does not conform to the product specification requirements for the characteristic in question, the lot represented by that specimen shall be rejected or reworked in accordance with Section 14.

9.4.1 If the results of the tension test do not conform to the requirements specified in the product specification, retests are permitted as outlined in the test methods specified herein. If the results of any tension test specimen are less than specified because a flaw becomes evident in the test specimen during testing, a retest shall be allowed provided that the defect is not attributable to ruptures, cracks, or flakes in the steel.

9.4.2 If the average impact energy value meets the product specification requirements, but one energy value is below the specified minimum value for individual specimens, a retest is permitted. The retest shall be conducted in accordance with the test methods specified herein.

9.5 For the purpose of determining conformance to the product specification requirements, specimens shall be obtained from a finished product, or from production material that is in the same condition of working and heat treatment as the production material.

10. Hardness Requirements

10.1 The part shall conform to the hardness requirements prescribed in the product specification.

10.2 Sampling for hardness testing shall conform to the product specification.

11. Tensile Requirements

11.1 The part shall conform to the tensile property requirements prescribed in the product specification.

11.2 Sampling for tensile testing shall conform to the product specification.

11.3 When the dimensions of the material to be tested will permit, the tension test specimens shall be machined to the form and dimensions of the standard 2-in. gauge length tension test specimens described in Test Methods and Definitions A370 if inch-pound units are specified or the standard 62.5 mm gauge length tension test specimens described in the applicable track of Test Methods A1058 if SI units are specified.

11.3.1 In the case of small sections, which will not permit taking the standard test specimen described in 11.3, the subsize round or strip specimen shall be machined as described in the test methods being used. The tension test specimen shall be as large as feasible.

12. Impact Requirements

12.1 The part shall conform to the impact requirements prescribed in the product specification.

12.2 Sampling for impact testing shall conform to the product specification.

12.3 Notched-bar impact specimens shall be simple-beam, Charpy-type A with a V-notch in accordance with Test Methods and Definitions A370 if the inch-pound units are specified or Test Methods A1058 if the M suffix (SI Units) standard is specified. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable standard subsize impact specimens shall be used. When the size or shape of the finished fittings is insufficient to permit obtaining the smallest standard subsize impact specimens, an impact test by the fitting manufacturer will not be required.

13. Hydrostatic Test Requirements

13.1 Parts manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the specified matching pipe of equivalent material. Such a test shall be conducted only when specified in the purchase order or when the hydrostatic test Supplementary Requirement is invoked by the purchaser.

14. Rework

14.1 When one or more representative test specimens or retest specimens do not conform to the requirements specified in the product specification for the tested characteristic, the lot of material represented by the test specimen may be reworked according to the following requirements.

14.1.1 If previously tested in the untreated condition, the product may be reworked by heat treatment, and subsequently retested, in accordance with the product specification.

14.1.2 If previously tested in the heat treated condition, the product may be reworked by reheat treatment, and subsequently retested, in accordance with the product specification.

15. Surface Finish, Appearance, and Corrosion Protection

15.1 The parts shall conform to the dimensions, tolerances and finish as specified in the purchaser's order and to the individual ASTM product specification.

15.2 The finished parts shall be cleaned to remove all scale and processing compounds prior to the final surface examination. The cleaning process shall not injure the surface finish, material properties, or the metallurgical structure.

15.2.1 The surface finish shall allow the detection of imperfections that can be disclosed by visual inspection.

15.2.2 The cleaned parts shall be protected to prevent recontamination.

15.2.2.1 Exterior and interior surfaces of carbon, low, and intermediate alloy steel fittings shall have a corrosion protective coating. Unless otherwise specified by the purchaser, the type of surface protection shall be at the option of the manufacturer.

15.2.2.2 Stainless steel and nickel alloy fittings need not be coated. Unmachined surfaces of stainless steel fittings shall be passivated by exposure to an acid bath, or electropolished.

15.2.3 Protective coatings on parts subsequently subjected to socket welds or butt welds shall be suitable for welding without removal of the coating. Threaded fittings shall be capable of installation without the removal of the coating.

15.2.4 When specified in the purchase order, parts may be furnished in the as-formed condition.

15.3 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. Unless otherwise specified in the purchase order, the following shall apply.

15.3.1 Fittings conforming to ASME B16.9, MSS-SP-43, and MSS-SP-95 shall be free of surface discontinuities that penetrate more than 5 % of the specified nominal wall thickness, except as defined in 15.3.3 and 15.3.4. Fittings conforming to ASME B16.11, MSS-SP-79, MSS-SP-83, and MSS-SP-97 shall be free of surface discontinuities that penetrate more than 5 % of the actual wall thickness at the point of interest, or 1⁄16 in. [1.6 mm], whichever is less, except as defined in 15.3.4. Fittings conforming to MSS-SP-75 shall be free of surface discontinuities that penetrate more than 6½ % of the specified nominal wall thickness.

15.3.2 Surface discontinuities deeper than 5 % of the specified nominal or actual wall thickness as applicable, except as defined in 15.3.3 and 15.3.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall blend smoothly into the contour of the finished fitting. Surface discontinuities on fittings conforming to MSS-SP-75 shall be removed or repaired in accordance with the requirements of that standard. Except for fittings conforming to MSS-SP-75, the wall thickness at all points shall be at least the specified minimum wall thickness, or 87½ % of the specified nominal wall thickness and the diameters shall be within the limits specified in the applicable dimensional standards.

15.3.3 Surface checks (fish scale) deeper than 1⁄64 in. [0.4 mm] shall be removed.

15.3.4 Mechanical marks deeper than 1⁄16 in. [1.6 mm] shall be removed.

15.3.5 When the removal of a surface discontinuity reduces the wall thickness below the specified minimum wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in Section 16, or in accordance with MSS-SP-75 for fittings conforming to that standard.

16. Repair by Welding

16.1 The purchaser may require the supplier to submit proposed weld repairs for approval by invoking the appropriate Supplementary Requirement in the purchase order.

16.2 If the purchaser does not require prior approval of the proposed weld repairs, these repairs shall be permitted at the discretion of the supplier. All weld repairs shall be performed in accordance with the following limitations and requirements.

16.2.1 The welding procedure, welders and operators shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. The composition of the weld deposit shall be compatible with the composition of the material being welded.

16.2.2 Defects shall be completely removed prior to welding by machining, chipping or grinding to sound metal. Removal of these defects shall be verified by magnetic particle examination in accordance with Guide E709 or liquid penetrant inspection in accordance with Test Method E165/E165M, as applicable.

16.2.3 After repair welding, the welded area shall be machined or ground smooth to the original contour and shall be completely free of defects as verified by magnetic particle examination in accordance with Guide E709 or liquid penetrant inspection in accordance with Test Method E165/E165M, as applicable.

16.2.4 Repair welding shall not exceed 10 % of the external surface area of the part, or 33⅓ % of the wall thickness of the finished product, or ⅜ in. [10 mm] deep maximum at the location of the repair, without prior approval of the purchaser.

16.2.5 Weld repaired material or parts, or both, shall be marked "RW" when required by the product specification.

16.3 The weld repair shall conform to the additional requirements, if any, invoked in the product specification.

17. Inspection

17.1 The supplier shall provide the purchaser's inspector with all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification and the applicable product specification. Site inspection by the purchaser shall not interfere unnecessarily with the supplier's operations.

18. Rejection and Rehearing

18.1 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed to between the supplier and the purchaser.

19. Marking

19.1 Each piece shall be legibly marked in a position as not to injure the usefulness of the fitting with the product specification number, grade or marking symbol, class, certifying organization's name or symbol, the heat number or heat identification, size, and schedule number or wall thickness, if applicable. Dual or multiple marking with the product specification number, grade or marking symbol, and class is acceptable provided the material meets all the requirements with which it is marked. It is not required to mark the product with the specification year and date of issue. When size or shape does not permit the inclusion of all the required marking as described, see 19.2. Manufacturer can also choose the use of tags, box labels, etc. for identification when per piece marking is not practical due to size or shape.

19.2 The Standard Marking System of Valves, Fittings, Flanges and Unions MSS-SP-25 shall be followed except the word "steel" shall not be substituted for the specification grade.

19.3 Product marking shall conform to the additional requirements, if any, invoked in the product specification or purchase order.

20. Certification

20.1 A test report and certificate of compliance are required.

20.2 Test reports shall include the product specification number and year/date of issue, the results of all tests required by this specification, and the purchaser order, and shall be traceable to the part represented.

20.3 A single document containing the test report information and certificate of compliance information may be used.

20.4 A certificate printed from or used in electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall conform to any existing EDI agreement between the purchaser and the supplier.

20.5 Not withstanding the absence of a signature, the organization submitting either a printed certificate or an EDI transmitted certificate is responsible for the content of the report.

21. Packaging, Marking and Loading for Shipment

21.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A700.

22. Keywords

22.1 austenitic stainless steel; corrosive service applications; ferritic/austenitic stainless steel; ferritic stainless steel; high strength low alloy steel; martensitic stainless steel; piping applications; pressure containing parts; pressure vessel service; stainless steel fittings; temperature service applications-elevated; temperature service applications-low; temperature service applications-moderate

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, in which event, the supplementary requirements specified shall be made at the place of manufacture, unless otherwise agreed upon, at the purchaser's expense. The test specified shall be witnessed by the purchaser's inspector before shipment of material, if so specified in the order. The rationale for beginning the section numbering with S50 is to eliminate the possibility of confusion with supplementary requirements existing in individual product specifications.

S50. Product Analysis (See Note S50.1)

S50.1 A product analysis shall be made from each heat of base metal and, if of welded construction, from each lot number of welding material of the fittings offered for delivery. The analysis shall conform to the requirements specified in Section 8.

S51. Tension Test (See Note S50.1)

S51.1 One tension test shall be made on one fitting or representative test piece (See Note S50.2) per lot (See Note S50.3) of fittings. If the fittings are of welded construction, the tension specimen shall include the weld and shall be prepared so that the weld is at the midlength location of the specimen.

However, in no case shall the tensile properties of the finished fitting be less than the requirements listed in the individual product specification.

NOTE S50.1—If the result of any of the tests specified in Supplementary Requirements S50, S51, or S63 do not conform to requirements, retests may be made at the manufacturer's expense on additional fittings or representative test pieces of double the original number from the same heat or lot as defined in Supplementary Requirements S50, S51, or S63, each of which shall conform to the requirements specified.

NOTE S50.2—Where the test specimen for the tension or intergranular corrosion bend test cannot be taken from a fitting due to size limitations, a representative test piece shall be obtained. The test piece shall be from the same lot it represents and shall have approximately the same amount of working. In addition, these pieces representing fittings manufactured from bars, plate, or forgings shall have a cross section equal to the greatest cross section of the fitting, and test pieces representing fittings manufactured from pipe shall have an outside diameter and wall thickness equal to those of the fitting. The test piece for fittings of welded construction shall be prepared to the same weld procedures and from the same heat of materials as the fittings it represents.

NOTE S50.3—A lot shall consist of all fittings of the same type, size, and wall thickness, manufactured from one heat of material (and, if fabrication welding is performed using one lot number of electrode or one heat of weld wire), and heat treated using the same heat-treat cycle in either a continuous or batch-type furnace controlling within a range of 50 °F [28 °C] and equipped with recording pyrometers so that complete records of heat treatment are available.

S52. Liquid Penetrant Examination

S52.1 All surfaces shall be liquid penetrant examined in accordance with Test Method E165/E165M. Acceptance limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A-1988 or later.

S53. Magnetic-Particle Examination

S53.1 All accessible surfaces shall be magnetic particle examined in accordance with Guide E709. Acceptance limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A-1988 or later.

S54. Hydrostatic Test

S54.1 A hydrostatic test shall be applied as agreed upon between the manufacturer and purchaser.

S55. Bar Stock Fittings

S55.1 Bar stock fittings shall not be permitted.

S56. Special Heat Treatment

S56.1 A special heat treatment shall be applied as agreed upon between the manufacturer and the purchaser.

S57. Hardness Test

S57.1 If actual hardness testing of fittings is required, the frequency and the method used shall be as agreed upon between the manufacturer and the purchaser.

S58. Special Fittings

S58.1 Partial compliance fittings of size or shape not conforming to the dimensional requirements of ASME B16.9, B16.11, MSS-SP-79, MSS-SP-83, MSS-SP-95, and MSS-SP-97 shall meet all other requirements of the individual product specification. In addition to the marking required by Section 19, the grade designation symbol of the individual product specification shall be followed by the symbol "S58".

S59. Heat Treatment of Concentric Reducers

S59.1 Concentric reducers formed by local heating of the fitting shall be subsequently annealed, normalized, or normalized and tempered.

S60. Marking Small Fittings

S60.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with test reports.

S60.2 When the configuration or size does not permit marking directly on the fitting, the marking method shall be a matter of agreement between the manufacturer and the purchaser.

S61. Phosphorous and Sulphur Content

S61.1 The phosphorous and sulphur contents of the fittings shall not exceed 0.025 %.

S62. Ultrasonic Test

S62.1 Each fitting or the raw material from which the fitting is made shall be ultrasonically tested to determine its soundness. The method, where applicable, shall be in accordance with Practice A388/A388M. Acceptance limits shall be specified by the purchaser. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A-1988 or later.

S62.2 Each fitting or the raw material from which each fitting is made shall be ultrasonically tested to determine its soundness. The method, where applicable, shall be in accordance with Practice E213. Acceptable limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A-1988 or later.

S63. Intergranular Corrosion Bend Test (See Note S50.1)

S63.1 An intergranular corrosion bend test shall be made on one fitting or representative test piece (See Note S50.2) per lot (See Note S50.3) of fittings. If the fittings are of welded construction, the bend specimen shall include the weld and be prepared so that the weld is at the midlength location of the specimen. Specimens containing a weld shall be bent so that the location of weld is at the point of maximum bend. The method of testing shall be in accordance with Practice E of Practices A262 (rapid screening is not allowed) or Practice Z of Practices A763, as applicable.

S64. Photomicrographs

S64.1 Photomicrographs at 100 diameters shall be made for information only of the actual base metal structure from one fitting as furnished in each lot. The photomicrographs shall be identified as to fitting size, wall thickness, lot identification, and heat. The definition of "lot" shall be as specified by the purchaser.

S65. Surface Finish

S65.1 Machined surfaces shall have a maximum roughness of 250 µin. AARH [6.3 µm]. All other surfaces shall be suitable for ultrasonic testing.

S66. Repair Welding

S66.1 No weld repair shall be permitted without prior approval of the purchaser.

S67. Charpy V-Notch Test

S67.1 Charpy V-notch test shall be made as specified on the order. The test temperature, acceptance criteria, number of tests, and location of tests (whether from base metal, weld metal, or heat affected zone of welds) shall be specified.

S68. Special Notch Toughness

S68.1 The impact test temperature or acceptance values, or both, shall be as agreed upon, but only with respect to lower temperatures or higher energy values.

S69. Magnetic Particle Examination—Weld Metal

S69.1 All accessible welds shall be examined in accordance with Guide E709. Accessible is defined as all outside surfaces, all inside fitting surfaces 24 in. [610 mm] in diameter and greater, and inside fitting surfaces less than 24 in. [610 mm] in diameter, for a distance of one diameter from the ends.

S69.2 *Acceptance Criteria*—The following indications are unacceptable:

S69.2.1 Any cracks and linear indications,

S69.2.2 Rounded indications with dimensions greater than 3⁄16 in. [4.8 mm],

S69.2.3 Four or more indications in any line separated by 1⁄16 in. [1.6 mm],

S69.2.4 Ten or more indications located in any 6 in.^{2} [4000 mm^2] of surface, with the major dimensions not to exceed 6 in. [150 mm] when the major dimension is oriented so that the area includes the maximum number of indications being evaluated.

S69.3 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A-1988 or later.

S70. Liquid Penetrant Examination of Weld Metal

S70.1 All accessible surfaces of fittings shall be examined in accordance with Test Method E165/E165M. Accessible is defined in S69.

S70.2 Acceptance criteria shall be in accordance with S69.2.

S70.3 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A-1988 or later.

S71. Product Marking

S71.1 Weld repaired parts shall be marked "S71".

S72. Nondestructive Electromagnetic (Eddy-Current) Test

S72.1 For eddy-current testing, the calibration tube shall contain, at the option of the manufacturer, any one of the following discontinuities placed in the weld to establish a minimum sensitivity level for rejection.

S72.2 *Drilled Hole*—A hole not larger than 0.031 in. [0.79 mm] in diameter shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling.

S72.3 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. [6-mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the tube. The notch shall have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. [0.102 mm], whichever is greater.

S72.4 *Longitudinal Notch*—A notch 0.031 in. [0.79 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. [0.102 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

S72.5 Fittings producing a signal equal to or greater than the calibration defect shall be subject to rejection. To be accepted, after rework, the fittings must pass the same test to which it was originally subjected.

S72.6 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A-1988 or later.

S73. Weld Metal Analysis

S73.1 Analysis of weld metal shall be reported.

S74. Welding Procedure Test Record

S74.1 A welding procedure test record shall be furnished.

S75. Chemical Analysis of Remelted Steel

S75.1 Each remelted ingot shall be assigned a unique identification number.

S75.2 A chemical analysis shall be made from each remelted ingot.

S76. Electropolished Austenitic Grades

S76.1 All electropolished austenitic fittings shall be of a cleanliness according to Specification A967/A967M.

S76.2 Details concerning which test method of Specification A967/A967M are to be a matter of agreement between the manufacturer and the purchaser.

S77. Positive Material Identification Examination

S77.1 Fittings shall be examined to assure that the purchaser is receiving fittings of the correct material grade prior to shipment of the fittings. This examination is to assure that no material grade mix-up has happened during manufacturing and marking of the fittings.

S77.2 Fittings shall receive a Positive Material Identification examination using the methods of Guide E1916.

S77.3 The quantity examined shall be 100 % of the fittings.

S77.4 All fittings that are not of the correct material grade shall be rejected.

S77.5 The method of fitting marking after this examination shall be agreed upon between the manufacturer and purchaser.

S78. Requirements for Carbon Steel Products for Concentrated Hydrofluoric Acid Service

S78.1 The maximum carbon equivalent based on heat analysis shall be as follows:

Maximum section thickness less than or equal to 1 in.	CE maximum = 0.43
Maximum section thickness greater than 1 in.	CE maximum = 0.45

S78.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S78.3 Vanadium and Niobium maximum content based on heat analysis shall be:

Maximum Vanadium = 0.02 wt %
Maximum Niobium = 0.02 wt %
Maximum Vanadium plus Niobium = 0.03 wt %
(Note Niobium = Columbium)

S78.4 The maximum composition based on heat analysis of Ni + Cu shall be 0.15 wt %.

S78.5 The minimum C content based on heat analysis shall be 0.18 wt %. The maximum C content shall be as specified in the appropriate material specification.

S78.6 Repair welds shall not be made with E60XX electrodes. Use of E70XX electrodes is recommended and the resulting weld chemistry should meet the same chemistry criteria as the base metal as listed above.

S78.7 In addition to the requirements of product marking of the specification, an "HF" stamp or marking shall be provided on each component to identify that component complies with this supplementary requirement.

S79 Pressure Equipment Directive—Mechanical Testing

S79.1 Charpy impact testing shall be done at the lowest scheduled operating temperature, but not higher than 68 °F [20 °C].

S79.2 The frequency of impact testing shall be the same as that specified in the product specification for the tension test, with three individual Charpy test specimens for each required tension test.

S79.3 The minimum impact absorption energy for the Charpy test specimen shall be at least 20 ft-lb [27 J].

S79.4 The minimum elongation in the tension test shall be measured on a gauge length of five times the diameter of the test specimen, and shall not be less than 14 %.

S79.5 Impact and tension test results shall be included in the product certification.

ANNEXES

(Mandatory Information)

A1. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A1.1.1 Application for the addition of a new grade to a specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A1.1.5 The application shall state whether the new grade is covered by patent.

A2. REQUIREMENTS FOR THE INTRODUCTION OF MATERIALS FROM OTHER A01 OR B02.07 SPECIFICATIONS

A2.1 Wrought materials that are already covered by another A01 or B02.07 specification may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A2.1.1 Application for the addition of a grade that is already covered in another A01 or B02.07 specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A2.1.2 The chemical requirements, the specified mechanical properties, and the heat treatment requirements of the grade being added shall be the same as those for the grade in the A01 or A01 specification in which the grade is presently covered.

A2.1.3 The application shall provide recommendations for all requirements appearing in the applicable specification.

A2.1.4 The application shall state whether or not the grade is covered by patent.

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SPECIFICATION FOR COMMON REQUIREMENTS FOR STEEL FLANGES, FORGED FITTINGS, VALVES, AND PARTS FOR PIPING APPLICATIONS

SA-961/SA-961M

(23)

(Identical with ASTM Specification A961/A961M-21.)

Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

1. Scope

1.1 This specification covers a group of common requirements that shall apply to steel flanges, forged fittings, valves, and parts for piping applications under any of the following individual product specifications:

Title of Specification	ASTM Designation
Forgings, Carbon Steel, for Piping Components	A105/A105M
Forgings, Carbon Steel, for General-Purpose Piping	A181/A181M
Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service	A182/A182M
Forgings, Carbon and Low Alloy Steel, Requiring Notch Toughness Testing for Piping Components	A350/A350M
Forged or Rolled 8 and 9 % Nickel Alloy Steel Flanges, Fittings, Valves, and Parts for Low-Temperature Service	A522/A522M
Forgings, Carbon and Alloy Steel, for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service	A694/A694M
Flanges, Forged, Carbon and Alloy Steel for Low Temperature Service	A707/A707M
Forgings, Carbon Steel, for Piping Components with Inherent Notch Toughness	A727/A727M
Forgings, Titanium-Stabilized Carbon Steel, for Glass-Lined Piping and Pressure Vessel Service	A836/A836M

1.2 In case of conflict between a requirement of the individual product specification and a requirement of this general requirement specification, the requirements of the individual product specification shall prevail over those of this specification.

1.3 By mutual agreement between the purchaser and the supplier, additional requirements may be specified (see Section 4.1.2). The acceptance of any such additional requirements shall be dependent on negotiations with the supplier and must be included in the order as agreed upon between the purchaser and supplier.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text and the tables, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply, unless the "M" designation (SI) of the product specification is specified in the order.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A105/A105M Specification for Carbon Steel Forgings for Piping Applications

A181/A181M Specification for Carbon Steel Forgings, for General-Purpose Piping

A182/A182M Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A350/A350M Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A522/A522M Specification for Forged or Rolled 8 and 9% Nickel Alloy Steel Flanges, Fittings, Valves, and Parts for Low-Temperature Service

A694/A694M Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service

A700 Guide for Packaging, Marking, and Loading Methods

for Steel Products for Shipment
A707/A707M Specification for Forged Carbon and Alloy Steel Flanges for Low-Temperature Service
A727/A727M Specification for Carbon Steel Forgings for Piping Components with Inherent Notch Toughness
A751 Test Methods and Practices for Chemical Analysis of Steel Products
A836/A836M Specification for Titanium-Stabilized Carbon Steel Forgings for Glass-Lined Piping and Pressure Vessel Service
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A967/A967M Specification for Chemical Passivation Treatments for Stainless Steel Parts
A991/A991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
A1058 Test Methods for Mechanical Testing of Steel Products—Metric
B880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys
E165/E165M Practice for Liquid Penetrant Testing for General Industry
E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
E709 Guide for Magnetic Particle Testing
E1916 Guide for Identification of Mixed Lots of Metals

2.2 *ASME Standard:*
ASME Boiler and Pressure Vessel Code–Section IX

2.3 *Manufacturer's Standardization Society Standard:*
SP 25 Standard Marking System of Valves, Fittings, Flanges and Unions

3. Terminology

3.1 *Definitions*—For definitions of other terms used in this specification, refer to Terminology A941.

3.2 *Definitions of Terms Specific to This Standard:*
3.2.1 *bar, n*—a solid rolled or forged section that is long in relationship to its cross sectional dimensions, with a relatively constant cross section throughout its length and a wrought microstructure.

3.2.2 *certifying organization, n*—the company or association responsible for the conformance of, the marking of, and the certification of the product to the specification requirements.

3.2.3 *fitting, n*—a component for non-bolted joints in piping systems.

3.2.4 *flange, n*—a component for bolted joints used in piping systems.

3.2.5 *forging, n*—the product of a substantially compressive hot or cold plastic working operation that consolidates the material and produces the required shape.
3.2.5.1 *Discussion*—The plastic working must be performed by a forging machine, such as a hammer, press, or ring rolling machine, and must deform the material to produce a wrought structure throughout the material cross section.

3.2.6 *seamless tubing, n*—a tubular product made without a welded seam.
3.2.6.1 *Discussion*—It is manufactured usually by hot working the material, and if necessary, by subsequently cold finishing the hot worked tubular product to produce the desired shape, dimensions and properties.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include, but are not limited to, the following:
4.1.1 Quantity,
4.1.2 Size and pressure class or dimensions, (tolerances and surface finishes should be included),
4.1.3 Specification number with grade or class, or both, as applicable, and year/date,
4.1.4 Choice of testing track from the options listed in Test Methods A1058 when material is ordered to an M suffix (SI units) product standard. If the choice of test track is not specified in the order, then the default ASTM track shall be used as noted in Test Methods A1058,
4.1.5 Supplementary requirements, and
4.1.6 Additional requirements.

5. Melting Process

5.1 Unless otherwise specified in the individual Product Specification, the steel shall be fully killed.

5.2 If a specific type of melting is required by the purchaser, it shall be stated on the purchase order.

5.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum remelting. If secondary melting is employed, the heat shall be defined as all of the ingot remelted from a single primary heat.

5.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The steel producer shall remove the transition material by an established procedure that positively separates the grades.

5.5 A sufficient discard shall be made from the source material to secure freedom from injurious porosity and shrinkage, and undue segregation.

6. Manufacture

6.1 The finished part shall be manufactured from a forging that is as close as practicable to the finished size or shape. Alternative starting materials may be used, but with the following exceptions and requirements.

6.1.1 *Bar*—Flanges, elbows, return bends, tees, and header tees shall not be machined directly from bar. Other cylindrical shaped parts up to, and including, NPS 4 can be machined from bar provided that the axial length of the part is approximately parallel to the metal flow lines of the starting stock.

6.1.2 *Wrought Seamless Pipe and Tubing*—Flanges shall not be machined directly from seamless pipe or tubing. Other hollow cylindrical shaped parts can be machined from seamless pipe and tubing provided that the axial length of the part is approximately parallel to the metal flow lines of the starting stock.

7. Heat Treatment

7.1 Material requiring heat treatment shall be treated as specified in the individual product specification using the following procedures that are defined in more detail in Terminology A941.

7.1.1 *Annealing*—Material shall be uniformly reheated to a temperature above the transformation range and, after holding for a sufficient time at this temperature, cooled slowly to a temperature below the transformation range.

7.1.2 *Solution Annealing (or Solution Treat or Treatment)*—Material shall be heated to a temperature that causes the chromium carbides to go into solution, and then, quenched in water or rapidly cooled by other means to prevent re-precipitation.

7.1.3 *Isothermal Annealing*—Isothermal annealing shall consist of austenitizing a ferrous alloy, and then, cooling to and holding within the range of temperature at which the austenite transforms to a relatively soft ferrite-carbide aggregate.

7.1.4 *Normalizing*—Material shall be uniformly reheated to a temperature above the transformation range, and subsequently, cooled in air at room temperature.

7.1.5 *Tempering and Post-Weld Heat Treatment*—Material shall be reheated to the prescribed temperature below the transformation range, held at temperature for the greater of 30 min or 1 h/in. [25.4 mm] of thickness at the thickest section and cooled in still air.

7.1.6 *Stress Relieving*—Material shall be uniformly heated to the selected stress relieving temperature, held long enough to reduce stresses and then cooled at a rate that will result in the properties required for the material grade and minimize the development of new residual stresses. The temperature shall not vary from the selected temperature by more than ±25 °F [±14 °C].

7.1.7 *Quench and Temper*—Material shall be fully austenitized and quenched immediately in a suitable liquid medium. The quenched material shall be reheated to a minimum temperature of 1100 °F [590 °C] and cooled in still air.

7.1.8 *Same Heat Treat Cycle*—Heat treat loads at the same temperature, equivalent soak times as appropriate for the maximum section size on the respective load and equivalent cooling methods.

8. Chemical Requirements

8.1 *Chemical Analysis*—Samples for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

8.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of those elements specified in the individual product specification. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot, or the product of one remelted ingot, from each primary melt. The chemical analysis thus determined shall conform to the requirements of the individual product specification. Note that the product analysis (check analysis) tolerances are not to be applied to the Heat Analysis requirements.

8.3 *Product Analysis*—If a product analysis is performed it shall be in accordance with Test Methods, Practices, and Terminology A751. Samples for analysis shall be taken from midway between center and surface of solid parts, midway between inner and outer surfaces of hollow parts, midway between center and surface of full-size prolongations or from broken mechanical test specimens. The chemical composition thus determined shall conform to the limits of the product specification, within the permissible variations of Table 1 of this specification.

8.3.1 Limits on formula calculations involving elemental contents shall apply only to the heat analysis, unless agreed upon between supplier and purchaser. Where limits on formula calculations involving elemental contents apply to product analysis by such agreement, permissible variations in the formula calculation results beyond the limits for the heat analysis shall also be agreed upon between supplier and purchaser. Examples of such formula calculations include, but are not limited to, the following: carbon equivalent $CE = C + Mn / 6 + (Cr + Mo + V) / 5 + (Ni + Cu) / 15$; J factor $= (Mn + Si) \times (P + Sn) \times 10^4$; or requirements for specific elemental balance or sufficiency, typically related to Ti, Nb, or Al and interstitials C and N, such as $Nb = 5 \times C$ minimum.

9. Mechanical Requirements

9.1 *Method of Mechanical Tests*—All tests shall be conducted in accordance with Test Methods and Definitions A370 if the inch-pound units are specified or Test Methods A1058 if the M suffix (SI units) is specified.

9.2 For the purpose of determining conformance to the product specification requirements, specimens shall be obtained from the production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. In either case, mechanical test specimens shall not be removed until after all heat treatment is complete. If repair welding is performed, test specimens shall not be removed until after post-weld heat treatment is complete, unless permitted by the product specification. The locations from which test specimens are removed shall be in accordance with the Product Specification.

9.3 If separately forged test blanks are used, they shall be of the same heat of steel, be subjected to substantially the same reduction and working as the production forging they represent, be heat treated in the same furnace charge except as provided for in the reduced testing provisions of the product specification, under the same conditions as the production forging, and be of the same nominal thickness as the maximum heat treated thickness of the production forging.

TABLE 1 Product Analysis Tolerances[A]

Element	Limit or Maximum of Specified Range, Wt %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	to 0.010, incl.	0.002
	over 0.010 to 0.030, incl.	0.005
	over 0.030 to 0.20 incl.	0.01
	over 0.20 to 0.80, incl.	0.02
Manganese	to 1.00 incl.	0.03
	over 1.00 to 3.00 incl.	0.04
	over 3.00 to 6.00, incl.	0.05
	over 6.00 to 10.00, incl.	0.06
Phosphorous	to 0.040, incl.	0.005
	over 0.040 to 0.20, incl.	0.010
Sulfur	to 0.040 incl.	0.005
	over 0.040 to 0.20, incl.	0.010
	over 0.20 to 0.50, incl.	0.020
Silicon	to 1.00, incl.	0.05
	over 1.00 to 3.00 incl.	0.10
	over 3.00 to 7.00, incl.	0.15
Chromium	0.90 and under	0.03
	over 0.90 to 2.10, incl.	0.05
	over 2.10 to 4.00, incl.	0.07
	over 4.00 to 10.00 incl.	0.10
	over 10.00 to 15.00 incl.	0.15
	over 15.00 to 20.00 incl.	0.20
	over 20.00 to 30.00 incl.	0.25
Nickel	to 1.00 incl.	0.03
	over 1.00 to 5.00 incl.	0.07
	over 5.00 to 10.00 incl.	0.10
	over 10.00 to 20.00 incl.	0.15
	over 20.00 to 30.00 incl.	0.20
	over 30.00 to 40.00, incl.	0.25
Molybdenum	to 0.20 incl.	0.01
	over 0.20 to 0.60 incl.	0.03
	over 0.60 to 2.00 incl.	0.05
	over 2.00 to 7.00 incl.	0.10
Titanium	to 1.15, incl.	0.05
Niobium (Columbium)	to 0.14, incl.	0.02
	over 0.14 to 5.50	0.05
Tantalum	to 0.10 incl.	0.02
Copper	to 0.50, incl.	0.03
	over 0.50 to 1.00, incl.	0.05
	over 1.00 to 5.00, incl.	0.10
Cobalt	0.05 to 0.25, incl.	0.01[B]
	0.25 to 5.00, incl.	0.07
Nitrogen	to 0.02, incl.	0.005
	over 0.02 to 0.19 incl.	0.01
	over 0.19 to 0.25	0.02
	over 0.25 to 0.35	0.03
	over 0.35 to 0.45	0.04
	over 0.45	0.05
Aluminum	to 0.15, incl.	–0.005 +0.01
	over 0.15 to 0.50, incl.	0.05
	over 0.50 to 0.80, incl.	0.07
Vanadium	to 0.10 incl.	0.01
	over 0.10 to 0.25 incl.	0.02
	over 0.25 to 0.50, incl.	0.03
	minimum value specified, under minimum limit only	0.01
Cerium	to 0.20, incl.	0.01
Selenium	to 0.35, incl.	0.001
Tungsten	to 0.50, incl.	0.02
	over 0.50 to 1.00, incl.	0.03
	over 1.00 to 2.00, incl.	0.05
	over 2.00 to 4.00, incl.	0.06
Lead	to 0.35, incl.	0.03
Zirconium	to 0.01, incl.	0.005
Boron	to 0.015, incl.	0.0005
Tin	to 0.010, incl.	[C]
Arsenic	to 0.010, incl.	[C]
Antimony	to 0.003, incl.	[C]

[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05 % have not been established and the producer should be consulted for those limits.
[C] No over tolerance allowed.

9.4 When parts are machined from bar or seamless tubing, as permitted in 6.1.1 and 6.1.2, the mechanical properties may be determined for the parts from the starting material, if the parts have not been subjected to any subsequent thermal processing since the time of mechanical test.

10. Hardness Requirements

10.1 The part shall conform to the hardness requirements prescribed in the product specification.

10.2 Sampling for hardness testing shall conform to the product specification.

11. Tensile Requirements

11.1 Sampling for tensile testing shall conform to the Product Specification.

11.2 When the dimensions of the material to be tested will permit, the tension test specimens shall be machined to standard round 2-in. gauge length tension test specimen described in Test Methods and Definitions A370 if inch-pound units are specified or the standard gauge length tension test specimens described in the applicable track of Test Methods A1058 if SI units are specified.

11.3 In the case of small sections, which will not permit taking of the standard test specimen described in 11.2, the subsize round specimen shall be machined. The tension test specimen shall be as large as feasible.

11.4 The results of the tensile tests shall conform to the tensile property requirements prescribed in the product specification.

11.5 If the results of tension tests do not conform to the requirements specified in the product specification, a retest shall be permitted on twice the number of test specimens as originally tested as outlined in the test methods specified herein. When any retest specimen does not conform to the product specification requirements for the characteristic in question, the lot represented by that specimen shall be rejected or reheat treated in accordance with Section 7.

11.5.1 If the results of any tension test specimen are less than specified because a flaw becomes evident in the test specimen during testing, a replacement test specimen shall be allowed provided that the defect is not attributable to ruptures, cracks, or flakes in the steel.

12. Impact Requirements

12.1 The part shall conform to the impact requirements prescribed in the product specification.

12.2 Sampling for impact testing shall conform to the Product Specification.

12.3 Notched-bar impact specimens shall be simple-beam, Charpy-type A with a V-notch in accordance with Test Methods and Definitions A370 if the inch-pound units are specified or Test Methods A1058 if the M suffix (SI Units) standard is specified. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable standard subsize impact specimens shall be used. When the size or shape of the finished part is insufficient to permit obtaining the smallest standard subsize impact specimens, an impact test by the part manufacturer will not be required.

12.4 If the average impact energy value meets the product specification requirements, but the energy value for one specimen is below the specified minimum value for individual specimens, a retest is permitted. This shall consist of two impact specimens from a location adjacent to, and on either side of, the specimen that failed. Each of the retested specimens must exhibit an energy value equal to or greater than the minimum average value required by the product specification.

13. Hydrostatic Test Requirements

13.1 Parts manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished part. Such tests shall be conducted by the supplier only when the hydrostatic test supplementary requirement in the product specification is invoked by the purchaser.

14. Rework

14.1 When one or more representative test specimens or retest specimens do not conform to the requirements specified in the product specification for the tested characteristic, the product may be reworked according to the following requirements:

14.1.1 If previously tested in the unheat treated condition, the product may be reworked by heat treatment, and subsequently retested, in accordance with the product specification.

14.1.2 If previously tested in the heat treated condition, the product may be reworked by reheat treatment, and subsequently retested, in accordance with the product specification.

15. Surface Finish, Appearance, and Corrosion Protection

15.1 The parts shall conform to the dimensions, tolerances, and finish as specified on the purchaser's drawing or order and the individual ASTM product specification.

15.2 The finished parts shall be cleaned to remove all scale and processing compounds prior to the final surface examination. The cleaning process shall not injure the surface finish, material properties, or the metallurgical structure.

15.2.1 The surface finish shall allow the detection of imperfections that can be disclosed by visual inspection.

15.2.2 The cleaned parts shall be protected to prevent recontamination.

15.2.2.1 Exterior and interior surfaces of carbon, low and intermediate alloy steel fittings shall have a corrosion protective coating. Unless otherwise specified by the purchaser, the type of surface protection shall be at the option of the manufacturer.

15.2.2.2 Stainless steel and nickel alloy fittings need not be coated. Unmachined surfaces of stainless steel fittings shall be passivated by exposure to an acid bath, or electropolished.

15.2.3 Protective coatings on parts subsequently subjected to socket welds or butt welds shall be suitable for welding without removal of the coating. Threaded fittings shall be capable of installation without the removal of the coating.

15.2.4 When specified in the purchase order, parts may be furnished in the as-formed or as-forged condition.

15.3 The parts shall be free of injurious imperfections as defined below. At the discretion of the inspector representing the purchaser, finished parts shall be subject to rejection if surface imperfections acceptable under 15.5 are not scattered, but appear over a large area.

15.4 *Depth of Injurious Imperfections*—Selected typical linear and other typical surface imperfections shall be explored for depth. When the depth encroaches on the minimum specified wall thickness of the finished part, such imperfections shall be considered injurious.

15.5 *Imperfections Not Classified as Injurious*—Surface imperfections not classified as injurious shall be treated as follows:

15.5.1 Seams, laps, tears, or slivers not deeper than 5 % of the actual wall thickness at the point of interest or 1⁄16 in. [1.6 mm], whichever is less, are acceptable. If deeper, these imperfections require removal, and shall be removed by machining or grinding.

15.5.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed 1⁄16 in. [1.6 mm]. If such imperfections are deeper than 1⁄16 in. [1.6 mm] but do not encroach on the minimum wall thickness of the forging they shall be removed by machining or grinding to sound metal.

15.5.3 The wall thickness at the point of grinding, or at imperfections not required to be removed, shall be determined by deducting the amount removed by grinding, from the nominal finished wall thickness of the part. In any case, the wall thickness shall not be less than the specified minimum value.

16. Repair by Welding

16.1 The purchaser may require the supplier to submit proposed weld repairs for approval by invoking the appropriate supplementary requirement from the applicable product specification in the purchase order. If the purchaser does not require prior approval of proposed weld repairs, these repairs shall be permitted at the discretion of the supplier. All weld repairs shall be performed in accordance with the following limitations and requirements.

16.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

16.1.2 Defects shall be completely removed prior to welding by chipping or grinding to sound metal. Removal of these defects shall be verified by magnetic particle inspection in accordance with Test Method A275/A275M or Guide E709 for the ferritic, martensitic, or ferritic/austenitic grades, or by liquid penetrant inspection in accordance with Test Method E165/E165M for ferritic, martensitic, or austenitic grades.

16.1.3 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic particle or liquid penetrant inspection, as applicable.

16.1.4 Repair by welding shall not exceed 10 % of the surface area of the part, or 33⅓ % of the wall thickness of the finished product, or ⅜ in. [10 mm] deep at the location of the repair.

16.2 The weld repair shall conform to 9.2 and to the additional requirements, if any, invoked in the Product Specification.

17. Inspection

17.1 The supplier shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with the general specification and the applicable product specification. Site inspection by the purchaser shall not interfere unnecessarily with the supplier's operations.

18. Rejection and Rehearing

18.1 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

18.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

19. Certification

19.1 A test report and a certificate of compliance are required.

19.2 Test reports shall include the product specification number and year/date of issue, the results of all tests required by this specification, and the purchaser order, and shall be traceable to the part represented.

19.3 A single document, containing the test report information and certificate of compliance information may be used.

19.4 A certificate printed from or used in electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpoint printed in the certifier's facility. The content of the EDI transmitted document shall conform to any existing EDI agreement between the purchaser and supplier.

19.5 Not withstanding the absence of a signature, the organization submitting either a printed certificate or an EDI transmitted certificate is responsible for the content of the report.

20. Marking

20.1 Each piece shall be legibly marked in a position as not to injure the usefulness of the forgings with the product specification number, grade or marking symbol, class, certifying organization's name or symbol, the heat number or heat identification, size, and service rating, if applicable. Dual or multiple marking with the product specification number, grade or marking symbol, and class is acceptable provided the material meets all the requirements with which it is marked. It is not required to mark the product with the specification year and date of issue. When size or shape does not permit the inclusion of all the required marking as described, see 20.2. Manufacturer can also choose the use of tags, box labels, etc. for identification when per piece marking is not practical due to size or shape.

20.2 The Standard Marking System of Valves, Fittings, Flanges and Unions MSS SP 25 shall be followed except the word "steel" shall not be substituted for the specification grade.

20.3 Product marking shall conform to the additional requirements, if any, invoked in the product specification or purchase order.

21. Packaging, Marking and Loading for Shipment

21.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A700.

22. Keywords

22.1 alloy steel; carbon steel; fittings; flanges; forgings; general requirement; piping applications; pressure containing parts; stainless steel; temperature service applications—elevated; temperature service applications—high; valves

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, in which event, the supplementary requirements specified shall be made at the place of manufacture, unless otherwise agreed upon, at the purchaser's expense. The test specified shall be witnessed by the purchaser's inspector before shipment of material, if so specified in the order. The rationale for beginning the section numbering with S50 is to eliminate the possibility of confusion with supplementary requirements existing in individual product specifications.

S50. Macroetch Test

S50.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted according to Method E381.

S50.2 Acceptance limits shall be as agreed upon between the certifying organization and the purchaser.

S51. Heat Analysis

S51.1 When secondary melting processes are employed, a heat analysis shall be obtained from each remelted ingot, or the product of each remelted ingot, from each primary melt. The chemical analysis thus determined shall conform to the requirements of the individual product specification. Note that the product analysis (check analysis) tolerances are not to be applied to the heat analysis requirements.

S52. Product Analysis

S52.1 A product analysis shall be made from one randomly selected forging representing each heat. The results shall comply with the product analysis limits listed in the applicable product specification. For Specification A182/A182M grades of F20 and F58, results shall comply with the product analysis limits listed in Specification B880.

S52.2 If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S53. Tension Tests

S53.1 In addition to the requirements of Section 9, one tension specimen shall be obtained from a representative forging from each heat at a location agreed upon between the certifying organization and the purchaser. The results of the test shall comply with the tensile property requirements listed in the applicable product specification and shall be reported to the purchaser.

S54. Impact Tests

S54.1 In addition to the requirements of Section 9, three CVN impact energy specimens shall be obtained from a representative forging from each heat at a location agreed upon between the certifying organization and the purchaser.

S54.2 The purchaser shall supply the impact test temperature and the required minimum requirements for the test, including the lowest single absorbed energy for a single specimen if an average absorbed energy value is required. The lateral expansion values and the fracture appearance of the specimens as percentage ductile fracture shall be reported for information if these parameters are not part of the acceptance requirements.

S55. Magnetic Particle Examination

S55.1 All accessible surfaces of the finished forging shall be examined by a magnetic particle method. The method shall be in accordance with Test Method A275/A275M. Acceptance limits shall be as agreed upon between the certifying organization and the purchaser.

S56. Liquid Penetrant Examination

S56.1 All accessible surfaces shall be examined by a liquid penetrant method in accordance with Test Method E165/E165M. Acceptance limits shall be as agreed upon between the certifying organization and the purchaser.

S57. Hydrostatic Testing

S57.1 A hydrostatic test at a pressure agreed upon between the certifying organization and the purchaser shall be applied by the certifying organization.

S58. Repair Welding

S58.1 No repair welding shall be permitted without prior approval of the purchaser. If permitted, the restrictions of Section 16 shall apply.

S59. Electropolished Austenitic and Ferritic–Austenitic Grades

S59.1 All electropolished austenitic and ferritic–austenitic products shall be of a cleanliness in accordance with Specification A967/A967M.

S59.2 Details concerning which test method of Specification A967/A967M are to be a matter of agreement between the manufacturer and the purchaser.

S60. Positive Material Identification Examination

S60.1 Forgings shall receive positive material identification to ensure that the purchaser is receiving forgings of the correct material grade prior to shipment of the forgings. This examination is a method to ensure that no material grade mix-up has occurred during the manufacturing and marking of the forgings.

S60.2 Forgings shall receive a positive material identification examination in accordance with Guide E1916.

S60.3 The quantity examined shall be 100 % of the forgings.

S60.4 All forgings that are not of the correct material grade shall be rejected.

S60.5 The method of forging marking after examination shall be agreed upon between the manufacturer and the purchaser.

S61. Heat Treatment in the Working Zone of a Surveyed Furnace

S61.1 Material shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A991/A991M, provided that such working zone was established using a variation of 25 °F [14 °C] or less from the furnace set point.

S61.2 The test report shall indicate that S61 applies.

S62. Requirements for Carbon Steel Products for Concentrated Hydrofluoric Acid Service

S62.1 The maximum carbon equivalent based on heat analysis shall be as follows:

Maximum section thickness less than or equal to 1 in.	CE maximum = 0.43
Maximum section thickness greater than 1 in.	CE maximum = 0.45

S62.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15 \quad (1)$$

S62.3 Vanadium and Niobium maximum content based on heat analysis shall be:

Maximum Vanadium = 0.02 wt %
Maximum Niobium[A] = 0.02 wt %
Maximum Vanadium plus Niobium[A] = 0.03 wt %

[A]Niobium = Columbium

S62.4 The maximum composition based on heat analysis of Ni + Cu shall be 0.15 wt %.

S62.5 The minimum C content based on heat analysis shall be 0.18 wt %. The maximum C content shall be as specified in the appropriate material specification.

S62.6 Repair welds shall not be made with E60XX electrodes. Use of E70XX electrodes is recommended, and the resulting weld chemistry should meet the same chemistry criteria as the base metal as listed above.

S62.7 In addition to the requirements of product marking of the specification, a "HF" stamp or marking shall be provided on each component to identify that component complies with this supplementary requirement.

S63 Pressure Equipment Directive—Mechanical Testing

S63.1 Charpy impact testing shall be done at the lowest scheduled operating temperature but not higher than 68 °F [20 °C].

S63.2 The frequency of impact testing shall be the same as that specified in the product specification for the tension test, with three individual Charpy test specimens for each required tension test.

S63.3 The minimum impact absorption energy for the Charpy test specimen shall be at least 20 ft/lb [27 J].

S63.4 The minimum elongation in the tension test shall be measured on a gauge length of five times the diameter of the test specimen, and it shall not be less than 14 %.

S63.5 Impact and tension test results shall be included in the product certification.

ANNEXES

(Mandatory Information)

A1. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A1.1.1 Application for the addition of a new grade to a specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A1.1.5 The application shall state whether or not the new grade is covered by patent.

A2. REQUIREMENTS FOR THE INTRODUCTION OF MATERIALS FROM OTHER A01 OR B02.07 SPECIFICATIONS

A2.1 Wrought materials that are already covered by another A01 or B02.07 specification may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A2.1.1 Application for the addition of a grade that is already covered in another A01 or B02.07 specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A2.1.2 The chemical requirements, the specified mechanical properties, and the heat treatment requirements of the grade being added shall be the same as those for the grade in the A01 or B02.07 specification in which the grade is presently covered.

A2.1.3 The application shall provide the recommendations for all requirements appearing in the applicable specification.

A2.1.4 The application shall state whether or not the grade is covered by patent.

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SPECIFICATION FOR COMMON REQUIREMENTS FOR BOLTING INTENDED FOR USE AT ANY TEMPERATURE FROM CRYOGENIC TO THE CREEP RANGE

SA-962/SA-962M

(23)

(Identical with ASTM Specification A962/A962M-22.)

Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

1. Scope

1.1 This specification covers a group of common requirements that shall apply to carbon, alloy, stainless steel, and nickel alloy bolting under any of the following ASTM Specifications (or under any other ASTM Specifications that invoke this specification or portions thereof):

Title of Specifications	ASTM Designation
Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications	A193/A193M
Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both	A194/A194M
Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service	A320/A320M
Stainless and Alloy-Steel Turbine-Type Bolting Specially Heat Treated for High-Temperature Service	A437/A437M
High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels	A453/A453M
Alloy-Steel Bolting for Special Applications	A540/A540M
Precipitation-Hardening Bolting (UNS N07718) for High Temperature Service	A1014/A1014M
High Strength Precipitation Hardening and Duplex Stainless Steel Bolting for Special Purpose Applications	A1082/A1082M

1.2 In case of conflict, the requirements of the individual product specification shall prevail over those of this specification.

1.3 Fasteners are a wide-ranging classification that includes screws, bolts, nuts, washers, stud bolts, rivets, powder-actuated studs, staples, tacks, and pins. Bolting, which is composed of bolting materials, such as rods, bars, flats, and forgings, which are subsequently manufactured into bolting components, are a special sub-group of fasteners. Bolting materials and components have designated compositions and specific properties intended for applications in aggressive service where commercial generic fasteners may not be suitable or have insufficient fitness for purpose under certain conditions. These conditions include cryogenic or high temperature service, or excessive vibration, impact, or shock. To further address any other special service conditions where bolting is intended for use, additional requirements may be specified by mutual agreement between the purchaser and supplier.

1.4 Supplementary requirements are provided for use at the option of the purchaser. The supplementary requirements only apply when specified individually by the purchaser in the purchase order or contract.

1.5 This specification is expressed in both inch-pound units and in SI units. Unless the purchase order or contract specifies the applicable "M" specification designation (SI units) the inch-pound units shall apply. The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

The following documents shall form a part of this specification to the extent specified. The latest issue shall apply unless otherwise specified.

2.1 *ASTM Standards:*

A29/A29M Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought

A193/A193M Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

A194/A194M Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A320/A320M Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A380/A380M Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
A437/A437M Specification for Stainless and Alloy-Steel Turbine-Type Bolting Specially Heat Treated for High-Temperature Service
A453/A453M Specification for High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels
A484/A484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
A540/A540M Specification for Alloy-Steel Bolting for Special Applications
A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A751 Test Methods and Practices for Chemical Analysis of Steel Products
A788/A788M Specification for Steel Forgings, General Requirements
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A967/A967M Specification for Chemical Passivation Treatments for Stainless Steel Parts
A1014/A1014M Specification for Precipitation-Hardening Bolting (UNS N07718) for High Temperature Service
A1058 Test Methods for Mechanical Testing of Steel Products—Metric
A1082/A1082M Specification for High Strength Precipitation Hardening and Duplex Stainless Steel Bolting for Special Purpose Applications
E3 Guide for Preparation of Metallographic Specimens
E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
E384 Test Method for Microindentation Hardness of Materials
E566 Practice for Electromagnetic (Eddy Current/Magnetic Induction) Sorting of Ferrous Metals
E1417/E1417M Practice for Liquid Penetrant Testing
E1444/E1444M Practice for Magnetic Particle Testing for Aerospace
E1916 Guide for Identification of Mixed Lots of Metals
F606/F606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
F788 Specification for Surface Discontinuities of Bolts, Screws, Studs, and Rivets, Inch and Metric Series
F812 Specification for Surface Discontinuities of Nuts, Inch and Metric Series
F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
F2328 Test Method for Determining Decarburization and Carburization in Hardened and Tempered Threaded Steel Bolts, Screws, Studs, and Nuts
F2328M Test Method for Determining Decarburization and Carburization in Hardened and Tempered Threaded Steel Bolts, Screws, Studs, and Nuts (Metric)

2.2 *AIAG Standard:*
AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

2.3 *ASME Standards:*
B1.1 Screw Threads
B1.13M Metric Screw Threads – M Profile
B1.2 Gages and Gaging for Unified Screw Threads
B1.3M Screw Thread Gaging Systems for Dimensional Acceptability of Metric Screw Threads
B18.2.1 Square and Hex Bolts and Screws
B18.2.2 Metric Heavy Hex Nuts
B18.2.3.3M Metric Heavy Hex Screws
B18.2.3.6M Metric Heavy Bolts
B18.2.4.6M Nuts for General Applications
B18.2.6 Fasteners Used in Structural Applications
B18.2.6M Metric Fasteners for Use in Structural Applications
B18.3 Hexagon Socket and Spline Socket Screws
B18.18 Quality Assurance for Fasteners
B18.31.2 Continuous Thread Stud, Double-End Stud, and Flange Bolting Stud (Stud Bolt) (Inch Series)

2.4 *ISO Standards:*
ISO 4762 Hex Socket Cap Screw

2.5 *Other Documents:*
ASNT Recommended Practice No. SNT-TC-1A

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *annealing*—material shall be uniformly reheated to a temperature above the transformation range and, after holding for a sufficient time at this temperature, cooled slowly to a temperature below the transformation range.

3.1.2 *bar*—a solid rolled or forged section that is long in relationship to its cross-sectional dimensions with a relatively constant cross section throughout its length. See Specification A29/A29M for definitions relating to the production of hot wrought and cold finished bars.

3.1.3 *bolting*—a general term which includes bolting materials (rolled or forged bars or blanks, wire, rod, threaded bar, rotary pierced or extruded seamless tubes, bored bars, or forged hollows from forged or rolled bar segments), which are manufactured into bolting components, including but not limited to, connectors, pins, restraining device components, shafts, bolts, nuts, screws, studs, and washers.

3.1.4 *bolting components*—components, such as bolts, nuts, screws, studs, washers, connectors, and pins, are finished products which join, fasten, restrain, or position objects.

3.1.5 *bolting materials*—starting materials used for the manufacture of bolting components, such as rolled or forged or threaded solid bars, blanks, wires, rods, or tubes or other hollow sections, that may be further processed by heat treatment, cold working, forging, threading, or machining.

3.1.6 *certifying organization*—the company or association responsible for the conformance and marking of the product to the specification requirements.

3.1.7 *class*—a term used to differentiate between different heat treatment conditions or strength levels, or both, often within the same grade but sometimes within the same family of materials. May also apply to work hardened condition or strength level, or both.

3.1.8 *grade*—an alloy described individually and identified by its own designation in a table of chemical requirements within any specification.

3.1.9 *length, components subject to full size testing*—that portion of the bolting component whose body diameter is approximately the same as the nominal thread size.

3.1.10 *lot*—unless otherwise specified, a lot shall consist of:

3.1.10.1 *bolting, heat treated in batch type furnaces*—all bolting material of the same heat or cast of material, condition, finish, and size subjected to the same heat treatment in one tempering charge and submitted for inspection at the same time.

3.1.10.2 *bolting, heat treated in continuous type furnaces*—all bolting material of the same heat or cast of material, condition, finish, and size heat treated without interruption in a continuous type furnace.

3.1.10.3 *bolting, non heat treated (strain hardened)*—all bolting material of the same heat or cast of material, condition, reduction (cold work), finish, and size.

3.1.10.4 *components, machined from bolting material*—all bolting components machined from the same lot of bolting material defined as outlined in either 3.1.10.1 or 3.1.10.2, above without any subsequent heat treatment or hot or cold forming.

3.1.10.5 *components, heat treated in batch type furnaces*—all bolting component items produced by any manufacturing process (such as rolling, forging, or machining) from the same heat or cast of material, of the same prior condition, the same size, and subjected to the same heat treatment in one tempering charge.

3.1.10.6 *components, heat treated in continuous type furnaces*—all bolting component items produced by any manufacturing process (such as rolling, forging, or machining) from the same heat or cast of material, of the same prior condition, of the same size, and then subjected to the same heat treatment in a four hour period and in one tempering charge.

3.1.10.7 *components, non heat treated (strain hardened)*—all bolting components of the same heat or cast of material, condition, reduction (cold work), finish, and size.

3.1.10.8 *solution treat or treatment (or solution annealing)*—material shall be heated to a temperature that causes the carbides to go into solution and then quenched in water or rapidly cooled by other means to prevent re-precipitation.

3.1.10.9 *stress relieving*—material shall be uniformly heated to the selected stress relieving temperature, held long enough to reduce stresses and then cooled at a rate that will result in the properties required for the material grade and minimize the development of new residual stresses.

3.1.10.10 *strain hardened material*—austenitic stainless steel material which has been subjected to cold working sufficient to cause a significant increase in strength.

3.2 *Definitions*—For definitions of other terms used in this specification, refer to Terminology A941.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order all information necessary to purchase the needed material. Examples of such information include, but are not limited, to the following:

4.1.1 Quantity and size,

4.1.2 Product specification number with grade, class, type, as applicable, and including the product specification year date,

4.1.3 Choice of testing track from the options listed in Test Methods A1058 when material is ordered to an M suffix (SI units) product standard. If the choice of test track is not specified in the order, then the default ASTM track shall be used as noted in Test Methods A1058.

4.1.4 Any additional information required by the individual product specification,

4.1.5 Supplementary requirements,

4.1.6 Additional requirements (see 5.3, 5.5, 5.6, 6.1, 7.4, 13.1, 13.3.1, 13.3.3, 13.5.2, 13.6, 15.8, and 19.1).

4.1.7 Additional ordering options provided in the individual product specification, and

4.1.8 Dimensions (diameter, length of point, overall length, finish, shape, threads, etc.).

5. Melting Process

5.1 The steel shall be produced by any of the following processes: basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting.

5.2 Unless otherwise specified in the individual product specification, the steel shall be fully killed. Use of the basic oxygen process shall be limited to grades containing less than 6 % chromium.

5.3 If a specific type of melting is required by the purchaser, it shall be stated on the purchase order.

5.4 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting such as electroslag remelting or vacuum remelting. If secondary melting is employed, the heat shall be defined as all of the ingot remelted from a single primary heat.

5.5 Steel may be cast in ingots or may be continuously cast. When steel of different grades is continuously cast identification of the resultant transition material is required. The steel producer shall remove the transition material by an established procedure that positively separates the grades. Should the purchaser deem it necessary to have the transition zone of two heats of the same grade which are continuously cast discarded, the purchaser shall invoke Supplementary Requirement S53.

5.6 *Quality*—The steel producer quality control procedures shall provide sufficient testing of carbon and alloy steels in accordance with Method E381 or other suitable method as agreed upon between the purchaser and the producer to assure the internal quality of the product.

5.6.1 *Ingot Cast Product*—Visual examination of transverse sections shall show no imperfections worse than the macrographs of Method E381 S2-R2-C3 or equivalent as agreed upon.

5.6.2 *Strand Cast Product*—Visual examination of traverse sections in accordance with Method E381 shall reveal none of the conditions shown in macrographs 1-5, 7, 12-18 of Plate III. Conditions 6, 8-11 shall not be present to a degree greater than the macrographs of Plates I and II, S2-R2-C3.

6. Materials and Manufacture

6.1 Bars shall be produced in accordance with Specifications A29/A29M or A484/A484M as applicable. Finish (hot rolled or cold drawn, rough turned, extruded, ground, or polished) shall be at the option of the manufacturer unless otherwise specified.

6.1.1 A sufficient discard shall be made from each ingot to ensure bars do not contain piping or segregation that precludes use of the product to manufacture bolting meeting the requirements of the individual product specifications.

6.2 Bolting components shall be produced in accordance with the product specification.

7. Chemical Composition

7.1 *Chemical Analysis*—Heat or product chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

7.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of those elements specified in the individual product specification. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical analysis thus determined shall conform to the requirements of the individual product specification. Product analysis (check analysis) tolerances shall not be applied to heat analysis requirements.

7.3 *Product Analysis*—When performed, by manufacturer, purchaser, end user, and so forth, samples for analysis shall be taken from midway between center and surface of solid parts, midway between inner and outer surfaces of hollow parts, midway between center and surface of full-size prolongations or from broken mechanical test specimens. The chemical composition thus determined shall conform to the limits of the product specification, within the permissible tolerances found in Tables 5 and 6 of Specification A29/A29M and Table 1 of Specification A484/A484M as appropriate for the grade being supplied. When multiple samples are taken from the same lot for product analysis, individual elements shall not vary both above and below the specified range.

7.4 For continuous cast materials the requirements of 8.2 or 8.3, as appropriate, of Specification A788/A788M shall be met.

7.5 Steels with intentional additions of lead, bismuth, or tellurium shall not be supplied or used. Steels with intentional additions of selenium may only be supplied or used when specifically called out in the product specification.

7.6 The starting material shall not contain any unspecified elements, other than nitrogen in austenitic stainless steels, for the ordered grade(s) to the extent that it then conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

8. Mechanical Properties

8.1 *Method of Mechanical Tests*—All tests shall be conducted in accordance with Test Methods and Definitions A370 if the inch-pound units are specified or Test Methods A1058 if the M suffix (SI units) is specified, unless otherwise specified.

8.2 For the purpose of determining conformance to the product specification requirements, specimens shall be obtained from the production material, or, in the case of forgings, from separately forged test blanks prepared from the stock used to make the finished product. Heat treatment shall be completed prior to removal of material for mechanical testing.

8.3 If separately forged test blanks are used, they shall be of the same heat of steel, be subjected to substantially the same reduction and working as the production forging they represent, be heat treated in the same furnace charge and under the same conditions as the production forging, and be of the same nominal thickness as the maximum heat treated thickness of the production forging.

8.4 *Bars*—Tension and impact tests representing bar stock shall be taken in accordance with the requirements of Annex A1 of Test Methods and Definitions A370. Impact tests are not required on bars ½ in. and under in diameter.

8.5 *Components, Machined from Heat Treated Bar*—Mechanical properties of bolting components machined from heat treated bar shall be represented by the tests conducted on the bar in accordance with 8.4.

8.6 *Components, All Classes—Produced by other methods*—When bolting components have been produced by upsetting or forging (hot or cold), when they have been subjected to heat treatment, or when the nominal thread size falls into a different diameter range than that of the starting bar as shown in the applicable specifications, then tests shall be conducted on material taken from those components.

8.6.1 Tension test specimens taken from finished components shall be machined to the form and dimensions and from the positions shown in Annex A3 of Test Methods and Definitions A370 when inch-pounds are specified and to the form and dimension shown in Test Methods F606/F606M when M suffix (SI units) is specified. Impact tests are not required on material from externally threaded components when the thread diameter is ½ in. and under.

9. Hardness Requirements

9.1 The material shall conform to the hardness requirements prescribed in the product specification. Hardness testing shall be performed in accordance with Test Methods and Definitions A370 when inch-pound units are specified or to the applicable track of Test Methods A1058 if SI units are specified.

9.2 Tensile tests prevail over hardness tests in the event a conflict exists relative to minimum strength unless otherwise specified in the product specification.

10. Tensile Requirements

10.1 *Bars and Specimens Machined From Components*— The bolting component material shall conform to the tensile property requirements prescribed in the product specification.

10.1.1 When the dimensions of the component material to be tested will permit, the tension test specimens shall be machined to the form and dimensions of the standard 2–in. [50–mm] gage length tension test specimen described in Test Methods and Definitions A370 when inch-pound units are specified or the standard length tension test specimens described in the applicable track of Test Methods A1058 if SI units are specified.

10.1.2 When the dimensions of the component material to be tested do not permit full size specimens, small size specimens meeting the requirements of Test Methods and Definitions A370 when inch-pound units are specified or the small size specimens described in the applicable track of Test Methods A1058 if SI units are specified shall be used.

10.2 *Testing of Full Size Components*—Full size testing shall be as described in Test Methods and Definitions A370 when inch-pound units are specified or as described in Test Methods F606/F606M when SI units are specified.

11. Proof Load and Cone Proof Requirements

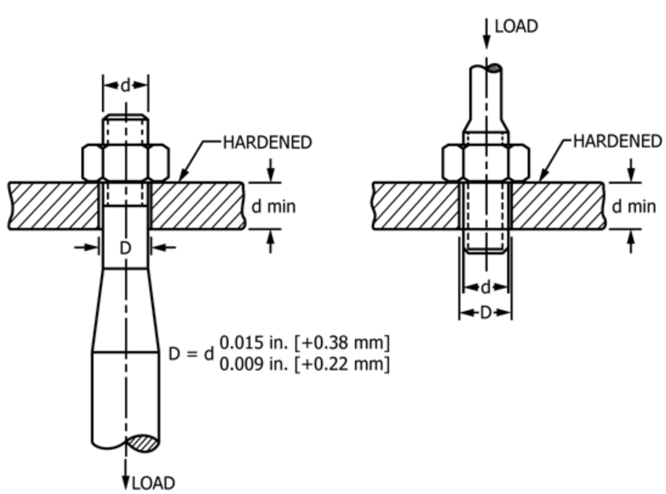
11.1 *Proof Load Test*—Nuts shall be assembled on a threaded mandrel or a test bolt as illustrated in Fig. 1(a) Tension Method or (b) Compression Method. The minimum proof load required by the product specification shall be applied using a free running cross head speed of 1.0 in. [25 mm] per minute maximum and shall be held for at least 10 s. The nut shall resist this load without stripping or rupture, and shall be removable by hand, without use of tooling, after the load is released. A wrench may be used to loosen the nut one-half turn maximum to start it in motion. The test shall be discarded if the threads of the mandrel or test bolt are damaged during the test.

11.1.1 Mandrels shall have a hardness of 45 HRC minimum with threads of the appropriate series and conforming to the requirements of ASME B1.1 Class 3A or ASME B1.13M tolerance 4H except that the maximum major diameter shall be the minimum major diameter plus 0.25 times the major diameter tolerance.

11.1.2 The test bolt shall have threads appropriate to the standard specified for the nut being tested and shall have a yield strength in excess of the specified proof load of the nut being tested.

11.1.3 The mandrel/tension method shall be used when arbitration is required.

11.2 *Cone Proof Load Test*—This test is performed when visible surface discontinuities become a matter of issue. The test uses a conical washer and threaded mandrel to determine the load-carrying ability of hardened steel nuts through 1½ in. [36 mm] in diameter assembled as shown in Fig. 2. The minimum cone proof load required by the product specification shall be applied using a free running cross head speed of 0.12



(a) Tension Method **(b)** Compression Method

FIG. 1 Proof Load Testing—Nuts

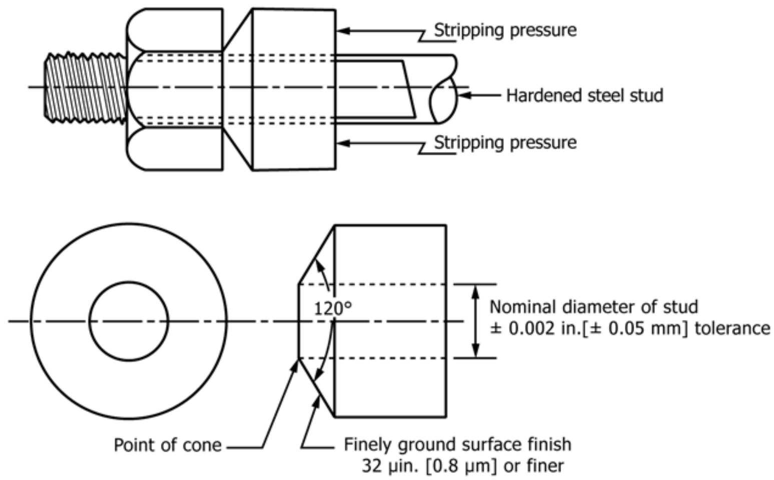


FIG. 2 Cone-Proof Test

in. [3 mm] per minute maximum and shall be held for at least 10 s. The nut shall support its specified cone proof load without stripping or rupture.

11.2.1 Mandrels shall conform to the requirements of 11.1.1.

11.2.2 Conical washers shall have a hardness of 57 HRC minimum and a hole diameter equivalent to the nominal diameter of the mandrel +0.002, -0.000 in. [+0.05 and -0.00 mm].

11.2.3 The contact point of the cone shall be sharp for nut sizes ½ in. [12 mm] or less. For sizes over ½ in. [12 mm], the point shall be flat and 0.015 ± 0.001 in. [0.38 + 0.03 mm] in width.

11.2.4 Cone proof loads may be determined as shown in Tables 1 and 2 when they are not specified in the product specification.

12. Impact Requirements

12.1 The material shall conform to the impact requirements prescribed in the product specification.

12.2 Sampling for impact testing shall conform to the product specification.

12.3 The impact test specimen shall have the form and dimensions shown in Fig. 10 of Test Methods and Definitions A370 for the Charpy V-notch specimen, Type A when inch-pound units are specified or to the test specimens described in the applicable track of Test Methods A1058 if SI units are specified. The longitudinal axis of the specimen shall be parallel to the direction of rolling or, in the case of forgings, to the longest axis of the component the test bar represents. The notch shall be located on the test specimen surface which most closely approaches a radial direction. The base of the notch shall be as nearly as practicable perpendicular to the longest axis of the component.

13. Workmanship, Finish, and Appearance

13.1 The bolting components shall conform to the dimensions, tolerances and finish as specified in the purchase order or in the individual product specification.

13.2 *Bars*—Bars shall meet the dimensional requirements of Specifications A29/A29M or A484/A484M as applicable.

13.3 *Bolts, Screws, Studs, and Stud Bolts*—Points shall be flat and chamfered or rounded at the option of the manufacturer. The length of the point on studs and stud bolts shall be not less than one nor more than two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be measured from first thread to first thread. Bolts, studs, and bolting material shall be capable of passing inspection in accordance with Specification F788.

13.3.1 *Hex Bolts*—Unless otherwise specified in the purchase order heads shall be in accordance with the dimensions of ASME B18.2.1 or B18.2.3.6M and the Heavy Hex screw series, should be used, except the maximum body diameter and radius of fillets may be the same as for the heavy hex bolt series. The body diameter and head fillet radius for sizes of heavy hex cap screws and bolts that are not shown in their respective tables in the ASME specifications may be that shown in the corresponding hex cap screw and bolt tables respectively. Unless otherwise specified on the purchase order Metric Heavy Hex Screws shall be in accordance with ASME B18.2.3.3M.

13.3.2 *Socket Heads*—Unless otherwise specified socket head screws shall be in accordance with ASME B18.3 or ISO 4762.

13.3.3 *Studs and Stud Bolts*—Unless otherwise specified in the purchase order, dimensions and tolerances for studs and stud bolts shall be in accordance with ASME B18.31.2.

13.4 *External Threads*—Threads shall either be formed after heat treatment or heat treatment shall be performed in atmosphere control furnaces.

13.4.1 *Thread Form*—Unless otherwise specified external threads shall be in accordance with ASME B1.1, Class 2A fit, or ASME B1.13M, Class 6g fit.

13.4.2 *Inch Series*—Sizes 1 in. and smaller in diameter shall be coarse thread series, and those 1⅛ in. and larger in diameter shall be eight pitch thread series, unless otherwise specified.

13.5 *Nuts*—Unless otherwise specified nuts shall be hexagonal in shape and the American National Standard Heavy Hex

TABLE 1 Cone Proof Load Using 120° Hardened Steel Cone—Inch[A]

Nominal Size, in.	Threads per inch	Stress Area, in.^{2}	Cone Proof Load, lbf Based on Proof Stress, psi, Shown in Column Header Below				
			120 000	130 000	135 000	150 000	175 000
¼	28	0.0364	4050	4375	4550	5050	5900
¼	20	0.0318	3525	3825	3975	4400	5150
5⁄16	24	0.0580	6300	6825	7100	7875	9200
5⁄16	18	0.0524	5700	6175	6400	7125	8300
⅜	24	0.0878	9350	10 125	10 525	11 700	13 625
⅜	16	0.0775	8250	8950	9300	10 300	12 050
7⁄16	20	0.1187	12 350	13 400	13 900	15 450	18 050
7⁄16	14	0.1063	11 100	12 000	12 450	13 850	16 150
½	20	0.1599	16 300	17 650	18 350	20 400	23 800
½	13	0.1419	14 500	15 700	16 300	18 100	21 100
9⁄16	18	0.203	20 200	21 900	22 800	25 300	29 500
9⁄16	12	0.182	18 200	19 700	20 400	22 700	26 500
⅝	18	0.256	25 000	27 000	28 100	31 200	36 400
⅝	11	0.226	22 000	23 900	24 800	27 500	32 100
¾	16	0.373	34 700	37 600	39 000	43 400	50 600
¾	10	0.334	31 000	33 600	35 000	38 800	45 200
⅞	14	0.509	45 000	48 800	50 600	56 400	65 600
⅞	9	0.462	40 800	44 200	46 000	51 200	59 600
1	12	0.663	55 600	60 400	62 600	69 600	81 200
1	8	0.606	51 000	55 200	57 200	63 600	74 200
1 ⅛	12	0.856	68 000	73 800	76 600	85 000	99 200
1 ⅛	8	0.790	62 800	68 000	70 600	78 600	91 600
1 ⅛	7	0.763	60 750	65 750	68 250	75 750	88 500
1 ¼	12	1.073	80 500	87 250	90 500	100 500	117 250
1 ¼	8	1.000	75 000	81 250	84 250	93 750	109 250
1 ¼	7	0.969	72 750	78 750	81 750	90 750	106 000
1 ⅜	12	1.315	92 750	100 500	104 250	116 000	135 250
1 ⅜	8	1.233	87 000	94 250	98 000	108 750	126 750
1 ⅜	6	1.155	81 500	88 250	91 500	101 750	118 750
1 ½	12	1.581	104 250	113 000	117 500	130 500	152 250
1 ½	8	1.492	98 500	106 750	110 750	123 000	143 500
1 ½	6	1.405	92 750	100 500	104 250	116 000	135 250

[A]Based upon the following equation (this equation should not be used for extrapolating values beyond the size ranges listed in this table) and rounded to nearest ½ ksi equivalent:

$$CPL = (1 - 0.30D) \times f \times As$$

where:

CPL = cone stripping proof load, lbf.,
D = nominal diameter of nut, in.,
f = minimum proof stress of nut, psi.,
As = tensile stress area of nut, in.^{2} = $0.7854\,[D - 0.9743/n]^2$, and
n = threads per inch.

Series shall be used. In addition nuts shall either be double chamfered or have a machined or forged washer face, at the option of the manufacturer, and shall conform to the angularity requirements of the applicable ASME specification. See ASME B18.2.2, B18.2.6, B18.2.4.6M, and B18.2.6M. Nuts shall be capable of passing inspection in accordance with Specification F812.

13.5.1 *Thread*—Unless otherwise specified threads in nuts shall be in accordance with ASME B1.1 Class 2B fit or B1.13M Class 6H fit, and shall be gauged in accordance with ASME B1.2 or B1.3M

13.5.2 *Inch Series*—Unless otherwise specified, nuts up to and including 1 in. in diameter shall be UNC Series Class 2B fit and nuts over 1 in. nominal size shall be 8 UN Series Class 2B fit.

13.6 If a scale-free bright finish is required, this finish shall be specified in the purchase order.

14. Decarburization / Carburization

14.1 *Depth*—The depth of decarburization (total + partial) and carburization shall be determined after completion of all heat treatment. Decarburization shall not exceed the limits shown in Test Method F2328 / F2328M Class 3, regardless of grade being tested. Carburization shall meet the requirements of Test Method F2328 / F2328M.

14.2 *Test Method*—Decarburization / carburization test shall be performed in accordance with Test Method F2328 / F2328M as applicable.

14.3 Decarburization / carburization test only applies to carbon and alloy steel bolting components.

15. Number of Tests

15.1 *Chemical Analysis*—One test per heat.

TABLE 2 Cone Proof Load Using 120° Hardened Steel Cone—Metric[A]

Nominal Size, mm	Thread Pitch	Stress Area, mm²	Cone Proof Load, kN Based on Proof Stress Shown in Column Header Below				
			825 MPa	895 MPa	930 MPa	1035 MPa	1205 MPa
M6	1	20.1	15.4	16.7	17.4	19.3	22.5
M8	1.25	36.6	27.3	29.6	30.8	34.3	39.9
M10	1.5	58.0	42.1	45.7	47.5	52.8	61.5
M12	1.75	84.3	59.5	64.5	67	74.5	87
M14	2	115	79	86	89.5	99.5	115.5
M16	2	157	104.5	113.5	117.5	131	152.5
M20	2.5	245	153	167	173	193	224
M22	2.5	303	184	200	208	231	269
M24	3	353	207	224	233	260	302
M27	3	459	256	278	289	322	374
M30	3.5	561	296	322	334	372	432
M36	4	817	382	416	432	480	558

[A]Based upon the following equation (this equation should not be used for extrapolating values beyond the size ranges listed in this table) and rounded to nearest 3.5 MPa equivalent:

$$CPL = (1 - 0.012D) \times f \times As \times 0.001$$

where:

CPL	=	Cone stripping proof load, kN,
D	=	Nominal diameter of nut, mm,
f	=	Minimum proof stress of nut, MPa,
As	=	Tensile stress area of nut, mm² = $0.7854\,[D - 0.9382P]^2$, and
P	=	Thread pitch, mm.

15.2 *Tension Tests, and, When Applicable, Impact Tests, Bar, Rod, or Wire or Components, or Both, Machined from Heat Treated Bar, Rod, or Wire*—Batch processing: One test per lot as defined in 3.1.10.1. Continuous processing as defined in 3.1.10.2: Not fewer than two tension and, when applicable, impact tests are required for each lot containing 20 000 lb [9000 kg] or less. Every additional 10 000 lb [4500 kg] or fraction thereof requires one additional test.

15.3 *Tension Tests, Components Produced as Defined in 8.6*—The number of machined specimens or full size bolting components tested shall be as follows:

Lot Size (pc)	Sample Size
50 and less	2
51 to 500	3
501 to 35 000	5
Over 35 000	8

15.4 *Decarburization / Carburization Test, Carbon and Alloy Steel, Components Produced as Defined in 8.6 and Studs Machined from Cold or Hot Rolled and Heat Treated Bar Whose Diameter Prior to Machining Threads is Within 0.06 in. [1.5 mm] in Diameter of the Maximum Thread Diameter*—One test per lot (see 3.1.10).

15.5 *Hardness Tests:*

15.5.1 *Hardness Tests, Bar, Rod, or Wire*—One test per lot.

15.5.2 *Hardness Tests, Components*—The minimum number of bolting components that must be hardness tested per lot, regardless of the manufacturing production process, shall conform to 15.3.

15.6 *Macroetch, Carbon and Alloy Steels Only*—One test per lot. A lot in this case is defined as a single diameter of a single heat or the largest diameter of a single heat.

15.7 *Impact Tests*—Three impact test specimens shall be made for each lot when impact testing is required by the product specification.

15.8 *Other Tests*—The number of tests shall be as specified by the purchaser or the individual product specification.

16. Retests and Rework

16.1 If the results of a mechanical test do not conform to specified requirements, the manufacturer may perform a double retest in compliance with the applicable governing test methods. If both retests pass, then the associated lot will be considered acceptable. In the case of impact testing, a single retest, consisting of three additional test specimens, may be performed. However, each individual impact value must be greater than the minimum specified average value.

16.2 A lot may undergo a full reheat treatment no more than twice. After reheat treatment, all required mechanical tests shall be performed.

16.3 *Rework*—Repair by welding is prohibited.

17. Inspection

17.1 The supplier shall afford the purchaser or inspector representing the purchaser all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification and the applicable product specification. Site inspection required by the purchaser shall not interfere unnecessarily with the supplier's operations.

17.2 Personnel performing the nondestructive examination shall be qualified and certified in accordance with a written procedure conforming to ASNT Recommended Practice No.

SNT-TC-1A (1988 or later) or another national standard that is acceptable to both the purchaser and the supplier.

18. Rejection and Rehearing

18.1 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed to between the supplier and the purchaser.

19. Certification

19.1 Certification shall include a statement that the material or parts, or both, were manufactured, sampled, tested, and inspected in accordance with the requirements of the individual product specification, including the specification number, year date of issue, grade symbol, and manufacturer's identification symbol. In addition, the certification shall include the results of all tests required by this specification, the product specification, and the purchase order. The supplier shall provide additional specific information as required by the product specification or purchase order.

19.2 A certificate printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall also conform to any existing EDI agreement between the purchaser and the supplier.

19.3 Notwithstanding the absence of a signature, the organization submitting either the EDI transmission or paper copies of certificates of test is responsible for the content of the report.

20. Product Marking

20.1 Bars shall be marked in accordance with Specifications A29/A29M or A484/A484M as applicable. Bolting materials, including threaded bar, furnished bundled and tagged, shall carry the grade symbol for the material and the manufacturer's identification symbol or name. Marking of individual bars is not required as long as the bars are bundled and tagged or boxed.

20.2 Bar coding is acceptable as a supplementary identification method. Coding should be consistent with AIAG B-5 02.00. If used on small items, the bar coding may be applied to the box or a substantially applied tag.

20.3 Grade and manufacturer's identification symbols shall be applied to one end of studs ⅜ in. [10 mm] in diameter and larger and to the heads of bolts and screws ¼ in. [6 mm] in diameter and larger. If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end of studs. Bolts and screws shall preferably be marked on top of the head. When necessary, bolts and screws may be marked on the side of the head provided the marking does not interfere with wrenchability or become damaged during tightening to the extent that legibility is lost. Products shall not be marked on the bearing surface or be marked in a way that alters the dimensions or geometric characteristics of the bearing surface.

20.4 Grade and manufacturer's identification symbols shall be applied to all nuts regardless of size.

20.5 Hollow forgings shall be marked with the heat number or heat symbol and grade.

20.6 When product is altered in a manner which changes specified requirements, it is the responsibility of the current certifying organization to ensure that the product marking is appropriately revised. This includes the removal of the name or symbol of the previous certifying organization.

20.7 For purposes of product marking and test reports, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of the specification.

20.8 *Dual Marking*—Product that meets all requirements of more than one grade within or between product specifications may be marked with both grade markings. The dual marking shall consist of the complete marking requirement for each grade, as required by the product specification, separated by a slash. For example, for Grade A193 B7 and A320 L7, the dual marking would be B7/L7.

21. Packaging, Package Marking and Loading for Shipment

21.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A700.

22. Keywords

22.1 austenitic stainless steel; bolts, steel; bolting components, steel; bolting materials; components, steel; nickel alloy bolting; nuts, steel; pressure vessel service; screws; stainless steel bolting; steel bars, alloy; steel bars, carbon; steel bars, stainless; steel bolting; studs; temperature service applications, high; temperature service applications, low; turbine materials; washers

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the purchase order or contract. The specified supplementary requirements shall be completed prior to shipment of the product.

S50. Product Marking

S50.1 Grade and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.

S51. Stress Relieving

S51.1 A stress relieving operation shall follow straightening after heat treatment. The minimum stress relieving temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

S52. Heat Analysis

S52.1 An analysis of each remelt ingot shall be made by the steel manufacturer to determine the percentages of those elements specified in the individual product specification. The chemical analysis thus determined shall conform to the requirements of the individual product specification.

S53. Sequential or Continuous Strand Casting

S53.1 When multiple heats of the same chemical composition range are sequentially strand cast, the heats shall be separated by an established procedure such that intermix material shall not be supplied.

S54. Bolting for Dynamic Service

S54.1 Bolting for dynamic service shall be examined for surface discontinuities and decarburization.

S54.2 *Surface Discontinuities:*

S54.2.1 The surface discontinuities shall conform to Specification F788 and the additional limitations in S54.2.2.

S54.2.2 Thread lap inspection shall be performed in accordance with Specification F788 Supplementary Requirement S50. The threads shall have no laps at the root, or on the flanks initiating or extending below the pitch line.

S54.2.3 Quench cracks of any depth, any length, or in any location are not permitted.

S54.2.4 Folds at the junction of the head and the shank are not permitted.

S54.3 *Decarburization:*

S54.3.1 Decarburization tests shall be conducted as follows, with the same number of tests as the tension test:

S54.3.2 Section the thread area longitudinally through the axis, and mount and polish the cut face in accordance with Practice E3. Use either optical or microhardness measurements for decarburization. In case of dispute, the microhardness method shall be used.

S54.3.3 For optical measurement, etch the metallographic section in 4 % Nital. Examine the surface of the etched sample under a microscope at 100× using a measuring eyepiece graduated in 0.001 in. [0.03 mm] increments, or on a ground glass screen or photomicrograph. There shall be no gross decarburization (clearly defined ferrite grains), and the depth of partial decarburization (light etching zone) anywhere below the pitch line shall be less than 5 % of the nominal thread height.

S54.3.4 For microhardness measurement, make hardness tests in accordance with Test Method E384 on unetched metallographic sections using either a DPH 136° indenter and a 200-gf load, or a Knoop indenter and a 200-gf load. Take measurements at the minor diameter on the thread crest bisector to determine the base metal hardness. On the same or an adjacent thread, take measurements within 0.003 in. [0.08 mm] of the flank surface at the pitch line, and 0.003 in. [0.08 mm] below the thread root. These two hardness readings shall be equal to or greater than the base metal hardness minus 30 DPH or KHN.

S55. Magnetic Particle Examination

S55.1 The wet fluorescent magnetic particle examination method shall be applied to 100 % of the lot in accordance with Practice E1444/E1444M. Acceptance criteria shall be in accordance with S57.

S56. Liquid Penetrant Examination

S56.1 The fluorescent liquid penetrant examination method shall be applied to 100 % of the lot in accordance with Practice E1417/E1417M. Acceptance criteria shall be in accordance with S57.

S57. Acceptance Criteria

S57.1 Only indications, which have a dimension greater than $\frac{1}{16}$ in., shall be considered relevant. A linear indication is one having a length greater than three times the width. A rounded indication is one of circular or elliptical shape with a length equal to or less than three times the width. All surfaces examined shall be free of the following:

S57.1.1 Relevant linear indications;

S57.1.2 Relevant rounded indications greater than $\frac{3}{16}$ in.; and,

S57.1.3 Four or more relevant rounded indications in a line separated by $\frac{1}{16}$ in. or less, edge to edge.

S58. Positive Material Identification Examination

S58.1 Bolting shall receive Positive Material Identification to ensure that the purchaser is receiving bolting of the correct material grade prior to shipment of the bolting. This examination is a method to assure that no material grade mix-up has happened during manufacturing and marking of bolting.

S58.2 Bolting shall receive a Positive Material Identification examination by Guide E1916.

S58.3 The quantity examined shall be 100 % of the bolting.

S58.4 All bolting that are not of the correct material grade shall be rejected.

S58.5 The method of bolting marking after examination shall be agreed upon between the manufacturer and purchaser.

S59. Pressure Equipment Directive—Mechanical Testing

S59.1 Charpy impact testing shall be done at the lowest scheduled operating temperature, but not higher than 20 °C [68 °F].

S59.2 The frequency of impact testing shall be the same as that specified in the product specification for the tension test, with three individual Charpy test specimens for each required tension test.

S59.3 The minimum individual energy for the Charpy impact test shall be 20 ft-lb [27 J].

S59.4 The minimum elongation in the tension test shall be measured on a gauge length of five times the diameter of the test specimen, and shall not be less than 14 %.

S59.5 Impact and tension test results shall be included in the product certification.

S60. Heat Treat Charts

S60.1 The supplier shall provide heat treat charts as a part of the order documentation.

S61. Hardness Testing

S61.1 Each piece of bolting shall be hardness tested and found to meet the requirements of the product specification or this standard, as applicable. A minimum sample consisting of 10 % of the pieces in each lot shall be tested using an indentation method in accordance with Test Methods and Definitions A370 when inch-pound units are specified or to the applicable track of Test Methods A1058 if SI units are specified. Each piece in the sample shall meet the hardness requirements. The balance of the lot may be tested using either the indentation method per Test Methods and Definitions A370 when inch-pound units are specified or to the applicable track of Test Methods A1058 if SI units are specified or electromagnetic sorting in accordance with Practice E566. If any piece in the sample is outside of the specified hardness requirements, then the lot shall be rejected and either reprocessed and resampled, or tested 100 % by indentation hardness methods.

S62. Ultrasonic Examination of Bolting in Sizes Greater than 2 in. [50 mm] in Cross Section

S62.1 All bolting with a major cross section greater than 2 in. [50 mm] shall be subjected to ultrasonic inspection (UT) prior to threading.

S62.2 Ultrasonic inspection shall be carried out using L-wave transducers in the radial direction.

S62.3 Search units shall not exceed 1 in.^{2} [645 mm^2] in area and shall have a nominal frequency of 2 or 2¼ MHz.

S62.4 Inspection sensitivity shall be established using a first back reflection set at 80 % of full screen height (FSH).

S62.5 Indications whose amplitude exceeds 20 % FSH and those which cause the back reflection signal amplitude to decrease to 40 % or less FSH are not acceptable.

S63. Phosphorus and Sulfur Maximums

S63.1 The phosphorus and sulfur content of carbon and low alloy steels shall be 0.025 % max.

S64. Product Inspection

S64.1 Sampling for dimensional, thread fit and visual inspection of product shall be performed in accordance with ASME B18.18 Category 2.

S65. Product Inspection

S65.1 Sampling for dimensional, thread fit and visual inspection of product shall be performed in accordance with ASME B18.18 Category 3.

S66. Marking for Lot Traceability

S66.1 In addition to the requirements stated in Section 20, bolting components (purchaser to designate whether bolts or nuts or other specific items apply) shall be individually hard marked with a traceability code that provides full traceability to the lot, with a lot as defined in 3.1.10 for fasteners. The traceability code shall be defined by the bolting manufacturer and shall be reported on the certification.

S67. Eddy Current Inspection

S67.1 Eddy current examination shall be applied to 100 % of the lot in accordance with a defined practice approved by the purchaser. Reject levels for linear indications shall be based on the alarm response from a surface notch with a maximum depth of 0.012 in. [0.030 mm] in a calibration bar.

S68. Ultrasonic Inspection

S68.1 Ultrasonic examination shall be applied to 100 % of the lot in accordance with a defined practice approved by the purchaser. Reject levels for linear indications shall be based on the alarm response from a surface notch with a maximum depth of 0.012 in. [0.030 mm] in a calibration bar.

S69. Sampling For Hardness Testing

S69.1 Finished components or blanks from each heat treatment charge shall be subjected to hardness testing. The number of samples tested shall meet the requirements of Guide F1470, Table 3, Sample Size B.

S70. Maximum Hardness for Carbon and Alloy Steel

S70.1 The maximum hardness of components shall not exceed 32 HRC [302 HBW].

S71. Passivation of Stainless Steel Bolting

S71.1 Stainless Steel Bolting components shall be passivated in accordance with Practice A380/A380M or Specification A967/A967M at the option of the manufacturer or shall be electropolished.

ANNEXES

(Mandatory Information)

A1. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in specifications referencing this Specification of General Requirements subject to the following conditions:

A1.1.1 Application for the addition of a new grade to a specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A1.1.5 The application shall state whether the new grade is covered by patent.

A2. CHANGES TO EXISTING GRADES

A2.1 When changes such as chemistry, heat treatment, or processing, or combinations thereof are proposed for grades in specifications under the purview of A01.22, it is the purview of the subcommittee to request additional data/tests. Testing required may include, but is not limited to, stress rupture, tensile, impact, and stress relaxation in order to validate that the changes have not adversely impacted those properties, even though the testing may not normally be required by the standard.

A3. REQUIREMENTS FOR THE INTRODUCTION OF MATERIALS FROM OTHER A01 OR B02.07 SPECIFICATIONS

A3.1 Wrought materials that are already covered by another A01 or B02.07 specification may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A3.1.1 Application for the addition of a grade that is already covered in another A01 or B02.07 specification shall be made to the chair of the subcommittee that has jurisdiction over the specification to which the addition is being proposed.

A3.1.2 The chemical requirements, the specified mechanical properties, and the heat treatment requirements of the grade being added shall be the same as those for the grade in the A01 or B02.07 specification in which the grade is presently covered.

A3.1.3 The application shall provide recommendations for all requirements appearing in the applicable specification.

A3.1.4 The application shall state whether or not the grade is covered by patent.

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SPECIFICATION FOR STEEL FORGINGS, AUSTENITIC, FOR PRESSURE AND HIGH-TEMPERATURE PARTS

SA-965/SA-965M

(23)

(Identical with ASTM Specification A965/A965M-21a.)

Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts

1. Scope

1.1 This specification covers austenitic stainless steel forgings for boilers, pressure vessels, high temperature parts, and associated equipment.

1.2 Supplementary requirements are provided for use when additional testing, inspection, or processing is required. In addition, supplementary requirements from Specification A788/A788M may be specified when appropriate.

1.3 This specification includes the austenitic steel forgings that were a part of Specification A336/A336M.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.5 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A336/A336M Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A745/A745M Practice for Ultrasonic Examination of Austenitic Steel Forgings

A788/A788M Specification for Steel Forgings, General Requirements

A1058 Test Methods for Mechanical Testing of Steel Products—Metric

E112 Test Methods for Determining Average Grain Size

2.2 *Other Standards:*

ASME Boiler and Pressure Vessel Code, including Section VIII Pressure Vessels and Section IX

A5.11/A5.11M Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding[4]

A5.14/A5.14M Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A788/A788M, the intended use should be stated if 5.1 is to be applicable.

3.2 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, the requirements of this specification shall prevail.

3.4 If the forgings are intended for use under the ASME Boiler and Pressure Vessel Code at temperatures exceeding 1000 °F [540 °C], then use Supplementary Requirement S7. Grain size requirements for service exceeding 1000 °F [540 °C] should be specified unless the required grade has the suffix "H."

4. Melting and Forging

4.1 In addition to the melting and forging requirements of Specification A788/A788M, which may include Supplementary Requirement S8, the following condition applies:

4.1.1 A sufficient discard shall be made to secure freedom from injurious pipe and undue segregation.

5. Machining

5.1 Forged pressure vessels for steam power service shall have the inner surface machined or ground. Unfired pressure vessels shall have the inner surfaces sufficiently free of scale to permit inspection.

5.2 When rough machining is performed, it may be done either before or after heat treatment.

6. Heat Treatment

6.1 Forgings shall be furnished in the solution treated condition. On completion of forging operations, the forgings shall be solution annealed and quenched in water, oil, or a polymer water solution. Direct quenching after completion of forging without subsequent reheating to the temperatures prescribed in 6.2 – 6.12 is not permissible.

6.2 For Grades F304H, F309H, F310H, F316H, F321H, F347H, and F348H, the minimum solution annealing temperature shall be 1925 °F [1050 °C].

6.3 Grade FXM-11 shall be solution annealed at a minimum of 1950 °F [1065 °C].

6.4 Grade F20 shall be solution annealed in the temperature range of 1700 °F to 1850 °F [925 °C to 1010 °C].

6.5 Grade F46 shall be solution annealed in the temperature range of 2010 °F to 2140 °F [1100 °C to 1170 °C].

6.6 Grade F62 shall be solution annealed at a minimum of 2025 °F [1107 °C].

6.7 Grade F904L shall be solution annealed in the temperature range of 1920 °F to 2100 °F [1050 °C to 1150 °C].

6.8 Grade F700 shall be solution annealed in the temperature range of 2025 °F to 2100 °F [1107 °C to 1150 °C].

6.9 Grades FNIC and F1925 shall be solution annealed in the temperature range of 1800 °F to 1900 °F [985 °C to 1040 °C].

6.10 Grades FNIC10 and FNIC11 shall be solution annealed in the temperature range of 2100 °F to 2150 °F [1150 °C to 1180 °C].

6.11 Grade F1925N shall be solution annealed at a minimum of 2150 °F [1180 °C].

6.12 The remaining grades in Table 1 shall be solution annealed at a minimum temperature of 1900 °F [1040 °C].

7. Chemical Composition

7.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A788/A788M shall comply with Table 1.

7.2 *Product Analysis*—The manufacturer shall use the product analysis provision of Specification A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat. The product analysis tolerances for carbon shall not apply, and the carbon requirements shall conform to Table 1.

7.3 Types (common names) and UNS designations follow:

Grade	Type	UNS Designation
F304	304	S30400
F304H	304H	S30409
F304L	304L	S30403
F304N	304N	S30451
F304LN	304LN	S30453
F309H	309H	S30909
F310	310	S31000
F310H	310H	S31009
F316	316	S31600
F316H	316H	S31609
F316L	316L	S31603
F316N	316N	S31651
F316LN	316LN	S31653
F70	...	S31730
F321	321	S32100
F321H	321H	S32109
F347	347	S34700
F347H	347H	S34709
F347LN	347LN	S34751
F348	348	S34800
F348H	348H	S34809
FXM-19	XM19	S20910
FXM-11	XM11	S21904
F20	Alloy 20	N08020
F46	...	S30600
F62	...	N08367
F904L	904L	N08904
F700	...	N08700
FNIC	NIC	N08800
FNIC10	NIC10	N08810
FNIC11	NIC11	N08811
F1925	1925	N08925
F1925N	1925N	N08926

8. Mechanical Properties

8.1 *Requirements*—The material shall conform to the requirements for mechanical properties prescribed in Table 2 or, if applicable, Supplementary Requirement S2. The largest obtainable tension test specimen as specified in Test Methods and Definitions A370 or Test Methods A1058 shall be used.

8.2 *Number of Tests*—The number and location of tests are based on the heat-treated weight of the forging(s) from the same heat, solution annealed in the same furnace charge.

8.2.1 For forgings weighing less than 5000 lb [2250 kg] as heat treated, one tension test shall be required on the basis of one test per heat in each heat treatment load. This test shall be taken from a prolongation of one of the forgings. Use of a

TABLE 1 Chemical Requirements[A]

		Element										
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Niobium	Nitrogen	Other
Grade	UNS Designation											
F304	S30400	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	...
F304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	...
F304L	S30403	0.030	2.00	0.045	0.030	1.00	8.0–12.0	18.0–20.0	...	...	...	...
F304N	S30451	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	0.10–0.16	...
F304LN	S30453	0.030	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	0.10–0.16	...
F309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	12.0–15.0	22.0–24.0	...	...	...	...
F310	S31000	0.15	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.00	...	...	...	...
F310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.00	...	...	...	...
F316	S31600	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F316L	S31603	0.035	2.00	0.040	0.030	1.00	10.0–15.0	16.0–18.0	2.00–3.00	...	...	...
F316N	S31651	0.08	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	...	0.10–0.16	...
F316LN	S31653	0.030	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	...	0.10–0.16	...
F70	S31730	0.030	2.00	0.040	0.010	1.00	15.0–16.5	17.0–19.0	3.0–4.0	...	0.045	Cu 4.0–5.0
F321	S32100	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	0.10	Ti 5×(C+N)–0.70
F321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	...	Ti 4×(C+N)–0.70
F347	S34700	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	10×C–1.10[B]	...	...
F347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	9.0-12.0	17.0–19.0	...	8×C-1.10	...	...
F347LN	S34751	0.005–0.020	2.00	0.045	0.030	1.00	9.0–13.0	17.0–19.0	...	0.20–0.50 15×C min	0.06–0.10	...
F348	S34800	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	10×C–1.10	...	Co 0.020, Ta 0.10
F348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	8×C–1.10	...	Co 0.020, Ta 0.10
FXM-19	S20910	0.06	4.0-6.0	0.045	0.030	1.00	11.5–13.5	20.5–23.5	1.50–3.00	0.10–0.30	0.20–0.40	V 0.10–0.30
FXM-11	S21904	0.04	8.0-10.0	0.045	0.030	1.00	5.5–7.5	19.0–21.5	...	...	0.15–0.40	...
F20	N08020	0.07	2.00	0.045	0.035	1.00	32.0–38.0	19.0–21.0	2.00–3.00	8×C min–1.00	...	Cu 3.0–4.0
F46	S30600	0.018	2.00	0.020	0.020	3.7-4.3	14.0–15.5	17.0-18.5	0.20	...	...	Cu 0.50
F62	N08367	0.030	2.00	0.040	0.030	1.00	23.5–25.5	20.0–22.0	6.0–7.0	...	0.18–0.25	...
F904L	N08904	0.020	2.00	0.040	0.030	1.00	23.0–28.0	19.0–23.0	4.0–5.0	...	0.10	Cu 1.00–2.00
F700	N08700	0.04	2.00	0.040	0.030	1.00	24.0–26.0	19.0–23.0	4.3–5.0	8×C min 0.40 max	...	Cu 0.50
FNIC	N08800	0.10	1.50	0.045	0.015	1.00	30.0–35.0	19.0–23.0	...	...	...	Ti 0.15–0.60 Al 0.15–0.60 Cu 0.75 Fe 39.5 min
FNIC10	N08810	0.05–0.10	1.50	0.045	0.015	1.00	30.0–35.0	19.0–23.0	...	...	...	Ti 0.15–0.60 Al 0.15–0.60 Cu 0.75 Fe 39.5 min
FNIC11	N08811	0.06–0.10	1.50	0.040	0.015	1.00	30.0–35.0	19.0–23.0	...	...	...	Ti 0.25–0.60[C] Al 0.25–0.60[C] Cu 0.75 Fe 39.5 min
F1925	N08925	0.020	1.00	0.045	0.030	0.50	24.0–26.0	19.0–21.0	6.0–7.0	...	0.10–0.20[D]	Cu 0.80–1.50
F1925N	N08926	0.020	2.00	0.030	0.010	0.50	24.0–26.0	19.0–21.0	6.0–7.0	...	0.15–0.25[D]	Cu 0.50–1.50

[A] Max. unless min or a range is indicated. Where ellipses (...) appear in this table, there is no requirement and the element need not be analyzed for or reported.
[B] Alternatively, tantalum may be substituted for part of the columbium as approved by the purchaser.
[C] Ti + Al shall be 0.85 % min: 1.20 % max.
[D] The method of analysis for nitrogen shall be a matter of agreement between purchaser and manufacturer.

separately forged test bar for the mechanical test specimens, instead of an integral prolongation, is acceptable for forgings weighing less than 5000 lb [2250 kg], provided that the heat-treated cross section of the test bar is not less than the maximum heat-treated cross section of the forgings it represents. The separately forged test bar shall be from the same heat as the forgings it represents and shall accompany the forgings during heat treatment.

8.2.2 When heat treatment is performed in continuous type furnaces equipped with recording pyrometers, such that complete heating records are available, a solution annealing charge may be considered as any continuous run not exceeding an 8 h period.

8.2.3 For forgings weighing over 5000 lb [2250 kg], as heat treated, one tension test shall be taken from a prolongation on each forging.

8.3 The longitudinal axis of the tension test specimen shall be parallel to the direction of major working of the forging, except when Supplementary Requirement S2 is specified. For

TABLE 2 Tensile Requirements

Austenitic Stainless Steel Grades	Tensile Strength, min ksi [MPa]	Yield Strength, 0.2 % Offset, min ksi [MPa]	Elongation in 2 in. or 50 mm, min %	Reduction of Area, min %
F304	70 [485]	30 [205]	30	45
F304H	70 [485]	30 [205]	30	45
F304L	66 [450]	25 [170]	30	45
F304N	80 [550]	35 [240]	25	45
F309H	70 [485]	30 [205]	30	45
F310	75 [515]	30 [205]	30	35
F310H	70 [485]	30 [205]	30	45
F316	70 [485]	30 [205]	30	45
F316H	70 [485]	30 [205]	30	45
F316L	65 [450]	25 [170]	30	45
F316N	80 [550]	35 [240]	25	45
F316LN	70 [485]	30 [205]	30	45
F70	70 [485]	25 [175]	35	50
F321	70 [485]	30 [205]	30	45
F321H	70 [485]	30 [205]	30	45
F347	70 [485]	30 [205]	30	45
F347H	70 [485]	30 [205]	30	45
F347LN	70 [485]	30 [205]	30	45
F348	70 [485]	30 [205]	30	45
F348H	70 [485]	30 [205]	30	45
FXM-19	100 [690]	55 [380]	30	50
FXM-11	90 [620]	50 [345]	40	50
F20	80 [550]	35 [240]	30	50
F46	78–100 [540–690]	32 [220]	40	50
F62	95 [655]	45 [310]	30	50
F904L	71 [490]	31 [215]	35	...
F700	80 [550]	35 [240]	30	...
FNIC	65n [450]	25 [170]	30	...
FNIC10	65n [450]	25 [170]	30	...
FNIC11	65n [450]	25 [170]	30	...
F1925	87 [600]	43 [295]	30	...
F1925N	94 [650]	43 [295]	35	...

upset disk forgings the longitudinal axis of the specimen shall be in either the tangential or radial direction.

8.3.1 The location of the longitudinal axis of the tension test specimen shall be located midway between the parallel surfaces of the test extension, if added to the periphery of disks, or midway between the center and surface of solid forgings. For hollow forgings, or those heat treated after boring, the specimen shall be located at midwall. For the special case of forgings that are heat treated solid, but are subsequently bored, the tension test specimen may be taken at the location of the minimum inside diameter after boring instead of the mid-radius position.

9. Grain Size

9.1 For Grades F304H, F316H, F309H, F310H, F321H, F347H, and F348H, the grain size of the forgings shall be ascertained according to Test Methods E112, after solution treatment. One sample shall be examined for each tensile specimen required in 8.2 and shall be taken from the tension test location. The grain size shall be number 6, or coarser, over at least 75 % of the surveyed area. For annealed Grades FNIC10 and FNIC11, the grain size shall be number 5 or coarser.

10. Repair Welding

10.1 Repair welding of forgings may be permitted but only at the option of the purchaser. Such repair welds shall be made in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

11. Marking

11.1 The marking requirements of Specification A788/A788M apply.

12. Test Reports

12.1 The certification requirements of Specification A788/A788M shall apply.

13. Keywords

13.1 austenitic stainless steel forgings; high temperature service; pressure containing parts; pressure vessel service

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Rough Turning and Boring

S1.1 The position of the rough turning and boring in the sequence of manufacturing operations shall be specified.

S2. Transverse Tension Test

S2.1 Instead of the test specimen orientation requirements in 8.3, the longitudinal axis of the test specimens shall be transverse to the direction of major working of the forging. The results shall conform with requirements of Table 2, with the exception of the ductility limits, which shall be as prescribed in Table S2.1.

S3. Hydrostatic Test

S3.1 A hydrostatic pressure test shall be applied. The details of the test, including its position in the sequence of manufacturing operations, shall be specified.

S4. Stabilization Heat Treatment

S4.1 When specified, Grades F347 and F321 shall receive stabilization treatment, which shall consist of holding the forging at 1500 to 1600 °F [815 to 870 °C], for not less than 2 h/in. of thickness and then cooling in the furnace or in still air.

S5. Marking

S5.1 Forgings shall be marked at a location indicated by the purchaser in the purchase order or drawing.

S6. Individual Forging

S6.1 Forgings, whether identical or not identical, shall be produced individually. They shall not be forged in multiple and separated prior to or after heat treatment.

S6.2 The shape and size of individual forgings shall be agreed between the manufacturer and the purchaser by means of a forging drawing or the purchase order.

S7. Grain Size Requirements for Service Exceeding 1000 °F [540 °C]

S7.1 For design metal temperatures above 1000 °F [540 °C], the forgings shall have a grain size of 7 or coarser as determined in accordance with Test Methods E112. The actual grain size shall be reported on the certificate of test.

S8. Ultrasonic Inspection

S8.1 An ultrasonic inspection of the machined forging shall be made in accordance with Practice A745/A745M to the quality acceptance level specified in the purchase order or contract.

TABLE S2.1 Ductility Limits

	Grade																						
	F304	F304H	F304L	F304N	F304LN	F309H	F310	F310H	F316	F316H	F316L	F316N	F316LN	F70	F321	F321H	F347	F347H	F347LN	F348	F348H	FXM19	FXM11	F46
Elongation in 2 in. or 50 mm, min, %	30	30	30	25	30	30	30	30	30	30	30	25	30	40	30	30	30	30	30	30	30	30	40	40
Reduction of area, min, %	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	37	35	35	35	35	35	40	40

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SPECIFICATION FOR STEEL INVESTMENT CASTINGS GENERAL REQUIREMENTS, FOR PRESSURE-CONTAINING PARTS

SA-985/SA-985M

(Identical with ASTM Specification A985/A985M-04a.)

SPECIFICATION FOR STEEL INVESTMENT CASTINGS GENERAL REQUIREMENTS, FOR PRESSURE-CONTAINING PARTS

SA-985/SA-985M

(Identical with ASTM Specification A 985/A 985M-04a.)

1. Scope

1.1 This specification covers a group of common requirements that are mandatory for steel castings produced by the investment casting process for pressure-containing parts under each of the following ASTM Specifications:

Title of Specification	ASTM Designation
Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service	A 216/A 216M
Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service	A 217/A 217M
Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts	A 351/A 351M
Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts Suitable for Low-Temperature Service	A 352/A 352M
Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High Temperature Service	A 389/A 389M
Steel Castings Suitable for Pressure Service	A 487/A 487M

1.2 This specification also covers a group of supplementary requirements, which may be applied to the above specifications as indicated therein. These requirements are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 When investment casting is ordered, the requirements of this specification shall take precedence over the individual material specification requirements.

1.4 The values stated in either inch-pound or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification. Inch-pound units are applicable for material ordered to Specification A 985 and SI units for material ordered to Specification A 985M.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 351/A 351M Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts

A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 389/A 389M Specification for Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 487/A 487M Specification for Steel Castings Suitable for Pressure Service

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 800/A 800M Practice for Steel Casting, Austentic Alloy, Estimating Ferrite Content Thereof
A 903/A 903M Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 991/A 991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 94 Guide for Radiographic Examination
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E 165 Test Method for Liquid Penetrant Examination
E 186 Reference Radiographs for Heavy-Walled (2 to 4½ in. (51 to 114 mm)) Steel Castings
E 192 Reference Radiographs for Investment Steel Castings of Aerospace Applications
E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
E 280 Reference Radiographs for Heavy-Walled (4½ to 12 in. (114 to 305 mm)) Steel Castings
E 340 Test Method for Macroetching Metals and Alloys
E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness
E 709 Guide for Magnetic Particle Examination

2.2 *ANSI Standard:*

B16.5 Steel Pipe Flanges and Flanged Fittings

2.3 *ASME Standard:*

ASME Boiler and Pressure Vessel Code, Section III, NB-2546

2.4 *Standards of the Manufacturer's Standardization Society of the Valve and Fitting Industry:*

MSS SP 53 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Dry Magnetic Particle Inspection Method)
MSS SP 54 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Radiographic Inspection Method)

2.5 *SAE Aerospace Recommended Practice:*

ARP 1341 Determining Decarburization and Carburization in Finished Parts of Carbon and Low-Alloy Steel

3. Terminology

3.1 *Definitions* — The definitions in Test Methods and Definitions A 370 and Terminology A 941 are applicable to this specification and those listed in 1.1.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *heat, n* — all the molten metal poured from a single furnace or all of the molten metal from two or more furnaces poured into a single ladle or casting prior to the replenishing of the furnace(s).

3.2.2 *investment casting, n* — a metal casting that is produced in a mold obtained by investing (surrounding) an expendable pattern with a ceramic slurry, which is allowed to solidify. The expendable pattern may consist of wax, plastic, or other material and is removed prior to filling the mold with liquid metal.

3.2.3 *master heat, n* — a single furnace charge of alloy that may be either poured directly into castings or into remelt alloy for individual melts.

3.2.4 *subheat, n* — a portion of master heat remelted with only minor additions for deoxidation for pouring into castings. Syn. melt, production heat.

4. Materials and Manufacture

4.1 *Melting Process* — Master heats shall be made by the electric furnace process with or without separate refining such as argon-oxygen-decarburization (AOD), vacuum-oxygen-degassing (VOD), vacuum-induction-melting (VIM), and so forth, unless otherwise specified in the individual specification or agreed upon between the customer and producer. Master heats may be used directly for producing castings or converted into ingot, bar, shot, or other suitable form, not including gates and risers from casting production, for later remelting as a subheat.

4.2 *Re-Melting Process* — Subheats shall be produced from master heat metal in suitable batch sizes by electric induction furnace, with or without atmosphere protection, such as vacuum or inert gas unless otherwise agreed upon between the customer and producer. Revert (gates, sprues, risers, and rejected castings) shall not be remelted except in master heats.

4.3 *Heat Treatment:*

4.3.1 Ferritic and martensitic steel shall be cooled after pouring to provide substantially complete transformation of austenite prior to heat treatment to enhance mechanical properties.

4.3.2 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A 991/A 991M.

4.3.2.1 When castings are heat treated at temperatures above 2000°F [1100°C], then the working zone shall have been established by a survey performed at not more than 25°F [15°C] below nor more than 200°F [110°C] above the minimum heat treatment temperature specified for the grade. If a minimum heat treatment temperature is not specified for the grade, then the survey temperature shall be not more than 50°F [30°C] below nor more than 175°F [100°C] above the furnace set point used.

4.3.2.2 The maximum variation in measured temperature as determined by the difference between the highest temperature and the lowest temperature shall be as agreed between the purchaser and producer except that during production heat treatment no portion of the furnace shall be below the minimum specified temperature nor above the maximum specified temperature for the grade being processed.

4.4 *Sampling:*

4.4.1 If castings are poured directly from one or more master heats, then the samples for chemical and other required testing also shall be poured directly from each of the master heats.

4.4.2 If castings are poured from a subheat, then the samples for chemical and other required testing also shall be poured from a subheat of that same master heat, but not necessarily from the same subheat as the castings. The subheat used for the test samples shall be produced using the same practices and additions as used for the castings.

4.4.3 Test specimens may be taken from castings or from coupons cast either integrally with the castings, in the same molds as the castings, or in separate molds.

4.4.4 Separately cast specimens for tension testing shall be cast in molds of the same type and material as those used for the castings, as shown in Figs. 1–4 and Table 2, except when Supplementary Requirement S26 is specified. The test coupon in Fig. 4 shall be employed only for austenitic alloy castings with cross sections less than 2½ in.

5. Chemical Composition

5.1 *Chemical Analysis* — Chemical analysis of materials covered by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Heat Analysis* — An analysis of samples obtained in accordance with 4.4 or Supplementary Requirement S27 as appropriate, shall be made by the manufacturer to determine the percentages of the elements specified for the grade being poured. When drillings are used, they shall be taken not less than $\frac{1}{16}$ in. [1.6 mm] beneath the surface. The chemical composition thus determined shall be reported to the purchaser, or his representative, and shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis* — A product analysis may be made by the purchaser from material representing each master heat, subheat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis shall be taken no closer than $\frac{1}{16}$ in. [1.6 mm] to a cast surface except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low-alloy steel castings may vary from the specified limits by the amounts shown in Table 1. The product analysis tolerances of Table 1 are not applicable as acceptance criteria for heat analysis by the casting manufacturer. When comparing product and heat analysis for other than carbon and low alloy steels, the reproducibility data R2, in Test Methods E 353 or E 354, as applicable, shall be taken into consideration.

5.4 *Unspecified Elements* — When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S1 may be specified.

NOTE 1 — All commercial metals contain small amounts of various elements in addition to those which are specified. It is neither practical nor necessary to specify limits for every unspecified element that might be present, despite the fact that the presence of many of these elements often is determined routinely by the producer.

5.5 The substitution of a grade or composition different from that specified by the purchaser is prohibited.

6. Mechanical Test Methods

6.1 All mechanical tests shall be conducted in accordance with Test Methods and Definitions A 370.

7. Tensile Requirements

7.1 Sampling for tension testing shall be in accordance with 4.4 or with Supplementary Requirement S28 as appropriate.

7.2 The coupon from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents.

7.3 If any specimen shows defective machining or develops flaws, it may be discarded and another substituted from the same heat.

7.4 To determine accordance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E 29 to the nearest 500 psi [51 MPa] for yield and tensile strength and to the nearest 1% for elongation and reduction of area.

8. Repair by Welding

8.1 Repair by welding shall be in accordance with the requirements of individual specifications using procedures and welders qualified in accordance with Practice A 488/A 488M.

9. Flanges

9.1 When a flange from a flanged casting is removed to make a weld-end casting, discontinuities may be observed that would not have been detrimental in a flanged casting. The disposition of the casting shall be subject to agreement between the purchaser and manufacturer.

10. Quality

10.1 The surface of the casting shall be free of adhering ceramic, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

10.2 The castings shall not be peened, plugged, or impregnated to stop leaks.

10.3 When additional inspection is desired, Supplementary Requirements S4, S5, S7, or S10 may be specified.

11. Hydrostatic Tests

11.1 Each casting shall be tested after machining to the hydrostatic shell test pressures prescribed in ANSI B16.5 for the applicable steel rating for which the casting is designed. The casting shall not show any leaks. Castings ordered for working pressures other than those in the standard ANSI ratings, or those listed for which test pressures are not specified by ANSI B16.5, shall be tested at a pressure agreed upon between the manufacturer and purchaser.

11.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. The foundry, however, is responsible for the satisfactory performance of the casting under the final test required in 11.1.

12. Workmanship, Finish, and Appearance

12.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. When the pattern is supplied by the purchaser or is produced using a die supplied by the purchaser, the dimensions of the casting shall be as predicated by the pattern or die, unless otherwise agreed upon.

12.2 Machined welding ends shall be suitably protected against damage during shipping.

13. Retests

13.1 If the results of the mechanical tests do not conform to the requirements specified, retests are permitted as outlined in Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat treated and retested. Testing after reheat treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.2), are the responsibility of the manufacturer.

15. Rejection and Rehearing

15.1 Any rejection based on test reports shall be reported to the manufacturer within 30 days from the receipt of the test reports by the purchaser.

15.2 Material that shows unacceptable discontinuities as determined by the acceptance standards specified in the order subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified within 30 days after discovery of the rejectable condition.

15.3 Samples that represent rejected material shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing with that time.

16. Certification

16.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year of issue) and was found to meet the requirements.

16.2 As applicable, the certification also shall include:

16.2.1 Material specification and grade,

16.2.2 Pattern or part number,

16.2.3 Master heat number or serial number traceable to the master heat number,

16.2.4 Chemical analysis results required by the specification and supplementary requirements specified in the purchase order,

16.2.5 Mechanical property results required by the specification and supplementary requirements specified in the purchase order,

16.2.6 Statement of satisfactory inspection, visual, and nondestructive testing specified in the purchase order,

16.2.7 Manufacturer's name, and

16.2.8 Additional purchase order requirements.

16.3 A signature is not required on the certification; however, the document shall identify clearly the organization submitting the certification. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

17. Product Marking

17.1 Castings shall be marked for material identification with the grade symbols (WCB, WC9, CF8M, and so forth). In addition, master heat numbers, or serial numbers that are traceable to master heat numbers, shall be marked on all pressure-containing casting individually weighing 50 lb [25 kg] or more. Pressure-containing castings weighing less than 50 lb [25 kg] shall be marked with either the master heat number or a lot number that will identify the casting as to the month in which it was poured. Marking shall be in such position as not to injure the usefulness of the casting.

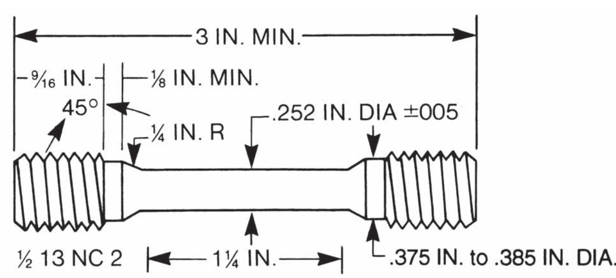
17.2 On casting for which impact property requirements are specified, stamped markings using low-stress stamps shall be on a raised pad when such pad can be made a part of the castings.

17.3 Castings shall be marked with the manufacturer's identification or symbols except when other provisions have been made between the manufacturer and purchaser.

18. Keywords

18.1 casting; investment casting; master heat; pressure containing; steel casting; subheat

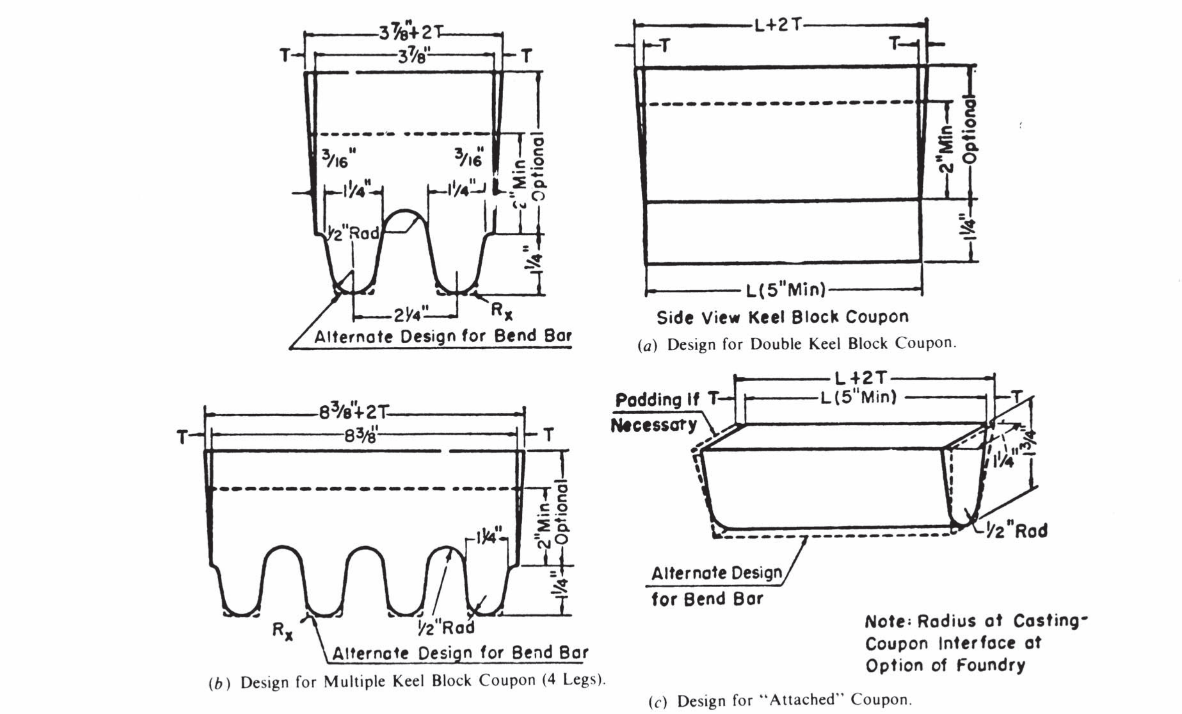
FIG. 1 DESIGN AND DIMENSIONS OF THE ICI TEST BAR



Metric Equivalents

in.	0.005	⅛	0.252	0.375	0.385	⁹⁄₁₆	1¼	3
[mm]	[0.15]	[3]	[6.40]	[9.50]	[9.75]	[15]	[30]	[75]

FIG. 2 TEST COUPONS FOR CASTINGS (SEE TABLE 2 FOR DETAILS OF DESIGN)



(a) Design for Double Keel Block Coupon.

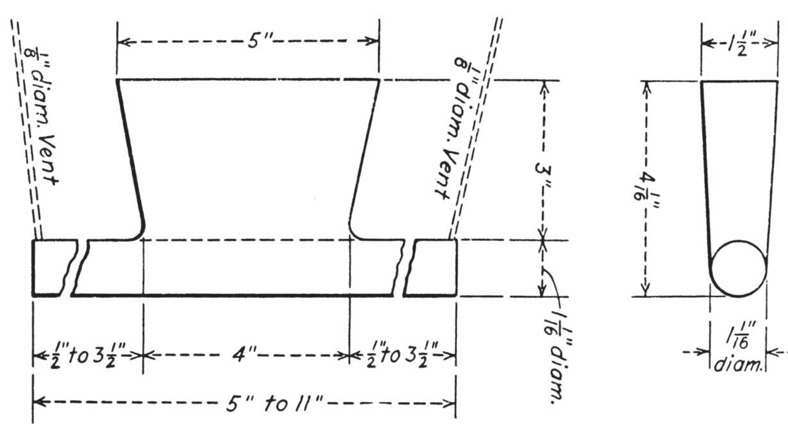
(b) Design for Multiple Keel Block Coupon (4 Legs).

(c) Design for "Attached" Coupon.

Metric Equivalents

in.	3/16	1/2	1 1/4	1 3/4	2	2 1/2	3 7/8	5	8 1/8
mm	4.8	13	32	45	51	57	98	127	213

FIG. 3 TEST BLOCK FOR TENSION TEST SPECIMEN

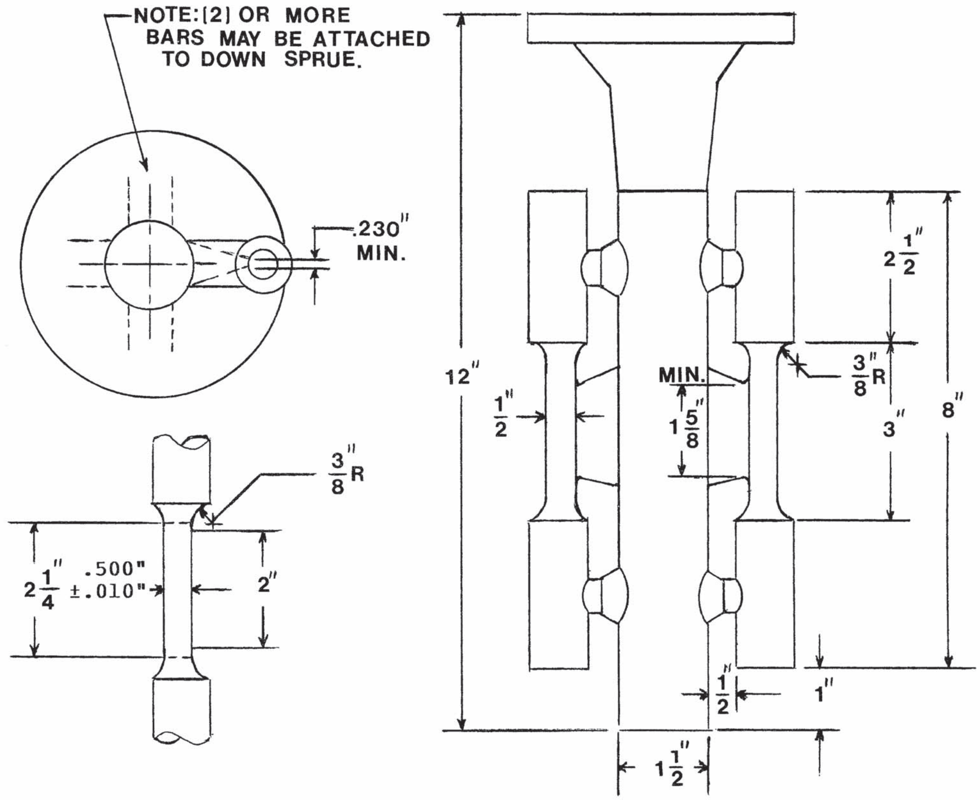


Metric Equivalents

in.	mm	in.	mm
1/8	3.2	3 1/2	88.9
1/2	12.7	4	101.6
1 1/16	27.0	4 1/16	103.2
1 1/2	38.1	5	127.0
3	76.2	11	279.4

NOTE—Pour through head; cover molten head with powdered charcoal, coke dust, etc., immediately after pouring, in order to keep head fluid as long as possible.

FIG. 4 CAST-TO-SHAPE TEST COUPON FOR TENSION TEST SPECIMEN



Metric Equivalents

in.	mm	in.	mm
0.010	0.254	1⅝	41.275
0.0230	5.842	2¼	57.15
⅜	9.525	2½	63.5
½	12.7	3	76.2
1	25.4	8	203.2
1½	38.1	12	304.8

NOTE—Coupons produced in this manner are suitable for austenitic alloys only. The mold may be preheated for pouring to produce a sound coupon.

TABLE 1
PRODUCT ANALYSIS TOLERANCES FOR CARBON AND LOW-ALLOY STEELS

Element	Range[A]	Tolerances[B,C] over max or under min, Limit, %
Carbon (C)	up to 0.65%	$0.03 \times \%\ C_L + 0.02$
	above 0.65%	0.04%
Manganese (Mn)	up to 1%	$0.08 \times \%\ Mn_L + 0.01$
	above 1%	0.09
Silicon (Si)	up to 0.60%	$0.22 \times \%\ Si_L - 0.01$
	above 0.60%	0.15%
Phosphorus (P)	all	$0.13 \times \%\ P_L + 0.005$
Sulfur (S)	all	$0.36 \times \%\ S_L + 0.001$
Nickel (Ni)	up to 2%	$0.10 \times \%\ Ni_L + 0.003$
	above 2%	0.25%
Chromium (Cr)	up to 2%	$0.07 \times \%\ Cr_L + 0.04$
	above 2%	0.18%
Molybdenum (Mo)	up to 0.6%	$0.04 \times \%\ Mo_L + 0.03$
	above 0.6%	0.06%
Vanadium (V)	up to 0.25%	$0.23 \times \%\ V_L + 0.004$
	above 0.25%	0.06%
Tungsten (W)	up to 0.10%	$0.08 \times \%\ W_L + 0.02$
	above 0.10%	0.02%
Copper (Cu)	up to 0.15%	$0.18 \times \%\ Cu_L + 0.02$
	above 0.15%	0.05%
Aluminum (Al)	up to 0.10%	$0.08 \times \%\ Al_L + 0.02$
	above 0.10%	0.03%

[A] The range denotes the composition limits up to which the tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript $_L$ for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit, if applicable, respectively. Examples of computing tolerances are presented in the footnote *C*.

[C] To compute the tolerances, consider the manganese limits 0.50 – 0.80% of Grade WC4 of Specification A 217/A 217M. According to Table 1, the maximum permissible deviation of a product analysis below the lower limit 0.50 is 0.05% = (0.08 × 0.50 + 0.01). The lowest acceptable product analysis of Grade WC4, therefore, is 0.45%. Similarly, the maximum permissible deviation above the upper limit of 0.80% is 0.074% = (0.08 × 0.08 + 0.01). The highest acceptable product analysis of Grade WC4, therefore, is 0.874. For Grade WCC of Specification A 216/A 216M, the maximum manganese content is 1.40% if the carbon content is 0.20%. In this case, the highest acceptable product analysis is 1.49 = (1.40 + 0.09).

TABLE 2
DETAILS OF TEST COUPON DESIGN FOR CASTING (SEE FIG. 2)

Leg Design [125 mm]		Riser Design	
1. *L* (length)	A 5 in. [125 mm] minimum length will be used. This length may be increased at the option of the foundry to accommodate additional test bars (see Note 1).	1. *L* (length)	The length of the riser at the base will be the same as the top length of the leg. The length of the riser at the top therefore depends on the amount of taper added to the riser.
2. End taper	Use of and size of end taper is at the option of the foundry.	2. Width	The width of the riser at the base of a multiple-leg coupon shall be *n,* $2\frac{1}{4}$ [57 mm] — $\frac{5}{8}$ [16 mm] where *n* equals the number of legs attached to the coupon. The width of the riser at the top is therefore dependent on the amount of taper added to the riser.
3. Height	$1\frac{1}{4}$ in. [32 mm]		
4. Width (at top)	$1\frac{1}{4}$ in. [32 mm] (see Note 1).		
5. Radius (at bottom)	$\frac{1}{2}$ in. [13 mm], max		
6. Spacing between legs	A $\frac{1}{2}$ in. [13 mm] radius will be used between the legs.		
7. Location of test bars	The tensile, bend, and impact bars will be taken from the lower portion of the leg (see Note 2).	3. *T* (riser taper)	Use of and size is at the option of the foundry.
8. Number of legs	The number of legs attached to the coupon is at the option of the foundry providing they are equispaced according to item 6.	4. Height	The minimum height of the riser shall be 2 in. [51 mm]. The maximum height is at the option of the foundry for the following reasons: (*a*) Many risers are cast open, (*b*) different compositions may require variation in risering for soundness, (*c*) different pouring temperatures may require variation in risering for soundness.
9. R_s	Radius from 0 to approximately $\frac{1}{16}$ in. [2 mm].		

NOTE 1 — *Test Coupons for Large and Heavy Steel Castings:* The test coupons in Fig. 2 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired.

NOTE 2 — *Bend Bar:* If a bend bar is required, an alternate design (as shown by dotted lines in Fig. 2) is indicated.

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser and when allowed by and listed in the individual specifications. They shall not apply unless specified in the order, in which event the specified tests shall be made by the manufacturer before shipment of the castings.

S1. Unspecified Elements

S1.1 Limits may be established for elements not specified for the grade ordered by agreement between the manufacturer and purchaser. The results of the analysis for the agreed upon elements shall be reported.

S2. Destruction Tests

S2.1 Purchaser may select representative castings from each heat and cut up and etch, or otherwise prepare, the sections for examination for internal defects. Should injurious defects be found that evidence unsound steel or faulty foundry technique, all of the castings made from that particular pattern, heat, and heat treatment charge may be rejected. All other rejected castings, including those cut up, shall be replaced by the manufacturer without charge.

S3. Bend Test

S3.1 One bend test shall be made from a test coupon from each master heat in accordance with Test Methods and Definitions A 370, and shall be machined to 1 by $\frac{1}{2}$ in. [25 by 13 mm] section with corners rounded to a radius not over $\frac{1}{16}$ in. [1.6 mm].

S3.2 The specimen shall withstand being bent longitudinally at room temperature through an angle of 90° about a pin, the diameter of which shall be the specimen thickness for carbon steels, and 1 in. [25 mm] for other steels. The specimen shall show no cracks on the outside of the bent portion of the specimen.

S3.3 Bend test specimens may be cut from heat-treated castings instead of from test bars when agreed upon between manufacturer and purchaser.

S3.4 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

S4. Magnetic Particle Inspection

S4.1 Castings shall be examined for surface and near-surface discontinuities by magnetic particle inspection. The examination shall be in accordance with Guide E 709, and types and degrees of discontinuities considered shall be judged by the Reference Photographs E 125. Extent of examination, time of examination, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. Specification, which may be used as a basis for such agreement, are Specifications A 903/A 903M and MSS SP 53.

S4.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S5. Radiographic Inspection

S5.1 Castings shall be examined for internal defects by means of X rays or gamma rays. The procedure shall be in accordance with Guide E 94 and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 186, E 192, E 280, or E 446. Extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification that may be used as a basis for such agreement is MSS SP 54.

S5.2 Radiographic examination of castings may be performed before or after any heat treatment.

S5.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S6. Liquid Penetrant Inspection

S6.1 Castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The examination shall be in accordance with Test Method E 165. Areas to be inspected, time of inspection, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification, which may be used as a basis for such agreement, is A 903/A 903M.

S6.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S7. Ultrasonic Inspection

S7.1 Castings shall be examined for internal defects by means of ultrasonic inspection. The inspection procedure shall be in accordance with Practice A 609/A 609M.

Extent of examination methods of testing and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S7.2 Ultrasonic examination of casting of carbon and low-alloy steels shall be performed after at least one heat treatment above the transformation temperature range but need not be repeated after subsequent heat treatment.

S7.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S8. Charpy Impact Test

S8.1 Charpy impact test properties shall be determined on each master heat from a set of three Charpy V-notch specimens made from a test coupon in accordance with Test Methods and Definitions A 370, and tested at a test temperature agreed upon by the manufacturer and purchaser. The sampling requirements shall be agreed upon between the manufacturer and purchaser (see 4.4). The acceptance requirements shall be energy absorbed, lateral expansion, percent shear area or any combination thereof, and shall be agreed upon by the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S8.2 *Absorbed Energy* — Average energy value of three specimens shall not be less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S8.3 *Lateral Expansion* — Lateral expansion value shall be agreed upon by the manufacturer and purchaser.

S8.4 *Percent Shear Area* — Percent shear area shall be agreed upon by the manufacturer and purchaser.

S9. Drop Weight Tests

S9.1 Drop weight test properties shall be determined from each heat by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Methods E 208. The crack starter weld shall be deposited on the surface of the specimen that was nearest to the casting surface. Each test shall consist of at least two specimens tested at a temperature agreed upon by the manufacturer and purchaser. Each specimen shall exhibit "no break" performance.

S10. Examination of Weld Preparation

S10.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing magnetic particle or liquid penetrant examination shall be in accordance with either Guide E 709 or Test Method E 165. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage of Reference Photographs E 125, of Degree 2 in sections up to 2 in. [50 mm] thick, and of Degree 3 in sections over 2 in. [50 mm] thick shall be acceptable.

S11. Prior Approval of Major Weld Repairs

S11.1 Major weld repairs shall be subject to the prior approval of the purchaser.

S12. Hardness Test

S12.1 A hardness test shall be made in accordance with Test Methods and Definitions A 370. The test location and the hardness requirements shall be agreed upon between the manufacturer and the purchaser.

S14. Tension Test From Each Heat and Heat Treatment Charge

S14.1 One tension test shall be made for each master heat and heat-treatment charge combination.

S15. Quench and Temper Heat Treatment

S15.1 The castings shall be quenched and tempered. Castings so treated shall be marked QT.

S17. Tension Test From Castings

S17.1 In addition to the tensile test required in Section 6, test material shall be cut from heat treated castings. The mechanical properties and location for the test material shall be agreed upon by the manufacturer and purchaser.

S20. Weld Repair Charts

S20.1 Weld repairs made to correct leakage on hydrostatic testing, weld repairs for which the depth of the cavity required for welding exceeds 20% of the actual wall thickness or 1 in. [25 mm], whichever is smaller, or weld repairs for which the area of the cavity required for welding exceeds approximately 10 in.^{2} [65 mm^2] shall be documented.

S20.2 Weld repairs requiring documentation shall be documented on sketches or photographs, or both. The sketches or photographs shall show the location and major dimensions of cavities prepared for weld repair. The weld repair documentation shall be submitted to the purchaser at the completion of the order.

S21. Heat-Treatment Furnace Record

S21.1 A heat-treatment chart showing time and temperature shall be prepared and be available for inspection by the purchaser.

S22. Heat Treatment

S22.1 Test specimens shall be heat treated together with the castings they represent. Heat-treated specimens shall be tested and shall meet the tensile and impact properties specified.

S22.2 The remaining test specimens from Supplementary Requirement S22.1 representing the casting shall be treated thermally after the final (foundry) heat treatment to simulate heat treatments below the transformation temperature, which the casting may receive during fabrication, and then tested for mechanical properties. Time, temperature, and cooling rate shall be as stated in the order. In the case of postweld heat treatment, the total time at temperature or temperatures for the test material shall be at least 80% of the total time at temperature or temperatures during actual postweld heat treatment of the fabrication of which the casting or castings are a part. The total time at temperature or temperatures for the test material may be performed in a single cycle. When this Supplementary Requirement is specified, the welding qualification test metal must be processed in the same manner.

S23. Macroetch Test

S23.1 Apply Supplementary Requirement S1 for the spectrographic determination and reporting of the total residual aluminum content of all heats of ferritic and martensitic steels subjected to this macroetch test.

S23.2 When the heat analysis indicates a total residual aluminum content in excess of 0.08%, the manufacturer shall etch a cross section of the casting with the heaviest section for which this supplementary requirement is invoked, or a coupon attached to that heaviest section or an area directly under a riser (see Note S23.1). Cross sections, from a separately cast test block from the same heat and a thickness representative of the heaviest section of castings purchased under this supplementary requirement, also may be used for macroetch testing. The etching shall be performed on the selected section after its heat treatment, that is, after annealing, normalizing, or quenching and tempering following the initial cooling of the steel below the transformation range.

NOTE S23.1 — High-strength martensitic castings, in particular, may be damaged beyond use if the etch is applied directly to the casting.

S23.3 The preparation of the surface and the macroetching procedure with solution No. 1 (1:1 HCl) of Table 5 in Test Method E 340 shall be followed. The resulting etched surface shall be compared and rated with the reference photographs in Fig. S23.1 depicting ten levels of severity of intergranular network structures indicative of the presence of aluminum nitride, or other constituents prone toward precipitating at grain boundaries during solidification and subsequent cooling. Table S23.1 relates the severity levels shown in these photographs with specific delineation widths and percent of boundary outlining in the etched structures.

S23.4 Castings represented by etched structures exhibiting a network rating in excess of Severity Level 4 shall be considered unacceptable until further evaluations are completed. The acceptability of individual castings may be determined by etching sections of each casting to ascertain the network severity level. Disposition of unacceptable castings shall be a matter of agreement between the manufacturer and purchaser. Those castings exhibiting etched severity levels greater than four may be further evaluated by any of the following agreed upon methods.

S23.4.1 Fracture testing to determine the amount of "rock candy" structure.

S23.4.2 Mechanical testing (bend, tensile, and so forth) to determine the ductility characteristics.

S23.4.3 Weld testing to determine crack susceptibility in the heat-affected zone of a circular groove welded with cellulose coated electrodes.

S23.5 Alternatively, by agreement, it is permissible to subject castings from an unacceptable heat to a high temperature solution treatment prior to the normal production heat-treatment and subsequently macroetch test each casting.

S24. Specified Ferrite Content Range

S24.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the chemical composition procedure of Practice A 800/A 800M, shall be in accordance with the specified ferrite content range.

S24.2 The specified ferrite content range shall be as agreed upon between the manufacturer and the purchaser. The minimum specified ferrite content range shall be 10% with the minimum ferrite content being no lower than the percent necessary to achieve the minimum mechanical properties required for the alloy.

S24.3 Should the purchaser wish to have the ferrite content determined by either magnetic response or metallographic methods, the purchaser should impose Supplementary Requirement S1 or S2 of Practice A 800/A 800M.

S25. Heat-Treatment Certification

S25.1 Heat-treatment temperature and cycle times shall be shown on the certification report.

S26. Alternative Tension Test Coupons and Specimen Locations for Castings (In-Lieu of Test Bars Poured from Special Blocks)

S26.1 Test blocks may be cast integrally with the castings or as separate blocks. Test blocks shall be heat treated together with the castings they represent.

S26.2 The casting thickness, *T*, is the maximum thickness of the pressure containing wall of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension, *T*, is for the casting.

S26.3 One of the following shall apply:

S26.3.1 The longitudinal centerline of the test specimen shall be taken at least $\frac{1}{4}T$ from the *T* dimension surface and all of the gage length must be at least 1*T* from any other heat-treated surface, exclusive of the surface opposite the *T* dimension surface (see Fig. S26.1 (a)). For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least $\frac{1}{4}T$ from the outside or inside and all of the gage length must be at least *T* from the as-heat treated end (see Fig. S26.1 (b)).

S26.3.2 For ferritic and martensitic castings, partial severing of test blocks prior to final heat treatment is permitted.

S26.3.3 Where separately cast test coupons are used, the dimensions shall not be less than 3*T* by 3*T* by *T* and each specimen shall meet the requirements of S26.3.1, except that when *T* exceeds 5 in. [125 mm], the dimension may be 15 by 15 by 5 in. [375 by 375 by 125 mm], by agreement between the manufacturer and the purchaser. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents (see Fig. S26.2).

S26.3.4 When agreed upon between the manufacturer and the purchaser, castings that are cast or machined to essentially the finished configuration prior to heat treatment, shall have test specimens removed from a prolongation or other stock on the casting at a location below the nearest heat-treated surface indicated on the order. The specimen location shall be at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high-tensile stress surface will be from the nearest heat-treated surface and a minimum of twice this distance from a second heat-treated surface, except that the test specimens shall be no nearer than $\frac{3}{4}$ in. [19 mm] to a heat-treated surface and $1\frac{1}{2}$ in. [33 mm] from a second heat-treated surface (see Fig. S26.3).

S26.3.5 Where specimens are to be removed from the body of quenched and tempered castings, either the requirements of S26.3.1 shall be met or a steel thermal buffer pad or thermal insulation or other thermal barriers shall be used during heat treatment. Steel thermal buffer pads shall be a minimum of *T* by *T* by 3*T* in length and shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface. Test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of $\frac{1}{2}$ in. [13 mm] from the buffered surface and $\frac{1}{4}T$ from other heat-treated surfaces (see Fig. S26.4). When thermal insulation is used, it shall be applied adjacent to the casting surface where the test specimens are to be removed. The producer shall demonstrate that the cooling rate of the test specimen location is no faster than that of specimens taken by the method described in S26.3.1.

S27. Increased Testing Frequency—Chemical Analysis

S27.1 Frequency of chemical analysis shall be as agreed upon between the purchaser and manufacturer.

S28. Increased Testing Frequency—Tensile Testing

S28.1 Frequency of tension tests shall be as agreed upon between the purchaser and manufacturer.

S29. Decarburization

S29.1 A representative casting or coupon shall be evaluated for total or complete decarburization, or both, in accordance with ARP 1341.

S29.2 The basis for acceptance shall be agreed upon between the purchaser and manufacturer. An example of an acceptance specification is zero total decarburization and no more than 0.020 in. partial decarburization.

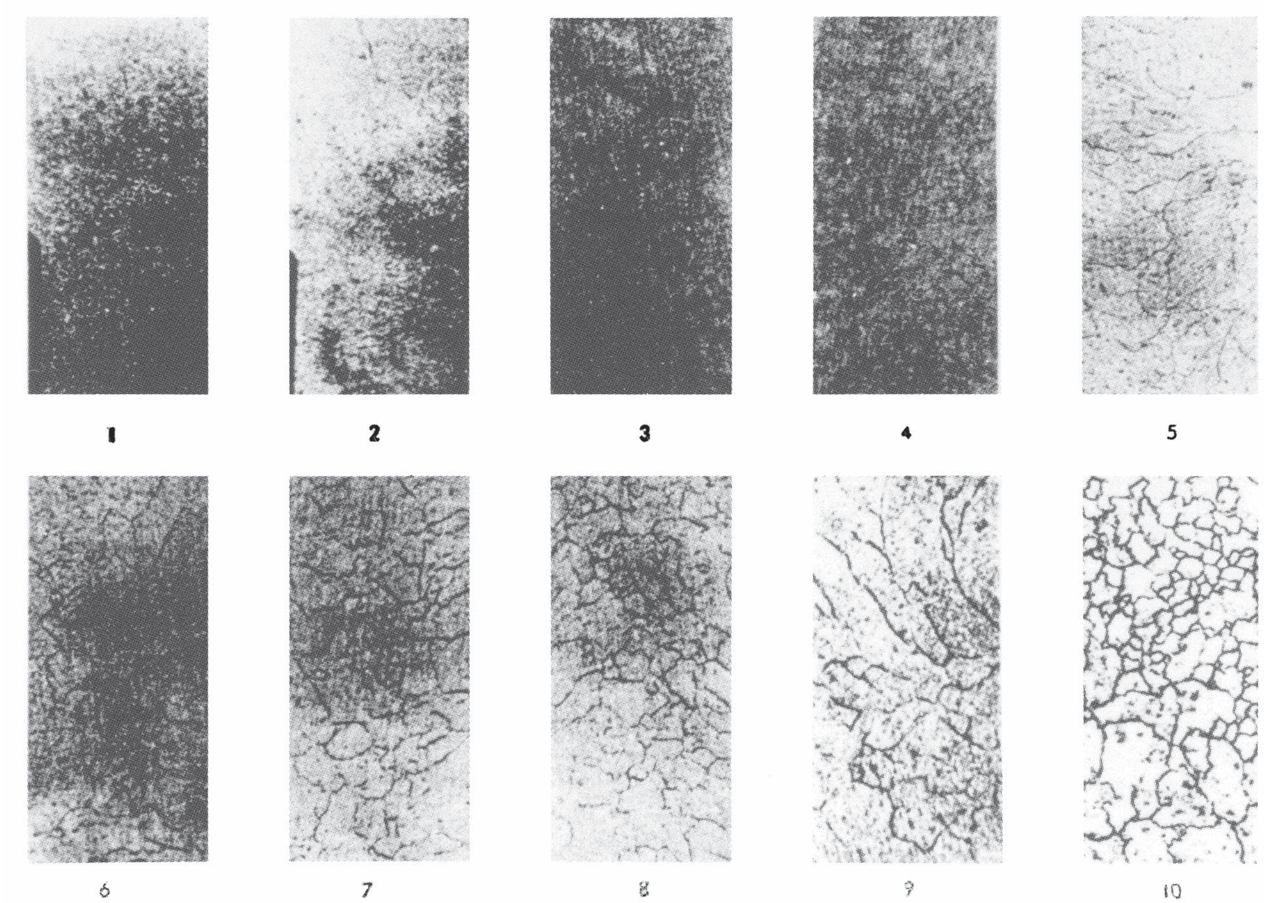
S30. Metallurgical Cleanliness

S30.1 After polishing, each casting shall be visually inspected for nonmetallic inclusions and porosity.

S30.2 The details of the method for inspection and the basis for acceptance shall be agreed upon between the purchaser and manufacturer.

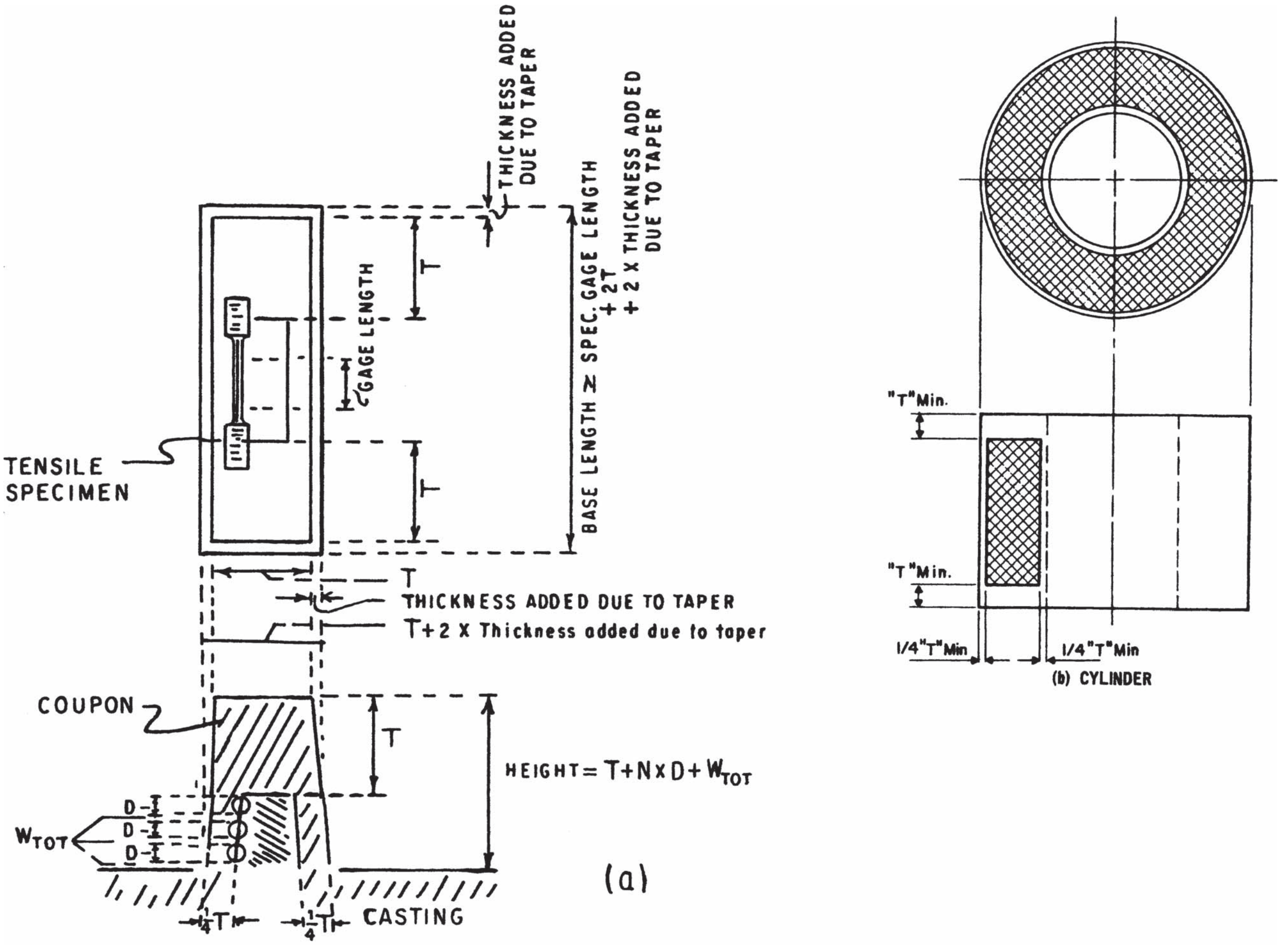
S30.3 It is realized that the foundry may be unable to perform the inspection for metallurgical cleanliness prior to shipment, or that the purchaser may wish to defer inspection until after additional work or machining has been performed on the casting. The foundry, however, is responsible for the satisfactory performance of the castings under the final inspection required in S30.1.

FIG. S23.1 REFERENCE PHOTOGRAPHS OF MACROETCHED CAST STEEL



NOTE—The 10 levels of severity of intergranular network structures shown are indicative of the presence of aluminum nitride precipitation in the primary austenitic grain boundaries.

FIG. S26.1 SPECIMEN FROM CASTING



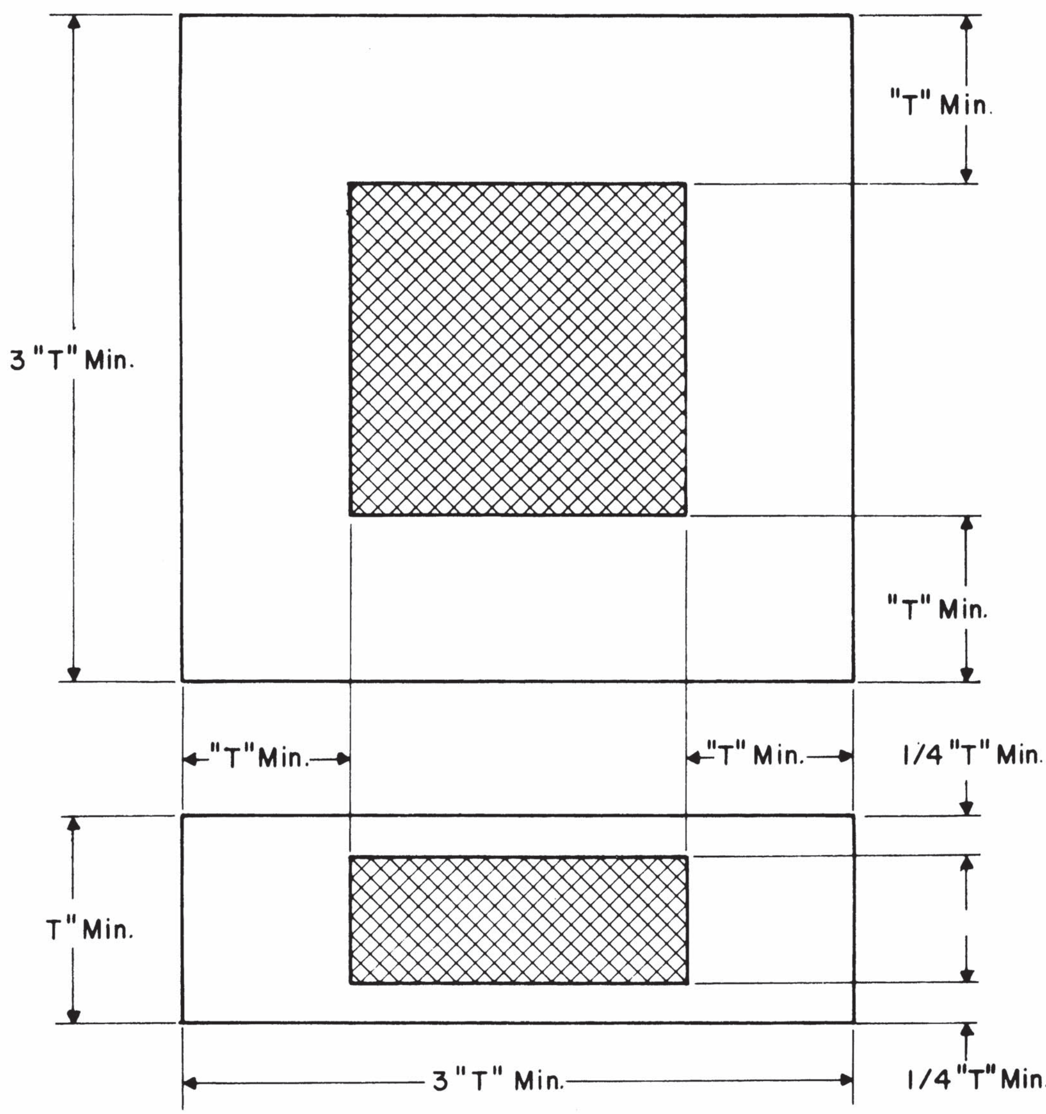
Minimum length of the base — Specimen gage length + 2*x*T + 2*x* the thickness due to the taper.
Minimum width of the base — T + 2*x* the thickness added due to the taper.
Minimum height — $T + NxD + W_{tot}$.

The taper is to be selected by the producer for ease of drawing the pattern from the mold.
where:

N = number of specimens to be cut from one side of the coupon,
D = diameter of the specimens, and
W_{tot} = total width of metal required to remove the coupon from the casting, and to machine specimens from the coupon.

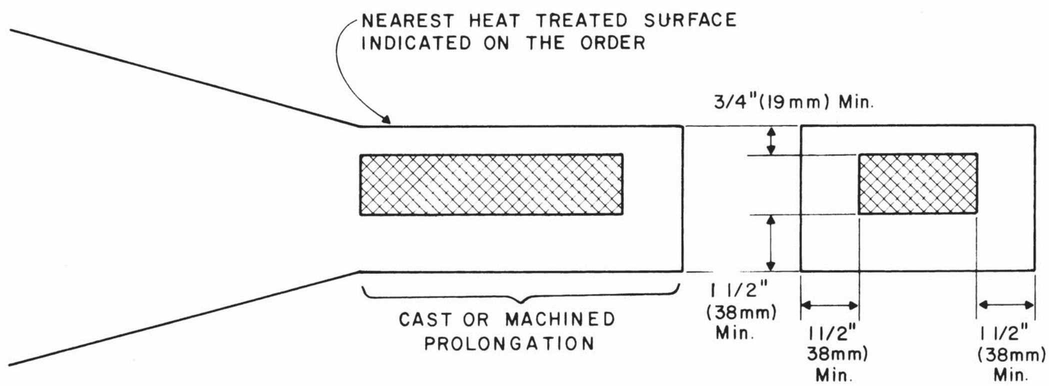
NOTE—Longitudinal axis and gage length of test specimen must be within shaded zone.

FIG. S26.2 SEPARATELY CAST BLOCK



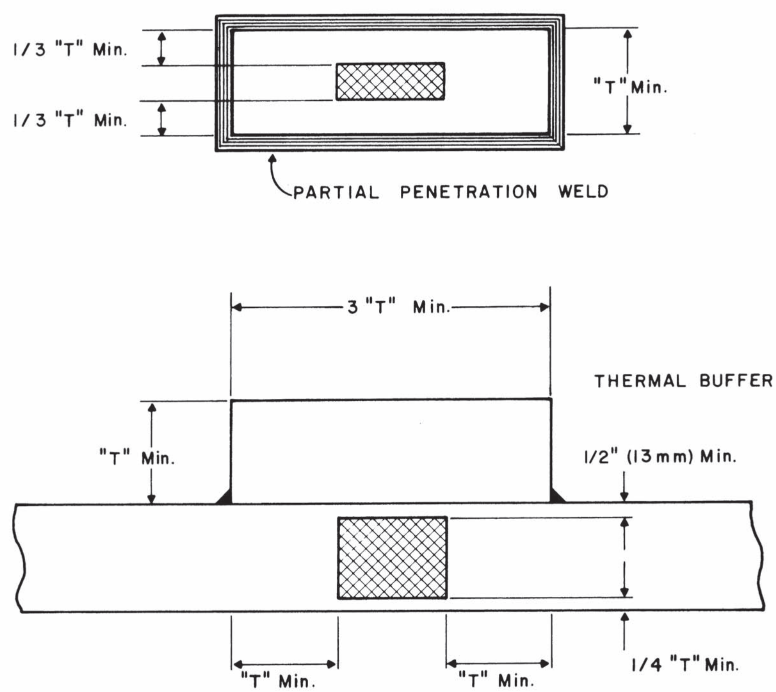
NOTE — Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.3 PROLONGATION TEST SPECIMEN



NOTE — Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.4 THERMAL BUFFER PADS



NOTE — Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

TABLE S23.1
DESCRIPTIVE DATA APPLICABLE TO NETWORK STRUCTURES SHOWN IN FIG. S23.1

Rating	Delineation Width, in.	Boundary Outline, %
1	Fine–0.001	20
2	Fine–0.001	40
3	Fine–0.001	60
4	Fine–0.002	80
5	Fine–0.002	100
6	Medium–0.005	100
7	Heavy–0.010	100
8	0.020	100
9	$\frac{1}{32}$	100
10	$\frac{1}{16}$	100

NOTE 1 — These ratings are based on the physical width and continuity of the precipitate pattern developed by the acid etchant on the primary austenitic grain boundaries of the cast steel. Supplementary testing is normally conducted to determine the final disposition of castings with ratings of 5 or greater.

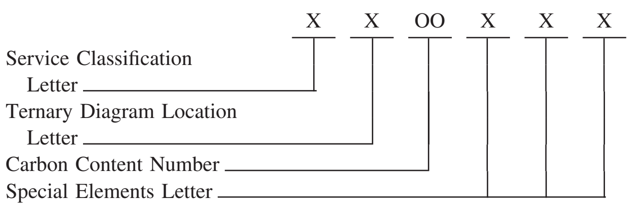
APPENDIX

(Nonmandatory Information)

X1. ALLOY DESIGNATIONS FOR CAST STAINLESS STEELS

X1.1 Cast stainless steels usually are specified on the basis of composition using the alloys designation system established by the Alloy Casting Institute (ACI). The ACI designations, for example, CF8M, have been adopted by ASTM and are preferred for cast alloys over the designations used by the American Iron and Steel Institute for similar wrought steels.

X1.2 This nomenclature system has served successfully to accommodate changes in old alloys and to designate new ones.



X1.2.1 *Service Classification Letter* — The first letter of the cast stainless steel designation system identifies the intended service application of the alloy. The letter *C* indicates corrosion-resistant service, and the letter *H* indicates the heat-resistant service at and above 1200°F [650°C].

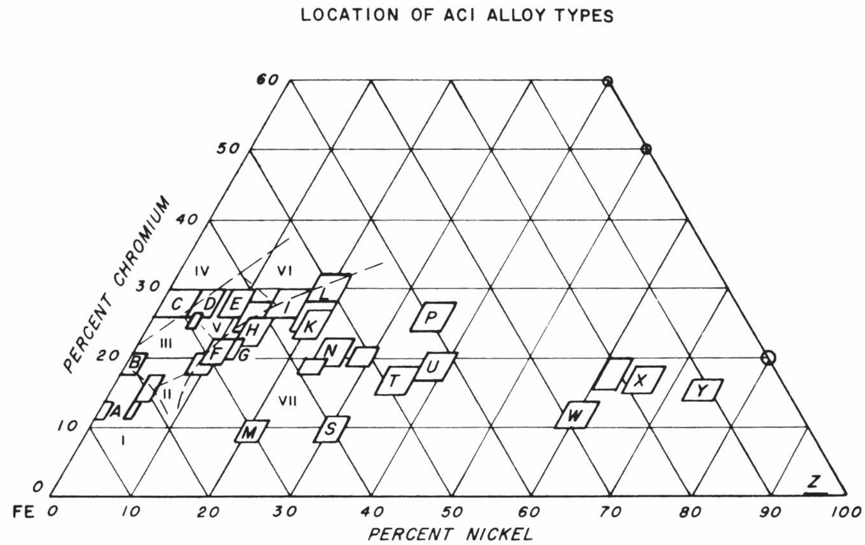
X1.2.2 *Ternary Diagram Location Letter* — The second letter indicates the approximate location of the nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram shown in Fig. X1.1.

X1.2.3 *Carbon Content Number* — For *C* service classifications, this single or dual digit numeral represents the maximum carbon content in units of 0.01%. For *H* service classifications, this number represents the midpoint of the range of carbon content in terms of 0.01% with a ±0.05% limit.

X1.2.4 *Special Elements Letters* — Additional letters following the numeral represents special chemical elements in the alloy grade, such as M for molybdenum, C for columbium, Cu for copper, and W for tungsten. There are two exceptions. The letter A indicates "Controlled Ferrite," and the letter F indicates "Free Machining."

X1.3 In Fig. X1.1, unlettered NiCr ranges are associated with the nearest lettered location. They may be the result of differences between corrosion and heat-resistance types or because of the influence of additional elements, for example, the precipitation hardening grade CB-7 Cu.

FIG. X1.1 LETTERS ASSIGNED TO CHROMIUM AND NICKEL RANGES IN ACI DESIGNATION SYSTEM



NOTE—The approximate areas of microstructures to be expected at room temperature are indicated as follows:

I—Martensite
II—Martensite and untransformed austenite
III—Ferrite plus martensite and untransformed austenite
IV—Ferrite
V—Ferrite plus austenite
VI—Ferrite plus austenite plus sigma
VII—Austenite
Carbides also may be present depending on carbon content and thermal history.

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SPECIFICATION FOR HOT ISOSTATICALLY-PRESSED STAINLESS STEEL FLANGES, FITTINGS, VALVES, AND PARTS FOR HIGH TEMPERATURE SERVICE

SA-988/SA-988M

(Identical with ASTM Specification A988/A988M-17 except for addition of para. 5.1.6; Supplementary Requirements S19, S20, S21, and S22 are mandatory; correction to S20 to add powder storage requirements.)

Specification for Hot Isostatically-Pressed Stainless Steel Flanges, Fittings, Valves, and Parts for High Temperature Service

1. Scope

1.1 This specification covers hot isostatically-pressed, powder metallurgy, stainless steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts made to specified dimensions or to dimensional standards, such as in ASME specification B16.5.

1.2 Several grades of martensitic, austenitic, age hardening, and austenitic-ferritic stainless steels are included in this specification.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. Unless the order specifies the applicable “M” specification designation (SI units), however, the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 The following safety hazards caveat pertains only to test methods portions 8.1, 8.2, 9.5 – 9.7, and Section 10 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A745/A745M Practice for Ultrasonic Examination of Austenitic Steel Forgings

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels

A961/A961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

B311 Test Method for Density of Powder Metallurgy (PM) Materials Containing Less Than Two Percent Porosity

E112 Test Methods for Determining Average Grain Size

E165/E165M Practice for Liquid Penetrant Examination for General Industry

E340 Practice for Macroetching Metals and Alloys

E606/E606M Test Method for Strain-Controlled Fatigue Testing

G48 Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution

2.2 *MSS Standard:*

SP 25 Standard Marking System for Valves, Fittings, Flanges, and Unions

2.3 *ASME Specifications and Boiler and Pressure Vessel Codes:*

B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings

2.4 *ASME Specification IX Welding Qualifications:*

SFA-5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes

SFA-5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes

SFA-5.11 Specification for Nickel and Nickel-Alloy Covered Welding Electrodes

SFA-5.14 Specification for Nickel and Nickel Alloy Bare Welding Electrodes and Rods

2.5 *AWS Standard:*

A5.11 Specification for Nickel and Nickel Alloy Welding Electrodes for Shielded Metal Arc Welding

A5.14 Specification for Nickel and Nickel Alloy Bare Welding Electrodes and Rods

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *can, n*—the container used to encapsulate the powder during the pressure consolidation process; it is partially or fully removed from the final part.

3.1.2 *compact, n*—the consolidated powder from one can. It may be used to make one or more parts.

3.1.3 *consolidation, n*—the bonding of adjacent powder particles in a compact under pressure by heating to a temperature below the melting point of the powder.

3.1.4 *fill stem, n*—the part of the compact used to fill the can. It is not usually integral to the part produced.

3.1.5 *hot isostatic-pressing, n*—a process for simultaneously heating and forming a compact in which the powder is contained in a sealed formable enclosure usually made from metal and the so-contained powder is subjected to equal pressure from all directions at a temperature high enough to permit plastic deformation and consolidation of the powder particles to take place.

3.1.6 *lot, n*—a number of parts made from a single powder blend following the same manufacturing practice.

3.1.7 *part, n*—a single item coming from a compact, either prior to or after machining.

3.1.8 *powder blend, n*—a homogeneous mixture of powder from one or more heats of the same grade.

3.1.9 *rough part, n*—the part prior to final machining.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify in the purchase order all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight or number of parts),

4.1.2 Name of material or UNS number,

4.1.3 ASTM designation and year of issue,

4.1.4 Dimensions (tolerances and surface finishes should be included),

4.1.5 Microstructure examination if required (5.1.4),

4.1.6 Inspection (15.1),

4.1.7 Whether rough part or finished machined part (8.2.2),

4.1.8 Supplementary requirements, if any,

4.1.9 Additional requirements (See 7.2 and 17.1), and

4.1.10 Requirement, if any, that the manufacturer shall submit drawings for approval showing the shape of the rough part before machining and the exact location of test specimen material (See 9.3).

5. Materials and Manufacture

5.1 *Manufacturing Practice:*

5.1.1 Compacts shall be manufactured by placing a single powder blend into a can, evacuating the can, and sealing it. The can material shall be selected to ensure that it has no deleterious effect on the final product. The entire assembly shall be heated and placed under sufficient pressure for a sufficient period of time to ensure that the final consolidated part meets the density requirements of 8.1.1.1. One or more parts shall be machined from a single compact.

5.1.2 The powder shall be prealloyed and made by a melting method capable of producing the specified chemical composition, such as but not limited to, air or vacuum induction melting, followed by gas atomization.

5.1.3 When powder from more than one heat of the same grade is used to make a blend, the heats shall be mixed thoroughly to ensure homogeneity.

5.1.4 The compact shall be sectioned and the microstructure examined to check for porosity and other internal imperfections. It shall meet the requirements of 8.1.2. The sample shall be taken from the fill stem or from a location in a part as agreed upon by the manufacturer and purchaser.

5.1.5 Unless otherwise specified in the purchase order, the manufacturer shall remove the can material from the surfaces of the consolidated compacts by chemical or mechanical methods such as by pickling or machining. This removal shall be done before or after heat treatment at the option of the manufacturer (See Note 1).

NOTE 1—Often, it is advantageous to leave the can material in place until after heat treatment or further thermal processing of the consolidated compact.

5.1.6 Supplementary Requirements S19, S20, S21, and S22 are mandatory.

6. Chemical Composition

6.1 The steel, both as a blend and as a part, shall conform to the requirements for chemical composition prescribed in Table 1. Test Methods, Practices, and Terminology of A751 shall apply.

6.1.1 A representative sample of each blend of powder shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 1. The blend shall conform to the chemical composition requirements prescribed in Table 1.

TABLE 1 Chemical Requirements

UNS Designation	Grade	Composition, %[A] Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Copper	Niobium[E]	Nitrogen	Other Elements
						Martensitic Stainless Steels							
S41000	13 chromium	0.15	1.00	0.040	0.030	1.00		11.5–13.5	. . .	. . .	. . .	. . .	
S41026	13 chromium 0.5 molybdenum	0.15	1.00	0.020	0.020	1.00	1.00–2.00	11.5–13.5	0.40–0.60	0.50		. . .	
S41500	13 chromium, 4 nickel	0.05	0.50–1.00	0.030	0.030	0.60	3.5–5.5	11.5–14.0	0.50–1.00	. . .	. . .	. . .	
S42390	12 chromium, 1.0 molybdenum, modified with vanadium	0.18–0.25	1.00	0.030	0.030	1.00	0.30–0.80	11.5–12.5	0.80–1.20	. . .	0.08–0.15	0.03–0.08	V 0.25–0.35
						Austenitic Stainless Steels							
N08028	32 nickel, 27 chromium, 3.5 molybdenum	0.030	2.50	0.030	0.030	1.0	30.0–34.0	26.0–28.0	3.0–4.0	0.60–1.4	. . .	. . .	
N08029	32 nickel, 27 chormium, 4.5 molybdenum	0.020	2.0	0.025	0.015	0.6	30.0–34.0	26.0–28.0	4.0–5.0	0.60–1.4	. . .	. . .	
S30400[B]	18 chromium, 8 nickel	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	
S30403[B]	18 chromium, 8 nickel, low carbon	0.035	2.00	0.045	0.030	1.00	8.0–13.0	18.0–20.0	. . .	. . .	. . .	. . .	
S30451[C]	18 chromium, 8 nickel, modified with nitrogen	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	
S30453	18 chromium, 8 nickel, modified with nitrogen	0.030	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	
S31600[B]	18 chromium, 8 nickel, modified with molybdenum	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	
S31603[B]	18 chromium, 8 nickel, modified with molybdenum, low carbon	0.030	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	
S31651[C]	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.08	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	
S31653[C]	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.030	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	
S31700	19 chromium, 13 nickel 3.5 molybdenum	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	
S31703	19 chromium, 13 nickel, 3.5 molybdenum	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	

TABLE 1 *Continued*

UNS Designation	Grade	Composition, %[A] Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Copper	Niobium[E]	Nitrogen	Other Elements
S21904	20 chromium, 6 nickel, 9 manganese	0.04	8.0–10.0	0.045	0.030	1.00	5.5–7.5	19.0–21.5	. . .	. . .	. . .	0.15–0.40	
S31254	20 chromium, 18 nickel, 6 molybdenum, low carbon	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5	0.50–1.00	. . .	0.18–0.22	
S31725	19 chromium, 15 nickel, 4 molybdenum	0.030	2.00	0.045	0.030	1.00	13.5–17.5	18.0–20.0	4.0–5.0	. . .	. . .	0.20	
S31726	19 chromium, 15 nickel, 4 molybdenum	0.030	2.00	0.045	0.030	1.00	14.5–17.5	17.0–20.0	4.0–5.0	. . .	. . .	0.10–0.20	
N08367	22 chromium, 25 nickel, 6.5 molybdenum, low carbon	0.030	2.00	0.040	0.030	1.00	23.50–25.50	20.0–22.0	6.0–7.0	0.75		0.18–0.25	
S32654	25 chromium, 22 nickel, 7 molybdenum, low carbon	0.020	2.0–4.0	0.030	0.005	0.50	21.0–23.0	24.0–25.0	7.0–8.0	0.30–0.60		0.45–0.55	
						Age-Hardening Stainless Steels							
S17400	17 chromium, 4 nickel, 3 copper	0.07	1.00	0.040	0.030	1.00	3.0–5.0	15.0–17.5	. . .	3.0–5.0	0.15–0.45		
						Austenitic-Ferritic Stainless Steels							
S31803	22 chromium, 5.5 nickel, modified with nitrogen	0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5	. . .	. . .	0.08–0.20	
S32205	22 chromium, 5.5 nickel, modified with high nitrogen	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	0.75	. . .	0.14–0.20	
S32906	29 chromium, 6.5 nickel, 2.0 molybdenum, modified with high nitrogen	0.030	0.80–1.50	0.030	0.030	0.50	5.8–7.5	28.0–30.0	1.50–2.60	0.80	. . .	0.30–0.40	
S32950	26 chromium, 3.5 nickel, 1.0 molybdenum	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	. . .	. . .	0.15–0.35	
S32750	25 chromium, 7 nickel, 4 molybdenum, modified with nitrogen	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0-5.0	0.50	. . .	0.24–0.32	
S39274	25 chromium, 7 nickel, modified with nitrogen and tungsten	0.030	1.0	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5	0.20–0.80	. . .	0.24–0.32	W 1.50–2.50

TABLE 1 *Continued*

		Composition, %[A]											
UNS Designation	Grade	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Copper	Niobium[E]	Nitrogen	Other Elements
S32760[D]	25 chromium, 7 nickel, 3.5 molybdenum, modified with nitrogen and tungsten	0.030	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0	0.50–1.00	. . .	0.20–0.30	W 0.50–1.00
S39277	25 chromium, 7 nickel, 3.7 molybdenum	0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.0–4.0	1.20–2.00	. . .	0.23–0.33	W 0.80–1.20
S32505	27 chromium, 7 nickel, 3 molybdenum, modified with nitrogen and copper	0.030	1.50	0.030	0.020	1.00	4.5–7.0	24.0–27.0	2.9–3.9	1.50–2.50	. . .	0.25–0.30	

[A] Maximum, unless otherwise specified. Where ellipses (. . .) appear in this table, there is no requirement, and analysis for the element need not be determined or reported.
[B] S30400, S30403, S31600, and S31603 shall have a maximum nitrogen content of 0.10 %.
[C] S30451, S31651, S30453, S31653 shall have a nitrogen content of 0.10 to 0.16 %.
[D] % Cr + 3.3 × % Mo + 16 × % N > 40 min.
[E] The terms Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

6.1.2 When required by the purchaser, the chemical composition of a sample from one part from each lot of parts shall be determined by the manufacturer. The composition of the sample shall conform to the chemical requirements prescribed in Table 1.

6.2 Addition of lead, selenium, or other unspecified elements for the purpose of improving the machinability of the compact shall not be permitted.

6.3 The steel shall not contain an unspecified element other than nitrogen, for the ordered grade, to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

7. Heat Treatment

7.1 Except as provided in 7.2, the final heat treatment of all parts shall be in compliance with the requirements of Table 2. After hot isostatic-pressing and prior to final heat treatment, the compacts are permitted to be annealed, at the option of the producer, either as a part of the consolidation process or as a separate operation.

7.2 When agreed upon by the purchaser, liquid quenching may be applied to the martensitic stainless steels in place of the furnace cool or air cool specified in Table 2, provided that such quenching is followed by tempering in the temperature ranges as required in Table 2. Martensitic parts that are liquid quenched and tempered shall be marked "QT."

7.3 The final heat treatment shall be performed before or after machining at the option of the producer.

7.4 See Section S16 if a particular heat treatment method is specified by the purchaser in the purchase order.

8. Structural Integrity Requirements

8.1 *Microporosity*—The parts shall be free of microporosity as demonstrated by measurement of density as provided in 8.1.1 or by microstructural examination as provided in 8.1.2.

8.1.1 *Density Measurement:*

8.1.1.1 The density measurement shall be used for acceptance of material but not for rejection of material. The measured density for each production lot shall exceed 99 % of the density typical of that grade when wrought and in the same heat treated condition as the sample. A production lot that fails to meet this acceptance criterion is permitted to be tested at the option of the producer, for microporosity in accordance with the microstructural examination as provided in 8.1.2.

8.1.1.2 Density shall be determined for one sample from each production lot by measuring the difference in mass of the sample when weighed in air and when weighed in water and multiplying this difference by the density of water (Archimede's principle). The equipment used shall be capable of determining density within ± 0.004 lb/in.^{3} [0.10 g/cm^3]. Alternatively, at the option of the producer, it is permitted to use Test Method B311 to determine the density.

8.1.1.3 At the option of the producer, the density shall be compared to the room temperature density typical of wrought steels of the same class of grades, 0.28 lb/in.^{3} [7.8 g/cm^3] for age-hardening, martensitic, and austenitic-ferritic grades, and 0.29 lb/in.^{3} [8.0 g/cm^3] for austenitic grades, or to the density of a wrought reference sample of the same grade heat treated in accordance with the requirements of Table 2 (See Note 2).

NOTE 2—The actual density of stainless steel varies slightly with composition and heat treatment. For this reason, small differences in the measured density from the typical density for a class of grades may be the result of differences in alloy content, heat treatment, or microporosity. When density values are measured that are less than the density typical of a class of grades, it is appropriate to examine the sample for microporosity by the more specific metallographic examination procedures.

8.1.2 *Microstructural Examination:*

8.1.2.1 The microstructure shall be examined at 20-50×, 100-200×, and 1000-2000× and shall be reasonably uniform and shall be free of voids, laps, cracks, and porosity.

8.1.2.2 One sample from each production lot shall be examined. The sample shall be taken after hot-isostatic pressing or after final heat treatment. The sample shall be taken from the component, stem, protrusion, or test part made from a single powder blend consolidated in the same hot isostatic press using the same pressure, temperature, and time parameters and heat-treated in the same final heat-treatment charge. The microstructure shall meet the requirements of 8.1.2.1.

8.1.2.3 If the sample fails to meet the requirements for acceptance, each part in the lot is permitted to be retested and those that pass shall be accepted.

8.2 *Hydrostatic Tests*—After they have been machined, pressure-containing parts shall be tested to the hydrostatic shell test pressures prescribed in ASME B16.5 for the applicable steel rating for which the part is designed and shall show no leaks. Parts ordered under these specifications for working pressures other than those listed in the ASME B16.5 ratings shall be tested to such pressures as may be agreed upon between the manufacturer and purchaser.

8.2.1 No hydrostatic test is required for weld neck or other flanges.

8.2.2 The compact manufacturer is not required to perform pressure tests on rough parts that are to be finish machined by others. The fabricator of the finished part is not required to pressure test parts that are designed to be pressure containing only after assembly by welding into a larger structure. The manufacturer of the compacts, however, shall be responsible, as required in 16.1 for the satisfactory performance of the parts under the final test required in 8.2.

8.3 *Ultrasonic Tests*—When specified in the order, austenitic-ferritic stainless steel parts made from S32505 shall be ultrasonic tested according to the procedures described in Section S7.

9. Mechanical Properties

9.1 The material shall conform to the requirements for mechanical properties prescribed in Table 3 at room temperature.

9.2 Sample shall be from the component, stem, protrusion, or test part made from a single powder blend consolidated in the same hot isostatic press using the same pressure, temperature, and time parameters and heat-treated in the same final heat-treatment charge. If repair welding is required (See

TABLE 2 Heat Treating Requirements

UNS No.	Heat Treat Type	Austenitizing/Solutioning Temperature °F [°C][A]	Cooling Media	Quenching, Cool to Below °F [°C]	Tempering Temperature, min° F [°C]
		Martensitic Stainless Steels			
S41000 Class 1	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1325 [725]
	temper	not required	[B]	[B]	1325 [725]
S41000 Class 2	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1250 [675]
	temper	not required	[B]	[B]	1250 [675]
S41000 Class 3	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1100 [595]
S41000 Class 4	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1000[540]
S41026	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	400 [205]	1150 [620]
S41500	normalize and temper	1850 [1010]	air cool	200 [95]	1040–1120 [560–600]
S42390	normalize and temper	1860–1960 [1015–1070]	air cool	200 [95]	1350–1440 [730–780]
		Austenitic Stainless Steels			
N08028	solution treat and quench	2000 [1100]	liquid	500 [260]	[B]
N08029	solution treat and quench	2000 [1100]	liquid	500 [260]	[B]
S30400	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S30403	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S30451	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S30453	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31600	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31603	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31651	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31653	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31700	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31703	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S21904	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31254	solution treat and quench	2100 [1150]	liquid	500 [260]	[B]
S31725	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31726	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
N08367	solution treat and quench	2025 [1105]	liquid	500 [260]	[B]
S32654	solution treat and quench	2050–2160 [1120–1180]	liquid	500 [260]	[B]
		Austenitic-Ferritic Stainless Steels			
S31803	solution treat and quench	1870 [1020]	liquid	500 [260]	[B]
S32205	solution treat and quench	1870 [1020]	liquid	500 [260]	[B]
S32906	solution treat and quench	1850–2100 [1010–1150]	liquid	500 [260]	[B]
S32950	solution treat and quench	1825–1875 [995–1025][C]	liquid	500 [260]	[B]
S32750	solution treat and quench	1880 [1025]	liquid	500 [260]	[B]
S39274	solution treat and quench	1920–2060 [1050–1125]	liquid	500 [260]	[B]
S32760	solution treat and quench	2010–2085 [1100–1140]	liquid	500 [260]	[B]
S39277	solution treat and quench	1940 [1060]	liquid	175 [80]	[B]
		Age-Hardening Stainless Steels			
		Solution Heat Treatment		Aging Heat Treatment[D]	
	Condition	Temperature °F [°C]	Cool as required to below °F [°C]	Temperature °F [°C], time (h), Required Cooling	
S17400	A	1875-1975 [1025-1055]	90 [32]	. . .	
	H900	1875-1975 [1025-1055]	90 [32]	900 [480], 1.0, air cool	
	H925	1875-1975 [1025-1055]	90 [32]	925 [495], 4.0, air cool	
	H1025	1875-1975 [1025-1055]	90 [32]	1025 [550], 4.0, air cool	
	H1075	1875-1975 [1025-1055]	90 [32]	1075 [580], 4.0, air cool	
	H1100	1875-1975 [1025-1055]	90 [32]	1100 [595], 4.0, air cool	
	H1150	1875-1975 [1025-1055]	90 [32]	1150 [620], 4.0, air cool	
	H1150M	1875-1975 [1025-1055]	90 [32]	1400 [760], 2.0, air cool plus 1150 [620], 4.0, air cool	

[A] Minimum unless temperature range is listed.
[B] Not applicable.
[C] 30 min/in. of thickness.
[D] Unless otherwise noted, it is permitted to vary the aging treatment temperature to obtain the required properties. The listed times are minimum time at temperature and the treatment is permitted to be extended to obtain the required ductility. Material treated at an intermediate temperature must meet the ductility requirements of the next higher hardening or aging temperature, or both.

Section 15), the test specimens prior to testing shall accompany the repaired parts if a post weld treatment is done.

9.3 For normalized and tempered parts, or quenched and tempered parts, the central axis of the test specimen shall correspond to the ¼ T plane or deeper position, where T is the maximum heat treated thickness of the represented part. In addition, for quenched and tempered parts, the midlength of the test specimen shall be at least T from any second heat treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

9.4 For all annealed stainless steels, the test specimen may be taken from any convenient location.

TABLE 3 Tensile and Hardness Requirements

UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa][A]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
		Martensitic Stainless Steels			
S41000 Class 1	70 [485]	40 [275]	18	35.0	143–187
S41000 Class 2	85 [585]	55 [380]	18	35.0	167–229
S41000 Class 3	110 [760]	85 [585]	15	35.0	235–302
S41000 Class 4	130 [895]	110 [760]	12	35.0	263–321
S41026	110–135 [760–930]	90 [620]	16	45.0	235–285
S41500	115 [790]	90 [620]	15	45.0	295 max
S42390	100–125 [690–862]	75 [517]	14.0	. . .	. . .
		Austenitic Stainless Steels			
N08028	73 [500]	31 [214]	40	50	. . .
N08029	73 [500]	31 [214]	40	50	. . .
S30400	75 [515][B]	30 [205]	30	50	. . .
S30403	70 [485][C]	25 [170]	30	50	. . .
S30451	80 [550]	35 [240]	30	50	. . .
S30453	75 [515][B]	30 [205]	30	50	. . .
S31600	75 [515][B]	30 [205]	30	50	. . .
S31603	70 [485][C]	25 [170]	30	50	. . .
S31651	80 [550]	35 [240]	30	50	. . .
S31653	75 [515][B]	30 [205]	30	50	. . .
S31700	75 [515][B]	30 [205]	30	50	. . .
S31703	70 [485][C]	25 [170]	30	50	. . .
S21904	90 [620]	50 [345]	45	60	. . .
S31254	94 [650]	44 [300]	35	50	. . .
S31725	75 [525]	30 [205]	40.0	50.0	. . .
S31726	80 [550]	35 [240]	40.0	50.0	. . .
N08367	95 [655]	45 [310]	30.0	50.0	
S32654	109 [750]	62 [430]	40.0	. . .	250 max
		Age-Hardening Stainless Steels			
UNS Designation, condition					
S17400, A	. . .	. . .	. . .	. . .	363 max
S17400, H900	190 [1310]	170 [1170]	6	15	388 min
S17400, H925	170 [1170]	155 [1070]	7	20	375 min
S17400, H1025	155 [1070]	145 [1000]	8	27	331 min
S17400, H1075	145 [1000]	125 [860]	9	28	311 min
S17400, H1100	140 [965]	115 [795]	10	29	302 min
S17400, H1150	135 [930]	105 [725]	11	30	277 min
S17400, H1150M	115 [795]	75 [520]	14	35	255 min
		Austenitic-Ferritic Stainless Steels			
S31803	90 [620]	65 [450]	25	45	. . .
S32205	95 [655]	65 [450]	25.0	. . .	293 max
S32906	109 [750]	80 [550]	25	. . .	310 max
S32950	100 [690]	70 [485]	15	. . .	. . .
S32750	116 [800]	80 [550]	15	. . .	310 max
S39274	116 [800]	80 [550]	15	30	310 max
S32760	109–130 [750–895]	80 [550]	25.0	45	. . .
S39277	118 [820]	85 [585]	25.0	50	. . .
S32505	116 [800]	80 [550]	25	50	310 max

[A] Determined by the 0.2 % offset method.
[B] For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 70 ksi [485 MPa].
[C] For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 65 ksi [450 MPa].

9.5 *Tension Tests:*

9.5.1 *Age-Hardening and Martensitic Stainless Steels*—One tension test shall be made for each production lot in each heat treatment charge. When the heat treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25 °F [±14 °C] and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each production lot of each type of part (See Note 3) and section size is required instead of one test from each production lot in each heat-treatment charge.

NOTE 3—"Type" in this case is used to describe the shape of the part such as a flange, elbow, tee, and so forth.

9.5.2 *Austenitic and Austenitic-Ferritic Stainless Steels*—One tension test shall be made for each production lot. The tension test specimen shall be made from material accompanying the parts in final heat treatment.

9.5.3 Testing shall be performed as specified in Specification A961/A961M using the largest feasible of the round specimens.

9.6 *Hardness Tests:*

9.6.1 When two or more parts are produced, a minimum of two pieces per batch or continuous run as defined in 9.6.2 shall be hardness tested as specified in Specification A961/A961M to ensure that the parts are within the hardness limits given for each grade in Table 3. When only one part is produced, it shall be hardness tested as required. The purchaser is permitted to verify that the requirement has been met by testing at any location on any part provided such testing does not render the part useless.

9.6.2 When the reduced number of tension tests permitted by 9.5.1 is applied, additional hardness tests shall be made on parts or samples as defined in 9.2 distributed throughout the charge. At least eight samples shall be checked from each batch load and a least one check/h shall be made from a continuous run. When the furnace charge is less than eight parts, each part shall be checked. If any hardness test result falls outside the prescribed limits, the entire lot of parts shall be reheat treated and the requirements of 9.5.1 shall apply.

9.7 *Fatigue Tests*—When specified in the order, the fatigue strength of austenitic stainless steel components intended for service above 1000 °F [540 °C] shall be determined in accordance with Section S18.

10. Corrosion Testing

10.1 Corrosion testing is not required by this specification.

10.2 Austenitic stainless steels shall be capable of meeting the intergranular corrosion test requirements described in Section S11.

10.3 When required by the purchaser, the stainless steels shall be tested in the final heat treated condition for pitting or crevice corrosion resistance according to the procedures described in Section S12.

10.4 Austenitic-ferritic stainless steels shall be capable of meeting the test requirements described in Section S13.

11. Product Analysis

11.1 The purchaser is permitted to make a product analysis on parts supplied to this specification. Samples for analysis shall be taken from midway between the center and surface of solid parts, midway between the inner and outer surfaces of hollow parts, midway between the center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1 with the tolerances as stated in Table 4.

12. Reheat Treatment

12.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer is permitted to reheat treat the parts and repeat the tests specified in Section 9, but not more than twice.

13. Surface Finish, Appearance, and Corrosion Protection

13.1 The requirements of Specification A961/A961M apply to hot isostatically pressed finished parts.

13.2 In addition to the requirements of Specification A961/A961M, the following requirements apply:

13.2.1 The parts shall be free of machining burrs, and machined surfaces, other than surfaces having special requirements, shall have a surface finish not to exceed R_a 250 microinch [6.3 micrometre] (arithmetic average) roughness height.

TABLE 4 Product Analysis Tolerances for Stainless Steels[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.030, incl	0.005
	over 0.030 to 0.20 incl	0.01
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00	0.05
	over 6.00 to 10.00	0.06
Phosphorus	to 0.040, incl	0.005
Sulfur	to 0.030, incl	0.005
Silicon	to 1.00, incl	0.05
	over 1.00 to 5.00, incl	0.10
Chromium	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	over 20.00 to 30.00, incl	0.25
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 30.00, incl	0.20
	over 30.00 to 40,00, incl	0.25
Molybdenum	to 0.20 incl	0.01
	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 7.00, incl	0.10
Titanium	all ranges	0.05
Columbium+tantalum	all ranges	0.05
Tantalum	to 0.10, incl	0.02
Cobalt	0.05 to 0.20, incl	0.01[B]
Nitrogen	to 0.19 incl	0.01
	over 0.19 to 0.25	0.02
	over 0.25 to 0.35	0.03
	over 0.35 to 0.45	0.04
	over 0.45 to 0.60	0.05
Columbium[C]	0.05 to 0.20, incl	0.01
Aluminum	to 0.05 incl	0.01
Vanadium	to 0.10 incl	0.01
	over 0.10 to 0.25 incl	0.02
Cerium	0.03 to 0.08	-0.005 +0.01
Tungsten	to 1.00, incl	0.04
Copper	to 0.50, incl	0.03
	Over 0.50 to 1.00, incl	0.05
	Over 1.00 to 3.00, incl	0.10
	Over 3.00 to 5.00, incl	0.15

[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05 % have not been established and the producer should be consulted for those limits.
[C] The terms Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

14. Repair by Welding

14.1 Weld repairs shall be permitted (See Section S8) only with prior approval of the purchaser and with the following limitations and requirements:

14.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

14.1.2 The weld metal shall be deposited using the electrodes specified in Table 5 except as otherwise provided in Section S14. The electrodes shall be purchased in accordance with ASME Specifications SFA-5.4, SFA-5.9, or SFA-5.11. The submerged arc process with neutral flux, the gas metal-arc welding and gas tungsten-arc welding processes are permitted to be used.

14.1.3 Defects shall be removed completely prior to welding by chipping or grinding to sound metal as verified by magnetic particle inspection in accordance with Test Method A275/A275M for the age-hardening, martensitic, or austenitic-ferritic stainless steels, or by liquid penetrant inspection in accordance with Test Method E165/E165M for all grades.

14.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

14.1.5 The preheat, interpass temperature, and post-weld heat treatment requirements given in Table 5 shall be met.

14.1.6 Repair by welding shall not exceed 10 % of the surface area of the part. Repair by welding shall not exceed 33⅓ % of the wall thickness of the finished part or ⅜ in. [9.5 mm], whichever is less.

14.1.7 No weld repairs are permitted for S41000 Classes 3 and 4.

15. Inspection

15.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy the inspector that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture unless otherwise agreed upon.

TABLE 5 Repair Welding Requirements

UNS Designation	Electrodes[A]	Preheat and Interpass Temperature Range, °F [°C][B]	Minimum Post-Weld Heat Treatment Temperature °F [°C][C]
		Age-Hardening Stainless Steels	
S17400	17 Cr, 4 Ni, 3 Cu	NR	1875-1925 [1025-1055], air cool, plus 900-1150 [480-620]
		Martensitic Stainless Steels	
S41000 Class 1	E 410-15 or 16	400-700 [205-370]	1250 [675]
S41000 Class 2	E 410-15 or 16	400-700 [205-370]	1250 [675]
S41026	13 % Cr, 1½ % Ni, ½ % Mo	400-700 [205-370]	1150 [620]
S41500	13 % Cr, 4 % Ni	300-700 [150-370]	1050 [565]
S42390		400-750 [205-400]	1350-1440 [730-780]
		Austenitic Stainless Steels	
N08028	ER383	NR	2010–2120 [1100–1160] + WQ
N08029	ERNiCrMo-3[E] ERNiCrMo-13[E]	NR	1975–2100 [1080–1150] + WQ
S30400	E 308-15 or 16	NR	1900 [1040] + WQ
S30403	E 308L-15 or 16	NR	1900 [1040] + WQ
S30451	E 308-15 or 16	NR	1900 [1040] + WQ
S30453	E 308L-15 or 16	NR	1900 [1040] + WQ
S31600	E 316-15 or 16	NR	1900 [1040] + WQ
S31603	E 316L-15 or 16	NR	1900 [1040] + WQ
S31651	E 316-15 or 16	NR	1900 [1040] + WQ
S31653	E 316L-15 or 16	NR	1900 [1040] + WQ
S31700	E 317-15 or 16	NR	1900 [1040] + WQ
S31703	E 317L-15 or 16	NR	1900 [1040] + WQ
S21904	XM-10W	NR	NR
S31254	E NiCrMo-3	NR	2100 [1150] + WQ
S31725	[D]	. . .	2100 [1150] + WQ
S31726	[D]	. . .	2100 [1150] + WQ
N08367	E NiCrMo-3	NR	2025 [1105] + WQ
S32654	25 % Cr, 61 % Ni, 14 % Mo	NR	2100 [1150] + WQ
		Austenitic-Ferritic Stainless Steels	
S31803	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
S32205	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
S32906	29 % Cr, 8 % Ni, 2 % Mo	NR	NR
S32950	26 % Cr, 8 % Ni, 2 % Mo	NR	NR
S32750	25 % Cr, 7 %, Ni, 4 % Mo	NR	NR
S39274	25 % Cr, 7 % Ni, 3 % Mo, W	NR	NR
S32760	25 % Cr, 7 % Ni, 3.5 Mo	NR	NR
S39277	25 % Cr, 7 % Ni, 3 % Mo, 1.5 % Cu, 1 % W	NR	NR
S32505	27 % Cr, 7 % Ni, 3 % Mo, 2 % Cu	NR	NR

[A] Electrodes shall comply with ASME SFA-5.4, and corresponding ER grades of SFA-5.9 or SFA-5.11.
[B] NR = not required.
[C] WQ = water quench.
[D] Match filler metal is available. Fabricators also have used AWS A5.14, Class ER, NiCrMo-3 and AWS A5.11, Class E, NiCrMo-3 filter metals.
[E] ASME SFA-5.14 Class.

16. Rejection

16.1 Each part that develops defects during shop working operations or in service shall be rejected and the manufacturer notified.

16.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

17. Certification

17.1 In addition to the certification requirements of Specification A961/A961M, test reports shall be furnished to the purchaser or his representative. Test reports shall provide the following as applicable:

17.1.1 Type of heat treatment, Section 7 (Table 2).

17.1.2 Chemical analysis results, Section 6 (Table 1), reported results shall be to the same number of significant figures as the limits specified in Table 1 for that element.

17.1.3 Product analysis results, Section 11 (Table 4),

17.1.4 Tensile property results, Section 9 (Table 3), report the yield strength and tensile strength, in ksi [MPa], elongation and reduction in area, in percent,

17.1.5 Hardness results, 9.6 (Table 3)

17.1.6 Structural integrity test results, Section 8, and

17.1.7 Any supplementary testing required by the purchase order.

18. Product Marking

18.1 In addition to marking requirements of Specification A961/A961M, the following additional marking requirements shall apply:

18.1.1 Quenched and tempered martensitic stainless steel parts shall be marked with the letters QT following the specification designation.

18.1.2 Hot isostatically-pressed parts repaired by welding shall be marked with the letter "W" following the specification designation.

18.1.3 Hot isostatically-pressed parts meeting all requirements for more than one class or grade are permitted, at the option of the producer, to be marked with more than one class or grade designation, such as S30400/S30409, S30400/S30403, etc.

18.2 *Bar Coding*—In addition to the requirements in 18.1, bar coding is acceptable as a supplemental identification method. The purchaser is permitted to specify in the order that a specific bar coding system be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 age-hardening stainless steel; austenitic stainless steels; austenitic-ferritic stainless steel; gas-atomized powder; hot isostatically-pressed stainless steel parts; martensitic stainless steel; pipe fittings, steel; piping applications; pressure containing parts; stainless steel fittings; stainless steel flanges; steel valves; temperature service applications, elevated; temperature service applications, high

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Macroetch Test

S1.1 A sample part shall be sectioned and etched to show internal imperfections. The test shall be conducted according to Test Method E340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Product Analysis

S2.1 A product analysis in accordance with Section 11 shall be made from one randomly selected part representing each size and type (See Note 3) of part on the order. If the analysis fails to comply, each part in that lot, at the option of the manufacturer, shall be checked and accepted if the analysis for the part complies with the requirements, or the lot shall be rejected. All results shall be reported to the purchaser.

S3. Tension Tests

S3.1 In addition to the requirements of Section 9, one tension specimen shall be obtained from a representative part from each production lot at a location agreed upon between the manufacturer and the purchaser. The results of the test shall comply with Table 3 and shall be reported to the purchaser.

S4. Magnetic Particle Examination

S4.1 All accessible surfaces of a finished martensitic, age hardening, or austenitic-ferritic stainless steel part, shall be examined by a magnetic-particle method. The method shall be in accordance with Test Method A275/A275M. Acceptance limits shall be agreed upon between the manufacturer and purchaser.

S5. Liquid Penetrant Examination

S5.1 All accessible surfaces shall be examined by a liquid penetrant method in accordance with Test Method E165/E165M. Acceptance limits shall be agreed upon between the manufacturer and the purchaser.

S6. Hydrostatic Testing

S6.1 A hydrostatic test at a pressure agreed upon between the manufacturer and the purchaser shall be applied by the manufacturer.

S7. Ultrasonic Testing

S7.1 Austenitic-Ferritic stainless steel parts made of S32505 shall be 100 % ultrasonic tested with straight and angle beam probes in accordance with Practice A745/A745M. Acceptance limits shall be agreed upon between the manufacturer and the purchaser.

S8. Repair Welding

S8.1 No repair welding shall be permitted without prior approval of the purchaser. If permitted, the restrictions of Section 14 shall apply.

S9. Heat Treatment Details

S9.1 The manufacturer shall furnish a detailed test report containing the information required in 17.1 and shall include all pertinent details of the heat treating cycle given the parts.

S10. Material for Optimum Resistance to Stress-Corrosion Cracking

S10.1 Austenitic stainless steel parts shall be furnished in the solution-annealed condition as a final operation with no subsequent cold working permitted unless specifically permitted by the purchaser.

S11. Intergranular Corrosion Tests

S11.1 Intergranular corrosion tests shall be performed on specimens of austenitic stainless steel in accordance with Practices A262.

S11.2 For the austenitic stainless steels, details concerning the number of specimens and their source and location are to be a matter of agreement between the manufacturer and the purchaser.

S12. Pitting and Crevice Corrosion Test

S12.1 The stainless steels in the final heat treated condition shall be tested in accordance with Test Method G48. Test procedures and acceptance criteria shall be a matter of agreement between the manufacturer and purchaser.

S13. Detrimental Intermetallic Phase Test

S13.1 The austenitic-ferritic stainless steels shall be tested in accordance with the test methods given in Test Methods A923. Acceptance criteria, if not specified in Test Methods A923, shall be a matter of agreement between the manufacturer and the purchaser.

S14. Special Filler Metal

S14.1 In repair welded S31600, S31603, S31609, and S31651 parts, the deposited weld metal shall conform to E 308 composition wire. Parts repair welded with E 308 weld metal shall be marked S___W308.

S15. Hardness Test

S15.1 Each part shall be hardness tested and shall meet the requirements of Table 3.

S16. Heat Treatment of Austenitic Stainless Parts

S16.1 The purchaser shall specify the heat treatment method in 7.1 that shall be employed.

S16.2 The manufacturer shall provide a test report containing the information required in 17.1 and shall include a statement of the heat treatment method employed.

S17. Grain Size for Austenitic Stainless Steels

S17.1 Hot isostatically-pressed parts made from austenitic stainless steel grades other than H grades shall be tested for average grain size by Test Methods E112. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S18. Fatigue Acceptance Test

S18.1 For austenitic stainless steel components intended for service above 1000 °F [540 °C], a uniaxial fatigue test shall be performed.

S18.2 The fatigue test shall be performed in air at 1100 °F [595 °C] at an axial strain range of 1.0 % with a one hour hold period at the maximum positive strain point in each cycle. Test specimen location and orientation shall be as specified in Specification A961/A961M and the applicable product specifications. Testing shall be conducted in accord with Practice E606/E606M. The test shall exceed 200 cycles without fracture or a 20 % drop in the load range.

S18.3 Failure to meet this requirement shall be cause for rejection of all parts from that blend.

S18.4 Test frequency shall be the same as for tension tests (See 9.5). Retesting is permitted. For a retest, two additional specimens produced from the same blend shall be tested and both specimens must pass the cyclic life requirement. Further retests are not permitted.

S19. Powder Size

S19.1 The maximum allowable powder size is 0.020 in. [0.5 mm], and the powder shall be produced by the gas atomization process.

S20. Powder Shielding

S20.1 Immediately following atomization, the powder shall remain shielded by an inert gas until the powder is below a temperature of 105 °F [40 °C] to ensure that the detrimental absorption of oxygen and other deleterious contaminants is no longer possible. Powder should be protected during storage to prevent the detrimental pick-up of oxygen and other contaminants.

S21. Chemical Analysis

S21.1 The chemical composition of a sample from one part from each lot of parts shall be determined by the manufacturer. The composition of the sample shall conform to the chemical requirements prescribed in Table 1.

S22. Manufacturer's Certification

S22.1 A manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. A report of the test results shall be furnished.

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SPECIFICATION FOR HOT ISOSTATICALLY-PRESSED ALLOY STEEL FLANGES, FITTINGS, VALVES, AND PARTS FOR HIGH TEMPERATURE SERVICE

SA-989/SA-989M

(Identical with ASTM Specification A989/A989M-18 except for addition of para. 5.1.7; Supplementary Requirements S2, S4, and S5 are mandatory.)

Specification for Hot Isostatically-Pressed Alloy Steel Flanges, Fittings, Valves, and Parts for High Temperature Service

1. Scope

1.1 This specification covers hot isostatically-pressed, powder metallurgy, alloy steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts made to specified dimensions or to dimensional standards, such as in ASME Specification B16.5.

1.2 Several grades of alloy steels are included in this specification.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. Unless the order specifies the applicable "M" specification designation (SI units), however, the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 The following safety hazards caveat pertains only to test methods portions, 8.1, 8.2, and 9.5 – 9.7 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and to determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A961/A961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

B311 Test Method for Density of Powder Metallurgy (PM) Materials Containing Less Than Two Percent Porosity

E165/E165M Practice for Liquid Penetrant Examination for General Industry

E340 Practice for Macroetching Metals and Alloys

E606/E606M Test Method for Strain-Controlled Fatigue Testing

2.2 *MSS Standard:*

SP 25 Standard Marking System for Valves, Fittings, Flanges, and Unions

2.3 *ASME Specifications and Boiler and Pressure Vessel Codes:*

B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings

2.4 *ASME Section IX Welding Qualifications:*

SFA-5.5 Specification for Low-Alloy Steel Covered Arc-Welding Electrodes

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *can, n*—the container used to encapsulate the powder during the pressure consolidation process that is removed partially or fully from the final part.

3.1.2 *compact, n*—the consolidated powder from one can that may be used to make one or more parts.

3.1.3 *consolidation, n*—the bonding of adjacent powder particles in a compact under pressure by heating to a temperature below the melting point of the powder.

3.1.4 *fill stem, n*—the part of the compact used to fill the can that is not usually integral to the part produced.

3.1.5 *hot isostatic-pressing, n*—a process for simultaneously heating and forming a compact in which the powder is contained in a sealed formable enclosure, usually made from metal, and the so-contained powder is subjected to equal pressure from all directions at a temperature high enough to permit plastic deformation and consolidation of the powder particles to take place.

3.1.6 *lot, n*—a number of parts produced from a single powder blend following the same manufacturing conditions.

3.1.7 *part, n*—a single item coming from a compact, either prior to or after machining.

3.1.8 *powder blend, n*—a homogeneous mixture of powder from one or more heats of the same grade.

3.1.9 *rough part, n*—the part prior to final machining.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify in the purchase order all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight or number of parts).

4.1.2 Name of material or UNS number.

4.1.3 ASTM designation and year of issue.

4.1.4 Dimensions (tolerances and surface finishes).

4.1.5 Microstructure examination, if required (5.1.5).

4.1.6 Inspection (14.1).

4.1.7 Whether rough part or finished machined part (8.2.2).

4.1.8 Supplementary requirements, if any.

4.1.9 Additional requirements (see 7.2.1 and 16.1).

4.1.10 Requirement, if any, that the manufacturer shall submit drawings for approval showing the shape of the rough part before machining and the exact location of test specimen material (see 9.3.1).

5. Materials and Manufacture

5.1 *Manufacturing Practice:*

5.1.1 Powder should be protected during storage to prevent the detrimental pick-up of oxygen and other contaminants.

5.1.2 Compacts shall be manufactured by placing a single powder blend into a can, evacuating the can, and sealing it. The can material shall be selected to ensure that it has no deleterious effect on the final product. The entire assembly shall be heated and placed under sufficient pressure for a sufficient period of time to ensure that the final consolidated part meets the density requirements of 8.1.2.1. One or more parts shall be machined from a single compact.

5.1.3 The powder shall be prealloyed and made by a melting method capable of producing the specified chemical composition, such as but not limited to air or vacuum induction melting, followed by gas atomization.

5.1.4 When powder from more than one heat is used to make a blend, the heats shall be mixed thoroughly to ensure homogeneity.

5.1.5 The compact shall be sectioned and the microstructure examined to check for porosity and other internal imperfections and shall meet the requirements of 8.1.3. The sample shall be taken from the fill stem or from a location in a part as agreed upon by the manufacturer and purchaser.

5.1.6 Unless otherwise specified in the purchase order, the manufacturer shall remove the can material from the surfaces of the consolidated compacts by chemical or mechanical methods, such as by pickling or machining. This removal shall be done before or after heat treatment at the option of the manufacturer (see Note 1).

NOTE 1—Often, it is advantageous to leave the can material in place until after heat treatment or further thermal processing of the consolidated compact.

5.1.7 Supplementary Requirements S2, S4, S5, and S14 are mandatory.

6. Chemical Composition

6.1 The steel both as a blend and as a part shall conform to the requirements for chemical composition prescribed in Table 1. Test Methods, Practices, and Terminology A751 shall apply.

6.1.1 A representative sample of each blend of powder shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 1. The blend shall conform to the chemical composition requirements prescribed in Table 1.

6.1.2 When required by the purchaser, the chemical composition of a sample from one part from each lot of parts shall be determined by the manufacturer. The composition of the sample shall conform to the chemical composition requirements prescribed in Table 1.

6.2 Addition of lead, selenium, or other unspecified elements for the purpose of improving the machinability of the compact shall not be permitted.

6.3 The steel shall not contain an unspecified element, for the ordered grade, to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

7. Heat Treatment

7.1 After hot isostatic-pressing, the compacts shall be annealed prior to heat treating in accordance with the requirements of Table 2. At the option of the producer, this anneal shall be a separate operation following powder consolidation or shall be a part of the consolidation process.

7.2 The alloy steels shall be heat treated in accordance with the requirements of 7.1 and Table 2.

7.2.1 *Liquid Quenching*—When agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in Table 2 for each grade are utilized.

7.2.1.1 *Marking*—Parts that are liquid quenched and tempered shall be marked "QT".

TABLE 1 Chemical Requirements

UNS Designation	Grade	Composition, %[A]										
		Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Niobium[B] plus Tantalum	Tantalum, max	Titanium
		Alloy Steels										
K90941	9 % chromium	0.15 max	0.30–0.60	0.030	0.030	0.50–1.00	. . .	8.0–10.0	0.90–1.10	. . .	. . .	. . .
K90901	9 % chromium, 1 % molybdenum, 0.2 % vanadium plus niobium[B] and nitrogen	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	0.40 max	8.0–9.5	0.85–1.05	Other Elements Nb[B] 0.06–0.10 N 0.03–0.07 Al 0.04 max V 0.18–0.25		
K31545	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	. . .	2.7–3.3	0.80–1.06	. . .	. . .	. . .
K21590 Class 1	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	. . .	2.00–2.50	0.87–1.13	. . .	. . .	. . .
K21590 Class 3	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	. . .	2.00–2.50	0.87–1.13	. . .	. . .	. . .

[A] Maximum, unless otherwise specified.
[B] Niobium and columbium are interchangeable names for the same element and both names are acceptable for use in A01.22 specifications.

TABLE 2 Heat Treating Requirements

UNS No.	Heat Treat Type	Austenitizing/Solutioning Temperature, °F [°C][A]	Cooling Media	Quenching, Cool to Below °F [°C]	Tempering Temperature, min °F [°C]
		Alloy Steels			
K90941	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
K90901	normalize and temper	1900–2000 [1040–1095]	air cool	[B]	1350 [730]
K31545	anneal	1750 [955]	furnace cool	[B]	[B]
K21590 Class 1, 3	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1250 [675]

[A] Minimum unless temperature range is listed.
[B] Not applicable.

7.3 See Supplementary Requirement S12 if a particular heat treatment method is specified by the purchaser in the purchase order.

7.4 *Time of Heat Treatment*—Heat treatment of the hot isostatically-pressed parts shall be performed before or after machining at the option of the manufacturer.

8. Structural Integrity Requirements

8.1 *Microporosity:*

8.1.1 The parts shall be free of microporosity as demonstrated by measurement of density as provided in 8.1.2 or by microstructural examination as provided in 8.1.3.

8.1.2 *Density Measurement:*

8.1.2.1 The density measurement shall be used for acceptance of material but not for rejection of material. The measured density for each production lot shall exceed 99 % of the density typical of that grade when wrought and in the same heat treated condition as the sample. A production lot that fails to meet this acceptance criterion is permitted, at the option of the producer, to be tested for microporosity in accordance with the microstructural examination as provided in 8.1.3.

8.1.2.2 Density shall be determined for one sample from each production lot by measuring the difference in weight of the sample when weighed in air and when weighed in water and multiplying this difference by the density of water (Archimede's principle). The equipment used shall be capable of determining density within ±0.004 lb/in.^{3} [0.10 g/cm^3]. Alternatively, at the option of the producer, it is permitted to use Test Method B311 to determine the density.

8.1.2.3 At the option of the producer, the density shall be compared to the room temperature density typical of wrought alloy steels or to the density of a wrought reference sample of the same grade heat treated in accordance with the requirements of Table 2 (see Note 2). The typical density for alloy steel in the annealed condition at room temperature is 0.28 lb/in.^{3} [7.8 g/cm^3].

NOTE 2—The actual density of alloy steel varies slightly with composition and heat treatment. For this reason, small differences in the measured density from the typical density for a given grade of steel may be the result of differences in alloy content, heat treatment, or microporosity. When density values are measured that are less than the density typical of a given grade of steel, it is appropriate to examine the sample for microporosity by the more specific metallographic examination procedures.

8.1.3 *Microstructural Examination:*

8.1.3.1 The microstructure shall be examined at 20-50×, 100-200×, and 1000-2000× and shall be reasonably uniform and shall be free of voids, laps, cracks, and porosity.

8.1.3.2 One sample from each production lot shall be examined. The sample shall be taken from the component, stem, protrusion, or test part made from a single powder blend consolidated in the same hot isostatic press using the same pressure, temperature, and time parameters and heat-treated in the same final heat treatment charge, after hot isostatic-pressing or after final heat treatment. The microstructure shall meet the requirements of 8.1.3.1.

8.1.3.3 If the sample fails to meet the requirements for acceptance, it is permitted to retest each part in the lot. Each part that passes the requirements of 8.1.3.1 shall be accepted.

8.2 *Hydrostatic Tests*—After they have been machined, pressure-containing parts shall be tested to the hydrostatic shell test pressures prescribed in ASME B16.5 for the applicable steel rating for which the part is designed, and shall show no leaks. Parts ordered under these specifications for working pressures other than those listed in the ASME B16.5 ratings shall be tested to such pressures as may be agreed upon between the manufacturer and purchaser.

8.2.1 No hydrostatic test is required for welding neck or other flanges.

8.2.2 The compact manufacturer is not required to perform pressure tests on rough parts that are to be finish machined by others. The fabricator of the finished part is not required to pressure test parts that are designed to be pressure-containing only after assembly by welding into a larger structure. The manufacturer of the compacts, however, shall be responsible as required in 15.1 for the satisfactory performance of the parts under the final test required in 8.2.

9. Mechanical Properties

9.1 The material shall conform to the requirements for mechanical properties prescribed in Table 3 at room temperature.

9.2 Mechanical test samples shall be obtained from the component stem, protrusion, or test part made from a single powder blend consolidated in the same hot-isostatic press using the same pressure, temperature, and time parameter and heat-treated in the same final heat-treatment charge. If repair welding is required (see Section 15), the test specimens prior to testing shall accompany the repaired parts if a post weld heat treatment is done.

9.3 For normalized and tempered parts, or quenched and tempered parts, the central axis of the test specimen shall correspond to the ¼ *T* plane or deeper position where *T* is the maximum heat treated thickness of the represented part. In addition, for quenched and tempered parts, the midlength of the test specimen shall be at least *T* from any second heat treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

9.3.1 Alternatively, with prior approval of the purchaser, it is permitted to take the test specimen for the steel parts at a depth (t) corresponding to the distance from the area of significant stress to the nearest heat treated surface and at least twice this distance ($2t$) from any second surface. The test depth, however, shall not be nearer to one treated surface than ¾ in. [19 mm] and to the second treated surface than 1½ in. [38 mm]. This method of test specimen location would normally apply to complex parts, or parts with thick cross-sectional areas where ¼ *T* and *T* testing (see 9.3) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

9.4 For annealed alloy steels the test specimen may be taken from any convenient location.

9.5 *Tension Test:*

9.5.1 One tension test shall be made for each production lot in each heat treatment charge.

9.5.1.1 When the heat treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25 °F [±14 °C] and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each production lot of each type of part, and section size is required instead of one test from each production lot in each heat-treatment charge. The term "type," as used here, designates a characteristic shape of a part, such as flange, elbow, tee, and so forth.

9.5.1.2 The tension test specimen shall be made from material accompanying the parts in final heat treatment.

9.5.2 Testing shall be performed as specified in Specification A961/A961M using the largest feasible of the round specimens.

9.6 *Hardness Tests:*

9.6.1 When two or more parts are produced, a minimum of two pieces per batch or continuous run as defined in 9.6.2 shall be hardness tested as specified in Specification A961/A961M to ensure that the parts are within the hardness limits given for each grade in Table 3. When only one part is produced, it shall be hardness tested as required. The purchaser is permitted to verify that the requirement has been met by testing at any location on any part, provided such testing does not render the part useless.

9.6.2 When the reduced number of tension tests permitted by 9.5.1.1 is applied, additional hardness tests shall be made on

TABLE 3 Tensile and Hardness Requirements

UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa][A]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
Alloy Steels					
K90941	85 [585]	55 [380]	20.0	40.0	179–217
K90901	85 [585]	60 [415]	20.0	40.0	248 max
K31545	75 [515]	45 [310]	20.0	30.0	156–207
K21590 Class 1	60 [415]	30 [205]	20.0	35.0	170 max
K21590 Class 3	75 [515]	45 [310]	20.0	30.0	156–207

[A] Determined by the 0.2 % offset method. For ferritic steels only, the 0.5 % extension-under-load method also may be used.

parts or samples as defined in 9.2 distributed throughout the charge. At least eight samples shall be checked from each batch load and a least one check/h shall be made from a continuous run. When the furnace batch charge is less than eight parts, each part shall be checked. If any hardness test result falls outside the prescribed limits, the entire lot of parts shall be reheat treated and the requirements of 9.5.1 shall apply.

9.7 *Fatigue Tests*—When specified in the order, the fatigue strength of alloy steel, except UNS K90901, components intended for service above 800 °F [425 °C] and for UNS K90901 components intended for service above 1000 °F [540 °C] shall be tested in accordance with the requirements of Supplementary Requirement S13.

10. Product Analysis

10.1 The purchaser is permitted to make a product analysis on parts supplied to this specification. The chemical composition of a sample from one part from each lot of parts shall be determined by the manufacturer. Samples for analysis shall be taken from midway between the center and surface of solid parts, midway between the inner and outer surfaces of hollow parts, midway between the center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1 with the tolerances as stated in Table 4 or Table 5.

TABLE 4 Product Analysis Tolerances for Alloy Steels with a Maximum Chromium Limit 4 % or More[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.030, incl	0.005
	over 0.030 to 0.20 incl	0.01
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
Phosphorus	to 0.040, incl	0.005
Sulfur	to 0.030, incl	0.005
Silicon	to 1.00, incl	0.05
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
Molybdenum	to 0.20 incl	0.01
	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
Titanium	all ranges	0.05
Niobium (columbium) + tantalum	all ranges	0.05
Tantalum	to 0.10, incl	0.02
Cobalt	0.05 to 0.20, incl	0.01[B]
Nitrogen	to 0.19 incl	0.01
Niobium (columbium)	0.05 to 0.20, incl	0.01
Aluminum	to 0.05 incl	0.01
Vanadium	to 0.10 incl	0.01
	over 0.10 to 0.25 incl	0.02
Cerium	0.03 to 0.08	–0.005 +0.01
Tungsten	to 1.00, incl	0.04
Copper	to 1.00, incl	0.03

[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05 % have not been established and the producer should be consulted for those limits.

TABLE 5 Product Analysis Tolerances for Alloy Steels with Maximum Chromium Limit Less than 4 %

Element[B]	Limit or Maximum of Specified Ranges, %	Tolerance Over Maximum Limit or Under Minimum Limit for Size Ranges Shown, %[A]			
		100 in.^{2} [6.45× 10^4 mm^2] or less	Over 100 to 200 in.^{2} [1.290 × 10^5 mm^2], incl	Over 200 to 400 in.^{2} [2.581 × 10^5 mm^2], incl	Over 400 in.^{2}
Manganese	to 0.90 incl	0.03	0.04	0.05	0.06
	over 0.90 to 1.00 incl	0.04	0.05	0.06	0.07
Phosphorus	to 0.045 incl	0.005	0.010	0.010	0.010
Sulfur	to 0.045 incl	0.005	0.010	0.010	0.010
Silicon	to 0.40 incl	0.02	0.02	0.03	0.04
	over 0.40 to 1.00 incl	0.05	0.06	0.06	0.07
Nickel	to 0.50	0.03	0.03	0.03	0.03
Chromium	to 0.90 incl	0.03	0.04	0.04	0.05
	over 0.90 to 2.10 incl	0.05	0.06	0.06	0.07
	over 2.10 to 3.99 incl	0.10	0.10	0.12	0.14
Molybdenum	to 0.20 incl	0.01	0.01	0.02	0.03
	over 0.20 to 0.40 incl	0.02	0.03	0.03	0.04
	over 0.40 to 1.15 incl	0.03	0.04	0.05	0.06
Copper	to 1.00 incl	0.03	0.03	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05	0.05	0.05
Titanium	to 0.10	0.01	0.01	0.01	0.01
Vanadium	to 0.10 incl	0.01	0.01	0.01	0.01
	0.11 to 0.25 incl	0.02	0.02	0.02	0.02
	0.26 to 0.50 incl	0.03	0.03	0.03	0.03

[A] Cross-sectional area.
[B] Product analysis for carbon, boron, niobium (columbium), and calcium shall conform to Table 1.

11. Reheat Treatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer is permitted to reheat treat the parts and repeat the tests specified in Section 9, but not more than twice.

12. Surface Finish, Appearance, and Corrosion Protection

12.1 The requirements of Specification A961/A961M apply to hot isostatically pressed finished parts.

12.2 In addition to the requirements of Specification A961/A961M, the following requirements apply:

12.2.1 The parts shall be free of machining burrs and machined surfaces, other than surfaces having special requirements, shall have a surface finish not to exceed R_a 250 microinch [6.3 micrometre] (arithmetic average) roughness height.

13. Repair by Welding

13.1 Weld repairs shall be permitted (see Supplementary Requirement S9) only with prior approval of the purchaser and with the following limitations and requirements:

13.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.1.2 The weld metal shall be deposited using the electrodes specified in Table 6. The electrodes shall be purchased

TABLE 6 Repair Welding Requirements

UNS Designation	Electrodes[A]	Preheat and Interpass Temperature Range, °F [°C]	Minimum Post-Weld Heat Treatment Temperature °F [°C]
	Alloy Steels		
K90941	E 505-15 or 16	400–700 [205–370]	1250 [675]
K91650	9 % Cr, 1 % Mo, VCbN	400–700 [205–370]	1300 [705]
K31545	E 9018-B 3	300–600 [150–315]	1250 [675]
K21590 Class 1	E 9018-B 3	300–600 [150–315]	1250 [675]
K21590 Class 3	E 9018-B 3	300–600 [150–315]	1250 [675]

[A] Electrodes shall comply with ASME SFA 5.5.

in accordance with ASME Specification SFA-5.5. The submerged arc process with neutral flux, the gas metal-arc welding and gas tungsten-arc welding processes are permitted.

13.1.3 Defects shall be completely removed prior to welding by chipping or grinding to sound metal as verified by magnetic particle inspection in accordance with Test Method A275/A275M for the alloy steels in this specification, or by liquid penetrant inspection in accordance with Test Method E165/E165M for all grades.

13.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

13.1.5 The preheat, interpass temperature, and post-weld heat treatment, requirements given in Table 6 shall be met.

13.1.6 Repair by welding shall not exceed 10 % of the surface area of the part. Repair by welding shall not exceed 33⅓ % of the wall thickness of the finished part or ⅜ in. [9.5 mm], whichever is less.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy the inspector that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture unless otherwise agreed upon.

15. Rejection

15.1 Each part that develops defects during shop working operations or in service shall be rejected and the manufacturer notified.

15.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

16. Certification

16.1 In addition to the certification requirements of Specification A961/A961M, test reports shall be furnished to the purchaser or his representative. Test reports shall provide the following as applicable:

16.1.1 Type of heat treatment, Section 7, (Table 2),

16.1.2 Chemical analysis results, Section 6 (Table 1), reported results shall be to the same number of significant figures as the limits specified in Table 1 for that element,

16.1.3 Product analysis results, Section 10 (Table 4 or Table 5),

16.1.4 Tensile property results, Section 9 (Table 3), report the yield strength and tensile strength, in ksi [MPa], elongation and reduction in area, in percent,

16.1.5 Hardness results, 9.6 (Table 3),

16.1.6 Structural integrity test results, Section 8, and

16.1.7 Any supplementary testing required by the purchase order.

17. Product Marking

17.1 In addition to marking requirements of Specification A961/A961M, the following additional marking requirements shall apply:

17.1.1 Quenched and tempered alloy steel parts shall be marked with the letters "QT" following the specification designation.

17.1.2 Hot isostatically-pressed parts repaired by welding shall be marked with the letter "W" following the specification designation.

17.1.3 Hot isostatically-pressed parts meeting all requirements for more than one class or grade are permitted at the option of the producer to be marked with more than one class or grade designation.

17.2 *Bar Coding*—In addition to the requirements in 17.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order that a specific bar coding system be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 alloy steel; chromium-alloy steel; chromium-molybdenum steel; gas-atomized powder; hot isostatically-pressed alloy steel parts; piping applications; pipe fittings, steel; pressure containing parts; steel flanges; steel valves; temperature service applications, elevated; temperature service applications, high

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Macroetch Test

S1.1 A sample part shall be sectioned and etched to show internal imperfections. The test shall be conducted according to Test Method E340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Chemical Composition

S2.1 The chemical composition of a sample from one part from each lot of parts shall be determined by the manufacturer. The composition of the sample shall conform to the chemical composition requirements prescribed in Table 1.

S2.2 A product analysis in accordance with Section 10 shall be made from one randomly selected part representing each size and type (See 9.5.1.1) of part on the order. If the analysis fails to comply, each part in that lot, at the option of the manufacturer, shall be checked and accepted if the analysis for the part complies with the requirements, or the lot shall be rejected. All results shall be reported to the purchaser.

S3. Tension Tests

S3.1 In addition to the requirements of Section 9, one tension specimen shall be obtained from a representative part from each production lot at a location agreed upon between the manufacturer and the purchaser. The results of the test shall comply with Table 3 and shall be reported to the purchaser.

S4. Particle Size

S4.1 In addition to the manufacturing process of 5.1, the maximum particle size is 0.020 in. [0.5 mm], and the powders shall be produced by the gas atomization process.

S5. Powder Shielding

S5.1 Immediately following atomization, the powder shall remain shielded by an inert gas, until the powder is below a temperature of 105 °F [40 °C] to ensure that the detrimental absorption of oxygen and other deleterious contaminants is no longer possible. The powder shall be stored under a positive nitrogen or argon atmosphere or vacuum to minimize potential oxidation or contamination.

S6. Magnetic Particle Examination

S6.1 All accessible surfaces of a finished alloy steel part shall be examined by a magnetic-particle method. The method shall be in accordance with Test Method A275/A275M. Acceptance limits shall be agreed upon between the manufacturer and purchaser.

S7. Liquid Penetrant Examination

S7.1 All accessible surfaces shall be examined by a liquid penetrant method in accordance with Test Method E165/E165M. Acceptance limits shall be agreed upon between the manufacturer and the purchaser.

S8. Hydrostatic Testing

S8.1 A hydrostatic test at a pressure agreed upon between the manufacturer and the purchaser shall be applied by the manufacturer.

S9. Repair Welding

S9.1 No repair welding shall be permitted without prior approval of the purchaser. If permitted, the restrictions of Section 15 shall apply.

S10. Heat Treatment Details

S10.1 The manufacturer shall furnish a detailed test report containing the information required in 16.1 and shall include all pertinent details of the heat treating cycle given the parts.

S11. Hardness Test

S11.1 Each part shall be hardness tested and shall meet the requirements of Table 3.

S12. Alternate Heat Treatment (Grade K90901)

S12.1 Grade K90901 shall be normalized in accordance with Section 7 and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be the purchaser's responsibility to subsequently temper at 1350 °F [730 °C] min to conform to the requirements of the specification. All mechanical tests shall be made on material heat treated in accordance with Section 7. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S10" shall be included with the required marking of the part.

S13. Fatigue Acceptance Test

S13.1 For alloy steel, except UNS K90901, components intended for service above 800 °F [425°C], and for UNS K90901 components intended for service above 1000 °F [540 °C] a uniaxial fatigue test shall be performed.

S13.2 The fatigue test shall be performed in air at 1100 °F [595 °C] at an axial strain range of 1.0 % with a one hour hold period at the maximum positive strain point in each cycle. Test specimen location and orientation shall be in accordance with the general guidance of Specification A961/A961M and the applicable product specifications. Testing shall be conducted in accordance with Practice E606/E606M. The test shall exceed 200 cycles without fracture or a 20 % drop in the load range.

S13.3 Failure to meet this requirement shall be cause for rejection of all parts from that powder blend.

S13.4 Test frequency shall be the same as for tension tests (see 9.5). Retesting is permitted. Two additional specimens produced from the same powder blend shall be tested and both specimens must pass the cyclic life requirement. Further retests are not permitted.

S14. Certification

S14.1 A manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with this specification, and that the test results on representative samples meet specification requirement. A report of the test results shall be furnished.

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SPECIFICATION FOR CASTINGS, AUSTENITIC-FERRITIC (DUPLEX) STAINLESS STEEL, FOR PRESSURE-CONTAINING PARTS

SA-995/SA-995M

(23)

(Identical with ASTM Specification A995/A995M-20.)

Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts

1. Scope

1.1 This specification covers austenitic-ferritic (duplex) stainless steel castings for valves, flanges, fittings, and other pressure-containing parts.

1.2 The duplex stainless steels offer a combination of enhanced mechanical properties and corrosion resistance when properly balanced in composition and properly heat treated. Ferrite levels are not specified, but these grades will develop a range of approximately 30 to 60 % ferrite with the balance austenite. It is the responsibility of the purchaser to determine which grade shall be furnished depending on design and service conditions, mechanical properties, and corrosion-resistant characteristics.

NOTE 1—Because of the possibility of precipitation of embrittling phases, the grades included in this specification are not recommended for service at temperatures above 600 °F [315 °C].

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

E125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings

E165/E165M Practice for Liquid Penetrant Testing for General Industry

E562 Test Method for Determining Volume Fraction by Systematic Manual Point Count

G48 Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *duplex stainless steel*—an iron-chromium-nickel-molybdenum alloy that, when properly heat treated, consists of approximately 30 to 60 % ferrite with the balance austenite.

4. General Conditions for Delivery

4.1 Material furnished to this specification shall conform to the applicable requirements of Specification A703/A703M, including the supplementary requirements that are indicated on the purchaser order. Failure to comply with the general requirements of Specification A703/A703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A703/A703M, this specification shall prevail.

5. Ordering Information

5.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

5.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

5.1.2 Quantity (weight and number of castings),

5.1.3 Specification designation and date of issue,

5.1.4 Grade of steel,

5.1.5 Supplementary requirements including acceptance criteria, and

TABLE 1 Heat Treatment Requirements

Grade	Heat Treatment
1B	Heat to 1900 °F [1040 °C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
2A	Heat to 2050 °F [1120 °C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
3A	Heat to 1950 °F [1070 °C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
4A	Heat to 2050 °F [1120 °C] minimum, hold for sufficient time to heat casting uniformly to temperature, and water quench; or the casting may be furnace cooled to a temperature no lower than 1850 °F [1010 °C], hold for 15 min minimum and then water quench. A rapid cool by other means may be employed in lieu of water quench.
5A	Heat to 2050 °F [1120 °C] minimum, hold for sufficient time to heat casting to temperature, furnace cool to a temperature no lower than 1910 °F [1045 °C], then quench in water or rapid cool by other means.
6A	Heat to 2010 °F [1100 °C] minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means, or the casting may be furnace cooled to a temperature no lower than 1925 °F [1050 °C], hold for 15 min minimum, and then quench in water or rapid cool by other means.
7A	Heat to 2065 °F [1130 °C] minimum, hold for sufficient time to heat casting to temperature, furnace cool to a temperature no lower than 1940 °F [1060 °C], then quench in water or rapid cool by other means.

5.1.6 Additional requirements.

6. Process

6.1 The steel shall be made by the electric furnace process with or without separate refining.

7. Heat Treatment

7.1 All castings shall be heat treated in accordance with Table 1.

8. Chemical Composition

8.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

9. Tensile Properties

9.1 One tension test shall be made from each heat and shall conform to the requirements as to tensile properties prescribed in Table 3.

10. Quality

10.1 When additional inspection is desired, Supplementary Requirements S5, S6, and S10 may be ordered.

11. Repair by Welding

11.1 Repairs shall be made using procedures and welders qualified under Practice A488/A488M.

11.2 The composition of the deposited weld metal may be similar to that of the casting or may be suitably alloyed to achieve the desired corrosion resistance and mechanical properties.

11.3 Weld repairs shall be subject to the same quality standards as used to inspect the castings.

12. Post-Weld Heat Treatment After Major Weld Repair

12.1 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic testing or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 $in.^2$ [65 cm^2]. All other weld repairs shall be considered minor.

12.2 Castings shall be heat treated after major weld repairs. Heat treatment after minor weld repairs is not required unless Supplementary Requirement S11 is included in the purchase order.

12.3 Post-weld heat treatment shall be in accordance with Table 1.

13. Keywords

13.1 austenitic-ferritic; duplex stainless steel; pressure-containing; steel castings

TABLE 2 Chemical Requirements[A,B]

Material Grade Type UNS	Element, %											
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Tungsten	Other
CD4MCuN (1B) 25Cr-5Ni-Mo-Cu-N J93372	0.040	1.00	0.040	0.040	1.00	24.5–26.5	4.7–6.0	1.70–2.30	0.10–0.25	2.7–3.3	. . .	. . .
CE8MN (2A) 24Cr-10Ni-Mo-N J93345	0.080	1.00	0.040	0.040	1.50	22.5–25.5	8.0–11.0	3.0–4.5	0.10–0.30	. . .	. . .	. . .
CD6MN (3A) 25Cr-5Ni-Mo-N J93371	0.060	1.00	0.040	0.040	1.00	24.0–27.0	4.0–6.0	1.75–2.50	0.15–0.25	. . .	. . .	. . .
CD3MN (4A) 22Cr-5Ni-Mo-N J92205	0.030	1.50	0.040	0.040	1.00	21.0–23.5	4.5–6.5	2.5–3.5	0.10–0.30	1.00	. . .	. . .
CE3MN (5A)[C] 25Cr-7Ni-Mo-N J93404	0.030	1.50	0.040	0.040	1.00	24.0–26.0	6.0–8.0	4.0–5.0	0.10–0.30	. . .	. . .	. . .
CD3MWCuN (6A)[D] 25Cr-7Ni-Mo-N J93380	0.030	1.00	0.030	0.025	1.00	24.0–26.0	6.5–8.5	3.0–4.0	0.20–0.30	0.50–1.00	0.50–1.00	. . .
CD3MWN (7A)[E] 27Cr-7Ni-Mo-W-N J93379	0.030	1.00–3.00	0.030	0.020	1.00	26.0–28.0	6.0–8.0	2.0–3.5	0.30–0.40	1.00	3.0–4.0	B: 0.0010–0.0100 Ba: 0.0002–0.0100 Ce + La: 0.005–0.030

[A] All values are maximums, except where a range is provided.
[B] Where ellipses (...) appear in this table, there is no requirement, and the element need not be analyzed for or reported.
[C] % Cr + 3.3 % Mo + 16 % N ≥ 40.
[D] % Cr + 3.3 (% Mo + 0.5 % W) + 16 % N ≥ 40.
[E] % Cr + 3.3 (% Mo + 0.5 % W) + 16 % N ≥ 45.

TABLE 3 Tensile Requirements

Grade Type	1B 25Cr-5Ni-Mo-Cu-N	2A 24Cr-10Ni-Mo-N	3A 25Cr-5Ni-Mo-N	4A 22Cr-5Ni-Mo-N	5A 25Cr-7Ni-Mo-N	6A 25Cr-7Ni-Mo-N	7A 27Cr-7Ni-Mo-W-N
Tensile strength, ksi [MPa], min	100 [690]	95 [655]	95 [655]	90 [620]	100 [690]	100 [690]	100 [690]
Yield strength (0.2 % offset), ksi [MPa], min	70 [485]	65 [450]	65 [450]	60 [415]	75 [515]	65 [450]	75 [515]
Elongation in 2 in. [50 mm], %, min[A]	16	25	25	25	18	25	20

[A] When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A703/A703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A703/A703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S2. Destruction Tests

S5. Radiographic Inspection

S6. Liquid Penetrant Inspection

S8. Charpy Impact Test

S10. Examination of Weld Preparation

S10.1 Liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing liquid penetrant examination shall be in accordance with Practice E165/E165M. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E125, of Degree 2 in sections up to 2 in. [50 mm] thick, and of Degree 3 in sections over 2 in. [50 mm] thick shall be acceptable.

S11. Post-Weld Heat Treatment

S11.1 Castings shall be given a post-weld solution heat treatment in accordance with Table 1.

S12. Prior Approval of Major Weld Repairs

Other supplementary requirements considered suitable for use with this specification are:

S50. Estimating Ferrite Content

S50.1 Ferrite contents shall be determined by point count (Test Method E562), by other quantitative metallographic methods such as image analysis, by measurement of magnetic response, or by other methods upon agreement between the manufacturer and the purchaser. Frequency of testing and location of tests shall be by agreement between the manufacturer and the purchaser.

S51. Prior Approval of Weld Material

S51.1 The purchaser must give approval of all weld filler materials to be used prior to any weld repairs.

S52. Additional Requirements for Grade 6A

S52.1 *Casting Thickness,* T—The casting thickness, *T*, is the maximum thickness of the pressure-containing wall of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension, *T*, is for the casting.

S52.2 *Charpy Impact Test*—Charpy impact test properties shall be determined by testing a set of three Charpy V-notch impact specimens made from each heat of material.

S52.2.1 The thickness of the test blocks used to create Charpy impact test specimens shall be equal to the casting thickness, *T*. Charpy impact test specimens shall be removed from a location at one-half the thickness of the test block.

S52.2.2 When the thickness of the test block is less than or equal to 4 in. [100 mm], Charpy impact testing shall be performed at one of the test temperatures listed in Table S52.1.

TABLE S52.1 Charpy Impact Testing of Base Material

NOTE 1—It is recommended that test temperature selection be determined based on the intended service temperature of the casting.

Test Temperature °F [°C]	Charpy V-Notch Impact Requirements	
	Energy Value, ft-lbf [J], min value for two specimens and min average of three specimens	Energy Value, ft-lbf [J], min for single specimen
–51 [–46]	103 [140]	77 [105]
–105 [–76]	66 [90]	48 [65]
–150 [–101]	44 [60]	33 [45]

The test temperature shall be provided by the purchaser. If the test temperature is not specified, the test temperature used shall be –51 °F [–46 °C]. The average value of the three specimens shall not be less than specified in Table S52.1, with no more than one value permitted below the average minimum specified and no value permitted below the minimum specified for a single specimen.

S52.2.3 When the thickness of the test block is greater than 4 in. [100 mm], test temperature and absorbed energy values shall be agreed upon between the purchaser and the manufacturer.

S52.3 *Corrosion Testing*—A Test Methods G48 Method A ferric chloride pitting resistance test shall be performed for a duration of 24 h at 60 °C.

S52.3.1 The thickness of the test blocks used to create corrosion test specimens shall be equal to the casting thickness, *T*. Corrosion test specimens shall be removed from a location at one quarter the thickness of the test block.

S52.3.2 When the thickness of the test block is less than or equal to 4 in. [100 mm], test specimens shall show no evidence of pitting when examined optically at 20× magnification, and have a weight loss of $<4 g/m^2$.

S52.3.3 When the thickness of the test block is greater than 4 in. [100 mm], test block size and acceptance criteria shall be agreed upon between the purchaser and the manufacturer.

S52.4 *Weld Qualifications*—Repairs shall be made utilizing welding procedures qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code, and repair welding shall be done by welders or welding operators meeting the qualification requirements of Section IX. In addition to the Section IX qualification limits, the weld test plate thickness shall be as agreed upon between the casting supplier and the purchaser, but no less than 1.5 times the maximum weld repair depth. The weld deposit thickness shall be at least 80 % of the maximum repair depth.

S52.4.1 When the thickness of the qualification coupon is less than or equal to 4 in. [100 mm], and the qualification coupon is subjected to a post-weld solution heat treatment in accordance with Table 1, Charpy impact testing shall be performed at one of the test temperatures listed in Table S52.2.

TABLE S52.2 Weld Qualification Impact Testing for Post-Weld Solution-Treated Coupons

NOTE 1—It is recommended that test temperature selection be determined based on the intended service temperature of the casting.

Test Temperature °F [°C]	Charpy V-Notch Impact Requirements	
	Energy Value, ft-lbf [J], min value for two specimens and min average of three specimens	Energy Value, ft-lbf [J], min for single specimen
–51 [–46]	74 [100]	55 [75]
–105 [–76]	44 [60]	33 [45]
–150 [–101]	33 [45]	26 [35]

The test temperature shall be provided by the purchaser. If the test temperature is not specified, the test temperature used shall be –51 °F [–46 °C]. Charpy impact test locations shall be at the weld cap and mid-thickness of the weld deposit. Three specimens shall be removed from each of these three locations: the fusion line, fusion line + 2 mm, and fusion line + 5 mm. The average value of the three specimens shall not be less than specified in Table Table S52.2, with no more than one value permitted below the average minimum specified and no value permitted below the minimum specified for a single specimen.

TABLE S52.3 Weld Qualification Impact Testing for As-Welded Coupons

Test Temperature °F [°C]	Charpy V-Notch Impact Requirements	
	Energy Value, ft-lbf [J], min value for two specimens and min average of three specimens	Energy Value, ft-lbf [J], min for single specimen
–51 [–46]	89 [120]	66 [90]
–105 [–76]	44 [60]	33 [45]
–150 [–101]	33 [45]	26 [35]

S52.4.2 When the thickness of the qualification coupon is less than or equal to 4 in. [100 mm], and the qualification coupon is not subjected to a post-weld solution heat treatment, Charpy impact testing shall be performed at one of the test temperatures listed in Table S52.3. The test temperature shall be provided by the purchaser. If the test temperature is not specified, the test temperature used shall be –51 °F [–46 °C]. Charpy impact test locations shall be at the weld cap and mid-thickness of the weld deposit. Three specimens shall be removed from each of these three locations: the fusion line, fusion line + 2 mm, and fusion line + 5 mm. The average value of the three specimens shall not be less than specified in Table S52.3, with no more than one value permitted below the average minimum specified and no value permitted below the minimum specified for a single specimen.

S52.4.3 When the thickness of the qualification coupon is greater than 4 in. [100 mm], test temperature, specimen location and quantity, and absorbed energy values shall be agreed upon between the purchaser and the manufacturer.

S52.4.4 A Test Methods G48 Method A test shall be performed on a sample removed from the weld qualification coupon; the sample shall include approximately 50 % weld material and 50 % base material. Weld test coupons subjected to a post-weld solution heat treatment shall be tested at 60 °C. Weld test coupons not being subjected to a post-weld solution heat treatment shall be tested at 50 °C. Regardless of heat treat condition, the acceptance criteria and test time shall be the same as outlined in S52.3.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR ALLOY AND STAINLESS STEEL PIPE

SA-999/SA-999M

(Identical with ASTM Specification A999/A999M-18.)

Standard Specification for
General Requirements for Alloy and Stainless Steel Pipe

1. Scope

1.1 This specification covers a group of general requirements that, unless otherwise specified in an individual specification, shall apply to the ASTM product specifications noted below.

1.2 In the case of conflict between a requirement of a product specification and a requirement of this specification, the product specification shall prevail. In the case of conflict between a requirement of the product specification or a requirement of this specification and a more stringent requirement of the purchase order, the purchase order shall prevail.

Title of Specification	ASTM Designation
Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes	A312/A312M
Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness	A333/A333M
Seamless Ferritic Alloy-Steel Pipe for High Temperature Service	A335/A335M
Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications	A358/A358M
Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service	A369/A369M
Seamless Austenitic Steel Pipe for High-Temperature Service	A376/A376M
Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service	A409/A409M
Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service	A426/A426M
Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service	A451/A451M
Centrifugally Cast Iron-Chromium-Nickel High-Alloy Tubing for Pressure Application at High Temperatures	A608/A608M
Welded, Unannealed Austenitic Stainless Steel Tubular Products	A778/A778M
Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe	A790/A790M
Single- or Double-Welded Austenitic Stainless Steel Pipe	A813/A813M
Cold-Worked Welded Austenitic Stainless Steel Pipe	A814/A814M
Centrifugally Cast Ferritic/Austenitic Stainless Steel Pipe for Corrosive Environments	A872/A872M
Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal	A928/A928M
Spray-Formed Seamless Austenitic Stainless Steel Pipes	A943/A943M
Spray-Formed Seamless Ferritic/Austenitic Stainless Steel Pipe	A949/A949M
Austenitic Chromium-Nickel-Silicon Alloy Steel Seamless and Welded Pipe	A954

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units apply unless the "M" designation (SI) of the product specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) is used in this standard for such traditional terms as "nominal diameter," "size," "nominal bore," and "nominal size."

1.4 The following precautionary statement pertains only to the test method portion, Section 22, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A312/A312M Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes

A333/A333M Specification for Seamless and Welded Steel

Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness
A335/A335M Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service
A358/A358M Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications
A369/A369M Specification for Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A376/A376M Specification for Seamless Austenitic Steel Pipe for High-Temperature Service
A409/A409M Specification for Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service
A426/A426M Specification for Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service
A451/A451M Specification for Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service
A608/A608M Specification for Centrifugally Cast Iron-Chromium-Nickel High-Alloy Tubing for Pressure Application at High Temperatures
A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A778/A778M Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products
A790/A790M Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe
A813/A813M Specification for Single- or Double-Welded Austenitic Stainless Steel Pipe
A814/A814M Specification for Cold-Worked Welded Austenitic Stainless Steel Pipe
A872/A872M Specification for Centrifugally Cast Ferritic/Austenitic Stainless Steel Pipe for Corrosive Environments
A928/A928M Specification for Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A943/A943M Specification for Spray-Formed Seamless Austenitic Stainless Steel Pipes
A949/A949M Specification for Spray-Formed Seamless Ferritic/Austenitic Stainless Steel Pipe
A954 Specification for Austenitic Chromium-Nickel-Silicon Alloy Steel Seamless and Welded Pipe (Withdrawn 2005)
A994 Guide for Editorial Procedures and Form of Product Specifications for Steel, Stainless Steel, and Related Alloys
A1058 Test Methods for Mechanical Testing of Steel Products—Metric
D3951 Practice for Commercial Packaging
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing
E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing
E309 Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation
E426 Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys
E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ANSI Standards:*
B36.10 Welded and Seamless Wrought Steel Pipe
B36.19 Stainless Steel Pipe

2.3 *Military Standards:*
MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage
MIL-STD-271 Nondestructive Testing Requirements for Metals[7]
MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment

2.4 *Federal Standard:*
Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.5 *Steel Structures Painting Council:*
SSPC-SP6 Surface Preparation Specification No. 6 Commercial Blast Cleaning

2.6 *ASNT Standards:*
SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

3. Materials and Manufacture

3.1 The steel shall be made by a suitable steelmaking process.

3.2 If secondary melting, such as electroslag remelting or vacuum remelting, is used, the heat shall be defined as all of the ingots remelted from a single primary heat.

3.3 If steels of different grades are sequentially strand cast, the resultant transition material shall be removed using an established procedure that positively separates the grades.

3.4 If a specific type of melting is required by the purchaser, it shall be specified in the purchase order.

4. Terminology

4.1 *Definitions*:

4.1.1 The definitions in Terminology A941, except as modified in this specification or in its referenced product specifications, are applicable to this specification.

5. Ordering Information

5.1 It is the responsibility of the purchaser to specify all requirements that are necessary for products ordered under the applicable product specification and this general requirements specification. Such requirements to be considered include, but are not limited to, the following:

5.1.1 ASTM product specification and year-date,

5.1.2 Name of product (for example, stainless steel pipe),

5.1.3 Quantity (feet, metres, or number of pieces),

5.1.4 Method of manufacture, where applicable (seamless or welded),

5.1.5 Specific type of melting, if required (see 3.4),

5.1.6 Grade or UNS number,

5.1.7 Size (NPS and outside diameter and schedule number, average (nominal) wall thickness (see 9.1 and 10.1), or minimum wall thickness (see 9.2 and 10.1.1), or minimum inside diameter (see 11.1)),

5.1.8 Length (specific or random),

5.1.9 End finish,

5.1.10 Optional requirements,

5.1.11 Specification designation and year of issue, and

5.1.12 Special requirements or any supplementary requirements, or both.

6. Chemical Composition

6.1 *Chemical Analysis*—Samples for chemical analysis and method of analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

6.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the specified elements. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer shall conform to the requirements specified.

6.2.1 For steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element, other than nitrogen for stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification.

6.3 *Product Analysis*—Product analysis requirements and options, if any, shall be as contained in the applicable product specification.

7. Mechanical Properties

7.1 *Method of Mechanical Tests*—The specimens and mechanical tests required shall be in accordance with Test Methods and Definitions A370, especially Annex A2 thereof, or Test Methods A1058.

7.1.1 Unless otherwise specified in the ordering requirements, Test Methods A1058 shall apply when the metric version of the product specification is specified.

7.2 Specimens shall be tested at room temperature.

7.3 Small or subsize specimens as described in Test Methods and Definitions A370 or Test Methods A1058 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties in the applicable product specification.

8.2 The yield strength, if specified, shall be determined corresponding to a permanent offset of 0.2 % of the gauge length or to a total extension of 0.5 % of the gauge length under load.

8.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. [19.0 mm] from the center of the gauge length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

9. Permissible Variation in Mass for Seamless Pipe

9.1 Except as allowed by 9.2, the mass of any length of seamless pipe in sizes NPS 12 and smaller shall not vary more than 10 % over or more than 3.5 % under that specified. For pipe in sizes larger than NPS 12, the mass of any length of pipe shall not vary more than 10 % over or more than 5 % under that specified. Unless otherwise specified, the mass of lengths of pipe in sizes NPS 4 and smaller shall be determined separately or in convenient lots; the mass of lengths of pipe in sizes larger than NPS 4 shall be determined separately.

9.2 *Minimum Wall*—If the wall thickness of the pipe is specified as minimum wall in the purchase order, the mass of any length of seamless pipe shall not vary more than 16 % over that calculated in accordance with 14.3. Unless otherwise specified, the mass of pipe in sizes NPS 4 and smaller shall be determined separately or in convenient lots; the mass of pipe in sizes larger than NPS 4 shall be determined separately.

9.3 The specified mass of pipe shall be determined by multiplying its specified or calculated mass per unit length (see 14.3) by its measured length.

10. Permissible Variations in Wall Thickness

10.1 *Seamless and Welded*—Except as required by 10.1.1, the minimum wall thickness at any point shall not be more than 12.5 % under the nominal wall thickness specified. The minimum wall thickness on inspection is shown in Table X1.1.

10.1.1 *Minimum Wall*—If the wall thickness of the pipe is specified as minimum wall in the purchase order, there shall be no variation under the specified wall thickness.

10.2 *Forged and Bored*—The wall thickness shall not vary over that specified by more than ⅛ in. [3.2 mm]. There shall be no variation under the specified wall thickness.

10.3 *Cast*—The wall thickness shall not vary over that specified by more than 1⁄16 in. [1.6 mm]. There shall be no variation under the specified wall thickness.

11. Permissible Variations in Inside Diameter

11.1 *Forged and Bored, and Cast*—The inside diameter shall not vary under that specified by more than 1⁄16 in. [1.6 mm]. There shall be no variation over the specified inside diameter.

12. Permissible Variation in Outside Diameter

12.1 Variations in outside diameter, unless otherwise agreed upon, shall not exceed the limits given in Table 1. The tolerances for outside diameter include ovality, except as provided for in 12.2 and 12.2.1. (See Note 2.)

12.2 For thin-wall pipe, defined as pipe having a wall thickness of 3 % or less of the specified outside diameter, the diameter tolerance of Table 1 is applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross-section.

12.2.1 For thin-wall pipe, the difference in extreme outside readings (ovality) in any one cross-section shall not exceed 1.5 % of the specified outside diameter.

NOTE 2—Thin-wall pipe usually develops significant ovality (out-of-roundness) during final annealing, straightening, or both. The diameter tolerances given in Table 1 are usually not sufficient to provide for additional ovality expected in thin-wall pipe.

13. Permissible Variations in Length

13.1 *Seamless and Welded (No Filler Metal Added)*—If specific cut lengths of 24 ft [7.3 m] or less are ordered, no length of pipe shall be under the length specified or more than ¼ in. [6 mm] over that specified.

13.1.1 Permissible variations in length for lengths greater than 24 ft [7.3 m] shall be subject to agreement between the manufacturer and purchaser.

13.2 *Forged and Bored, Cast, and Cast Cold-Wrought*—If specific cut lengths are ordered, no length of pipe shall be under the length specified or more than ⅛ in. [3 mm] over that specified.

13.3 For pipe ordered to random lengths, the lengths and variations shall be agreed upon between the manufacturer and purchaser.

13.4 No girth welds are permitted unless agreed upon by the manufacturer and purchaser.

14. Mass per Unit Length

14.1 A system of standard pipe sizes has been approved by the American National Standards Institute as ANSI B36.10 and B36.19. The standard sizes do not prohibit the production and use of other sizes of pipe produced to the various product specifications referenced in 1.1. (See Note 3.)

14.2 For nonstandard sizes of pipe, the calculated mass per unit length shall be determined using the following equation:

$$M = C(D - t)t \tag{1}$$

where:

C = 10.69 [0.0246615],
M = mass per unit length, lb_m/ft [kg/m],
D = specified or calculated (from specified inside diameter and wall thickness) outside diameter, in. [mm], and
t = specified wall thickness, in. (to 3 decimal places) [mm to 2 decimal places].

14.3 When minimum wall thickness is specified in the purchase order, the calculated mass per unit length shall be determined using Eq 1, obtaining from Table X1.1 the nominal wall thickness, t, corresponding to that minimum wall.

NOTE 3—The mass per unit length values given in the American National Standards and the calculated masses per unit length determined using Eq 1 are based upon carbon steel pipe. The mass per unit length of pipe made of ferritic stainless steels may be up to about 5 % less, and that made of austenitic stainless steel up to about 2 % greater, than the values given.

15. Ends

15.1 Unless otherwise specified, the pipe shall be furnished with plain ends. All burrs at the ends of the pipe shall be removed.

16. Straightness

16.1 The finished pipe shall be reasonably straight.

16.2 For metal-arc welded pipe, the maximum deviation from a 10-ft [3.0-m] straightedge placed so that both ends are in contact with the pipe shall be ⅛ in. [3.2 mm]. For metal-arc welded pipe with lengths shorter than 10 ft [3.0 m], this maximum deviation shall be prorated with respect to the ratio of the actual length to 10 ft [3.0 m].

TABLE 1 Permissible Variations in Outside Diameter

NPS Designator	Permissible Variations in Outside Diameter		DN Designator	Permissible Variations in Outside Diameter	
	Over in.	Under in.		Over [mm]	Under [mm]
⅛ –1½, incl	1⁄64 (0.015)	1⁄32 (0.031)	[6–40], incl	[0.4]	[0.8]
Over 1½ to 4, incl	1⁄32 (0.031)	1⁄32 (0.031)	Over [40 to 100]	[0.8]	[0.8]
Over 4 to 8, incl	1⁄16 (0.062)	1⁄32 (0.031)	Over [100 to 200]	[1.6]	[0.8]
Over 8 to 18, incl	3⁄32 (0.093)	1⁄32 (0.031)	Over [200 to 450]	[2.4]	[0.8]
Over 18 to 26, incl	⅛ (0.125)	1⁄32 (0.031)	Over [450 to 650]	[3.2]	[0.8]
Over 26 to 34, incl	5⁄32 (0.156)	1⁄32 (0.031)	Over [650 to 850]	[4.0]	[0.8]
Over 34 to 48, incl	3⁄16 (0.187)	1⁄32 (0.031)	Over [850 to 1200]	[4.8]	[0.8]

17. Repair by Welding

17.1 Repair by welding of defects in seamless pipe (including centrifugally cast pipe and forged and bored pipe) and of plate defects in welded pipe and, if specifically stated by the applicable product specification, weld seam defects in welded pipe shall be permitted subject to the approval of the purchaser and with the further understanding that the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable product specification. Each length of repaired pipe shall be nondestructively tested as required by the applicable product specification.

17.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

18. Retests

18.1 If the results of the qualification tests of any lot do not conform to the requirements specified in the applicable product specification, retests are permitted on additional lengths of pipe of double the original number from the same lot, each of which shall conform to the requirements specified. Only one retest of any lot is permitted. Nonconformance of the retest is cause for the rejection of the lot.

18.2 Any individual length of pipe that meets the test requirements is acceptable. It is permitted to retest individual lengths that do not conform to the test requirements, provided that the reason for nonconformance is established and the nonconforming portion is removed.

19. Retreatment

19.1 If individual lengths of pipe selected to represent any lot fail to conform to the test requirements, the lot represented may be reheat treated and resubmitted for test. The manufacturer may reheat treat the pipe, but not more than twice, except with the approval of the purchaser.

20. Test Specimens

20.1 Test specimens shall be taken from the ends of finished pipe prior to any forming operations, or being cut to length.

20.2 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

20.3 If any test specimen shows flaws or defective machining, the specimen may be discarded and another substituted.

21. Flattening Test Requirements

21.1 *Seamless and Centrifugally Cast Pipe*—A section of pipe not less than 2½ in. [60 mm] in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside, or end surfaces, except as allowed by 21.3.4, shall occur before the distance between the plates is less than the value of H calculated as follows:

$$H = (1 + e)t/(e + t/D) \tag{2}$$

where:

H = distance between flattening plates, in. [mm],
t = specified wall thickness, in. [mm],
D = specified outside diameter, outside diameter corresponding to specified ANSI pipe size, or outside diameter calculated by adding $2t$ (as defined above) to the specified inside diameter in. [mm], and
e = deformation per unit length (constant for a given grade of steel, 0.07 for medium carbon steel (maximum specified carbon 0.19 % or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, 0.09 for duplex (ferritic/austenitic) stainless steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18 % or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the specimen meet.

21.2 *Welded Pipe*—A section of welded pipe not less than 4 in. [100 mm] in length shall be flattened cold between parallel plates in two steps. The weld shall be placed at 90° from the direction of the applied force (at the point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks on the inside or outside surfaces, except as provided for in 21.3.4, shall occur before the distance between the plates is less than the value of H calculated by Eq 2. During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the specimen meet.

21.3 *Seamless, Centrifugally Cast, and Welded Pipe:*

21.3.1 Evidence of laminated or defective material or weld that is revealed at any time during the entire flattening test shall be cause for rejection.

21.3.2 Surface imperfections not evident in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

21.3.3 Superficial ruptures resulting from surface imperfections shall not be a cause for rejection.

21.3.4 When low D-to-t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

22. Nondestructive Test Requirements

22.1 If required by the applicable product specification or the purchase order, the pipe shall be tested by the hydrostatic test (see 22.2) or by the nondestructive electric test (see 22.3).

22.2 *Hydrostatic Test:*

22.2.1 Except as allowed by 22.2.2 and 22.2.3, each length of pipe shall be tested by the manufacturer to a hydrostatic pressure that will produce in the pipe wall a stress not less than 60 % of the specified minimum yield strength for ferritic alloy steel and stainless steel pipe, or 50 % of the specified minimum yield strength for austenitic alloy and stainless steel pipe and for ferritic/austenitic stainless steel pipe. The test pressure or stress shall be determined using the following equation:

$$P = 2St/D \quad or \quad S = PD/2t \tag{3}$$

where:

P = hydrostatic test pressure in psi [MPa],
S = pipe wall stress in psi or [MPa],
t = specified wall thickness, nominal wall thickness according to specified ANSI schedule number, or 1.143 times the specified minimum wall thickness, in. [mm], and
D = specified outside diameter, outside diameter corresponding to specified ANSI pipe size, or outside diameter calculated by adding $2t$ (as defined above) to the specified inside diameter, in. [mm].

22.2.1.1 The hydrostatic test pressure determined by Eq 3 shall be rounded to the nearest 50 psi [0.5 MPa] for pressures below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending, or other forming operations.

22.2.2 Regardless of pipe-wall stress-level determined by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed 2500 psi [17.0 MPa] for outside diameters (see D in 22.2) of 3.5 in. [88.9 mm] or less, or 2800 psi [19.0 MPa] for outside diameters over 3.5 in. [88.9 mm]. This does not prohibit testing at higher pressures at the option of the manufacturer or as allowed by 22.2.3.

22.2.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 22.1 or 22.2, or both, may be stated in the purchase order.

22.2.4 The test pressure shall be held for a minimum of 5 s. For welded pipe, the test pressure shall be held for a time sufficient to permit the entire length of the welded seam to be inspected.

22.2.5 The hydrostatic test may not be capable of testing the end portion of the pipe. The length of pipe that cannot be tested shall be determined by the manufacturer and, if specified in the purchase order, reported to the purchaser.

22.3 *Nondestructive Electric Test:*

22.3.1 Each pipe shall be examined with a nondestructive test in accordance with Practices E213, E309, E426, or E570. Unless specifically called out by the purchaser, the selection of the nondestructive electric test shall be at the option of the manufacturer. Upon agreement between the purchaser and the manufacturer, Practice E273 shall be employed in addition to one of the full periphery tests. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

22.3.2 The following information is for the benefit of the user of this specification:

22.3.2.1 The reference discontinuities defined in 22.3.8.2 – 22.3.8.7 are convenient standards for the standardization of nondestructive testing equipment. The dimensions of such reference discontinuities should not be construed as the minimum size imperfection detectable by such equipment.

22.3.2.2 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented imperfections. It should be recognized that different techniques should be used to detect differently oriented imperfections. The examination may not detect short deep imperfections.

22.3.2.3 The eddy-current testing (ET) referenced in this specification, (see Practices E426 and E309), has the capability of detecting significant imperfections, especially of the short abrupt type. The sensitivity of this test decreases with wall thickness over 0.250 in. (6.4 mm).

22.3.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented imperfections; however, sensitivity of the test to various types of imperfections is affected by the calibration, and different techniques should be employed to detect differently oriented imperfections.

22.3.2.5 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of imperfections that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

22.3.3 *Time of Examination:*

22.3.3.1 Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

22.3.4 *Surface Condition:*

22.3.4.1 All surfaces shall be free of scale, dirt, grease, paint, and other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

22.3.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

22.3.5 *Extent of Examination:*

22.3.5.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as allowed by 22.3.5.2.

22.3.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

22.3.6 *Operator Qualifications:*

22.3.6.1 The test unit operator shall be qualified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

22.3.7 *Test Conditions:*

22.3.7.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide a good signal-to-noise ratio.

22.3.7.2 The eddy-current coil frequency used shall not exceed the following:

On specified walls up to 0.050 in. [1.3 mm] - 100 kHz
On specified walls up to 0.150 in. [3.8 mm] - 50 kHz
On specified walls equal to or greater than 0.150 in. [3.8 mm] - 10 kHz

22.3.7.3 *Ultrasonic*—For examination by the ultrasonic method, the nominal transducer frequency shall be 2.00 MHz or more and the nominal transducer size shall be 1.5 in. [38 mm] or less.

22.3.7.4 If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at the setting.

22.3.8 *Reference Standards:*

22.3.8.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish, and heat treatment conditions as the pipe to be examined.

22.3.8.2 *For Ultrasonic Testing,* the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E213, at the option of the manufacturer. The depth of each notch shall not exceed 12.5 % of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is the greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

22.3.8.3 *For Eddy-Current Testing,* the reference standard shall contain, at the option of the manufacturer, any one of the following reference discontinuities:

22.3.8.4 *Drilled Hole*—The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternatively, the manufacturer of welded pipe is permitted to drill one hole in the weld and run the calibration standard through the test coils three times, with the weld turned at 120° on each pass. The hole diameter shall not exceed the following:

NPS Designator	Hole Diameter
½	0.039 in. [1.0 mm]
above ½ to 1 ¼	0.055 in. [1.4 mm]
above 1 ¼ to 2	0.071 in. [1.8 mm]
above 2 to 5	0.087 in. [2.2 mm]
above 5	0.106 in. [2.7 mm]

22.3.8.5 *Transverse Tangential Notch*—Using a round tool or a file with a ¼-in. [6.4-mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Such a notch shall have a depth not exceeding 12.5 % of the specified wall thickness of the pipe or 0.004 in. [0.10 mm], whichever is the greater.

22.3.8.6 *Longitudinal Notch*—A notch of 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe, to have a depth not exceeding 12.5 % of the specified wall thickness of the pipe or 0.004 in. [0.10 mm], whichever is the greater.

22.3.8.7 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

22.3.9 *Standardization Procedure:*

22.3.9.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option and may be required upon agreement between the purchaser and the manufacturer.

22.3.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, process shutdown, or when a problem is suspected.

22.3.9.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

22.3.9.4 The signal-to-noise ratio for the reference standard shall be 2½ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, etc., shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50 % of full scale of the readout display.

22.3.9.5 If upon any standardization, the rejection amplitude has decreased by at least 29 % (3 dB) of peak height from the last standardization, the pipe tested since the last calibration shall be rejected or retested for acceptance after the test apparatus settings have been changed, or the transducer(s), coil(s), or sensor(s) have been adjusted, and the test apparatus has been restandardized.

22.3.10 *Evaluation of Imperfections:*

22.3.10.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference discontinuities shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

22.3.10.2 Such pipes shall be rejected if the test signals were produced by imperfections that cannot be identified or were produced by cracks or crack-like imperfections. Such pipes may be repaired if such repair is permitted by the applicable product specification. To be accepted, a repaired pipe shall pass the same nondestructive test by which it was rejected, and it shall meet the minimum wall thickness requirements of the applicable product specification.

22.3.10.3 If the test signals were produced by visual imperfections such as scratches, surface roughness, dings, straightener marks, cutting chips, steel die stamps, stop marks, or pipe reducer ripple, the pipe is permitted to be accepted based upon visual examination provided that the depth of the imperfection is less than 0.004 in. [0.1 mm] or 12.5 % of the specified wall thickness, whichever is the greater.

22.3.10.4 Rejected pipe may be reconditioned and retested, provided that the wall thickness is not decreased to less than that required by the applicable product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

22.3.10.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test provided that the imperfection does not encroach on the minimum required wall thickness.

23. Inspection

23.1 The inspector representing the purchaser shall have entry at all times work on the contract of the purchaser is being performed, to all parts of the manufacturer's facilities that concern the manufacture of the product ordered. The manufacturer shall afford the inspector all reasonable facilities to be satisfied that the product is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the manufacturer's operations.

24. Rejection

24.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based upon the inspection and test method as outlined in the applicable product specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

24.2 Pipe that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the suitability of the pipe. Disposition of such pipe shall be matter for agreement.

25. Certification

25.1 The manufacturer or supplier shall furnish to the purchaser a certificate of compliance stating that the product was manufactured, sampled, tested, and inspected in accordance with the specification, including year-date, the supplementary requirements, and any other requirements designated in the purchase order or contract, and has been found to meet such requirements. A signature or notarization is not required; however, the document shall be dated and shall clearly identify the organization submitting it.

25.1.1 Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

25.2 In addition to the certificate of compliance, the manufacturer or supplier shall furnish to the purchaser a test report that includes the following information and test results, as applicable:

25.2.1 Heat number,

25.2.2 Heat analysis,

25.2.3 Product analysis if specified or required,

25.2.4 Tensile properties,

25.2.5 Width in the gauge length, if longitudinal strip tension test specimens were used,

25.2.6 Bend test acceptable,

25.2.7 Flattening test acceptable,

25.2.8 Hydrostatic test pressure,

25.2.9 Nondestructive electric test method,

25.2.10 Impact test results, and

25.2.11 Other test results or information required to be reported by the applicable product specification.

25.3 Test results or information required to be reported by supplementary requirements, or other requirements designated in the purchase order or contract shall be reported but may be reported in a separate document.

25.4 The test report shall include a statement of explanation for the letter added to the specification number marked on the tubes (see 26.5) if all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before the removal of the letter (that is, X, Y, or Z).

25.5 A test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) shall be regarded as having the same validity as a counterpart printed in the certifying organization's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for its content.

26. Product Marking

26.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number (year of issue not required) and grade. Marking shall begin approximately 12 in. [300 mm] from the end of each length of pipe. For pipe less than NPS 2 and pipe under 3 ft [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the pipes are shipped.

26.2 When pipe marked as specified is rejected, the ASTM designation shall be canceled.

26.3 For austenitic steel pipe, the marking paint or ink shall not contain detrimental amounts of harmful metals, or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

26.4 Pipes that have been weld repaired in accordance with 17.1 shall be marked WR.

26.5 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as X, Y, or Z, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in 25.1.

27. Packaging, Marking, and Loading

27.1 If specified in the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A700.

28. Government Procurement

28.1 If specified in the contract or purchase order, the following requirements shall be considered in the inquiry, contract, or order for agencies of the U.S. Government where scale-free pipe is required. Such requirements shall take precedence if there is a conflict between these requirements and those of the applicable product specification.

28.2 Pipe shall be ordered to nominal pipe size (NPS) and schedule. Nominal pipe shall be as specified in ANSI B36.10 or B36.19.

28.3 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the government for acceptance comply with all requirements of the contract or purchase order. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements; however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use its own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth if such inspections and tests are deemed necessary to ensure that the products conform to the prescribed requirements.

28.4 *Sampling for Flattening and Flaring Test and for Visual and Dimensional Examination*—Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (Pieces per Lot)	Sample Size
2 to 8	Entire Lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

28.5 *Sampling for Chemical Analysis*—One sample for chemical analysis shall be selected from each two pipes chosen from each lot. A lot shall be all material poured from one heat.

28.6 *Sampling for Tension and Bend Test*—One sample shall be taken from each lot. A lot shall consist of all pipe of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch-type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

28.7 *Hydrostatic and Ultrasonic Tests*—Each pipe shall be tested by the ultrasonic (if specified) and hydrostatic tests.

28.8 Pipe shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel pipe shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

28.9 In addition to the marking required by this specification, each length of pipe NPS ¼ or larger shall be marked, in accordance with FED-STD-183 and MIL-STD-792, with the nominal pipe size, schedule number, length, and heat number or lot identification number.

28.10 Pipe shall be straight to within the tolerance given in Table 2.

28.11 If specified, each pipe shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the reference standard shall be 5 % of the wall thickness or 0.005 in. [0.1 mm], whichever is the greater. Any pipe that produces an indication equal to or greater than 100 % of the indication from the reference discontinuity shall be rejected.

28.12 The pipe shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the pipe as determined by visual and ultrasonic examination, or alternate tests, as specified.

28.13 Pipe shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality pipe. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered defects if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in. [0.1 mm], whichever is the greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

28.14 No weld repair by the manufacturer is permitted.

28.15 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163 and commercial preservation and packing shall be in accordance with Practices A700 or Practice D3951.

29. Keywords

29.1 alloy steel pipe; austenitic stainless steel; duplex stainless steel; ferritic/austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

TABLE 2 Straightness Tolerances

Specified OD, in.[A]	Specified Wall Thickness, in.[A]	Maximum Curvature in any 3 ft, in.[A]	Maximum Curvature in Total Length, in.[A]
Up to 5.0, incl.	Over 3 % OD to 0.5, incl.	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl.	Over 4 % OD to 0.75 incl.	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl.	Over 4 % OD to 1.0, incl.	0.060	0.020 × length, ft

[A] 1 in. = 25.4 mm.

ANNEXES

(Mandatory Information)

A1. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in product specifications referencing this general requirements specification subject to the following conditions:

A1.1.1 Application for the addition of a new grade to a specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable product specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable product specification. Test data from a minimum of three test lots, as defined by the applicable product specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable product specification.

A1.1.5 The application shall state whether the new grade is covered by patent.

A2. REQUIREMENTS FOR THE INTRODUCTION OF MATERIALS FROM OTHER A01 OR B02.07 SPECIFICATIONS

A2.1 Wrought materials that are already covered by another A01 or B02.07 specification may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A2.1.1 Application for the addition of a grade that is already covered in another A01 or B02.07 specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A2.1.2 The chemical requirements, the specified mechanical properties, and the heat treatment requirements of the grade being added shall be the same as those for the grade in the A01 or B02.07 specification in which the grade is presently covered.

A2.1.3 The application shall provide recommendations for all requirements appearing in the applicable specification.

A2.1.4 The application shall state whether or not the grade is covered by patent.

APPENDIX

(Nonmandatory Information)

X1. MINIMUM WALL THICKNESS ON INSPECTION FOR NOMINAL (AVERAGE) PIPE WALL THICKNESS

TABLE X1.1 Minimum Wall Thicknesses on Inspection for Nominal (Average) Pipe Wall Thicknesses

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in. [mm], and
t_m = minimum wall thicknesses, in. [mm],
The wall thickness in inch-pound units is rounded to three decimal places in accordance with the rounding method of Practice E29. The wall thickness in SI units is rounded to one decimal place in accordance with the rounding method of Practice E29.

NOTE 2—This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed herein are necessarily obtainable for the applicable product specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	[mm]	in.	[mm]	in.	[mm]	in.	[mm]	in.	mm	in.	[mm]
0.068	[1.7]	0.060	[1.5]	0.294	[7.5]	0.257	[6.5]	0.750	[19.0]	0.658	[16.6]
0.068	[2.2]	0.077	[2.0]	0.300	[7.6]	0.262	[6.7]	0.812	[20.6]	0.710	[18.0]
0.091	[2.3]	0.080	[2.0]	0.307	[7.8]	0.269	[6.8]	0.843	[21.4]	0.736	[18.7]
0.095	[2.4]	0.083	[2.1]	0.308	[7.8]	0.270	[6.9]	0.854	[21.7]	0.756	[19.2]
0.113	[2.9]	0.099	[2.5]	0.312	[7.9]	0.273	[6.9]	0.875	[22.2]	0.766	[19.5]
0.119	[3.0]	0.104	[2.6]	0.318	[8.1]	0.278	[7.1]	0.906	[23.0]	0.783	[20.1]
0.125	[3.2]	0.109	[2.8]	0.322	[8.2]	0.282	[7.2]	0.937	[23.8]	0.820	[20.8]
0.126	[3.2]	0.110	[2.8]	0.330	[8.4]	0.289	[7.3]	0.968	[24.6]	0.847	[21.5]
0.133	[3.4]	0.116	[2.9]	0.337	[8.6]	0.295	[7.5]	1.000	[25.4]	0.875	[22.2]
0.140	[3.6]	0.122	[3.1]	0.343	[8.7]	0.300	[7.6]	1.031	[26.2]	0.902	[22.9]
0.145	[3.7]	0.127	[3.2]	0.344	[8.7]	0.301	[7.6]	1.062	[27.0]	0.929	[23.6]
0.147	[3.7]	0.129	[3.3]	0.358	[9.1]	0.313	[8.0]	1.083	[27.8]	0.956	[24.3]
0.154	[3.9]	0.135	[3.4]	0.365	[9.3]	0.319	[8.1]	1.125	[28.6]	0.984	[25.0]
0.156	[4.0]	0.136	[3.5]	0.375	[9.5]	0.328	[8.3]	1.156	[29.4]	1.012	[25.7]
0.179	[4.5]	0.157	[4.0]	0.382	[9.7]	0.334	[8.5]	1.218	[30.9]	1.066	[27.1]
0.187	[4.7]	0.164	[4.2]	0.400	[10.2]	0.350	[8.9]	1.250	[31.8]	1.094	[27.8]
0.188	[4.8]	0.164	[4.2]	0.406	[10.3]	0.355	[9.0]	1.281	[32.5]	1.121	[28.5]
0.191	[4.9]	0.167	[4.2]	0.432	[10.4]	0.378	[9.6]	1.312	[33.3]	1.148	[29.2]
0.200	[5.1]	0.175	[4.4]	0.436	[11.1]	0.382	[9.7]	1.343	[34.1]	1.175	[29.8]
0.203	[5.2]	0.178	[4.5]	0.437	[11.1]	0.382	[9.7]	1.375	[34.9]	1.203	[30.6]
0.216	[5.5]	0.189	[4.8]	0.438	[11.1]	0.383	[9.7]	1.406	[35.7]	1.230	[31.2]
0.218	[5.5]	0.191	[4.9]	0.500	[12.7]	0.438	[11.1]	1.436	[36.5]	1.258	[32.0]
0.219	[5.6]	0.192	[4.9]	0.531	[13.5]	0.465	[11.8]	1.500	[36.1]	1.312	[33.3]
0.226	[5.7]	0.196	[5.0]	0.552	[14.0]	0.483	[12.3]	1.531	[38.9]	1.340	[34.0]
0.237	[6.0]	0.207	[5.2]	0.562	[14.3]	0.492	[12.5]	1.562	[39.7]	1.367	[34.7]
0.250	[6.4]	0.219	[5.6]	0.593	[15.1]	0.519	[13.2]	1.593	[40.5]	1.394	[35.4]
0.258	[6.6]	0.226	[5.7]	0.600	[15.2]	0.525	[13.3]	1.750	[44.5]	1.531	[38.9]
0.276	[7.0]	0.242	[6.1]	0.625	[15.9]	0.547	[13.9]	1.781	[45.2]	1.558	[39.6]
0.277	[7.0]	0.242	[6.1]	0.656	[16.6]	0.573	[14.6]	1.812	[46.0]	1.586	[49.3]
0.279	[7.1]	0.244	[6.2]	0.674	[17.1]	0.590	[15.0]	1.968	[50.0]	1.772	[43.7]
0.280	[7.1]	0.245	[6.2]	0.687	[17.4]	0.601	[15.3]	2.062	[52.4]	1.804	[45.8]
0.281	[7.1]	0.246	[6.2]	0.719	[18.3]	0.629	[16.0]	2.343	[59.5]	2.050	[52.1]

SPECIFICATION FOR STEEL, SHEET, COLD-ROLLED, CARBON, STRUCTURAL, HIGH-STRENGTH LOW-ALLOY AND HIGH-STRENGTH LOW-ALLOY WITH IMPROVED FORMABILITY

SA-1008/SA-1008M

(Identical with ASTM Specification A1008/A1008M-01a except for the addition of 8.1.1.1 on mechanical properties for pressure vessel design.)

SPECIFICATION FOR STEEL, SHEET, COLD-ROLLED, CARBON, STRUCTURAL, HIGH-STRENGTH LOW-ALLOY AND HIGH-STRENGTH LOW-ALLOY WITH IMPROVED FORMABILITY

SA-1008/SA-1008M

(Identical with ASTM Specification A 1008/A 1008M-01a except for the addition of 8.1.1.1 on mechanical properties for pressure vessel design.)

1. Scope

1.1 This specification covers cold rolled structural, high-strength low-alloy, and high-strength low-alloy with improved formability steel sheet, in coils and cut lengths.

1.2 Cold rolled steel sheet is available in the designations as listed in 4.1.

1.3 This specification does not apply to steel strip as described in Specification A 109.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:*

A 109 Specification for Steel, Strip, Carbon, Cold Rolled
A 366/A 366M Specification for Commercial Steel (CS), Sheet, Carbon (0.15 Maximum Percentage), Cold-Rolled
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
A 620/A 620M Specification for Drawing Steel (DS), Sheet, Carbon, Cold-Rolled
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
E 517 Test Method for Plastic Strain Ratio r for Sheet Metal
E 646 Test Method for Tensile Strain-Hardening Exponents (n-Values) of Metallic Sheet Materials

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of other terms used in this specification, refer to Terminology A 941.

3.1.2 *stabilization* — the addition of one or more nitride or carbide forming elements, or both, such as titanium and columbium, to control the level of the interstitial elements of carbon and nitrogen in the steel.

3.1.2.1 *Discussion* — Stabilizing improves formability and increases resistance to aging.

3.1.3 *vacuum degassing* — a process of refining liquid steel in which the liquid is exposed to a vacuum as part of a special technique for removing impurities or for decarburizing the steel.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aging* — loss of ductility with an increase in hardness, yield strength, and tensile strength that occurs when steel that has been slightly cold worked (such as by temper rolling) is stored for some time.

3.2.1.1 *Discussion* — Aging increases the tendency of a steel to exhibit stretcher strains and fluting.

4. Classification

4.1 Cold-rolled steel sheet is available in the following designations:

4.1.1 Commercial Steel (CS Types A, B, and C),

4.1.2 Drawing Steel (DS Types A and B),

NOTE 1 — CS Type B and DS Type B describe the most common product previously included, respectively, in Specifications A 366/A 366M and A 620/A 620M.

4.1.3 Deep Drawing Steel (DDS),

4.1.4 Extra Deep Drawing Steel (EDDS),

4.1.5 Structural Steel (SS grades 25[170], 30[205], 33[230] Types 1 and 2, 40[275] Types 1 and 2, and 80[550]),

4.1.6 High-Strength Low-Alloy Steel (HSLAS, in classes 1 and 2, in grades 45[310], 50[340], 55[380], 60[410], 65[450], and 70[480] in Classes 1 and 2), and

4.1.7 High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F grades 50 [340], 60 [410], 70 [480], and 80 [550]).

4.1.7.1 HSLAS-F steel has improved formability when compared to HSLAS. The steel is fully deoxidized, made to fine grain practice and includes microalloying elements such as columbium, vanadium, zirconium, etc. The steel may be treated to achieve inclusion control.

4.2 Cold-rolled steel sheet is supplied for either exposed or unexposed applications. Within the latter category, cold-rolled sheet is specified either "temper rolled" or "annealed last." For details on processing, attributes and limitations, and inspection standards, refer to Specification A 568/A 568M.

5. Ordering Information

5.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to describe the required material. Examples of such information include, but are not limited to, the following:

5.1.1 ASTM specification number and year of issue,

5.1.2 Name of material and designation (cold-rolled steel sheet) (include grade, type, and class, as appropriate, for CS, DS, DDS, EDDS, SS, HSLAS, or HSLAS-F) (see 4.1),

5.1.2.1 When a type is not specified for CS or DS, Type B will be furnished (see 4.1),

5.1.2.2 When a class is not specified for HSLAS, Class 1 will be furnished (see 4.1),

5.1.2.3 When a type is not specified for SS33 [230] and SS40 [275], Type 1 will be furnished (see 4.1),

5.1.3 Classification (either exposed, unexposed, temper rolled, or annealed last) (see 4.2),

5.1.4 Finish (see 9.1),

5.1.5 Oiled or not oiled, as required (see 9.2),

5.1.6 Dimensions (thickness, thickness tolerance table (see 5.1.6.1), width, and whether cut lengths or coils),

5.1.6.1 As agreed upon between the purchaser and the producer, material ordered to this specification will be supplied to meet the applicable thickness tolerance table shown in Specification A 568/A 568M,

NOTE 2 — Not all producers are capable of meeting all the limitations of the thickness tolerance tables in Specification A 568/A 568M. The purchaser should contact the producer regarding possible limitations prior to placing an order.

5.1.7 Coil size (must include inside diameter, outside diameter, and maximum weight),

5.1.8 Copper bearing steel (if required),

5.1.9 Quantity,

5.1.10 Application (part identification and description),

5.1.11 Special requirements (if required), or supplementary requirement S1 for HSLAS, and

5.1.12 A report of heat analysis will be supplied, if requested, for CS, DS, DDS, and EDDS. For materials with required mechanical properties, SS, HSLAS, and HSLAS-F, a report is required of heat analysis and mechanical properties as determined by the tension test.

NOTE 3 — A typical ordering description is as follows: ASTM A 1008-XX, cold rolled steel sheet, CS Type A, exposed, matte finish, oiled, 0.035 by 30 in. by coil, ID 24 in., OD 48 in., max weight 15 000 lbs, thickness tolerance Table 18 of Specification A 568/A 568M, 100 000 lb, for part No. 4560, Door Panel.
or:
ASTM A 1008M-XX, cold-rolled steel sheet, SS grade 275, unexposed, matte finish, oiled, 0.88 mm by 760 mm by 2440 mm, thickness tolerance Table A1.15 of Specification A 568/A 568M, 10 000 kg, for shelf bracket.

6. General Requirements for Delivery

6.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 568/A 568M unless otherwise provided herein.

7. Chemical Composition

7.1 The heat analysis of the steel shall conform to the chemical composition requirements of the appropriate designation shown in Table 1 for CS, DS, DDS, and EDDS and in Table 2 for SS, HSLAS, and HSLAS-F.

7.2 Each of the elements listed in Table 1 and Table 2 shall be included in the report of the heat analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02%, the analysis may be reported as < 0.02%. When the amount of vanadium, columbium, or titanium is less than 0.008%, the analysis may be reported as < 0.008%.

7.3 Sheet steel grades defined by this specification are suitable for welding if appropriate welding conditions are selected. For certain welding processes, more restrictive composition limits may be desirable and should be requested at the time of inquiry and ordering.

8. Mechanical Properties

8.1 *CS, DS, DDS, and EDDS:*

8.1.1 Typical nonmandatory mechanical properties for CS, DS, DDS and EDDS are shown in Table 3.

8.1.1.1 For the purposes of pressure vessel design, the following minimum tensile properties may be assumed, 20 ksi [140 MPa] yield strength and 40 ksi [275 MPa] tensile strength.

8.1.2 The material shall be capable of being bent, at room temperature, in any direction through 180° flat on itself without cracking on the outside of the bent portion (see Section 14 of Test Methods and Definitions A 370).

8.1.3 Sheet of these designations except for EDDS may be subject to aging dependent upon processing factors such as the method of annealing (continuous annealing or box annealing), and chemical composition. For additional information on aging, see Appendix X1 of Specification A 568/A 568M.

8.1.4 EDDS steel is stabilized to be nonaging and so is not subject to stretcher strains and fluting. Other steels may be processed to be nonaging; please consult your supplier.

8.2 *SS, HSLAS and HSLAS-F:*

8.2.1 The available strength grades for SS, HSLAS and HSLAS-F are shown in Table 4.

8.2.2 *Tension Tests:*

8.2.2.1 *Requirements* — Material as represented by the test specimen shall conform to the mechanical property requirements specified in Table 4. These requirements do not apply to the uncropped ends of unprecessed coils.

8.2.2.2 *Number of Tests* — Two tension tests shall be made from each heat or from each 50 tons [45 000 kg]. When the amount of finished material from a heat is less than 50 tons [45 000 kg], one test shall be made. When material rolled from heat differs 0.050 in. [1.27 mm] or more in thickness, one tension test shall be made from the thickest and thinnest matereial regardless of the weight represented.

8.2.2.3 Tension test specimens shall be taken at a point immediately adjacent to the material to be qualified.

8.2.2.4 Tension test specimens shall be taken from the full thickness of the sheet.

8.2.2.5 Tension test specimens shall be taken from a location approximately halfway between the center of the sheet and the edge of the material as rolled.

8.2.2.6 Tension test samples shall be taken with the lengthwise axis of the test specimen parallel to the rolling direction (longitudinal test).

8.2.2.7 *Test Method* — Yield strength shall be determined by either the 0.2% offset method or the 0.5% extension under load method unless otherwise specified.

8.2.3 *Bending Properties:*

8.2.3.1 The suggested minimum inside radii for cold bending are listed in Appendix X1 and is discussed in more detail in Specification A 568/A 568M (Section 6). Where a tighter bend radius is required, where curved or offset bends are involved, or where stretching or drawing are also a consideration, the producer should be consulted.

9. Finish and Appearance

9.1 *Surface Finish:*

9.1.1 Unless otherwise specified, the sheet shall have a matte finish. When required, a controlled surface texture and condition may be specified.

For additional information see "Finish and Condition" section of Specification A 568/A 568M.

9.2 *Oiling:*

9.2.1 Unless otherwise specified, the sheet shall be oiled.

9.2.2 When required, the sheet may be specified to be furnished not oiled (dry).

10. Retests and Resamples

10.1 *Retests* — If the results on an original tension test specimen are within 2 ksi [14 MPa] of the required tensile strength, within 1 ksi [7 MPa] of the required yield point, or within two percentage points of the required elongation, a retest shall be permitted for which one test specimen selected at random shall be tested. If the results of this retest specimen satisfy the specified mechanical properties and all other requirements of the applicable specification are satisfied, the material shall be accepted. Retests are permitted in accordance with Specification A 568/A 568M.

10.2 *Resamples* — Resamples are permitted in accordance with Specification A 568/A 568M.

11. Certification

11.1 A report of heat analysis shall be supplied, if requested, for CS, DS, DDS, and EDDS steels. For material with required mechanical properties, SS, HSLAS, and HSLAS-F, a report is required of heat analysis and mechanical properties as determined by the tension test.

11.2 The report shall include the purchase order number, the ASTM designation number and year date, product designation, grade, type or class, as applicable, the heat number, and as required, heat analysis and mechanical properties as indicated by the tension test.

11.3 A signature is not required on the test report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

11.4 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

12. Product Marking

12.1 In addition to the requirements of Specification A 568/A 568M, each lift or coil shall be marked with the designation shown on the order {CS (Type A, B, or C), DS (Type A or B), DDS, EDDS, SS, HSLAS, or HSLAS-F}. The designation shall be legibly stenciled on the top of each lift or shown on a tag attached to each coil or shipping unit.

13. Keywords

13.1 carbon steel sheet; cold-rolled steel sheet; steel sheet; commercial steel; drawing steel; deep drawing steel; extra deep drawing steel; high-strength low-alloy steel; high-strength low-alloy steel with improved formability; structural steel

TABLE 1 CHEMICAL COMPOSITION[A]
FOR COLD ROLLED STEEL SHEET DESIGNATIONS CS, DS, DDS, AND EDDS

Designation	Composition, % Heat Analysis (Element Maximum Unless Otherwise Shown)												
	C	Mn	P	S	Al	Si	Cu[B]	Ni[B]	Cr[B, C]	Mo[B]	V	Cb	Ti	N
CS Type A[D, E, F, G]	0.10	0.60	0.030	0.035	. . .	. . .	0.20[H]	0.20	0.15	0.06	0.008	0.008	0.008[I]	. . .
CS Type B[D]	0.02 to 0.15	0.60	0.030	0.035	. . .	. . .	0.20[H]	0.20	0.15	0.06	0.008	0.008	0.008[I]	. . .
CS Type C[D, E, F, G]	0.08	0.60	0.10	0.035	. . .	. . .	0.20[H]	0.20	0.15	0.06	0.008	0.008	0.008[I]	. . .
DS Type A[E, J]	0.08	0.50	0.020	0.030	0.01 min	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.008[I]	. . .
DS Type B	0.02 to 0.08	0.50	0.020	0.030	0.02 min	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.008[I]	. . .
DDS[F, G]	0.06	0.50	0.020	0.025	0.01 min	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.008[I]	. . .
EDDS[K]	0.02	0.40	0.020	0.020	0.01 min	. . .	0.10	0.10	0.15	0.03	0.008	0.10	0.15	. . .

[A] Where an ellipsis (. . .) appears in the table, there is no requirement, but the analysis result shall be reported.
[B] The sum of copper, nickel, chromium, and molybdenum shall not exceed 0.50% on heat analysis. When one or more of these elements is specified by the purchaser, the sum does not apply, in which case only the individual limits on the remaining elements shall apply.
[C] Chromium is permitted, at the producer's option, to 0.25% maximum when the carbon content is less than or equal to 0.05%. In such case the limit on the sum of the four elements in Footnote B does not apply.
[D] When an aluminum deoxidized steel is required for the application, Commercial Steel (CS) may be ordered to a minimum of 0.01% total aluminum.
[E] Specify Type B to avoid carbon levels below 0.02%.
[F] May be furnished as a vacuum degassed or chemically stabilized steel, or both, at the producer's option.
[G] For carbon levels less than or equal to 0.02%, columbium or titanium, or both, may be used as stabilizing elements at the producer's option. In such cases, the applicable limit for columbium shall be 0.10% max. and the limit on titanium shall be 0.15% max.
[H] When copper steel is specified, the copper limit is a minimum requirement. When copper steel is not specified, the copper limit is a maximum requirement.
[I] Except for EDDS, titanium is permitted, at producer's option, to 0.025% provided the ratio of % titanium to % nitrogen does not exceed 3.4.
[J] DS Type A may be furnished as a vacuum degassed steel, at the producers option.
[K] Shall be furnished as a vacuum degassed and stabilized steel.

TABLE 2
CHEMICAL COMPOSITION[A]
FOR COLD ROLLED STEEL SHEET DESIGNATIONS SS, HSLAS, AND HSLAS-F

Designation	% Heat Analysis, Element Maximum unless otherwise shown												
	C	Mn	P	S	Al	Si	Cu[B, C]	Ni[B]	Cr[B]	Mo[B]	V	Cb	N
SS:													
Grade 25 [170]	0.20	0.60	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 30 [205]	0.20	0.60	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 33 [230] Type 1	0.20	0.60	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 33 [230] Type 2	0.15	0.60	0.20	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 40 [275] Type 1	0.20	0.90	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 40 [275] Type 2	0.15	0.60	0.20	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
Grade 80 [550]	0.20	0.60	0.035	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	. . .
HSLAS:[D]													
Grade 45 [310] Class 1	0.22	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 45 [310] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 50 [340] Class 1	0.23	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 50 [340] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 55 [380] Class 1	0.25	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 55 [380] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 60 [410] Class 1	0.26	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	. . .
Grade 60 [410] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	0.020
Grade 65 [450] Class 1	0.26	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	0.012
Grade 65 [450] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	0.020
Grade 70 [780] Class 1	0.26	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	0.012
Grade 70 [780] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.20	0.20	0.15	0.06	0.01 min	0.005 min	0.020
HSLAS-F:[E]													
Grade 50 [340], 60 [410], 70 [480], and 80 [550]	0.15	1.65	0.020	0.025	. . .	. . .	0.20	0.20	0.15	0.06	. . .	. . .	. . .

[A] Where an ellipsis (. . .) appears in the table, there is no requirement but, the analysis shall be reported.

[B] The sum of copper, nickel, chromium, and molybdenum shall not exceed 0.50%. When one or more of these elements are specified by the purchaser, the sum does not apply, in which case, only the individual limits on the remaining unspecified elements will apply.

[C] When copper is specified, the copper limit is a minimum requirement. When copper steel is not specified, the copper limit is a maximum requirement.

[D] For HSLAS steels, columbium and vanadium may be added singly or in combination.

[E] These steels shall also contain one or more of the following elements: vanadium, titanium, and columbium. Other alloying elements may be present, but are not required.

TABLE 3
TYPICAL RANGES OF MECHANICAL PROPERTIES[A] (NONMANDATORY)[B]
FOR COLD ROLLED STEEL SHEET DESIGNATIONS CS, DS, DDS, AND EDDS

Designation	Yield Strength[C] ksi	Yield Strength[C] MPa	Elongation in 2 in. [50 mm] %[C]	r_m Value[D]	n-Value[E]
CS Types A, B, and C	20 to 40	[140 to 275]	≥ 30	[F]	[F]
DS Types A and B	22 to 35	[150 to 240]	≥ 36	1.3 to 1.7	0.17 to 0.22
DDS	17 to 29	[115 to 200]	≥ 38	1.4 to 1.8	0.20 to 0.25
EDDS	15 to 25	[105 to 170]	≥ 40	1.7 to 2.1	0.23 to 0.27

[A] These typical mechanical properties apply to the full range of steel sheet thicknesses. The yield strength tends to increase, the elongation decreases, and some of the formability values tend to decrease as the sheet thickness decreases.

[B] The typical mechanical property values presented here are nonmandatory. They are provided to assist the purchaser in specifying a suitable steel for a given application. Values outside of these ranges are to be expected.

[C] Yield Strength and elongation are measured in the longitudinal direction in accordance with Test Methods A 370.

[D] Average plastic strain ratio (r_m value) as determined by Test Method E 517.

[E] The strain hardening exponent (n-value) as determined by Test Method E 646.

[F] No typical properties have been established.

TABLE 4
MECHANICAL PROPERTY REQUIREMENTS[A]
FOR COLD ROLLED STEEL SHEET DESIGNATIONS SS, HSLAS, AND HSLAS-F

Designation	Yield Strength, min. ksi	Yield Strength, min. [MPa]	Tensile Strength, min. ksi	Tensile Strength, min. [MPa]	Elongation in 2 in. or 50 mm, min., %
SS:					
Grade 25 [170]	25	[170]	42	[290]	26
Grade 30 [205]	30	[205]	45	[310]	24
Grade 33 [230] Types 1 and 2	33	[230]	48	[330]	22
Grade 40 [275] Types 1 and 2	40	[275]	52	[360]	20
Grade 80 [550]	80[B]	[550]	82	[565]	[C]
HSLAS:					
Grade 45 [310] Class 1	45	[310]	60	[410]	22
Grade 45 [310] Class 2	45	[310]	55	[380]	22
Grade 50 [340] Class 1	50	[340]	65	[450]	20
Grade 50 [340] Class 2	50	[340]	60	[410]	20
Grade 55 [380] Class 1	55	[380]	70	[480]	18
Grade 55 [380] Class 2	55	[380]	65	[450]	18
Grade 60 [410] Class 1	60	[410]	75	[520]	16
Grade 60 [410] Class 2	60	[410]	70	[480]	16
Grade 65 [450] Class 1	65	[450]	80	[550]	15
Grade 65 [450] Class 2	65	[450]	75	[520]	15
Grade 70 [480] Class 1	70	[480]	85	[585]	14
Grade 70 [480] Class 2	70	[480]	80	[550]	14
HSLAS-F:					
Grade 50 [340]	50	[340]	60	[410]	22
Grade 60 [410]	60	[410]	70	[480]	18
Grade 70 [480]	70	[480]	80	[550]	16
Grade 80 [550]	80	[550]	90	[620]	14

[A] For coil products, testing by the producer is limited to the end of the coil. Mechanical properties throughout the coil shall comply with the minimum values specified.

[B] On this full-hard product, the yield strength approaches the tensile strength, and since there is no halt in the gage or drop in the beam, the yield point shall be taken as the yield stress at 0.5% extension under load.

[C] There is no requirement for elongation in 2 in. for SS Grade 80.

SUPPLEMENTARY REQUIREMENTS FOR COLD ROLLED HSLAS STEEL SHEET

The following supplementary requirements shall apply when specified in the order or contract:

S1. Elements

S1.1 When a purchaser prefers to designate the specific elements (columbium, vanadium, nitrogen, or combinations thereof), one of the types listed below shall be specified. The type, in addition to the grade, must be shown on the order:

Type 1 — Columbium
Type 2 — Vanadium
Type 3 — Columbium and Vanadium
Type 4 — Vanadium and Nitrogen

S1.2 The composition limits of Section 7 shall apply for any of these elements.

APPENDIX

(Nonmandatory Information)

X1. BENDING PROPERTIES

TABLE X1.1
SUGGESTED MINIMUM INSIDE RADIUS FOR COLD BENDING

Product	Grade	Minimum Inside Radius for Cold Bending	
Structural Steel	25[170]	½ t	
	30[205]	1 t	
	33[230]	1½ t	
	40[275]	2 t	
	80[550]	not applicable	
High-Strength Low-Alloy Steel		Class 1	Class 2
	45[310]	1½ t	1½ t
	50[340]	2 t	1½ t
	55[380]	2 t	2 t
	60[410]	2½ t	2 t
	65[450]	3 t	2½ t
	70[480]	3½ t	3 t
High-Strength Low-Alloy Steel with Improved Formability	50[340]	1 t	
	60[410]	1½ t	
	70[480]	2 t	
	80[550]	2 t	

NOTE 1 — (t) Equals a radius equivalent to the steel thickness.
NOTE 2 — The suggested radius should be used as a minimum for 90° bends in actual shop practice.
NOTE 3 — Material which does not perform satisfactorily, when fabricated in accordance with the requirements, may be subject to rejection pending negotiation with the steel supplier.

SPECIFICATION FOR HIGHER-STRENGTH MARTENSITIC STAINLESS STEEL PLATE, SHEET, AND STRIP

SA-1010/SA-1010M

(Identical with ASTM Specification A1010/A1010M-01(2009) except for an editorial correction to a column heading in Table 2.)

SPECIFICATION FOR HIGHER-STRENGTH MARTENSITIC STAINLESS STEEL PLATE, SHEET, AND STRIP

SA-1010/SA-1010M

[Identical with ASTM Specification A 1010/A1010M-01(2009) except for an editorial correction to a column heading in Table 2.]

1. Scope

1.1 This specification covers martensitic stainless steels for various structural, architectural, pressure vessel, and heat-resisting applications. The mechanical properties of these steels are customarily, but not necessarily, developed by a suitable heat treatment generally referred to as tempering.

1.2 Steel products under this specification are available in two grades:

Grade	Yield Strength, min, ksi [MPa]
40 [275]	40 [275]
50 [350]	50 [350]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification to 1 in. [25 mm].

1.4 The values stated in inch-pound or SI units are to be regarded separately as the standard. Within the text, SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the purchase order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 673/A 673M Specification for Sampling Procedure for Impact Testing of Structural Steel

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *Other Document:*

SAE J 1086 Recommended Practice for Numbering Metals and Alloys

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 480/A 480M.

3.1.1 Terminology,

3.1.2 Ordering Information,

3.1.3 Process,

3.1.4 Heat Analysis,

3.1.5 Product Analysis,

3.1.6 Finish for Sheet,

3.1.7 Finish for Strip,

3.1.8 Finish for Plates,

3.1.9 Test Specimens,

3.1.10 Number of Tests,

3.1.11 Test Methods,

3.1.12 Retests and Retreatment,

3.1.13 Dimensions and Permissible Variations,

3.1.14 Workmanship,

3.1.15 Packaging, Marking, and Loading,

3.1.16 Inspection,

3.1.17 Rejection and Rehearing, and

3.1.18 Material Test Report and Certification.

4. Chemical Composition

4.1 The steel shall conform to the requirements as to chemical composition specified in Table 1, and shall conform to applicable requirements specified in the current edition of Specification A 480/A 480M.

5. Heat Treatment

5.1 The material shall be heat-treated by tempering to meet the requirements of this specification. The tempering temperature shall not exceed 1400°F [760°C]. Prior to tempering, the steel shall be in the as-rolled, normalized or quenched condition.

6. Mechanical Properties

6.1 The material shall conform to the mechanical properties specified in Table 2.

7. Keywords

7.1 architectural steel; martensitic; plate; stainless steel; steel; structural steel; tempered

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS, %[A]

UNS Designation[B]	Type	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Other Elements
S41003	. . .	0.030	1.50	0.040	0.030	1.00	10.5-12.5	1.50	. . .	0.030	. . .

[A] Maximum, unless range or minimum is indicated.
[B] Designation established in accordance with Practice E 527 and SAE J 1086.

TABLE 2
MECHANICAL TEST REQUIREMENTS

Grade	Yield Strength, min, ksi, [MPa]	Tensile Strength, min, ksi [MPa]	Elongation in 2 in. [50 mm], min %	Brinell Hardness, max	Cold Bend
40	40 [275]	66 [455]	18	223	not required
50	50 [350]	70 [485]	18	223	not required

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified on the purchase order. Requirements other than those shown in this section may be specified subject to agreement between the supplier and the purchaser. The following supplementary requirements are suitable for use with this specification.

S1. Charpy V-Notch Impact Test

S1.1 Charpy V-notch impact tests shall be conducted in accordance with Specification A 673/A 673M.

S1.2 The frequency of testing, the test temperature to be used, and the absorbed energy requirements shall be as specified on the order.

S2. Ultrasonic Examination

S2.1 The material shall be ultrasonically examined in accordance with the requirements specified on the order.

SPECIFICATION FOR STEEL, SHEET AND STRIP, HOT-ROLLED, CARBON, STRUCTURAL, HIGH-STRENGTH LOW-ALLOY, HIGH-STRENGTH LOW-ALLOY WITH IMPROVED FORMABILITY, AND ULTRA-HIGH-STRENGTH

SA-1011/SA-1011M

(Identical with ASTM Specification A1011/A1011M-06b.)

SPECIFICATION FOR STEEL, SHEET AND STRIP, HOT-ROLLED, CARBON, STRUCTURAL, HIGH-STRENGTH LOW-ALLOY, HIGH-STRENGTH LOW-ALLOY WITH IMPROVED FORMABILITY, AND ULTRA-HIGH STRENGTH

SA-1011/SA-1011M

(Identical with ASTM Specification A 1011/A 1011M-06b.)

1. Scope

1.1 This specification covers hot-rolled, carbon, structural, high-strength low-alloy, high-strength low-alloy with improved formability, and ultra-high strength steel sheet and strip, in coils and cut lengths.

1.2 Hot rolled steel sheet and strip is available in the designations as listed in 4.1.

1.3 This specification is not applicable to the steel covered by Specification A 635/A 635M.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 568/A 568M Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

A 569/A 569M Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial

A 622/A 622M Specification for Drawing Steel (DS), Sheet and Strip, Carbon, Hot-Rolled[W]

A 635/A 635M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for

A 749/A 749M Specification for Steel, Strip, Carbon and High-Strength, Low-Alloy, Hot-Rolled, General Requirements for

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

E 18 Test Methods for Rockwell Hardness of Metallic Materials

3. Terminology

3.1 *Definitions* — For definitions of other terms used in this specification refer to Terminology A 941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aging* — loss of ductility with an increase in hardness, yield strength, and tensile strength that occurs when steel, which has been slightly cold worked (such as by temper rolling) is stored for some time.

3.2.1.1 *Discussion* — Aging also increases the tendency toward stretcher strains and fluting.

3.2.2 *stabilization* — addition of one or more nitride or carbide forming elements, or both, such as titanium and columbium, to control the level of the interstitial elements carbon and nitrogen in the steel.

3.2.2.1 *Discussion* — Stabilization improves formability and increases resistance to aging.

3.2.3 *vacuum degassing* — process of refining liquid steel in which the liquid is exposed to a vacuum as part of a special technique for removing impurities or for decarburizing the steel.

4. Classification

4.1 Hot-rolled steel sheet and steel strip is available in the following designations:

4.1.1 Commercial Steel (CS Types A, B, C, and D),

4.1.2 Drawing Steel (DS Types A and B),

NOTE 1 — CS Type B and DS Type B describe the most common product previously included, respectively, in Specifications A 569/A 569M and A 622/A 622M.

4.1.3 Structural Steel (SS grades 30[205], 33[230], 36[250] Types 1 and 2, 40[275], 45[310], 50[340], 55[380], 60[410], 70[480], and 80[550]),

4.1.4 High-Strength Low-Alloy Steel (HSLAS, classes 1 and 2, in grades 45[310], 50[340], 55[380], 60[410], 65[450], and 70[480].

4.1.5 High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F grades 50[340], 60[410], 70[480], and 80[550]).

4.1.5.1 HSLAS-F steel has improved formability when compared to HSLAS. The steel is fully deoxidized, made to a fine grain practice, and includes microalloying elements such as columbium, vanadium, and zirconium. The steel shall be treated to achieve inclusion control.

4.1.6 Ultra-High Strength (UHSS Types 1 and 2, in Grades 90 [620] and 100 [690]).

4.1.6.1 UHSS steel has increased strength compared with HSLAS-F. The steel is killed and made to a fine ferritic grain practice, and includes microalloying elements such as columbium (niobium), titanium, vanadium, molybdenum, and so forth. The steel shall be treated to achieve inclusion control. The material is intended for miscellaneous applications where higher strength, savings in weight, and weldability are important. Atmospheric corrosion resistance of these steels is equivalent to plain carbon steels. With copper specified, the atmospheric corrosion resistance is somewhat enhanced.

4.1.7 When required for HSLAS, HSLAS-F, and UHSS steels, limitations on the use of one or more of the microalloy elements shall be specified on the order.

5. Ordering Information

5.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to describe the required material. Examples of such information include, but are not limited to, the following:

5.1.1 ASTM specification number and year of issue,

5.1.2 Name of material and designation (hot-rolled steel sheet) (include grade, type and class, as appropriate, for CS, DS, SS, HSLAS, HSLAS-F, and UHSS) (see 4.1),

5.1.2.1 When a type is not specified for CS or DS, Type B will be furnished (see 4.1),

5.1.2.2 When a class is not specified for HSLAS, Class 1 will be furnished (see 4.1),

5.1.2.3 When a type is not specified for SS Grade 36, Type 1 will be furnished (see 4.1),

5.1.2.4 When a type is not specified for UHSS, Type 1 shall be furnished (see 4.1).

5.1.3 Finish (see 9.1)

5.1.4 Type of edge (see 9.3),

5.1.5 Oiled or not oiled, as required (see 9.2),

5.1.6 Dimensions (thickness, thickness tolerance table (see 5.1.6.1), width, and whether cut lengths or coils),

5.1.6.1 As agreed upon between the purchaser and the producer, material ordered to this specification will be supplied to meet the appropriate thickness tolerance table shown in Specifications A 568/A 568M for sheet and A 749/A 749M for strip.

NOTE 2 — Not all producers are capable of meeting all the limitations of the thickness tolerance tables in Specifications A 568/A 568M and A 749/A 749M. The purchaser should contact the producer prior to placing an order.

5.1.7 Coil size (inside diameter, outside diameter, and maximum weight),

5.1.8 Copper bearing steel (if required),

5.1.9 Quantity,

5.1.10 Application (part identification and description),

5.1.11 Special requirements (if required), and

5.1.12 A report of heat analysis will be supplied, if requested, for CS and DS. For materials with required mechanical properties, SS, HSLAS, HSLAS-F, and UHSS, a report is required of heat analysis and mechanical properties as determined by the tension test.

NOTE 3 — A typical ordering description is as follows: ASTM A 1011-XX, hot rolled steel sheet, CS Type A, pickled and oiled, cut edge, 0.075 by 36 by 96 in., thickness tolerance Table 4 of Specification A 568/A 568M, 100 000 lb, for part no. 6310, for shelf bracket.

or:

ASTM A 1011M-XX, hot rolled steel sheet, CS Type B, pickled and oiled, cut edge, 3.7 by 117 mm by coil, ID 600 mm, OD 1500 mm, max weight 10 000 kg, thickness tolerance Table A1.1 of Specification A 568/A 568M, 50 000 kg, for upper control arm.

6. General Requirements for Delivery

6.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 568/A 568M for sheets and Specification A 749/A 749M for strip, unless otherwise provided for herein.

7. Chemical Composition

7.1 The heat analysis of the steel shall conform to the chemical composition requirements of the appropriate designation shown in Table 1 for CS and DS and Table 2 for SS, HSLAS, HSLAS-F, and UHSS.

7.2 Each of the elements listed in Tables 1 and 2 shall be included in the report of the heat analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02%, report the analysis as <0.02% or the actual determined value. When the amount of vanadium, columbium, or titanium is less than 0.008%, report the analysis as <0.008% or the actual determined value. When the amount of boron is less than 0.0005%, report the analysis as <0.0005 % or the actual determined value.

7.3 Sheet steel grades defined by this specification are suitable for welding if appropriate welding conditions are selected. For certain welding processes, if more restrictive composition limits are desirable, they shall be specified at the time of inquiry and confirmed at the time of ordering.

8. Mechanical Properties

8.1 *CS and DS*:

8.1.1 Typical, nonmandatory mechanical properties for CS and DS are found in Table 3.

8.1.2 The material shall be capable of being bent at room temperature in any direction through 180° flat on itself without cracking on the outside of the bent portion (see the section on bend test in Test Methods and Definitions A 370).

8.2 *SS, HSLAS, HSLAS-F, and UHSS*:

8.2.1 The available grades and corresponding mechanical properties for SS, HSLAS, HSLAS-F, and UHSS are shown in Table 4.

8.2.2 *Tension Tests:*

8.2.2.1 *Requirements* — Material as represented by the test specimen shall conform to the mechanical property requirements specified in Table 4. These requirements do not apply to the uncropped ends of unprocessed coils.

8.2.2.2 *Number of Tests* — Two tension tests shall be made from each heat or from each 50 tons [45 000 kg]. When the amount of finished material from a heat is less than 50 tons [45 000 kg], one tension test shall be made. When material rolled from one heat differs 0.050 in. [1.27 mm] or more in thickness, one tension test shall be made from the thickest and thinnest material regardless of the weight represented.

8.2.2.3 Tension test specimens shall be taken at a point immediately adjacent to the material to be qualified.

8.2.2.4 Tension test specimens shall be taken from the full thickness of the sheet as-rolled.

8.2.2.5 Tension test specimens shall be taken from a location approximately halfway between the center of sheet and the edge of the material as-rolled.

8.2.2.6 Tension test specimens shall be taken with the lengthwise axis of the test specimen parallel to the rolling direction (longitudinal test)

8.2.2.7 *Test Method* — Yield strength shall be determined by either the 0.2 % offset method or the 0.5% extension under load method unless otherwise specified.

8.2.3 *Bending Properties*:

8.2.3.1 The suggested minimum inside radii for cold bending are listed in Appendix X1 and is discussed in more detail in Specifications A 568/A 568M (6.6) and A 749/A 749M (7.6). Where a tighter bend radius is required, where curved or offset bends are involved, or where stretching or drawing are also a consideration, the producer shall be consulted.

9. Finish and Appearance

9.1 *Surface Finish*:

9.1.1 Unless otherwise specified, the material shall be furnished as rolled, that is, without removing the hot-rolled oxide or scale.

9.1.2 When required, it is permissible to specify that the material be pickled or blast cleaned (descaled).

9.2 *Oiling*:

9.2.1 Unless otherwise specified, as-rolled material shall be furnished not oiled (that is, dry), and pickled or blast cleaned material shall be furnished oiled.

9.3 *Edges*:

9.3.1 Steel sheet is available with mill edge or cut edge.

9.3.2 Steel strip is available with mill edge or cut edge.

10. Retests and Disposition of Non-Conforming Material

10.1 Retests, conducted in accordance with the requirements of Section 11.1 of Specification A 568/A 568M, are permitted when an unsatisfactorily test result is suspected to be the consequence of the test method procedure.

10.2 Disposition of non-conforming material shall be subject to the requirements of Section 11.2 of Specification A 568/A 568M.

11. Certification

11.1 A report of heat analysis shall be supplied, if requested, for CS and DS steels. For material with required mechanical properties, SS, HSLAS, HSLAS-F, and UHSS a report is required of heat analysis and mechanical properties as determined by the tension test.

11.2 The report shall include the purchase order number; the ASTM designation number and year date; product designation; grade; type or class, as applicable; the heat number; and as required, heat analysis and mechanical properties as indicated by the tension test.

11.3 A signature is not required on the test report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

11.4 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard and the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

12. Product Marking

12.1 In addition to the requirements of Specification A 568/A 568M for sheet and Specification A 749/A 749M for strip, each lift or coil shall be marked with the designation shown on the order {CS (Type A, B, or C), DS (Type A or B), SS (Grade and for SS36, Type), HSLAS (Grade and Class), HSLAS-F (Grade), or UHSS (Type and Grade)}. The designation shall be legibly stenciled on the top of each lift or shown on a tag attached to each coil or shipping unit.

13. Keywords

13.1 carbon steel sheet; carbon steel strip; commercial steel; drawing steel; high strength-low alloy steel; high strength-low alloy steel with improved formability; hot-rolled steel sheet; hot-rolled steel strip; steel sheet; steel strip; structural steel; ultra-high strength steel

TABLE 1
CHEMICAL COMPOSITION[A] FOR HOT ROLLED STEEL SHEET AND STRIP DESIGNATIONS CS AND DS

	Composition, % Heat Analysis Element Maximum Unless Otherwise Shown														
	C	Mn	P	S	Al	Si	Cu	Ni	Cr[B]	Mo	V	Cb	Ti[C]	N	B
CS Type A[D, E, F, G]	0.10	0.60	0.030	0.035	. . .	. . .	0.20[H]	0.20	0.15	0.06	0.008	0.008	0.025	. . .	. . .
CS Type B[F]	0.02 to 0.15	0.60	0.030	0.035	. . .	. . .	0.20[H]	0.20	0.15	0.06	0.008	0.008	0.025	. . .	. . .
CS Type C[D, E, F, G]	0.08	0.60	0.10	0.035	. . .	. . .	0.20[H]	0.20	0.15	0.06	0.008	0.008	0.025	. . .	. . .
CS Type D[F]	0.10	0.70	0.030	0.035	. . .	. . .	0.20[H]	0.20	0.15	0.06	0.008	0.008	0.025	. . .	. . .
DS Type A[D, E, G]	0.08	0.50	0.020	0.030	0.01 min	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .	. . .
DS Type B	0.02 to 0.08	0.50	0.020	0.030	0.01 min	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .	. . .

[A] Where an ellipsis (. . .) appears in the table, there is no specified limit, but the analysis shall be reported.

[B] Chromium is permitted, at the producer's option, to 0.25% maximum when the carbon content is less than or equal to 0.05%.

[C] For steels containing more than 0.02% carbon, titanium is permitted at the producer's options, to the lesser of 3.4N + 1.5S or 0.025%, for the purpose of stabilization.

[D] Specify Type B to avoid carbon levels below 0.02%.

[E] For carbon levels less than or equal to 0.02%, it is permissible to use vanadium, columbium, or titanium, or combinations thereof, as stabilizing elements at the producer's option. In such case, the limits for these elements are 0.10% for vanadium or columbium and 0.15% for titanium.

[F] When an aluminum deoxidized steel is required, it is permissible to order to a minimum of 0.01% total aluminum.

[G] It is permissible to furnish as a vacuum degassed or chemically stabilized steel, or both, at producer's option.

[H] When copper steel is specified, the copper limit is a minimum requirement. When copper steel is not specified, the copper limit is a maximum requirement.

TABLE 2
CHEMICAL COMPOSITION[A] FOR HOT ROLLED STEEL SHEET AND STRIP DESIGNATIONS SS, HSLAS, HSLAS-F, AND UHSS

	% Heat Analysis, Element Maximum Unless Otherwise Shown													
Designation	C	Mn	P	S	Al	Si	Cu[B]	Ni	Cr	Mo	V	Cb	Ti	N
SS:[C]														
Grade 30 [205]	0.25	0.90	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 33 [230]	0.25	0.90	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 36 [250] Type 1	0.25	0.90	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 36 [250] Type 2[D]	0.25	1.35	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 40 [275]	0.25	0.90	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 45 [310][D]	0.25	1.35	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 50 [340][D]	0.25	1.35	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 55 [380][D]	0.25	1.35	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 60 [410]	0.25	1.35	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 70 [480]	0.25	1.35	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
Grade 80 [550]	0.25	1.35	0.035	0.04	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
HSLAS:[E]														
Grade 45 [310] Class 1[D]	0.22	1.35	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	...
Grade 45 [310] Class 2	0.15	1.35	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	...
Grade 50 [340] Class 1[D]	0.23	1.35	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	...
Grade 50 [340] Class 2	0.15	1.35	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	...
Grade 55 [380] Class 1[D]	0.25	1.35	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	...
Grade 55 [380] Class 2	0.15	1.35	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	...
Grade 60 [410] Class 1	0.26	1.50	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	...
Grade 60 [410] Class 2	0.15	1.50	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	...
Grade 65 [450] Class 1	0.26	1.50	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	[F]
Grade 65 [450] Class 2	0.15	1.50	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	[F]
Grade 70 [480] Class 1	0.26	1.65	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	[F]
Grade 70 [480] Class 2	0.15	1.65	0.04	0.04	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	[F]
HSLAS-F:[E]														
Grade 50 [340], 60 [410],	0.15	1.65	0.020	0.025	...	...	0.20	0.20	0.15	0.06	0.005 min	0.005 min	0.005 min	[F]
Grade 70 [480], and 80 [550]	0.15	1.65	0.020	0.025	...	...	0.20	0.20	0.15	0.16	0.005 min	0.005 min	0.005 min	[F]
UHSS:[E]														
Grade 90 [620] and 100 [690] Type 1	0.15	2.00	0.020	0.025	...	...	0.20	0.20	0.15	0.40	0.005 min	0.005 min	0.005 min	[F]
Grade 90 [620] and 100 [690] Type 2	0.15	2.00	0.020	0.025	...	...	0.60	0.50	0.30	0.40	0.005 min	0.005 min	0.005 min	[F]

[A] Where an ellipsis (. . .) appears in the table, there is no requirement but the analysis shall be reported.

[B] When copper is specified, a minimum of 0.20% is required. When copper steel is not specified, the copper limit is a maximum requirement.

[C] Titanium is permitted for SS designations, at the producer's option, to the lesser of 3.4N + 1.5S or 0.025%, for the purpose of stabilization.

[D] For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to a maximum of 1.50%.

[E] HSLAS, HSLAS-F, and UHSS steels contain the strengthening elements columbium (niobium), vanadium, titanium, and molybdenum added singly or in combination. The minimum requirements only apply to the microalloy elements selected for strengthening of the steel.

[F] The purchaser has the option of restricting the nitrogen content. It should be noted that, depending on the microalloying scheme (for example, use of vanadium) of the producer, nitrogen may be a deliberate addition. Consideration should be made for the use of nitrogen binding elements (for example, vanadium, titanium).

TABLE 3
TYPICAL RANGES OF MECHANICAL PROPERTIES[A] (NONMANDATORY)[B] FOR HOT-ROLLED STEEL SHEET AND STRIP DESIGNATIONS CS AND DS

Designation	Yield Strength[C] ksi	Yield Strength[C] MPa	Elongation in 2 in. [50 mm] %[C]
CS Types A, B, C, and D	30 to 50	[205 to 340]	≥ 25
DS Types A and B	30 to 45	[205 to 310]	≥ 28

[A] The yield strength tends to increase and the elongation tends to decrease as the sheet thickness decreases. These properties represent those typical of material in the thickness range of 0.100 to 0.150 in. [2.5 to 3.5 mm] for CS Types A, B, and DS Types A and B and in the thickness ranges of 0.060 to 0.075 in. [1.5 to 1.9 mm] for CS Type D.

[B] The typical mechanical property values presented here are nonmandatory. They are provided to assist the purchaser in specifying a suitable steel for a given application. Values outside these ranges are to be expected.

[C] Yield strength and elongation are measured in the longitudinal direction in accordance with Test Methods and Definitions A 370.

TABLE 4
MECHANICAL PROPERTY REQUIREMENTS[A]
FOR HOT ROLLED STEEL SHEET AND STRIP DESIGNATIONS SS, HSLAS, HSLAS-F, AND UHSS

Designation	Yield Strength ksi [MPa] min	Tensile Strength[B] ksi [MPa] min	Elongation in 2 in. [50 mm] min, % for Thicknesses: Under 0.230 [6.0 mm] to 0.097 [2.5 mm]	Under 0.097 [2.5 mm] to 0.064 [1.6 mm]		Under 0.064 [1.6 mm] to 0.025 [0.65 mm]	Elongation in 8 in. [200 mm], % for Thickness: Under 0.230 [6.0 mm]
SS:							
Grade 30 [205]	30 [205]	49 [340]	25	24		21	19
Grade 33 [230]	33 [230]	52 [360]	23	22		18	18
Grade 36 [250] Type 1	36 [250]	53 [365]	22	21		17	17
Grade 36 [250] Type 2	36 [250]	58-80 [400-550]	21	20		16	16
Grade 40 [275]	40 [275]	55 [380]	21	20		15	16
Grade 45 [310]	45 [310]	60 [410]	19	18		13	14
Grade 50 [340]	50 [340]	65 [450]	17	16		11	12
Grade 55 [380]	55 [380]	70 [480]	15	14		9	10
Grade 60 [410]	60 [410]	75 [480]	14	13		8	9
Grade 70 [480]	70 [480]	85 [550]	13	12		7	8
Grade 80 [550]	80 [550]	95 [620]	12	11		6	7
HSLAS:			Over 0.097 in. [2.5 mm]		Up to 0.097 in. [2.5 mm]		
Grade 45 [310] Class 1	45 [310]	60 [410]	25	...	23	...	...
Grade 45 [310] Class 2	45 [310]	55 [380]	25	...	23	...	...
Grade 50 [340] Class 1	50 [340]	65 [450]	22	...	20	...	...
Grade 50 [340] Class 2	50 [340]	60 [410]	22	...	20	...	...
Grade 55 [380] Class 1	55 [380]	70 [480]	20	...	18	...	...
Grade 55 [380] Class 2	55 [380]	65 [450]	20	...	18	...	...
Grade 60 [410] Class 1	60 [410]	75 [520]	18	...	16	...	...
Grade 60 [410] Class 2	60 [410]	70 [480]	18	...	16	...	...
Grade 65 [450] Class 1	65 [450]	80 [550]	16	...	14	...	...
Grade 65 [450] Class 2	65 [450]	75 [520]	16	...	14	...	...
Grade 70 [480] Class 1	70 [480]	85 [585]	14	...	12	...	...
Grade 70 [480] Class 2	70 [480]	80 [550]	14	...	12	...	...
HSLAS-F:							
Grade 50 [340]	50 [340]	60 [410]	24	...	22	...	...
Grade 60 [410]	60 [410]	70 [480]	22	...	20	...	...
Grade 70 [480]	70 [480]	80 [550]	20	...	18	...	...
Grade 80 [550]	80 [550]	90 [620]	18	...	16	...	...
UHSS:							
Grade 90 [620] Types 1 and 2	90 [620]	100 [690]	16	...	14	...	...
Grade 100 [690] Types 1 and 2	100 [690]	110 [760]	14	...	12	...	...

[A] For coil products, testing by the producer is limited to the end of the coil. Mechanical properties throughout the coil shall comply with the minimum values specified.

[B] A minimum and maximum tensile strength has been specified for SS36 Type 2.

APPENDIXES

(Nonmandatory Information)

X1. BENDING PROPERTIES

X2. RELATED ISO STANDARDS

The ISO standards listed below may be reviewed for comparison with this ASTM standard. The relationship between the standards may only be approximate; therefore, the respective standards should be consulted for actual requirements. Those who use these documents must determine which specifications address their needs.

ISO 3573 Hot-rolled Carbon Steel Sheet of Commercial and Drawing Qualities
ISO 4995 Hot-rolled Steel Sheet of Structural Quality
ISO 4996 Hot-rolled Steel Sheet of High Yield Stress Structural Quality
ISO 5951 Hot-rolled Steel Sheet of Higher Yield Strength with Improved Formability
ISO 6316 Hot-rolled Carbon Steel Strip of Structural Quality
ISO 6317 Hot-rolled Carbon Steel Strip of Commercial and Drawing Qualities

X3. HARDNESS PROPERTIES

X3.1 Table X3.1 lists the typical hardness values.

TABLE X1.1
SUGGESTED MINIMUM INSIDE RADIUS FOR COLD BENDING

Designation	Grade	Minimum Inside Radius for Cold Bending	
Structural Steel	30 [205]	1 t	
	33 [230]	1 t	
	36 [250] Type 1	1½ t	
	36 [250] Type 2	2 t	
	40 [275]	2 t	
	45 [310]	2 t	
	50 [340]	2½ t	
	55 [380]	3 t	
	60 [410]	3½ t	
	70 [480]	4 t	
	80 [550]	4 t	
High-Strength Low-Alloy Steel		Class 1	Class 2
	45 [310]	1½ t	1½ t
	50 [340]	2 t	1½ t
	55 [380]	2 t	2 t
	60 [410]	2½ t	2 t
	65 [450]	3 t	2½ t
	70 [480]	3½ t	3 t
High-Strength Low-Alloy Steel with Improved Formability			
	50 [340]	1 t	
	60 [410]	1½ t	
	70 [480]	2 t	
	80 [550]	2 t	
Ultra-High Strength Steel Types 1 and 2			
	90 [620]	2½ t	
	100 [690]	2½ t	

NOTE 1 — (t) Equals a radius equivalent to the steel thickness.

NOTE 2 — The suggested radius should be used as a minimum for 90° bends in actual shop practice.

NOTE 3 — Material which does not perform satisfactorily, when fabricated in accordance with the above requirements, may be subject to rejection pending negotiation with the steel supplier.

TABLE X3.1
TYPICAL HARDNESS VALUES

Designation	Hardness-Rockwell B Scale
CS Type A	75 or less
CS Type B	75 or less
CS Type C	75 or less
DS	65 or less

NOTE 1 — The hardness values shown are at the time of shipment.

NOTE 2 — Tests for hardness shall be conducted in accordance with the requirements of Test Methods E 18.

NOTE 3 — The hardness values are Rockwell B scale as measured or converted from the appropriate Rockwell scales.

NOTE 4 — The typical hardness values apply to the full range of steel sheet thickness. Hardness tends to increase as the steel sheet thickness decreases.

NOTE 5 — Hardness testing is commonly used to assess the relative formability of various designations of uncoated steel sheet. This assessment done by many users is recognized to be only an approximation of the relative formability and therefore cannot be used as a specification requirement.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR FERRITIC ALLOY STEEL, AUSTENITIC ALLOY STEEL, AND STAINLESS STEEL TUBES

SA-1016/SA-1016M

(Identical with ASTM Specification A1016/A1016M-17a.)

Standard Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

1. Scope

1.1 This specification covers a group of requirements that, unless otherwise specified in an individual specification, shall apply to the ASTM product specifications noted below.

Title of Specification	ASTM Designation[A]
Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes	A209/A209M
Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes	A213/A213M
Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes	A249/A249M
Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes	A250/A250M
Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service	A268/A268M
Seamless and Welded Austenitic Stainless Steel Tubing for General Service	A269/A269M
Seamless and Welded Austenitic Stainless Steel Sanitary Tubing	A270/A270M
Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service	A334/A334M
Welded Austenitic Stainless Steel Feedwater Heater Tubes	A688/A688M
Austenitic Stainless Steel Tubing for Breeder Reactor Core Components	A771/A771M
Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service	A789/A789M
Welded Ferritic Stainless Steel Feedwater Heater Tubes	A803/A803M
Austenitic and Ferritic Stainless Steel Duct Tubes for Breeder Reactor Core Components	A826/A826M
High-Frequency Induction Welded, Unannealed Austenitic Steel Condenser Tubes	A851

[A] These designations refer to the latest issue of the respective specifications.

1.2 In the case of conflict between a requirement of a product specification and a requirement of this general requirements specification, the product specification shall prevail. In the case of conflict between a requirement of the product specification or a requirement of this general requirements specification and a more stringent requirement of the purchase order, the purchase order shall prevail.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the "M" designation (SI) of the product specification is specified in the order.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A209/A209M Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

A213/A213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

A249/A249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes

A250/A250M Specification for Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes

A268/A268M Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service

A269/A269M Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

A270/A270M Specification for Seamless and Welded Austenitic and Ferritic/Austenitic Stainless Steel Sanitary Tubing

A334/A334M Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service

A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A688/A688M Specification for Seamless and Welded Austenitic Stainless Steel Feedwater Heater Tubes
A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A771/A771M Specification for Seamless Austenitic and Martensitic Stainless Steel Tubing for Liquid Metal-Cooled Reactor Core Components (Withdrawn 2004)[3]
A789/A789M Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service
A803/A803M Specification for Seamless and Welded Ferritic Stainless Steel Feedwater Heater Tubes
A826/A826M Specification for Seamless Austenitic and Martensitic Stainless Steel Duct Tubes for Liquid Metal-Cooled Reactor Core Components (Withdrawn 2004)[3]
A851 Specification for High-Frequency Induction Welded, Unannealed, Austenitic Steel Condenser Tubes (Withdrawn 2002)[3]
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A1047/A1047M Test Method for Pneumatic Leak Testing of Tubing
A1058 Test Methods for Mechanical Testing of Steel Products—Metric
D3951 Practice for Commercial Packaging
E92 Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials
E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing
E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing
E309 Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation
E426 Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys
E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ASME Boiler and Pressure Vessel Code:*
Section IX

2.3 *Federal Standard:*
FED-STD-183 Continuous Identification Marking of Iron and Steel Products

2.4 *Military Standards:*
MIL-STD-271 Nondestructive Testing Requirements for Metals
MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage
MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment

2.5 *Steel Structures Painting Council:*
SSPC-SP6 Surface Preparation Specification No. 6 Commercial Blast Cleaning

2.6 *Other Documents:*
SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification
AIAG Bar Code Symbology Standard

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Test Methods and Definitions A370 or Test Methods A1058, Test Methods, Practices, and Terminology A751, and Terminology A941 are applicable to this specification and to those listed in 1.1.

3.1.2 *heat, n*—in secondary melting, all of the ingots remelted from a single primary heat.

3.1.3 *imperfection, n*—any discontinuity or irregularity found in a tube.

4. Manufacture

4.1 The steel shall made by any process.

4.2 The primary melting is permitted to incorporate separate degassing or refining and is permitted to be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting.

4.3 When steel of different grades is sequentially strand cast, the resultant transition material shall be removed using an established procedure that positively separates the grades.

5. Ordering Information

5.1 It is the responsibility of the purchaser to specify all requirements that are necessary for product ordered under the product specification. Such requirements to be considered include, but are not limited to, the following:

5.1.1 Quantity (feet, metres, or number of pieces),

5.1.2 Name of material (stainless steel tubing),

5.1.3 Method of manufacture, when applicable (seamless (SML), welded (WLD), or heavily cold-worked (HCW)),

5.1.4 Grade or UNS number,

5.1.5 Size (outside diameter and average or minimum wall thickness),

5.1.6 Length (specific or random),

5.1.7 End finish if required,

5.1.8 Optional requirements,

5.1.9 Specific type of melting, if required,

5.1.10 Test report requirements,

5.1.11 Specification designation and year of issue, and

5.1.12 Special requirements or any supplementary requirements, or both.

6. Chemical Composition

6.1 *Chemical Analysis*—Samples for chemical analysis, and method of analysis, shall be in accordance with Test Methods, Practices, and Terminology A751.

6.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall conform to the requirements specified in the product specification.

6.2.1 For steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element, other than nitrogen for stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification.

6.3 *Product Analysis*—Product analysis requirements and options, if any, shall be as contained in the product specification.

7. Tensile Properties

7.1 The material shall conform to the tensile property requirements prescribed in the individual product specification.

7.2 The yield strength, when specified, shall be determined corresponding to a permanent offset of 0.2 % of the gauge length or to a total extension of 0.5 % of the gauge length under load.

7.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. [19.0 mm] from the center of the gauge length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

8. Standard Mass per Unit Length

8.1 The calculated mass per foot, based upon a specified minimum wall thickness, shall be determined by the following equation (see Note 1):

$$W = C(D - t)t \tag{1}$$

where:

C = 10.69 [0.0246615],
W = mass per unit length, lb/ft [kg/m],
D = specified outside diameter, in. [mm], and
t = specified minimum wall thickness, in. [mm].

NOTE 1—The calculated masses given by Eq 1 are based on the masses for carbon steel tubing. The mass of tubing made of ferritic stainless steels may be up to about 5 % less, and that made of austenitic stainless steel up to about 2 % greater than the values given. Mass of ferritic/austenitic (duplex) stainless steel will be intermediate to the mass of fully austenitic and fully ferritic stainless steel tubing.

8.2 The permitted variations from the calculated mass per foot [kilogram per metre] shall be as prescribed in Table 1.

9. Permitted Variations in Wall Thickness

9.1 Variations from the specified minimum wall thickness shall not exceed the amounts prescribed in Table 2.

9.2 For tubes 2 in. [50 mm] and over in outside diameter and 0.220 in. [5.6 mm] and over in thickness, the variation in wall thickness in any one cross section of any one tube shall not exceed the following percentage of the actual mean wall at the section. The actual mean wall is defined as the average of the thickest and thinnest wall in that section.

Seamless tubes ±10 %
Welded tubes ±5 %

9.3 When cold-finished tubes as ordered require wall thicknesses ¾ in. [19.1 mm] or over, or an inside diameter 60 % or less of the outside diameter, the permitted variations in wall thickness for hot-finished tubes shall apply.

10. Permitted Variations in Outside Diameter

10.1 Except as provided in 10.2.1, 10.3, and 25.10.4, variations from the specified outside diameter shall not exceed the amounts prescribed in Table 3.

10.2 Thin-wall tubes usually develop significant ovality (out-of-roundness) during final annealing, or straightening, or both. Thin-wall tubes are defined as those with a specified wall 3 % or less than the specified OD, or with a wall specified as 0.020 in. [0.5 mm] or less.

10.2.1 1 The diameter tolerances of Table 3 are not sufficient to provide for additional ovality expected in thin-wall tubes, and, for such tubes, are applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross section. However, for thin wall tubes the difference in extreme outside diameter readings (ovality) in any one cross section shall not exceed the following ovality allowances:

Outside Diameter, in. [mm]	Ovality Allowance
1 [25.4] and under	0.020 [0.5]
Over 1 [25.4]	2.0 % of specified outside diameter

TABLE 1 Permitted Variations in Mass Per Foot[A]

Method of Manufacture	Permitted Variation in Mass per Foot, %	
	Over	Under
Seamless, hot-finished	16	0
Seamless, cold-finished		
1½ in. [38 mm] and under OD	12	0
Over 1½ in. [38 mm] OD	13	0
Welded	10	0

[A] These permitted variations in mass apply to lots of 50 tubes or more in sizes 4 in. [101.6 mm] and under in outside diameter, and to lots of 20 tubes or more in sizes over 4 in. [101.6 mm] in outside diameter.

TABLE 2 Permitted Variations in Wall Thickness[A]

Outside Diameter in. [mm]	Wall Thickness, %: 0.095 [2.4] and Under		Over 0.095 to 0.150 [2.4 to 3.8], incl		Over 0.150 to 0.180 [3.8 to 4.6], incl		Over 0.180 [4.6]	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
4 [100] and under	40	0	35	0	33	0	28	0
Over 4 [100]	. . .	. . .	35	0	33	0	28	0
Seamless, Cold-Finished Tubes								
			Over	Under				
1½ [38.1] and under			20	0				
Over 1½ [38.1]			22	0				
Welded Tubes								
All sizes			18	0				

[A] These permitted variations in wall thickness apply only to tubes, except internal-upset tubes, as rolled or cold-finished, and before swaging, expanding, bending, polishing, or other fabricating operations.

TABLE 3 Permitted Variations in Outside Diameter[A]

Specified Outside Diameter, in. [mm]	Permitted Variations, in. [mm] Over	Under
Hot-Finished Seamless Tubes		
4 [100] or under	1⁄64 [0.4]	1⁄32 [0.8]
Over 4 to 7½ [100 to 200], incl	1⁄64 [0.4]	3⁄64 [1.2]
Over 7½ to 9 [200 to 225], incl	1⁄64 [0.4]	1⁄16 [1.6]
Welded Tubes and Cold-Finished Seamless Tubes		
Under 1 [25]	0.004 [0.1]	0.004 [0.11]
1 to 1½ [25 to 40], incl	0.006 [0.15]	0.006 [0.15]
Over 1½ to 2 [40 to 50], excl	0.008 [0.2]	0.008 [0.2]
2 to 2½ [50 to 65], excl	0.010 [0.25]	0.010 [0.25]
2½ to 3 [65 to 75], excl	0.012 [0.3]	0.012 [0.3]
3 to 4 [75 to 100], incl	0.015 [0.38]	0.015 [0.38]
Over 4 to 7½ [100 to 200], incl	0.015 [0.38]	0.025 [0.64]
Over 7½ to 9 [200 to 225], incl	0.015 [0.38]	0.045 [1.14]

[A] Except as provided in 10.2 and 10.3, these permitted variations include out-of-roundness. These permitted variations in outside diameter apply to hot-finished seamless, welded and cold-finished seamless tubes before other fabricating operations such as upsetting, swaging, expanding, bending, or polishing.

10.3 For cold-finished seamless austenitic and ferritic/austenitic tubes, an ovality allowance is necessary for all sizes less than 2 in. [50.8 mm] outside diameter, because they are likely to become out of round during their final heat treatment. For such tubes, the maximum and minimum outside diameter at any cross section shall not deviate from the nominal diameter by more than ±0.010 in. [±0.25 mm]. However, the mean diameter at that cross section must still be within the given permitted variation given in Table 3. In the event of conflict between the provisions of 10.2.1 and those of 10.3, the larger value of ovality tolerance shall apply.

10.4 When the specified wall is 2 % or less of the specified OD, the method of measurement is per agreement between purchaser and manufacturer (see Note 2).

NOTE 2—Very thin wall tubing may not be stiff enough for the outside diameter to be accurately measured with a point contact method, such as with the use of a micrometer or caliper. When very thin walls are specified, "go" – "no go" ring gauges are commonly used to measure diameters of 1½ in. [38.1 mm] or less. A 0.002 in. [0.05 mm] additional tolerance is usually added on the "go" ring gauge to allow clearance for sliding. On larger diameters, measurement is commonly performed with a pi tape. Other methods, such as optical methods, may also be considered.

11. Permitted Variations in Length

11.1 Variations from the specified length shall not exceed the amounts prescribed in Table 4.

12. Permitted Variations in Height of Flash on Electric-Resistance-Welded Tubes

12.1 For tubes over 2 in. [50.8 mm] in outside diameter, or over 0.135 in. [3.44 mm] in wall thickness, the flash on the inside of the tubes shall be mechanically removed by cutting to a maximum height of 0.010 in. [0.25 mm] at any point on the tube.

12.2 For tubes 2 in. [50.8 mm] and under in outside diameter and 0.135 in. [3.44 mm] and under in wall thickness, the flash on the inside of the tube shall be mechanically removed by cutting to a maximum height of 0.006 in. [0.15 mm] at any point on the tube.

13. Straightness and Finish

13.1 Finished tubes shall be reasonably straight and have smooth ends free of burrs. They shall have a workmanlike finish. It is permitted to remove surface imperfections by grinding, provided that a smooth curved surface is maintained, and the wall thickness is not decreased to less than that permitted by this or the product specification, or the purchase order. The outside diameter at the point of grinding may be reduced by the amount so removed.

14. Repair by Welding

14.1 Repair welding of base metal defects in tubing is permitted only with the approval of the purchaser and with the further understanding that the tube shall be marked "WR" and the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired tube shall be examined by a nondestructive test as required by the product specification.

14.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

TABLE 4 Permitted Variations in Length[A]

Method of Manufacture	Specified Outside Diameter, in. [mm]	Cut Length, in. [mm] Over	Under
Seamless, hot-finished	All sizes	3⁄16 [5]	0 [0]
Seamless, cold-finished	Under 2 [50.8]	1⁄8 [3]	0 [0]
	2 [50.8] or over	3⁄16 [5]	0 [0]
Welded	Under 2 [50.8]	1⁄8 [3]	0 [0]
	2 [50.8] or over	3⁄16 [5]	0 [0]

[A] These permitted variations in length apply to tubes before bending. They apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over-tolerances shall be increased by 1⁄8 in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or ½ in. [13 mm], whichever is the lesser.

15. Retests

15.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

16. Reheat Treatment

16.1 If the individual tubes or the tubes selected to represent any group or lot fail to conform to the test requirements, the individual tubes or the group or lot represented may be reheat treated and resubmitted for test. Not more than two reheat treatments shall be permitted.

17. Test Specimens

17.1 Test specimens shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free of burrs and flaws.

17.2 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

18. Method of Mechanical Testing

18.1 The specimens and mechanical tests required shall be made in accordance with Test Methods and Definitions A370 or Test Methods A1058.

18.1.1 Unless otherwise specified in the ordering requirements, Test Methods A1058 shall apply when the metric version of the product specification is specified.

18.2 Specimens shall be tested at room temperature.

18.3 Small or subsize specimens as described in Test Methods and Definitions A370 or Test Methods A1058 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

19. Flattening Test

19.1 A section of tube not less than 2½ in. [60 mm] in length for seamless tubes and not less than 4 in. [100 mm] in length for welded tubes and for heavily cold-worked tubes shall be flattened cold between parallel plates in two steps. For welded tubes, the weld shall be placed 90° from the direction of the applied force (at a point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 19.4, on the inside, outside, or end surfaces shall occur in seamless tubes, or on the inside or outside surfaces of welded tubes and heavily cold-worked tubes, until the distance between the plates is less than the value of H calculated by the following equation:

$$H = \frac{(1+e)t}{e+t/D} \quad (2)$$

where:

H = distance between flattening plates, in. [mm],
t = specified wall thickness of the tube, in. [mm],
D = specified outside diameter of the tube, in. [mm], and
e = deformation per unit length (constant for a given grade of steel: 0.07 for medium-carbon steel (maximum specified carbon 0.19 % or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, 0.09 for duplex (ferritic/austenitic) stainless steels, and 0.09 for low-carbon steel (maximum specified carbon 0.18 % or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the specimen meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

19.2 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

19.3 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

19.4 When low D-to-t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

20. Reverse Flattening Test

20.1 A section 4 in. [100 mm] in length of finished welded tubing in sizes down to and including ½ in. [12.7 mm] in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

21. Reverse Bend Test

21.1 A section 4 in. [100 mm] minimum in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a maximum thickness of four times the wall thickness, with the mandrel parallel to the weld and against the original outside surface of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks or of overlaps resulting from the reduction in thickness of the weld area by cold working. When the geometry or size of the tubing make it difficult to test the sample as a single piece, the sample may be sectioned into smaller pieces provided a minimum of 4 in. of weld is subjected to reverse bending.

21.2 The reverse bend test is not applicable when the wall is 10 % or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter is less than 0.375 in. [9.5 mm]. Under these conditions, the reverse flattening test shall apply.

22. Flaring Test

22.1 A section of tube approximately 4 in. [100 mm] in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded to the percentages specified in Table 5 without cracking or showing imperfections rejectable under the provisions of the product specification.

23. Flange Test

23.1 A section of tube shall be capable of having a flange turned over at a right angle to the body of the tube without cracking or showing imperfections rejectable under the provisions of the product specification. The width of the flange for carbon and alloy steels shall be not less than the percentages specified in Table 6. For the austenitic grades, the width of the flange for all sizes listed in Table 6 shall be not less than 15 %.

24. Hardness Test

24.1 For tubes with wall thickness 0.200 in. [5.1 mm] or over, either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used, a 10-mm ball with 3000, 1500, or 500-kg load, or a 5-mm ball with 750-kg load shall be used, at the option of the manufacturer.

24.2 For tubes with wall thickness 0.065 in. [1.7 mm] or over but less than 0.200 in. [5.1 mm], the Rockwell hardness test shall be used.

24.3 For tubes with wall thickness less than 0.065 in. [1.7 mm], the hardness test shall not be required.

24.4 The Brinell hardness test shall, at the option of the manufacturer, be made on the outside of the tube near the end, on the outside of a specimen cut from the tube, or on the wall cross section of a specimen cut from the tube. This test shall be made so that the distance from the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

24.5 The Rockwell hardness test shall, at the option of the manufacturer, be made on the inside surface, on the wall cross section, or on a flat on the outside surface.

24.6 For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test shall be made as prescribed in 24.1 and 24.2 on the outside of the tube near the end after the forming operation and heat treatment.

24.7 For welded or brazed tubes, the hardness test shall be made away from the joints.

TABLE 5 Flaring Test Requirements

Ratio of Inside Diameter to Specified Outside Diameter[A]	Minimum Expansion of Inside Diameter, %	
	Carbon-Molybdenum and Austenitic Steels	Other Ferritic Alloy Steels and Other Stainless Steels
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

[A] In determining the ratio of inside diameter to specified outside diameter, the inside diameter shall be defined as the actual mean inside diameter of the material tested.

TABLE 6 Flange Requirements

Specified Outside Diameter of Tube, in. [mm]	Width of Flange
To 2½ [63.5], incl	15 % of Specified Outside Diameter
Over 2½ to 3¾ [63.5 to 95.2], incl	12½ % of Specified Outside Diameter
Over 3¾ to 8 [95.2 to 203.2], incl	10 % of Specified Outside Diameter

24.8 When the product specification provides for Vickers hardness, such testing shall be in accordance with Test Method E92.

25. Nondestructive Examination

25.1 Except as provided in 26.1, each tube shall be examined by a nondestructive examination method in accordance with Practice E213, Practice E309 (for ferromagnetic materials), Practice E426 (for non-magnetic materials), or Practice E570. Upon agreement, Practice E273 shall be employed in addition to one of the full periphery tests. The range of tube sizes that may be examined by each method shall be subject to the limitations in the scope of that practice. In case of conflict between these methods and practices and this specification, the requirements of this specification shall prevail.

25.2 The following information is for the benefit of the user of this specification.

25.2.1 Calibration standards for the nondestructive electric test are convenient standards for calibration of nondestructive testing equipment only. For several reasons, including shape, orientation, width, and so forth, the correlation between the signal produced in the electric test from an imperfection and from calibration standards is only approximate. A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

25.2.2 The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in 25.8. The examination may not detect circumferentially oriented imperfections or short, deep defects.

25.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type. Practices E309 and E426 contain additional information regarding the capabilities and limitations of eddy-current examination.

25.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only provide for longitudinal calibration for flux leakage. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

25.2.5 The hydrostatic test referred to in Section 26 is a test method provided for in many product specifications. This test has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

25.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

25.3 *Time of Examination*—Nondestructive examination for specification acceptance shall be performed after all deformation processing, heat treating, welding, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

25.4 *Surface Condition:*

25.4.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

25.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

25.5 *Extent of Examination:*

25.5.1 The relative motion of the tube and the transducer(s), coil(s), or sensor(s) shall be such that the entire tube surface is scanned, except for end effects as noted in 25.5.2.

25.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

25.6 *Operator Qualifications:*

25.6.1 The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent documented standard agreeable to both purchaser and manufacturer.

25.7 *Test Conditions:*

25.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.0 MHz, and the maximum transducer size shall be 1.5 in. [38 mm].

25.7.2 For eddy current testing, the excitation coil frequency shall be chosen to ensure adequate penetration, yet provide good signal-to-noise ratio.

25.7.2.1 The maximum coil frequency shall be:

Specified Wall Thickness, in. [mm]	Maximum Frequency, kHz
<0.050 in. [1.25]	100
0.050 to 0.150 [1.25 to 3.80]	50
>0.150 [3.80]	10

25.8 *Reference Standards:*

25.8.1 Reference standards of convenient length shall be prepared from a length of tube of the same grade, specified size (outside diameter and wall thickness), surface finish, and heat treatment condition as the tubing to be examined.

25.8.2 For eddy current testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

25.8.2.1 *Drilled Hole*—The reference standard shall contain three or more holes, equally spaced circumferentially around the tube and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling. The holes shall not be larger than 0.031 in. [0.8 mm] in diameter. As an alternative, the producer may choose to drill one hole and run the calibration standard through the test coil three times, rotating the tube approximately 120° each time. More passes with smaller angular increments may be used, provided testing of the full 360° of the coil is obtained. For welded tubing, if the weld is visible, one of the multiple holes or the single hole shall be drilled in the weld.

25.8.2.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼ in. [6.4 mm] diameter, a notch shall be milled or filed tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding 12.5 % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater.

25.8.2.3 *Longitudinal Notch*—A notch 0.031 in. (0.8 mm) or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12.5 % of the specified wall thickness of the tube or 0.004 in. (0.1 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

25.8.2.4 When minimum wall tubing is specified, the notch depth shall be based on the calculated average wall thickness from Table 2 (see Note 3).

25.8.3 *For ultrasonic testing,* the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E213, at the option of the manufacturer. The depth of the notches shall not exceed 12.5 % of the specified average wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. When minimum tubing is specified, the notch depth shall be based on the calculated average wall thickness from Table 2 (see Note 3). The width of the notch shall not exceed two times the depth. For welded tubing, the notches shall be placed in the weld, if the weld is visible. When the notch is placed in the weld, the notch depth shall be measured from the surface of the weld.

NOTE 3—To calculate the average wall thickness when minimum wall tubing is specified, the calculated average wall shall be the specified minimum wall plus ½ of the Permitted Maximum Variation in Wall Thickness cited in Table 2. For example, when a cold finished, 1 by 0.083 in. [25 by 2 mm] minimum wall seamless tube is specified, the calculated average thickness will be 0.091 in. (0.083 in. + ½ (20 %)) [2.2 mm (2 mm + ½ (20 %))].

25.8.4 *For flux leakage testing,* the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the tube axis on the inside and outside surfaces of the tube. Notch depth shall not exceed 12.5 % of the specified wall thickness or 0.004 in. [0.1 mm], whichever is greater. Notch length shall not exceed 1 in. [25.4 mm], and the width shall not exceed the depth. Outside and inside notches shall have sufficient separation to allow distinct identification of the signal from each notch.

25.8.5 When minimum wall tubing is specified, the notch depth shall be based on the calculated average wall thickness from Table 2 (see Note 3).

25.8.6 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

25.9 *Standardization Procedure:*

25.9.1 The test apparatus shall be standardized at the beginning and end of each series of tubes of the same specified size (diameter and wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such tubing. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

25.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss or shutdown.

25.9.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the tube to be tested, except that, at the manufacturer's discretion, the tubes may be tested at a higher sensitivity.

25.9.4 The signal-to-noise ratio for the reference standard shall be 2.5 to 1 or greater, and the reference signal amplitude for each discontinuity shall be at least 50 % of full scale of the display. In establishing the noise level, extraneous signals from identifiable surface imperfections on the reference standard may be ignored. When reject filtering is used during UT testing, linearity must be demonstrated.

25.9.5 If, upon any standardization, the reference signal amplitude has decreased by at least 29 % (3.0 dB), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s), or sensor(s) adjusted, and the unit restandardized, but all tubes tested since the last acceptable standardization must be retested.

25.10 *Evaluation of Imperfections:*

25.10.1 Tubing producing a test signal equal to or greater than the lowest signal produced by the reference standard shall be designated suspect, shall be clearly marked or identified, and shall be separated from the acceptable tubing.

25.10.2 Such suspect tubing shall be subject to one of the following three dispositions:

25.10.2.1 The tubes shall be rejected without further examination, at the discretion of the manufacturer.

25.10.2.2 If the test signal was produced by imperfections such as scratches, surface roughness, dings, straightener marks, loose ID bead and cutting chips, steel die stamps, stop marks, tube reducer ripple, or chattered flash trim, the tubing shall be accepted or rejected depending on visual observation of the severity of the imperfection, the type of signal it produces on the testing equipment used, or both.

25.10.2.3 If the test signal was produced by imperfections that cannot be identified, or was produced by cracks or crack-like imperfections, the tubing shall be rejected.

25.10.3 Any tubes with imperfections of the types in 25.10.2.2 and 25.10.2.3, exceeding 0.004 in. [0.1 mm] or 12.5 % of the specified minimum wall thickness (whichever is greater) in depth shall be rejected.

25.10.4 Rejected tubes may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. If grinding is performed, the outside diameter in the area of grinding may be reduced by the amount so removed. To be accepted, reconditioned tubes must pass the nondestructive examination by which they were originally rejected.

26. Hydrostatic Test

26.1 In lieu of nondestructive electric examination, and when specified by the purchaser, and, except as provided in 26.2 and 26.3, each tube shall be tested by the manufacturer to a minimum hydrostatic test pressure determined by the following equation:

$$Inch - Pound\ Units{:}P = 32000\ t/D \tag{3}$$

$$SI\ Units{:}P = 220.6\ t/D$$

where:

P = hydrostatic test pressure, psi or MPa,
t = specified wall thickness, in. or mm, and
D = specified outside diameter, in. or mm.

26.1.1 The hydrostatic test pressure determined by Eq 3 shall be rounded to the nearest 50 psi [0.5 MPa] for pressure below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending or other forming operations, or both.

26.2 Regardless of the determination made by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed 1000 psi [7 MPa]. This does not prohibit testing at higher pressures at manufacturer's option or as provided in 26.3.

26.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 26.2 or 26.1, or both, may be stated on the order. The tube wall stress shall be determined by the following equation:

$$S = PD/2t \tag{4}$$

where:

S = tube wall stress, psi or MPa, and all other symbols as defined in 24.1.

26.4 The test pressure shall be held for a minimum of 5 s.

26.5 If any tube shows leaks during the hydrostatic test, it shall be rejected.

26.6 The hydrostatic test may not be capable of testing the end portion of the pipe. The lengths of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

27. Pneumatic Test

27.1 *Air Underwater Test*—When this test is required, each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi [1000 kPa] minimum with clean and dry compressed air while being submerged in clear water. The tube shall be well lighted, preferably by underwater illumination. Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing. Inspection shall be made of the entire external surface of the tube after holding the pressure for not less than 5 s after the surface of the water has become calm. If any tube shows leakage during the air underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested.

27.2 *Air Pressure Test*—When agreed to by the purchaser and supplier, a pneumatic pressure test in accordance with Test Method A1047/A1047M may be used in lieu of the air underwater test.

Acceptance criteria shall be as follows:

≤1.5 [≤40]	0.003 [0.076]
>1.5 ≤2.0 [>40 ≤50]	0.004 [0.162]
>2.0 ≤2.5 [>50 ≤65]	0.005 [0.127]
>2.5 ≤3.0 [>65 ≤75]	0.006 [0.152]
>3.0 [>7.5]	By agreement

28. Certification and Test Reports

28.1 The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the specification, including year date, the supplementary requirements, and any other requirements designated in the purchase order or contract, and the results met the requirements of that specification, the supplementary requirements and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

28.2 In addition to the certificate of compliance, the manufacturer shall furnish test reports that include the following information and test results, where applicable:

28.2.1 Heat number,

28.2.2 Heat analysis,

28.2.3 Product analysis, when specified,

28.2.4 Tensile properties,

28.2.5 Width of the gauge length, when longitudinal strip tension test specimens are used,

28.2.6 Flattening test acceptable,

28.2.7 Reverse flattening test acceptable,

28.2.8 Flaring test acceptable,

28.2.9 Flange test acceptable,

28.2.10 Hardness test values,

28.2.11 Hydrostatic test pressure,

28.2.12 Nondestructive electric test method,

28.2.13 Impact test results, and

28.2.14 Any other test results or information required to be reported by the product specification or the purchase order or contract.

28.3 The manufacturer shall report, along with the test report or in a separate document, any other information that is required to be reported by the product specification or the purchase order or contract.

28.4 The certificate of compliance shall include a statement of explanation for the letter added to the specification number marked on the tubes (see 30.3) when all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before the removal of the letter (that is, X, Y, or Z).

28.5 A test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

29. Inspection

29.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to be satisfied that the product is being produced and furnished in accordance with the ordered product specification. Mill inspection by the purchaser shall not interfere with the manufacturer's operations.

30. Rejection

30.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the ordered product specification based on the inspection and test method as outlined in the ordered product specification, the length shall be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

30.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

31. Product Marking

31.1 Each length of tube shall be legibly stenciled with the manufacturer's name or brand, the specification number, and grade. The marking need not include the year of issue of the specification. For tubes less than 1¼ in. [31.8 mm] in diameter and tubes under 3 ft [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the tubes are shipped.

31.2 For austenitic steel pipe, the marking paint or ink shall not contain detrimental amounts of harmful metals, or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

31.3 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as X, Y, or Z, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in 28.4.

31.4 *Bar Coding*—In addition to the requirements in 31.1 – 31.3, the manufacturer shall have the option of using bar coding as a supplementary identification method. Bar coding should be consistent with the (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

32. Packaging, Marking, and Loading

32.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A700.

33. Government Procurement

33.1 *Scale Free Tube:*

33.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale-free tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

33.1.2 Tube shall be ordered to outside diameter (OD) and wall thickness.

33.1.3 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements; however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

33.1.4 *Sampling for Flattening and Flaring Test and for Visual and Dimensional Examination*—Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (pieces per lot)	Sample Size
2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

33.1.5 *Sampling for Chemical Analysis*—One sample for chemical analysis shall be selected from each of two tubes chosen from each lot. A lot shall be all material poured from one heat.

33.1.6 *Sampling for Tension and Bend Test*—One sample shall be taken from each lot. A lot shall consist of all tube of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

33.1.7 *Hydrostatic and Ultrasonic Tests*—Each tube shall be tested by the ultrasonic (when specified) and hydrostatic tests.

33.1.8 Tube shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel tube shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

33.1.9 In addition to the marking in Specification A530/A530M, each length of tube ¼ in. outside diameter and larger shall be marked with the following listed information. Marking shall be in accordance with FED-STD-183 and MIL-STD-792: (*a*) Outside diameter, wall thickness, and length (*b*) Heat or lot identification number.

33.1.10 Tube shall be straight to within the tolerances specified in Table 7.

TABLE 7 Straightness Tolerances

Specified OD (in.)	Specified wall thickness (in.)	Maximum curvature in any 3 ft (in.)	Maximum curvature in total length (in.)
Up to 5.0, incl	Over 3 % OD to 0.5, incl	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl	Over 4 % OD to 0.75, incl	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl	Over 4 % OD to 1.0, incl	0.060	0.020 × length, ft

33.1.11 When specified, each tube shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the calibration standard shall be 5 % of the wall thickness or 0.005 in., whichever is greater. Any tube that produces an indication equal to or greater than 100 % of the indication from the calibration standard shall be rejected.

33.1.12 The tube shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the tube as determined by visual and ultrasonic examination, or alternate tests, as specified.

33.1.13 Tube shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality tubing. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in. [0.1 mm], whichever is greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

33.1.14 No weld repair by the manufacturer is permitted.

33.1.15 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163 and commercial preservation and packing shall be in accordance with Practices A700 or Practice D3951.

34. Keywords

34.1 alloy steel tube; austenitic stainless steel; duplex stainless steel; ferritic stainless steel; ferritic/austenitic stainless steel; heavily cold-worked steel tube; seamless steel tube; stainless steel tube; steel tube; welded steel tube

ANNEXES

A1. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in specifications referencing this Specification of General Requirements subject to the following conditions:

A1.1.1 Application for the addition of a new grade to a specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A1.1.5 The application shall state whether the new grade is covered by patent.

A2. REQUIREMENTS FOR THE INTRODUCTION OF MATERIALS FROM OTHER A01 OR B02.07 SPECIFICATION

A2.1 Wrought materials that are already covered by another A01 or B02.07 specification may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A2.1.1 Application for the addition of a grade that is already covered in another A01 or B02.07 specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A2.1.2 The chemical requirements, the specified mechanical properties, and the heat treatment requirements of the grade being added shall be the same as those for the grade in the A01 or B02.07 specification in which the grade is presently covered.

A2.1.3 The application shall provide recommendations for all requirements appearing in the applicable specification.

A2.1.4 The application shall state whether or not the grade is covered by patent.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY-STEEL, CHROMIUM-MOLYBDENUM-TUNGSTEN

SA-1017/SA-1017M

(Identical with ASTM Specification A1017/A1017M-17.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Tungsten

1. Scope

1.1 This specification covers Chromium-Molybdenum-Tungsten alloy steel plates intended primarily for welded boilers and pressure vessels designed for elevated temperature service.

1.2 Plates are available under this specification in grades having different alloy contents as follows:

Grade	Nominal Chromium Content, %	Nominal Molybdenum Content, %	Nominal Tungsten Content, %
23	2.25	0.20	1.60
911	9.00	1.00	1.00
92	9.00	0.45	1.75
122	12.00	0.40	2.00

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.4 The specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

5. Heat Treatment

5.1 Except as allowed by 5.2 and 5.3, all plates shall be normalized at 1900 to 1975°F [1040 to 1080°C]. Plates for Grades 23, 92, and 122 shall be tempered at 1350 to 1470°F [730 to 800°C]. Grade 911 plates shall be tempered at 1365 to 1435°F [740 to 780°C].

TABLE 1 Chemical Requirements

NOTE 1—Where " . . . " appears in this table there is no requirement.

Element	Composition %			
	Grade 23	Grade 911	Grade 122	Grade 92
Carbon				
Heat Analysis	0.04–0.10	0.09–0.13	0.07–0.14	0.07–0.13
Product Analysis	0.03–0.10	0.08–0.14	0.05–0.17	0.05–0.16
Manganese				
Heat Analysis	0.10–0.60	0.30–0.60	0.70 max	0.30–0.60
Product Analysis	0.09–0.66	0.25–0.66	0.77 max	0.25–0.66
Phosphorus, max.				
Heat Analysis	0.030	0.020	0.020	0.020
Product Analysis	0.030	0.025	0.025	0.025
Sulfur, max.				
Heat Analysis	0.010	0.010	0.010	0.010
Product Analysis	0.012	0.012	0.012	0.012
Silicon				
Heat Analysis	0.50 max	0.10–0.50	0.50 max	0.50 max
Product Analysis	0.50 max	0.08–0.56	0.56 max	0.50 max
Chromium				
Heat Analysis	1.90–2.60	8.5–9.5	10.0–11.5	8.5–9.5
Product Analysis	1.78–2.72	8.4–9.7	9.9–11.6	8.4–9.6
Molybdenum				
Heat Analysis	0.05–0.30	0.90–1.10	0.25–0.60	0.30–0.60
Product Analysis	0.04–0.35	0.85–1.15	0.20–0.65	0.25–0.65
Nickel, max.				
Heat Analysis	0.40	0.40	0.50	0.40
Product Analysis	0.40	0.43	0.54	0.40
Vanadium				
Heat Analysis	0.20–0.30	0.18–0.25	0.15–0.30	0.15–0.25
Product Analysis	0.18–0.33	0.16–0.27	0.13–0.32	0.13–0.27
Columbium (Niobium)[A]				
Heat Analysis	0.02–0.08	0.06–0.10	0.04–0.10	0.04–0.09
Product Analysis	0.02–0.10	0.05–0.11	0.03–0.11	0.03–0.10
Boron				
Heat Analysis	0.0010–0.006	0.0003–0.006	0.005 max	0.001–0.006
Product Analysis	0.0009–0.007	0.0002–0.007	0.006 max	0.0009–0.007
Nitrogen				
Heat Analysis	0.015 max[B]	0.04–0.09	0.04–0.10	0.030–0.070
Product Analysis	0.015 max[B]	0.035–0.095	0.03–0.11	0.025–0.075
Aluminum, max.				
Heat Analysis	0.03[C]	0.02	0.02	0.02
Product Analysis	0.04[C]	0.02	0.02	0.02
Tungsten				
Heat Analysis	1.45–1.75	0.90–1.10	1.50–2.50	1.50–2.00
Product Analysis	1.40–1.80	0.85–1.15	1.40–2.60	1.40–2.0
Copper				
Heat Analysis	. . .	. . .	0.30–1.70	. . .
Product Analysis	. . .	. . .	0.20–1.80	. . .
Titanium, max				
Heat Analysis	0.005–0.060[B]	0.01	0.01	0.01
Product Analysis	0.005–0.060[B]	0.01	0.01	0.01
Zirconium, max				
Heat Analysis	. . .	0.01	0.01	0.01
Product Analysis	. . .	0.01	0.01	0.01

[A] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.
[B] The Ti/N ratio of Grade 23 shall be greater than or equal to 3.5.
[C] Acid Soluble Aluminum.

TABLE 2 Tensile Requirements

	Grade 23	Grade 911	Grade 122	Grade 92
Tensile Strength, ksi [MPa]	74 to 100 [510 to 690]	90 to 120 [620 to 840]	90 [620] min	90 to 120 [620 to 840]
Yield Strength ksi [MPa], min	58 [400]	64 [440]	58 [400]	64 [440]
Elongation in 2 in. or 50 mm, % min	20	18	20	20

5.2 If permitted by the purchaser, plates for Grades 23, 92, and 122 may be austenitized at 1900 to 1975°F [1040 to 1080°C], subjected to accelerated cooling from the austenitizing temperature by air blasting or liquid quenching, and then tempered at 1350 to 1470°F [730 to 800°C].

5.3 Plates ordered without the heat treatment required by either 5.1 or 5.2 shall be furnished in either the stress-relieved or annealed condition, and the purchaser shall be responsible for the heat treatment of such plates to conform to either 5.1 or 5.2.

6. Chemical Composition

6.1 The steel shall conform to the requirements for chemical composition given in Table 1.

7. Mechanical Properties

7.1 *Tension Test:*

7.1.1 The material as represented by the tension test specimens shall conform to the applicable requirements given in Table 2.

7.2 *Hardness Test:*

7.2.1 Grade 23 plates shall have a hardness not exceeding 220 HB [97HRB].

7.2.2 Grade 122 plates shall have a hardness not exceeding 250 HB [25HRC].

8. Marking

8.1 In addition to the marking required in Specification A20/A20M, each plate shall be legibly stamped or stenciled, dependent upon the ordered thickness, with the letter "N" for normalized and tempered, "Q" for accelerated cooled and tempered, "S" for stress relieved, or "A" for annealed, whichever is applicable.

9. Keywords

9.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessels

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and Over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in Accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in Accordance with Specification A577/A577M,

S12. Ultrasonic Examination in Accordance with Specification A578/A578M, and

S17. Vacuum Carbon Deoxidized Steel.

TEST METHODS FOR MECHANICAL TESTING OF STEEL PRODUCTS—METRIC

SA-1058 (**23**)

(Identical with ASTM Specification A1058-19.)

Test Methods for Mechanical Testing of Steel Products—Metric

1. Scope

1.1 These test methods cover mechanical tests described in ASTM, EN, ISO, and JIS standards that utilize the SI system of units. The test methods in each system are not exact equivalents. Each standards system (ASTM, EN, ISO, and JIS) shall be used independently of the other. Combining requirements from any two or more systems may result in nonconformance with the purchase order.

1.2 These test methods cover procedures for the mechanical testing of steels, stainless steels, and related alloys. The various mechanical tests herein described are used to determine properties required in the product specifications. Variations in testing methods are to be avoided, and standard methods of testing are to be followed to obtain reproducible and comparable results. In those cases in which the testing requirements for certain products are unique or at variance with these general procedures, the product specification testing requirements shall control.

1.3 Only one of the testing procedure tracks shall be followed: ASTM, EN, ISO, or JIS. When a test method or practice is not available in one of the tracks then an appropriate test method or practice from an alternative track shall be used. The respective tests are listed in the column shown in Table 1.

NOTE 1—The test methods in each system are not exact equivalents.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 Attention is directed to Practice ISO 17025 when there may be a need for information on criteria for evaluation of testing laboratories.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A833 Test Method for Indentation Hardness of Metallic Materials by Comparison Hardness Testers

A956/A956M Test Method for Leeb Hardness Testing of Steel Products

A1038 Test Method for Portable Hardness Testing by the Ultrasonic Contact Impedance Method

E8/E8M Test Methods for Tension Testing of Metallic Materials

E10 Test Method for Brinell Hardness of Metallic Materials

E18 Test Methods for Rockwell Hardness of Metallic Materials

E23 Test Methods for Notched Bar Impact Testing of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E110 Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers

E190 Test Method for Guided Bend Test for Ductility of Welds

TABLE 1 Tests and Applicable Standards

Test	Sections	ASTM	EN	ISO	JIS
Tension	5 to 12	E8/E8M	10002-1	6892-1	Z 2241
Bend	13	E190 E290	7438[A]	7438	Z 2248
Bend (tube)	13	...	10232	8491	...
Hardness	14				
Brinell	15	E10	6506-1[A]	6506-1	Z 2243
Rockwell	16	E18	6508-1[A]	6508-1	Z 2245
Portable	17	A833 E110 A1038	...	...	...
Impact	18 to 26	E23	148-1[A]	148-1	Z 2242
Keywords	27	...	...	...	...

[A] These standards are designated EN ISO; this identifies the adoption of ISO standards by EN. "EN ISO" is part of the designation.

E290 Test Methods for Bend Testing of Material for Ductility

2.2 *Other Documents:*

ASME Boiler and Pressure Vessel Code Section VIII, Division I

ISO 148-1 Metallic Materials—Charpy Pendulum Impact Test—Part 1: Test Method

ISO 148-2 Metallic Materials—Charpy Pendulum Impact Test—Part 2: Verification of Test Machines

ISO 2566-1 Steel—Conversion of Elongation Values—Part 1: Carbon and Low Alloy Steels

ISO 2566-2 Steel—Conversion of Elongation Values—Part 2: Austenitic Steels

ISO 6506-1 Metallic Materials—Brinell Hardness Test—Part 1: Test Method[7]

ISO 6508-1 Metallic Materials—Rockwell Hardness Test—Part 1: Test Method (Scales A, B, C, D, E, F, G, H, K, N, T)

ISO 6892-1 Metallic Materials—Tensile Testing at Ambient Temperature

ISO 7438 Metallic Materials—Bend Test

ISO 8491 Metallic Materials—Tube (in Full Section)—Bend Test

ISO 17025 General Requirements for the Competence of Testing and Calibration Laboratories

JIS B 7722 Charpy Pendulum Impact Test—Verification of Testing Machines

JIS Z 2201 Test Pieces for Tensile Test for Metallic Materials

JIS Z 2241 Method of Tensile Test for Metallic Materials

JIS Z 2242 Method of Charpy Pendulum Impact Test for Metallic Materials

JIS Z 2243 Brinell Hardness Test—Test Method

JIS Z 2245 Rockwell Hardness Test—Test Method

JIS Z 2248 Method of Bend Test for Metallic Materials

3. General Precautions

3.1 The ASTM track is the default track; if other than the ASTM track is used that track shall be reported.

3.2 Certain methods of fabrication, such as bending, forming, and welding, or operations involving heating, may affect the properties of the material under test. Therefore, the product specifications cover the stage of manufacture at which mechanical testing is to be performed. The properties shown by testing prior to fabrication may not necessarily be representative of the product after it has been completely fabricated.

3.3 Improper machining or preparation of test specimens may give erroneous results. Care should be exercised to assure good workmanship in machining. Improperly machined specimens should be discarded and other specimens substituted.

3.4 Flaws in the specimen may also affect results. If any test specimen develops flaws, the retest provision of the applicable product specification shall govern.

3.5 If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

4. Orientation of Test Specimens

4.1 The terms "longitudinal test" and "transverse test" are used only in material specifications for wrought products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.1.1 *Longitudinal Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is parallel to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a longitudinal tension test specimen is in the direction of the greatest extension, and the axis of the fold of a longitudinal bend test specimen is at right angles to the direction of greatest extension.

4.1.2 *Transverse Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is at right angles to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a transverse tension test specimen is at right angles to the greatest extension, and the axis of the fold of a transverse bend test specimen is parallel to the greatest extension.

4.2 The terms "radial test" and "tangential test" are used in material specifications for some wrought circular products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.2.1 *Radial Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to the axis of the product and coincident with one of the radii of a circle drawn with a point on the axis of the product as a center.

4.2.2 *Tangential Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a center.

TENSION TEST

5. Description

5.1 The tension test related to the mechanical testing of steel products subjects a machined or full-section specimen of the material under examination to a measured load sufficient to cause rupture. The resulting properties sought are defined in Test Methods E8/E8M, ISO 6892-1, or JIS Z 2241 as applicable.

5.2 In general, the testing equipment and methods are given in Test Methods E8/E8M, ISO 6892-1, and JIS Z 2241. However, there are certain exceptions to these practices; these exceptions are covered in this standard.

6. Testing Apparatus and Operations

6.1 *Loading Systems*—There are two general types of loading systems, mechanical (screw power) and hydraulic. These differ chiefly in the variability of the rate of load application. The older screw power machines are limited to a small number of fixed free running crosshead speeds. Some modern screw power machines, and all hydraulic machines permit stepless variation throughout the range of speeds.

6.2 The tension testing machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision of the appropriate practices.

NOTE 2—Many machines are equipped with stress-strain recorders for autographic plotting of stress-strain curves. It should be noted that some recorders have a load measuring component entirely separate from the load indicator of the testing machine. Such recorders are calibrated separately.

6.3 *Loading*—It is the function of the gripping or holding device of the testing machine to transmit the load from the heads of the machine to the specimen under test. The essential requirement is that the load shall be transmitted axially. This implies that the centers of the action of the grips shall be in alignment, insofar as practicable, with the axis of the specimen at the beginning and during the test and that bending and twisting be held to a minimum.

6.4 *Speed of Testing*—The speed of testing shall not be greater than that at which load and strain readings can be made accurately. In production testing, speed of testing is commonly expressed *(1)* in terms of free running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), or *(2)* in terms of rate of separation of the two heads of the testing machine under load, or *(3)* in terms of rate of stressing the specimen, or *(4)* in terms of rate of straining the specimen. The following limitations on the speed of testing are recommended as adequate for most steel products:

NOTE 3—Tension tests using closed-loop machines (with feedback control of rate) should not be performed using load control, as this mode of testing will result in acceleration of the crosshead upon yielding and elevation of the measured yield strength.

6.4.1 Any convenient speed of testing may be used up to one half the specified yield point or yield strength. When this point is reached, the free-running rate of separation of the crossheads shall be adjusted so as not to exceed 0.025 mm per second per 25 mm of reduced section, or the distance between the grips for test specimens not having reduced sections. This speed shall be maintained through the yield point or yield strength. In determining the tensile strength, the free-running rate of separation of the heads shall not exceed 13 mm per min per 25 mm of reduced section, or the distance between the grips for test specimens not having reduced sections. In any event, the minimum speed of testing shall not be less than 1⁄10 the specified maximum rates for determining yield point or yield strength and tensile strength.

6.4.2 It shall be permissible to set the speed of the testing machine by adjusting the free running crosshead speed to the above specified values, inasmuch as the rate of separation of heads under load at these machine settings is less than the specified values of free running crosshead speed.

6.4.3 As an alternative, if the machine is equipped with a device to indicate the rate of loading, the speed of the machine from half the specified yield point or yield strength through the yield point or yield strength may be adjusted so that the rate of stressing does not exceed 11 MPa per second. However, the minimum rate of stressing shall not be less than 1 MPa per second.

7. Test Specimen Parameters

7.1 *Selection*—Test coupons shall be selected in accordance with the applicable product specifications.

7.2 *Size and Tolerances*—Test specimen dimensions and tolerances shall comply with the requirements of the relevant standards.

7.3 *Procurement of Test Specimens*—Specimens shall be prepared from portions of the material. They are usually machined so as to have a reduced cross section at mid-length in order to obtain uniform distribution of the stress over the cross section and to localize the zone of fracture. Care shall be taken to remove by machining all distorted, cold-worked, or heat-affected areas from the edges of the section used in evaluating the test.

7.4 *Aging of Test Specimens*—Unless otherwise specified, it shall be permissible to age tension test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water, heating in oil or in an oven.

7.5 *Measurement of Dimensions of Test Specimens*—Test specimens shall be measured in accordance with the requirements of 7.5.1 and 7.5.2 for ASTM or the appropriate paragraphs of ISO 6892-1 or JIS Z 2241, as applicable.

7.5.1 *Rectangular Tension Test*—These forms of specimens are shown in Test Methods E8/E8M. To determine the cross-sectional area, the center width dimension shall be measured to the nearest 0.15 mm for the 200-mm gauge length specimen and 0.025 mm for the 50-mm gauge length specimen. The center thickness dimension shall be measured to the nearest 0.025 mm for both specimens.

7.5.2 *Round Tension Test Specimens*—These forms of specimens are shown in Test Methods E8/E8M. To determine the cross-sectional area, the diameter shall be measured at the center of the gauge length to the nearest 0.025 mm.

7.6 *General*—Test specimens shall be either substantially full size or machined, as prescribed in the product specifications for the material being tested.

7.6.1 It is desirable to have the cross-sectional area of the specimen smallest at the center of the gauge length to ensure fracture within the gauge length. This is provided for by the taper in the gauge length permitted for each of the specimens described in the following sections.

7.6.2 For low ductility materials it is desirable to have fillets of large radius at the ends of the gauge length.

8. Plate-Type Specimen

8.1 The standard plate-type test specimen is shown in Test Methods E8/E8M, ISO 6892-1, or JIS Z 2241. This specimen is used for testing metallic materials in the form of plate, structural and bar-size shapes, and flat material having a nominal thickness of 5 mm or over. When product specifications so permit, other types of specimens may be used.

9. Sheet-Type Specimen

9.1 The standard sheet-type test specimen is shown in Test Methods E8/E8M, ISO 6892-1, or JIS Z 2241. This specimen is used for testing metallic materials in the form of sheet, plate, flat wire, strip, band, and hoop ranging in nominal thickness from 0.13 to 19 mm. When product specifications so permit, other types of specimens may be used, as specified in Test Methods E8/E8M.

10. Round Specimens

10.1 The standard diameter round test specimen as shown in Test Methods E8/E8M, ISO 6892-1, or JIS Z 2241 is frequently used for testing metallic materials.

10.2 Small size specimens proportional to standard specimens may be used when it is necessary to test material from which the standard specimens cannot be prepared. When small size specimens are used, the gauge length for measurement of elongation shall be five times the diameter of the specimen.

10.3 The type of specimen ends outside of the gauge length shall accommodate the shape of the product tested, and shall properly fit the holders or grips of the testing machine so that axial loads are applied with a minimum of load eccentricity and slippage.

11. Gauge Marks

11.1 Test specimens shall be marked in accordance with the requirements of the relevant standards.

12. Determination of Tensile Properties

12.1 The determination and description of the tensile properties shall be in accordance with the requirements of the relevant standards.

12.2 Elongation values may be converted from (*i*) 4d gauge length to a 5d gauge length, or (*ii*) 5d gage length to a 4d gage length by use of the multiplication factors shown in Table 2. If this conversion is used, the supplier must show the calculation on the certification.

TABLE 2 Conversion Factors for 4d and 5d Gauge Lengths (ISO 2566-1 and ISO 2566-2)

Conversion from	4d to 5d	5d to 4d
Carbon and low alloy steels	0.916	1.093
Austenitic steels	0.972	1.029

12.2.1 *Example 1*—Conversion of Carbon and low alloy steel elongation derived from 4d gauge length to a 5d gauge length elongation value:

$$23\ \% \times 0.916 = 21\ \%$$

12.2.2 *Example 2*—Conversion of Austenitic steel elongation derived from 5d gauge length to a 4d gauge length elongation value:

$$23\ \% \times 1.029 = 24\ \%$$

12.3 *Reduction of Area*—Fit the ends of the fractured specimen together and measure the mean diameter or the width and thickness at the smallest cross section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area is the reduction of area.

BEND TEST

13. Description

13.1 The bend test is one method for evaluating ductility, but it cannot be considered as a quantitative means of predicting service performance in all bending operations. The severity of the bend test is primarily a function of the angle of bend and inside diameter to which the specimen is bent, and of the cross section of the specimen. These conditions are varied according to location and orientation of the test specimen and the chemical composition, tensile properties, hardness, type, and quality of the steel specified. Test Method E190, Test Methods E290, EN ISO 7438, EN 10232 (tube), ISO 7438, or ISO 8491 (tube) and JIS Z 2248 may be consulted for methods of performing the test.

13.2 Unless otherwise specified, it shall be permissible to age bend test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water or by heating in oil or in an oven.

13.3 Bend the test specimen at room temperature to an inside diameter, as designated by the applicable product specifications, to the extent specified. The speed of bending is ordinarily not an important factor.

HARDNESS TEST

14. General

14.1 A hardness test is a means of determining resistance to penetration and is occasionally employed to obtain a quick approximation of tensile strength. Table 3, Table 4, Table 5, and Table 6 are for the conversion of hardness measurements from one scale to another or to approximate tensile strength.

TABLE 3 Approximate Hardness Conversion Numbers for Nonaustenitic Steels[A] (Rockwell C to Other Hardness Numbers)

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 15N Scale, 15-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 30N Scale 30-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness: 45N Scale, 45-kgf Load, Diamond Penetrator	Approximate Tensile Strength, ksi (MPa)
68	940	. . .	920	85.6	93.2	84.4	75.4	. . .
67	900	. . .	895	85.0	92.9	83.6	74.2	. . .
66	865	. . .	870	84.5	92.5	82.8	73.3	. . .
65	832	739	846	83.9	92.2	81.9	72.0	. . .
64	800	722	822	83.4	91.8	81.1	71.0	. . .
63	772	706	799	82.8	91.4	80.1	69.9	. . .
62	746	688	776	82.3	91.1	79.3	68.8	. . .
61	720	670	754	81.8	90.7	78.4	67.7	. . .
60	697	654	732	81.2	90.2	77.5	66.6	. . .
59	674	634	710	80.7	89.8	76.6	65.5	351 (2420)
58	653	615	690	80.1	89.3	75.7	64.3	338 (2330)
57	633	595	670	79.6	88.9	74.8	63.2	325 (2240)
56	613	577	650	79.0	88.3	73.9	62.0	313 (2160)
55	595	560	630	78.5	87.9	73.0	60.9	301 (2070)
54	577	543	612	78.0	87.4	72.0	59.8	292 (2010)
53	560	525	594	77.4	86.9	71.2	58.6	283 (1950)
52	544	512	576	76.8	86.4	70.2	57.4	273 (1880)
51	528	496	558	76.3	85.9	69.4	56.1	264 (1820)
50	513	482	542	75.9	85.5	68.5	55.0	255 (1760)
49	498	468	526	75.2	85.0	67.6	53.8	246 (1700)
48	484	455	510	74.7	84.5	66.7	52.5	238 (1640)
47	471	442	495	74.1	83.9	65.8	51.4	229 (1580)
46	458	432	480	73.6	83.5	64.8	50.3	221 (1520)
45	446	421	466	73.1	83.0	64.0	49.0	215 (1480)
44	434	409	452	72.5	82.5	63.1	47.8	208 (1430)
43	423	400	438	72.0	82.0	62.2	46.7	201 (1390)
42	412	390	426	71.5	81.5	61.3	45.5	194 (1340)
41	402	381	414	70.9	80.9	60.4	44.3	188 (1300)
40	392	371	402	70.4	80.4	59.5	43.1	182 (1250)
39	382	362	391	69.9	79.9	58.6	41.9	177 (1220)
38	372	353	380	69.4	79.4	57.7	40.8	171 (1180)
37	363	344	370	68.9	78.8	56.8	39.6	166 (1140)
36	354	336	360	68.4	78.3	55.9	38.4	161 (1110)
35	345	327	351	67.9	77.7	55.0	37.2	156 (1080)
34	336	319	342	67.4	77.2	54.2	36.1	152 (1050)
33	327	311	334	66.8	76.6	53.3	34.9	149 (1030)
32	318	301	326	66.3	76.1	52.1	33.7	146 (1010)
31	310	294	318	65.8	75.6	51.3	32.5	141 (970)
30	302	286	311	65.3	75.0	50.4	31.3	138 (950)
29	294	279	304	64.6	74.5	49.5	30.1	135 (930)
28	286	271	297	64.3	73.9	48.6	28.9	131 (900)
27	279	264	290	63.8	73.3	47.7	27.8	128 (880)
26	272	258	284	63.3	72.8	46.8	26.7	125 (860)
25	266	253	278	62.8	72.2	45.9	25.5	123 (850)
24	260	247	272	62.4	71.6	45.0	24.3	119 (820)
23	254	243	266	62.0	71.0	44.0	23.1	117 (810)
22	248	237	261	61.5	70.5	43.2	22.0	115 (790)
21	243	231	256	61.0	69.9	42.3	20.7	112 (770)
20	238	226	251	60.5	69.4	41.5	19.6	110 (760)

[A] This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 4 Approximate Hardness Conversion Numbers for Nonaustenitic Steels[A] (Rockwell B to Other Hardness Numbers)

Rockwell B Scale, 100-kgf Load 1/16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15-kgf Load, 1/16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1/16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1/16-in. (1.588-mm) Ball	
100	240	240	251	61.5	. . .	93.1	83.1	72.9	116 (800)
99	234	234	246	60.9	. . .	92.8	82.5	71.9	114 (785)
98	228	228	241	60.2	. . .	92.5	81.8	70.9	109 (750)
97	222	222	236	59.5	. . .	92.1	81.1	69.9	104 (715)
96	216	216	231	58.9	. . .	91.8	80.4	68.9	102 (705)
95	210	210	226	58.3	. . .	91.5	79.8	67.9	100 (690)
94	205	205	221	57.6	. . .	91.2	79.1	66.9	98 (675)
93	200	200	216	57.0	. . .	90.8	78.4	65.9	94 (650)
92	195	195	211	56.4	. . .	90.5	77.8	64.8	92 (635)
91	190	190	206	55.8	. . .	90.2	77.1	63.8	90 (620)
90	185	185	201	55.2	. . .	89.9	76.4	62.8	89 (615)
89	180	180	196	54.6	. . .	89.5	75.8	61.8	88 (605)
88	176	176	192	54.0	. . .	89.2	75.1	60.8	86 (590)
87	172	172	188	53.4	. . .	88.9	74.4	59.8	84 (580)
86	169	169	184	52.8	. . .	88.6	73.8	58.8	83 (570)
85	165	165	180	52.3	. . .	88.2	73.1	57.8	82 (565)
84	162	162	176	51.7	. . .	87.9	72.4	56.8	81 (560)
83	159	159	173	51.1	. . .	87.6	71.8	55.8	80 (550)
82	156	156	170	50.6	. . .	87.3	71.1	54.8	77 (530)
81	153	153	167	50.0	. . .	86.9	70.4	53.8	73 (505)
80	150	150	164	49.5	. . .	86.6	69.7	52.8	72 (495)
79	147	147	161	48.9	. . .	86.3	69.1	51.8	70 (485)
78	144	144	158	48.4	. . .	86.0	68.4	50.8	69 (475)
77	141	141	155	47.9	. . .	85.6	67.7	49.8	68 (470)
76	139	139	152	47.3	. . .	85.3	67.1	48.8	67 (460)
75	137	137	150	46.8	99.6	85.0	66.4	47.8	66 (455)
74	135	135	147	46.3	99.1	84.7	65.7	46.8	65 (450)
73	132	132	145	45.8	98.5	84.3	65.1	45.8	64 (440)
72	130	130	143	45.3	98.0	84.0	64.4	44.8	63 (435)
71	127	127	141	44.8	97.4	83.7	63.7	43.8	62 (425)
70	125	125	139	44.3	96.8	83.4	63.1	42.8	61 (420)
69	123	123	137	43.8	96.2	83.0	62.4	41.8	60 (415)
68	121	121	135	43.3	95.6	82.7	61.7	40.8	59 (405)
67	119	119	133	42.8	95.1	82.4	61.0	39.8	58 (400)
66	117	117	131	42.3	94.5	82.1	60.4	38.7	57 (395)
65	116	116	129	41.8	93.9	81.8	59.7	37.7	56 (385)
64	114	114	127	41.4	93.4	81.4	59.0	36.7	. . .
63	112	112	125	40.9	92.8	81.1	58.4	35.7	. . .
62	110	110	124	40.4	92.2	80.8	57.7	34.7	. . .
61	108	108	122	40.0	91.7	80.5	57.0	33.7	. . .
60	107	107	120	39.5	91.1	80.1	56.4	32.7	. . .
59	106	106	118	39.0	90.5	79.8	55.7	31.7	. . .
58	104	104	117	38.6	90.0	79.5	55.0	30.7	. . .
57	103	103	115	38.1	89.4	79.2	54.4	29.7	. . .
56	101	101	114	37.7	88.8	78.8	53.7	28.7	. . .
55	100	100	112	37.2	88.2	78.5	53.0	27.7	. . .
54	. . .	. . .	111	36.8	87.7	78.2	52.4	26.7	. . .
53	. . .	. . .	110	36.3	87.1	77.9	51.7	25.7	. . .
52	. . .	. . .	109	35.9	86.5	77.5	51.0	24.7	. . .
51	. . .	. . .	108	35.5	86.0	77.2	50.3	23.7	. . .
50	. . .	. . .	107	35.0	85.4	76.9	49.7	22.7	. . .
49	. . .	. . .	106	34.6	84.8	76.6	49.0	21.7	. . .
48	. . .	. . .	105	34.1	84.3	76.2	48.3	20.7	. . .
47	. . .	. . .	104	33.7	83.7	75.9	47.7	19.7	. . .
46	. . .	. . .	103	33.3	83.1	75.6	47.0	18.7	. . .
45	. . .	. . .	102	32.9	82.6	75.3	46.3	17.7	. . .
44	. . .	. . .	101	32.4	82.0	74.9	45.7	16.7	. . .
43	. . .	. . .	100	32.0	81.4	74.6	45.0	15.7	. . .
42	. . .	. . .	99	31.6	80.8	74.3	44.3	14.7	. . .
41	. . .	. . .	98	31.2	80.3	74.0	43.7	13.6	. . .
40	. . .	. . .	97	30.7	79.7	73.6	43.0	12.6	. . .
39	. . .	. . .	96	30.3	79.1	73.3	42.3	11.6	. . .
38	. . .	. . .	95	29.9	78.6	73.0	41.6	10.6	. . .
37	. . .	. . .	94	29.5	78.0	72.7	41.0	9.6	. . .
36	. . .	. . .	93	29.1	77.4	72.3	40.3	8.6	. . .
35	. . .	. . .	92	28.7	76.9	72.0	39.6	7.6	. . .
34	. . .	. . .	91	28.2	76.3	71.7	39.0	6.6	. . .
33	. . .	. . .	90	27.8	75.7	71.4	38.3	5.6	. . .

TABLE 4 *Continued*

Rockwell B Scale, 100-kgf Load 1⁄16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1⁄16-in. (1.588-mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15-kgf Load, 1⁄16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1⁄16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1⁄16-in. (1.588-mm) Ball	
32	. . .	. . .	89	27.4	75.2	71.0	37.6	4.6	. . .
31	. . .	. . .	88	27.0	74.6	70.7	37.0	3.6	. . .
30	. . .	. . .	87	26.6	74.0	70.4	36.3	2.6	. . .

[A] This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 5 Approximate Hardness Conversion Numbers for Austenitic Steels (Rockwell C to other Hardness Numbers)

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
		15N Scale, 15-kgf Load, Diamond Penetrator	30N Scale, 30-kgf Load, Diamond Penetrator	45N Scale, 45-kgf Load, Diamond Penetrator
48	74.4	84.1	66.2	52.1
47	73.9	83.6	65.3	50.9
46	73.4	83.1	64.5	49.8
45	72.9	82.6	63.6	48.7
44	72.4	82.1	62.7	47.5
43	71.9	81.6	61.8	46.4
42	71.4	81.0	61.0	45.2
41	70.9	80.5	60.1	44.1
40	70.4	80.0	59.2	43.0
39	69.9	79.5	58.4	41.8
38	69.3	79.0	57.5	40.7
37	68.8	78.5	56.6	39.6
36	68.3	78.0	55.7	38.4
35	67.8	77.5	54.9	37.3
34	67.3	77.0	54.0	36.1
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

These conversion values have been obtained from computer-generated curves and are presented to the nearest 0.1 point to permit accurate reproduction of those curves. Since all converted hardness values must be considered approximate, however, all converted Rockwell hardness numbers shall be rounded to the nearest whole number.

14.2 *Hardness Testing:*

14.2.1 If the product specification permits alternative hardness testing to determine conformance to a specified hardness requirement, the conversions listed in Table 3, Table 4, Table 5, and Table 6 shall be used.

14.2.2 When recording converted hardness numbers, the measured hardness and test scale shall be indicated in parentheses, for example: 353 HBW (38 HRC). This means that a hardness value of 38 was obtained using the Rockwell C scale and converted to a Brinell hardness of 353.

15. Brinell Test

15.1 The Brinell Test shall be carried out in accordance with the requirements of Test Method E10, ISO 6506-1, or JIS Z 2243.

TABLE 6 Approximate Hardness Conversion Numbers for Austenitic Steels (Rockwell B to other Hardness Numbers)

Rockwell B Scale, 100-kgf Load, 1⁄16-in. (1.588-mm) Ball	Brinell Indentation Diameter, mm	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
				15T Scale, 15-kgf Load, 1⁄16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1⁄16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1⁄16-in. (1.588-mm) Ball
100	3.79	256	61.5	91.5	80.4	70.2
99	3.85	248	60.9	91.2	79.7	69.2
98	3.91	240	60.3	90.8	79.0	68.2
97	3.96	233	59.7	90.4	78.3	67.2
96	4.02	226	59.1	90.1	77.7	66.1
95	4.08	219	58.5	89.7	77.0	65.1
94	4.14	213	58.0	89.3	76.3	64.1
93	4.20	207	57.4	88.9	75.6	63.1
92	4.24	202	56.8	88.6	74.9	62.1
91	4.30	197	56.2	88.2	74.2	61.1
90	4.35	192	55.6	87.8	73.5	60.1
89	4.40	187	55.0	87.5	72.8	59.0
88	4.45	183	54.5	87.1	72.1	58.0
87	4.51	178	53.9	86.7	71.4	57.0
86	4.55	174	53.3	86.4	70.7	56.0
85	4.60	170	52.7	86.0	70.0	55.0
84	4.65	167	52.1	85.6	69.3	54.0
83	4.70	163	51.5	85.2	68.6	52.9
82	4.74	160	50.9	84.9	67.9	51.9
81	4.79	156	50.4	84.5	67.2	50.9
80	4.84	153	49.8	84.1	66.5	49.9

15.1.1 A range of hardness can properly be specified only for quenched and tempered or normalized and tempered material. For annealed material a maximum figure only should be specified. For normalized material a minimum or a maximum hardness may be specified by agreement. In general, no hardness requirements should be applied to untreated material.

15.1.2 Brinell hardness may be required when tensile properties are not specified.

15.2 *Test Specimen*—Brinell hardness tests are made on prepared areas and sufficient metal must be removed from the surface to eliminate decarburized metal and other surface irregularities. The thickness of the piece tested must be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the indentation.

15.3 *Procedure:*

15.3.1 It is essential that the applicable product specifications state clearly the position at which Brinell hardness indentations are to be made and the number of such indentations required. The distance of the center of the indentation from the edge of the specimen or edge of another indentation must be at least two and one-half times the diameter of the indentation.

15.3.2 Measure two diameters of the indentation at right angles to the nearest 0.1 mm, estimate to the nearest 0.05 mm, and average to the nearest 0.05 mm. If the two diameters differ by more than 0.1 mm, discard the readings and make a new indentation.

16. Rockwell Test

16.1 The Rockwell Test shall be carried out in accordance with the requirements of Test Methods E18, ISO 6508-1, or JIS Z 2245.

17. Portable Hardness Test

17.1 Although this standard generally prefers the use of fixed-location Brinell or Rockwell hardness test methods, it is not always possible to perform the hardness test using such equipment due to the part size, location, or other logistical reasons. In this event, hardness testing using portable equipment as described in Test Methods A956/A956M, A1038, and E110 shall be used with strict compliance for reporting the test results in accordance with the selected standard (see examples below). Standard Practice A833 may be used, although it might not always be suitable as a criterion for acceptance or rejection since Practice A833 does not contain a precision and bias statement.

17.1.1 *Practice A833*—The measured hardness number shall be reported in accordance with the standard methods and given the HBC designation followed by the comparative test bar hardness to indicate that it was determined by a portable comparative hardness tester, as in the following example:

17.1.1.1 *232 HBC/240* where 232 is the hardness test result using the portable comparative test method (HBC) and 240 is the Brinell hardness of the comparative test bar.

17.1.2 *Practice A956/A956M:*

17.1.2.1 The measured hardness number shall be reported in accordance with the standard methods and appended with a Leeb impact device in parenthesis to indicate that it was determined by a portable hardness tester, as in the following example:

(1) 350 HLD where 350 is the hardness test result using the portable Leeb hardness test method with the HLD impact device.

17.1.2.2 When hardness values converted from the Leeb number are reported, the portable instrument used shall be reported in parentheses, for example:

(1) 350 HB (HLD) where the original hardness test was performed using the portable Leeb hardness test method with the HLD impact device and converted to the Brinell hardness value (HB).

17.1.3 *Test Method A1038*—The measured hardness number shall be reported in accordance with the standard methods and appended with UCI in parenthesis to indicate that it was determined by a portable hardness tester, as in the following example:

17.1.3.1 *446 HV (UCI) 10* where 446 is the hardness test result using the portable UCI test method under a force of 10 kgf.

17.1.4 *Test Method E110:* The measured hardness number shall be reported in accordance with the standard methods and appended with a /P to indicate that it was determined by a portable hardness tester, as follows:

17.1.4.1 *Rockwell Hardness Examples:*

(1) 40 HRC/P where 40 is the hardness test result using the Rockwell C portable test method.

(2) 72 HRBW/P where 72 is the hardness test result using the Rockwell B portable test method using a tungsten carbide ball indenter.

17.1.4.2 *Brinell Hardness Examples:*

(1) 220 HBW/P 10/3000 where 220 is the hardness test result using the Brinell portable test method with a ball of 10 mm diameter and with a test force of 3000 kgf (29.42 kN) applied for 10 s to 15 s.

(2) 350 HBW/P 5/750 where 350 is the hardness test result using the Brinell portable test method with a ball of 5 mm diameter and with a test force of 750 kgf (7.355 kN) applied for 10 s to 15 s.

CHARPY IMPACT TESTING

18. Description

18.1 The equipment, test specimen and testing procedures shall comply with the requirements of Test Methods E23, ISO 148-1, or JIS Z 2242.

19. Testing Machines

19.1 Charpy machines used for testing steel generally have capacities in the 300 to 400 J energy range. Sometimes machines of lesser capacity are used; however, the capacity of the machine should be substantially in excess of the absorbed energy of the specimens (see Test Methods E23). The linear velocity at the point of impact should be in the range of 4.9 to 5.8 m/s or in accordance with ISO 148-1, or JIS Z 2242.

20. Sampling and Number of Specimens

20.1 *Sampling:*

20.1.1 Test location and orientation should be addressed by the product specifications. If not, for wrought products, the test location shall be the same as that for the tensile specimen and the orientation shall be longitudinal with the notch perpendicular to the major surface of the product being tested.

20.1.2 *Number of Specimens:*

20.1.2.1 All specimens used for a Charpy impact test shall be taken from a single test coupon or test location.

20.1.2.2 When the specification calls for a minimum average test result, three specimens shall be tested.

20.1.2.3 When the specification requires determination of a transition temperature, eight to twelve specimens are usually needed.

20.2 *Type and Size:*

20.2.1 A standard full size Charpy V-notch specimen as shown in Test Methods E23, ISO 148-1, or JIS Z 2242 shall be used except as provided in the following sub-paragraphs.

20.2.2 If a standard full-size specimen cannot be prepared, the largest feasible standard subsize specimen shall be prepared. The specimens shall be machined so that the specimen does not include material nearer to the surface than 0.5 mm.

20.2.3 Tolerances for standard subsize specimens are shown in Test Methods E23, ISO 148-1, or JIS Z 2242.

20.3 *Notch Preparation*—The machining of the notch is critical, as it has been demonstrated that extremely minor variations in notch radius and profile, or tool marks at the bottom of the notch may result in erratic test data.

21. Calibration

21.1 *Accuracy and Sensitivity*—Calibrate and adjust Charpy impact machines in accordance with the requirements of the test methods used Test Methods E23, ISO 148-2, or JIS B 7722.

22. Conditioning—Temperature Control

22.1 When a specific test temperature is required by the specification or purchaser, control the temperature of the heating or cooling medium within ±2 °F (1 °C).

23. Procedure

23.1 *Individual Test Values:*

23.1.1 *Impact Energy*—Record the impact energy absorbed to the nearest J.

23.1.2 *Fracture Appearance:*

23.1.2.1 Determine the percentage of shear fracture area by any of the methods described in Test Methods E23, ISO 148-1, or JIS Z 2242.

23.1.2.2 Determine the individual fracture appearance values to the nearest 5 % shear fracture and record the value.

23.1.3 *Lateral Expansion:*

23.1.3.1 Methods of measurement and precautions are described in Test Methods E23.

23.1.3.2 Measure the individual lateral expansion values to the nearest 0.025 mm and record the values.

23.1.3.3 With the exception described as follows, any specimen that does not separate into two pieces when struck by a single blow may be reported as unbroken. If the specimen can be separated by force applied by bare hands, the specimen may be considered as having been separated by the blow.

24. Interpretation of Test Result

24.1 When the acceptance criterion of any impact test is specified to be a minimum average value at a given temperature, the test result shall be the average (arithmetic mean) of the individual test values of three specimens from one test location.

24.1.1 When a minimum average test result is specified:

24.1.1.1 The test result is acceptable when all of the below are met:

(1) The test result equals or exceeds the specified minimum average (given in the specification),

(2) The individual test value for not more than one specimen measures less than the specified minimum average, and

(3) The individual test value for any specimen measures not less than two-thirds of the specified minimum average.

24.1.1.2 If the acceptance requirements of 24.1.1.1 are not met, perform one retest of three additional specimens from the same test location. Each individual test value of the retested specimens shall be equal to or greater than the specified minimum average value.

24.2 *Test Specifying a Minimum Transition Temperature:*

24.2.1 *Definition of Transition Temperature*—For specification purposes, the transition temperature is the temperature at which the designated material test value equals or exceeds a specified minimum test value.

24.2.2 *Determination of Transition Temperature:*

24.2.2.1 Break one specimen at each of a series of temperatures above and below the anticipated transition temperature using the procedures in Section 23. Record each test temperature to the nearest 0.5 °C.

24.2.2.2 Plot the individual test results (J or percent shear) as the ordinate versus the corresponding test temperature as the abscissa and construct a best-fit curve through the plotted data points.

24.2.2.3 If transition temperature is specified as the temperature at which a test value is achieved, determine the temperature at which the plotted curve intersects the specified test value by graphical interpolation (extrapolation is not permitted). Record this transition temperature to the nearest 3 °C. If the tabulated test results clearly indicate a transition temperature lower than specified, it is not necessary to plot the data. Report the lowest test temperature for which test value exceeds the specified value.

24.2.2.4 Accept the test result if the determined transition temperature is equal to or lower than the specified value.

24.2.2.5 If the determined transition temperature is higher than the specified value, but not more than 12 °C higher than the specified value, test sufficient samples in accordance with Section 25 to plot two additional curves. Accept the test results if the temperatures determined from both additional tests are equal to or lower than the specified value.

24.3 When subsize specimens are permitted or necessary, or both, modify the specified test requirement according to Table 7 or test temperature according to codes such as ASME Boiler and Pressure Vessel Code, Section VIII, Division I Table UG-84.2, or both. Greater energies or lower test temperatures may be agreed upon by purchaser and supplier.

TABLE 7 Charpy V-Notch Test Acceptance Criteria for Various Sub-Size Specimens described by Test Methods E23

Full Size 10 by 10 mm	¾ Size 10 by 7.5 mm	⅔ Size 10 by 6.7 mm	½ Size 10 by 5 mm	⅓ Size 10 by 3.3 mm	¼ Size 10 by 2.5 mm
J	J	J	J	J	J
54	41	37	27	18	14
48	35	31	24	16	12
41	30	27	20	14	11
34	26	23	16	11	8
27	20	18	14	10	7
22	16	15	11	7	5
20	15	14	11	7	5
18	14	12	8	5	4
16	12	11	8	5	4
14	11	10	7	4	3
10	7	7	5	3	3

25. Records

25.1 The test record should contain the following information as appropriate:

25.1.1 Full description of material tested (that is, specification number, grade, class or type, size, heat number).

25.1.2 Specimen orientation with respect to the material axis.

25.1.3 Specimen size.

25.1.4 Test temperature and individual test value for each specimen broken, including initial tests and retests.

25.1.5 Test results.

25.1.6 Transition temperature and criterion for its determination, including initial tests and retests.

26. Report

26.1 The specification should designate the information to be reported.

27. Keywords

27.1 bend test; Brinell hardness; Charpy impact test; elongation; hardness test; portable hardness; reduction of area; Rockwell hardness; tensile strength; tension test; yield strength

ANNEX

(Mandatory Information)

A1. ROUNDING OF TEST DATA

A1.1 Application

A1.1.1 This annex shall apply to rounding test data for the purpose of determining conformance to product specification requirements.

A1.1.1.1 This annex shall apply only when rounding is not specified in the product specifications.

A1.1.1.2 Observed or calculated test results and records maintained by testing laboratories are not subject to this annex.

A1.2 Method

A1.2.1 Values shall be rounded in accordance with the rules of Practice E29 unless otherwise stated herein.

A1.2.2 In the special case of rounding the number "5" when no additional numbers other than "0" follow the "5," rounding shall be in accordance with Practice E29 except where this would result in rejection of the product.

A1.2.3 Requirements for rounding levels for determining conformance to product specification requirements are given in Table A1.1. Specific reported test data values shall be rounded to Table A1.1 for determining conformance to product specification requirements.

A1.2.4 Table A1.1 values are designed to provide uniformity in determining conformance to product specification requirements and should be considered when rounding requirements are stated in product specifications.

A1.2.5 When rounding requirements for product acceptance are neither stated in the product specification nor listed in Table A1.1, an observed or calculated value shall be rounded to the nearest unit in the last right hand digit used in expressing the specification requirement.

TABLE A1.1 Rounded Test Data for Determining Conformance to Specification

Test Quantity	Test Data Range	Rounded Value[A]
Yield Point, Yield Strength, Tensile Strength	<500 MPa,	1 MPa
	≥500 to <1000 MPa,	5 MPa
	≥1000 MPa	10 MPa
Elongation	0 to <10 %,	0.5 %
	≥10 %	1 %
Reduction of Area	0 to <10 %,	0.5 %
	≥10 %	1 %
Absorbed Energy	0 to ≤ 325 J	1 J
Brinell Hardness	all values	tabular value[B]
Rockwell Hardness	all values	1 Rockwell Number

[A] Round test data to the nearest integral multiple to the nearest values in this column. If the data value is exactly midway between two rounded values, round in accordance with A1.2.2.

[B] Round the mean diameter of the Brinell impression to the nearest 0.05 mm and report the corresponding Brinell hardness number from the table without further rounding.

SPECIFICATION FOR CARBON AND ALLOY STEEL EXTERNALLY THREADED METRIC FASTENERS

SF-568M

(Identical with ASTM Specification F568M-98.)

SPECIFICATION FOR CARBON AND ALLOY STEEL EXTERNALLY THREADED METRIC FASTENERS

SF-568M

(Identical with ASTM Specification F 568M-98)

1. Scope

1.1 This specification covers chemical and mechanical requirements for nine property classes of carbon and alloy steel externally threaded metric fasteners in nominal thread diameters M1.6 through M100 suited for use in general engineering applications.

1.2 This specification does not cover dimensional requirements for fasteners of any property class. When referencing this specification for procurement purposes, it is mandatory that size, type, style, and any special dimensions of the product be additionally specified.

1.2.1 In case of any conflict in requirements, the requirements of the individual product specification shall take precedence over those of this general specification.

1.2.2 The purchaser may specify additional requirements which do not negate any of the provisions of this general specification or of the individual product specification. Such additional requirements, the acceptance of which are subject to negotiation with the supplier, must be included in the order information (see Section 3).

1.3 Requirements for seven of the nine property classes, 4.6, 4.8, 5.8, 8.8, 9.8, 10.9, and 12.9, are essentially identical with requirements given for these classes in ISO 898/I. The other two, 8.8.3 and 10.9.3, are not recognized in ISO standards.

1.4 Classes 8.8.3 and 10.9.3 bolts, screws, and studs have atmospheric corrosion resistance and weathering characteristics comparable to those of the steels covered in Specification A 588. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition. See 5.2. When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

1.5 When agreed on by the purchaser, Class 5.8 fasteners may be supplied when either Classes 4.6 or 4.8 are ordered; Class 4.8 may be supplied when Class 4.6 is ordered; Class 8.8.3 may be supplied when Class 8.8 is ordered; and Class 10.9.3 may be supplied when Class 10.9 is ordered.

1.6 The product size range for which each property class is applicable is given in Table 1 and Table 2 on chemical composition requirements, and the mechanical requirements table (see Table 3).

1.7 Appendix X1 gives conversion guidance to assist designers and purchasers in the selection of a suitable property class.

1.8 Appendix X2 explains the significance of the property class designation numerals.

2. Referenced Documents

2.1 *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength

A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

A 325M Specification for High-Strength Bolts for Structural Steel Joints [Metric]

A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A 449 Specification for Quenched and Tempered Steel Bolts and Studs

A 490 Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength

A 490M Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric]

A 574 Specification for Alloy Steel Socket-Head Cap Screws

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in. [100 mm] Thick
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
D 3951 Practice for Commercial Packaging
F 606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]
F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

2.2 *ISO Standard:*
ISO 898/I, Mechanical Properties of Fasteners, Part I, Bolts, Screws, and Studs

2.3 *ANSI Standards:*
B 18.2.3.1M Metric Hex Cap Screws
B 18.2.3.2M Metric Formed Hex Screws
B 18.2.3.3M Metric Heavy Hex Screws
B 18.2.3.4M Metric Hex Flange Screws
B 18.2.3.5M Metric Hex Bolts
B 18.2.3.6M Metric Heavy Hex Bolts
B 18.5.2.1M Metric Round Head Short Square Neck Bolts

2.4 *ANSI/ASME Standard:*
B18.5.2.2M Metric Round Head Square Neck Bolts

3. Ordering Information

3.1 Orders for products referencing this specification shall include the following:

3.1.1 Quantity (number of pieces),

3.1.2 Name of product (that is, type and style of bolt, screw, or stud),

3.1.3 Dimensions, including nominal thread diameter, thread pitch, and length,

3.1.4 Property class,

3.1.5 *Zinc Coating*— Specify the zinc coating process required, for example, hot dip, mechanically deposited, or no preference (see 4.5),

3.1.6 *Other Finishes*— Specify other protective finish, if required,

3.1.7 ASTM designation and year of issue, and

3.1.8 Any special requirements (for example, mechanical requirements, see Table 3, or proof load testing, see Table 4; stud marking, see 12.2.3; additional testing, see 8.3).

3.2 *Government Provisioning* — Government procurement and design selection criteria shall be specified in accordance with ANSI (or ANSI/ASME) B18.2.3.1M, B18.2.3.2M, B18.2.3.3M, B18.2.3.4M, B18.2.3.5M, B18.2.3.6M, B18.5.2.1M, or B18.5.2.2M, as appropriate.

4. Materials and Manufacture

4.1 Steel for bolts, screws, and studs shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 *Heading Practice:*

4.2.1 Methods other than upsetting or extrusion, or both, are permitted only by special agreement between purchaser and producer.

4.2.2 Class 4.6 may be hot or cold headed at the option of the manufacturer.

4.2.3 Classes 4.8, 5.8, 8.8, 8.8.3, 9.8, 10.9, 10.9.3, and 12.9 bolts and screws in nominal thread diameters up to M20 inclusive with lengths up to 10 times the nominal product size or 150 mm, whichever is shorter, shall be cold headed, except that they may be hot headed by special agreement with the purchaser. Larger diameters and longer lengths may be cold or hot headed at the option of the manufacturer.

4.3 *Threading Practice:*

4.3.1 Threads on Class 4.6 bolts and screws and on all classes of studs may be cut, rolled, or ground at the option of the manufacturer.

4.3.2 Threads on Classes 4.8, 5.8, 8.8, 8.8.3, 9.8, 10.9, 10.9.3, and 12.9 bolts and screws in nominal thread diameters up to M20 inclusive, and product lengths up to 150 mm inclusive, shall be roll threaded, except by special agreement with the purchaser. Threads of these classes on bolts and screws larger than M20 or longer than 150 mm or both, may be rolled, cut, or ground at the option of the manufacturer.

4.4 *Heat Treatment:*

4.4.1 Class 4.6 bolts and screws and Classes 4.6, 4.8, and 5.8 studs need not be heat treated.

4.4.2 Classes 4.8 and 5.8 bolts and screws shall be stress relieved if necessary to assure the soundness of the head to shank junction. When stress relieving is specified by the purchaser, Class 5.8 bolts and screws shall be stress relieved at a minimum stress-relief temperature of 470°C. Where higher stress-relief temperatures are necessary to relieve stresses in severely upset heads, mechanical requirements shall be agreed upon between the purchaser and producer.

4.4.3 Classes 8.8, 8.8.3, and 9.8 bolts, screws, and studs shall be heat treated by quenching in a liquid medium from above the transformation temperature and reheating to the tempering temperature given in Table 1.

4.4.4 Classes 10.9, 10.9.3, and 12.9 bolts, screws, and studs shall be heat treated by quenching in oil from above the transformation temperature and reheating to the tempering temperature given in Table 1.

4.4.5 *Tempering-Temperature-Audit Test*— This test is a means for checking whether products were tempered at the specified temperature. The hardness (mean hardness of three hardness readings) of a bolt, screw, or stud as manufactured shall be measured. The product shall then be retempered for a minimum of 30 min per 25 mm of nominal diameter, but not less than 30 min, at a temperature 10°C less than the minimum tempering temperature specified for the property class and material in Table 1. The hardness of the retempered product shall then be measured. The difference between the hardness of the product before and after retempering shall not exceed 20 HV points.

4.5 *Zinc Coatings, Hot-Dip, and Mechanically Deposited:*

4.5.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot dip, mechanically deposited, or no preference.

4.5.2 When hot-dip is specified, the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153.

4.5.3 When mechanically deposited is specified, the fasteners shall be zinc coated by the mechanical deposition process in accordance with the requirements of Class 50 of Specification B 695.

4.5.4 When no preference is specified, the supplier may furnish either a hot dip zinc coating in accordance with Specification A 153, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. All components of mating fasteners (for example, bolts, nuts, and washers) shall be coated by the same zinc coating process, and the suppliers option is limited to one process per item with no mixed processes in a lot.

4.6 Bolts, screws, and studs of Classes 10.9 and 12.9 should not be hot-dip zinc-coated.

NOTE 1 — Research conducted on bolts with properties equivalent to Class 10.9 indicated that hydrogen-stress corrosion cracking may occur in hot-dip zinc-coated fasteners of Classes 10.9 and 12.9.

5. Chemical Composition

5.1 For all classes except 8.8.3 and 10.9.3, the bolts, screws, and studs shall conform to the chemical composition specified in Table 1.

5.2 *Classes 8.8.3 and 10.9.3:*

5.2.1 Sizes M20 and smaller shall conform to any one of the compositions (A, B, C, D, E, or F) specified in Table 2, at the suppliers option.

5.2.2 Sizes larger than M20 shall conform to Compositions A or B specified in Table 2, at the suppliers option.

5.2.3 See Guide G 101 for methods of estimation corrosion resistance of low alloy steels.

5.3 Material analyses may be made by the purchaser from finished products representing each lot. The chemical composition thus determined shall conform to the requirements specified for the product analysis in Table 1 and Table 2.

5.4 Use of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.5 Chemical analyses shall be performed in accordance with Test Methods A 751.

6. Mechanical Properties

6.1 Bolts, screws, and studs shall be tested in accordance with the mechanical testing requirements for the applicable type, property class, size, and length of product as specified in Table 4, and shall meet the mechanical requirements specified for that product in Tables 3-5.

6.2 For products on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence over low readings of hardness tests.

7. Workmanship

7.1 Surface discontinuity limits shall be in accordance with Specification F 788/F 788M.

8. Number of Tests and Retests

8.1 The requirements of this specification shall be met in continuous mass production for stock; the manufacturer shall inspect to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of product are not ordinarily required. Individual heats of steel are not identified in the finished product.

8.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

8.3 When testing of a specific lot is specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all products of one type, that is, bolts, screws, or studs having the same nominal diameter, length, and property class, offered for inspection at one time. Unless otherwise specified, the number of tests for each specified property shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and less	1
over 800 to 8 000, incl	2
over 8 000 to 22 000, incl	3
over 22 000	5

8.4 If any test specimen shows defective machining, it may be discarded and another specimen substituted.

9. Test Methods

9.1 Bolts, screws, and studs shall be tested in accordance with the methods described in Test Methods F 606M, with tension test wedge angles as specified in Table 6.

10. Inspection

10.1 If the inspection described in 10.2 is required by the purchaser, it shall be specified in the inquiry, order, or contract.

10.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests and inspection shall be made prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the work.

11. Responsibility

11.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

12. Product Marking

12.1 *Bolts and Screws:*

12.1.1 Bolts and screws of nominal thread diameters smaller than M5 need not be marked. Additionally, slotted and recessed screws of nominal thread diameters M5 and larger need not be marked.

12.1.2 Bolts and screws, except those covered in 12.1.1, shall be marked permanently and clearly to identify the property class and the manufacturer. The property class symbols shall be as given in Table 7. The manufacturer's identification symbol shall be of his design.

12.1.3 For Classes 8.8.3 and 10.9.3, the manufacturer may add other distinguishing marks indicating that the bolt or screw is atmospheric corrosion resistant and of a weathering grade of steel.

12.1.4 Markings shall be located on the top of the head with the base of the property class symbols positioned toward the closest periphery of the head. Markings may be either raised or depressed at the option of the manufacturer. Alternatively, for hex head products, the markings may be indented on the side of the head with the base of the property class symbols positioned toward the bearing surface.

12.1.5 Metric bolts and screws shall not be marked with radial line symbols.

12.2 *Studs:*

12.2.1 Studs shall be marked permanently and clearly to identify the property class. The property class symbols and sizes to be marked shall be as given in Table 7.

12.2.2 Markings shall be located on the extreme end of the stud and may be raised or depressed at the option of the manufacturer. For studs with an interference-fit thread, the markings shall be located on the nut end.

12.2.3 When ordered by the purchaser, studs shall be marked on both ends.

13. Packaging and Package Marking

13.1 *Packaging:*

13.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

13.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

13.2 *Package Marking:*

13.2.1 Each shipping unit shall include or be plainly marked with the following information:

13.2.1.1 ASTM designation and type,

13.2.1.2 Size,

13.2.1.3 Name and brand or trademark of the manufacturer,

13.2.1.4 Number of pieces,

13.2.1.5 Purchase order number, and

13.2.1.6 Country of origin.

14. Keywords

14.1 alloy steel; bolts; carbon steel; metric; screws; steel; structural; weathering steel

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS

Property Class	Nominal Product Diameter, mm	Material and Treatment	Product Analysis Element (% by Weight)						Tempering Temperature, °C
			C		Mn	B	P	S	
			Min	Max	Min	Min	Max	Max	Min
4.6	M5–M100	low or medium carbon steel	. . .	0.55	. . .	. . .	0.048	0.058	. . .
4.8	M1.6–M16	low or medium carbon steel, partially or fully annealed as required	. . .	0.55	. . .	. . .	0.048	0.058	. . .
5.8	M5–M24	low or medium carbon steel, cold worked	0.13	0.55	. . .	. . .	0.048	0.058[A]	. . .
8.8	M20–M80	medium carbon steel, product is quenched and tempered[B]	0.25	0.55	. . .	. . .	0.048	0.058[C]	425
8.8	M20–M36	low carbon martensite steel, product is quenched and tempered[D]	0.15	0.40	0.74	0.0005	0.048	0.058	425
8.8.3	M20–M36	atmospheric corrosion resistant steel, product is quenched and tempered				see Table 2			425
9.8	M1.6–M16	medium carbon steel, product is quenched and tempered	0.25	0.55	. . .	. . .	0.048	0.058	425
9.8	M1.6–M16	low carbon martensite steel, product is quenched and tempered[D]	0.15	0.40	0.74	0.0005	0.048	0.058	425
10.9	M5–M20	medium carbon steel, product is quenched and tempered[E,F]	0.25	0.55	. . .	. . .	0.048	0.058	425
10.9	M5–M100	medium carbon alloy steel, product is quenched and tempered[E]	0.20	0.55	. . .	. . .	0.040	0.045	425
10.9	M5–M36	low carbon martensite steel, product is quenched and tempered[E,F]	0.15	0.40	0.74	0.0005	0.048	0.058	340
10.9.3	M16–M36	atmospheric corrosion resistant steel, product is quenched and tempered[E]				see Table 2			425
12.9	M1.6–M100	alloy steel, product is quenched and tempered[E,G]	0.31	0.65	. . .	. . .	0.045	0.045	380

[A] For studs only, sulfur content may be 0.33%, max.

[B] At the manufacturer's option, medium-carbon-alloy steel may be used for nominal thread diameters over M24.

[C] For studs only, sulfur content may be 0.13%, max.

[D] Products made using this material shall be specially identified as specified in Section 12.

[E] Steel for Classes 10.9, 10.9.3, and 12.9 products shall be fine grain and have a hardenability that will achieve a structure of approximately 90% martensite at the center of a transverse section one diameter from the threaded end of the product after oil quenching.

[F] Carbon steel may be used at the option of the manufacturer for products of nominal thread diameters M12 and smaller. When approved by the purchaser, carbon steel may be used for products of diameters larger than M12 through M20, inclusive.

[G] Alloy steel shall be used. Steel is considered to be alloy by the American Iron and Steel Institute when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65%; silicon, 0.60%; copper, 0.60%; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99%, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

TABLE 2
CHEMICAL COMPOSITION REQUIREMENTS FOR CLASSES 8.8.3 AND 10.9.3

Element	Composition, %[A]					
	A	B	C	D	E	F
Carbon:						
Heat analysis	0.33–0.40	0.38–0.48	0.15–0.25	0.15–0.25	0.20–0.25	0.20–0.25
Product analysis	0.31–0.42	0.36–0.50	0.14–0.26	0.14–0.26	0.18–0.27	0.19–0.26
Manganese:						
Heat analysis	0.90–1.20	0.70–0.90	0.80–1.35	0.40–1.20	0.60–1.00	0.90–1.20
Product analysis	0.86–1.24	0.67–0.93	0.76–1.39	0.36–1.24	0.56–1.04	0.86–1.24
Phosphorus:						
Heat analysis	0.040 max	0.06–0.12	0.035 max	0.040 max	0.040 max	0.040 max
Product analysis	0.045 max	0.06–0.125	0.040 max	0.045 max	0.045 max	0.045 max
Sulfur:						
Heat analysis	0.050 max	0.050 max	0.040 max	0.050 max	0.040 max	0.040 max
Product analysis	0.055 max	0.055 max	0.045 max	0.055 max	0.045 max	0.045 max
Silicon:						
Heat analysis	0.15–0.35	0.30–0.50	0.15–0.35	0.25–0.50	0.15–0.35	0.15–0.35
Product analysis	0.13–0.37	0.25–0.55	0.13–0.37	0.20–0.55	0.13–0.37	0.13–0.37
Copper:						
Heat analysis	0.25–0.45	0.20–0.40	0.20–0.50	0.30–0.50	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.17–0.43	0.17–0.53	0.27–0.53	0.27–0.63	0.17–0.43
Nickel:						
Heat analysis	0.25–0.45	0.50–0.80	0.25–0.50	0.50–0.80	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.47–0.83	0.22–0.53	0.47–0.83	0.27–0.63	0.17–0.43
Chromium:						
Heat analysis	0.45–0.65	0.50–0.75	0.30–0.50	0.50–1.00	0.60–0.90	0.45–0.65
Product analysis	0.42–0.68	0.47–0.83	0.27–0.53	0.45–1.05	0.55–0.95	0.42–0.68
Vanadium:						
Heat analysis	. . .	. . .	0.020 min	. . .	. . .	. . .
Product analysis	. . .	. . .	0.010 min	. . .	. . .	. . .
Molybdenum:						
Heat analysis	. . .	0.06 max	. . .	0.10 max	. . .	. . .
Product analysis	. . .	0.07 max	. . .	0.11 max	. . .	. . .
Titanium:						
Heat analysis	. . .	. . .	. . .	0.05 max	. . .	. . .
Product analysis	. . .	. . .	. . .	. . .	. . .	. . .

[A] A, B, C, D, E, and F are types of material used for Property Classes 8.8.3 and 10.9.3 bolts, screws, and studs. Selection of composition shall be at the option of the product manufacturer except that sizes M20 and larger shall conform to Composition A or B only.

TABLE 3
MECHANICAL REQUIREMENTS FOR BOLTS, SCREWS, AND STUDS

		Full Size Bolts, Screws, and Studs			Machined Test Specimens of Bolts, Screws, and Studs					Product Hardness			
		Proof Load[A]							Surface Hardness	Rockwell		Vickers	
Property Class	Nominal Diameter of Product	Length Measurement Method, MPa	Yield Strength Method, MPa	Tensile Strength, MPa[A]	Yield Strength, MPa[B]	Tensile Strength, MPa	Elonga-tion, %	Reduction of Area, %	Rockwell 30N				
				min	min	min	min	min	max	min	max	min	max
4.6	M5–M100	225	240	400	240[C]	400	22	35	. . .	B67	B95	120	220
4.8	M1.6–M16	310	340	420	340	420	14	35	. . .	B71	B95	130	220
5.8	M5–M24[D]	380	420	520	420	520	10	35	. . .	B82	B95	160	220
8.8	M20–M80	600	660	830	660	830	12	35	53	C23	C34	255	336
8.8.3	M20–M36	600	660	830	660	830	12	35	53	C23	C34	255	336
9.8	M1.6–M16	650	720	900	720	900	10	35	56	C27	C36	280	360
10.9	M5–M100	830	940	1040	940	1040	9	35	59	C33	C39	327	382
10.9.3	M16–M36	830	940	1040	940	1040	9	35	59	C33	C39	327	382
12.9[E]	M1.6–M100	970	1100	1220	1100	1220	8	35	63	C38	C44	372	434

[A] Proof load and tensile strength values for full size products of each property class are given in Table 5.
[B] Yield strength is stress at which a permanent set of 0.2% of gage length occurs.
[C] Yield point shall apply instead of yield strength at 0.2% offset for Class 4.6 products.
[D] Class 5.8 applies only to bolts and screws with lengths 150 mm and shorter and to studs of all lengths.
[E] Caution is advised when considering the use of Class 12.9 bolts, screws, and studs. Capability of the bolt manufacturer, as well as the anticipated in-use environment, should be considered. High-strength products of Class 12.9 require rigid control of heat-treating operations and careful monitoring of as-quenched hardness, surface discontinuities, depth of partial decarburization, and freedom from carburization. Some environments may cause stress corrosion cracking of nonplated as well as electroplated products.

TABLE 4
MECHANICAL TESTING REQUIREMENTS FOR BOLTS, SCREWS, AND STUDS[A]

Item	Product	Property Class	Specified Min Tensile Strength of Product (See Table 5) kN	Length of Product[B]	Product Hardness max	Product Hardness min	Surface Hardness[C] max	Tests Conducted Using Full-Size Products: Proof Load	Tests Conducted Using Full-Size Products: Wedge Tensile Strength[D]	Tests Conducted Using Full-Size Products: Axial Tensile Strength	Tests Conducted Using Machined Test Specimens: Yield Strength	Tests Conducted Using Machined Test Specimens: Tensile Strength	Tests Conducted Using Machined Test Specimens: Elongation	Tests Conducted Using Machined Test Specimens: Reduction of Area
1	short length bolts and screws	all	all	less than x	●	●	●	...	...	...	...	...	...	...
2	special head bolts and screws[E]	all	all	all	●	●	●	...	...	...	...	...	...	...
3	bolts and screws with hex or hex flange heads except items 1 and 2	all	450 and less	x to 8D or 200 mm, whichever is greater	●	...	●	○	●	...	...	...	...	...
				over 8D or 200 mm, whichever is greater through and incl 300 mm	●	...	●	○	●	...	...	...	...	...
				over 300 mm	●	...	●	○	A	...	B	B	B	B
			over 450	x and longer	●	...	●	○	A	...	B	B	B	B
4	all bolts and screws except items 1, 2, and 3	all	450 and less	x to 8D or 200 mm, whichever is greater	●	...	●	○	...	●	...	...	...	...
				over 8D or 200 mm, whichever is greater	●	...	●	○	...	A	B	B	B	B
			over 450	x and longer	●	...	●	○	...	A	B	B	B	B
5	short length studs	all	all	less than x	●	●	●	...	...	...	...	...	...	...
6	all studs except item 5	all	450 and less	x to 8D or 200 mm, whichever is greater	●	...	●	○	●	...	...	...	...	...
				over 8D or 200 mm, whichever is greater	●	...	●	○	A	...	B	B	B	B
			over 450	x and longer	●	...	●	○	A	...	B	B	B	B
Tests to be conducted in accordance with the following paragraph of Method F 606:					3.1			3.2.1	3.5	3.4	3.6			

[A] ● denotes a mandatory test. For each product all mandatory tests (●) shall be performed. In addition, either all tests denoted A (which apply to full-size products) or all tests denoted B (which apply to machined test specimens) shall be performed. ○ denotes tests to be performed when specifically required in the original inquiry and purchase order. In case arbitration is necessary, A tests and proof load test shall be performed. Leaders (. . .) indicate tests that are not required.

[B] D equals nominal diameter of product. x equals the minimum length of product subject to tensile testing. Values of x are as follows:

Nominal Product Diameter	x, mm
M5	12
M6	14
M8	20
M10	25
M12	30
M14	35
M16	40
M20	45
M24 and larger	30

[C] Surface hardness requirements apply only to Property Classes 8.8, 8.8.3, 9.8, 10.9, 10.9.3, and 12.9.

[D] Tensile test wedge angles are specified in Table 6.

[E] Special head bolts and screws are those with special configurations or with drilled heads which are weaker than the threaded section.

TABLE 5
PROOF LOAD AND TENSILE STRENGTH VALUES, kN[A]

Nominal Product Diameter and Thread Pitch	Stress Area,[B] mm^2	Class 4.6			Class 4.8			Class 5.8			Classes 8.8 and 8.8.3			Class 9.8			Classes 10.9 and 10.9.3			Class 12.9		
		Proof Load[C]			Proof Load			Proof Load			Proof Load			Proof Load			Proof Load			Proof Load		
		Method 1	Method 2	Tensile Strength, min	Method 1	Method 2	Tensile Strength, min	Method 1	Method 2	Tensile Strength, min	Method 1	Method 2	Tensile Strength, min	Method 1	Method 2	Tensile Strength, min	Method 1	Method 2	Tensile Strength, min	Method 1	Method 2	Tensile Strength, min
M1.6 × 0.35	1.27	...	...	...	0.39	0.43	0.53	...	...	...	...	...	...	0.83	0.91	1.14	...	...	...	1.23	1.40	1.55
M2 × 0.4	2.07	...	...	...	0.64	0.70	0.87	...	...	...	...	...	...	1.35	1.49	1.86	...	...	...	2.01	2.28	2.53
M2.5 × 0.45	3.39	...	...	...	1.05	1.15	1.42	...	...	...	...	...	...	2.20	2.44	3.05	...	...	...	3.29	3.73	4.14
M3 × 0.5	5.03	...	...	...	1.56	1.71	2.11	...	...	...	...	...	...	3.27	3.62	4.53	...	...	...	4.88	5.53	6.14
M3.5 × 0.6	6.78	...	...	...	2.10	2.31	2.85	...	...	...	...	...	...	4.41	4.88	6.10	...	...	...	6.58	7.13	8.27
M4 × 0.7	8.78	...	...	...	2.72	2.99	3.69	...	...	...	...	...	...	5.71	6.32	7.90	...	...	...	8.52	9.66	10.7
M5 × 0.8	14.2	3.20	3.41	5.68	4.40	4.83	5.96	5.40	5.96	7.38	...	...	...	9.23	10.2	12.8	11.8	13.3	14.8	13.8	15.6	17.3
M6 × 1	20.1	4.52	4.82	8.04	6.23	6.83	8.44	7.64	8.44	10.5	...	...	...	31.1	14.5	18.1	16.7	18.9	20.9	19.5	22.1	24.5
M8 × 1.25	36.6	8.24	8.78	14.6	11.3	12.4	15.4	13.9	15.4	19.0	...	...	...	23.8	26.4	32.9	30.4	34.4	38.1	35.5	40.3	44.7
M10 × 1.5	58.0	13.1	13.9	23.2	18.0	19.7	24.4	22.0	24.4	30.2	...	...	...	37.7	41.8	52.2	48.1	54.5	60.3	56.3	63.8	70.8
M12 × 1.75	84.3	19.0	20.2	33.7	26.1	28.7	35.4	32.0	35.4	43.8	...	...	...	54.8	60.7	75.9	70.0	79.2	87.7	81.8	92.7	103
M14 × 2	115	25.9	27.6	46.0	35.7	39.1	48.3	43.7	48.3	59.8	...	...	...	74.8	82.8	104	95.5	108	120	112	127	140
M16 × 2	157	35.3	37.7	62.8	48.7	53.4	65.9	59.7	65.9	81.6	[D]	[D]	[D]	102	113	141	130	148	163	152	173	192
M20 × 2.5	245	55.1	58.8	98.0	...	...	...	93.1	103	127	147	162	203	...	...	...	203	230	255	238	270	299
M22 × 2.5[E]	303	...	...	...	...	...	...	...	...	...	182	200	251	...	...	...	251	285	315	...	...	...
M24 × 3	353	79.4	84.7	141	...	...	...	134	148	184	212	233	293	...	...	...	293	332	367	342	388	431
M27 × 3[E]	459	...	...	...	...	...	...	...	...	...	275	303	381	...	...	...	381	431	477	...	...	...
M30 × 3.5	561	126	135	224	...	...	...	...	...	...	337	370	466	...	...	...	466	527	583	544	617	684
M36 × 4	817	184	196	327	...	...	...	...	...	...	490	539	678	...	...	...	678	763	850	792	899	997
M42 × 4.5	1120	252	269	448	...	...	...	...	...	...	672	739	930	...	...	...	930	1050	1160	1090	1230	1370
M48 × 5	1470	331	353	588	...	...	...	...	...	...	882	970	1220	...	...	...	1220	1380	1530	1430	1620	1790
M56 × 5.5	2030	457	487	812	...	...	...	...	...	...	1220	1340	1680	...	...	...	1680	1910	2110	1970	2230	2480
M64 × 6	2680	603	643	1070	...	...	...	...	...	...	1610	1790	2220	...	...	...	2220	2520	2790	2600	2850	3270
M72 × 6	3460	779	830	1380	...	...	...	...	...	...	2080	2280	2870	...	...	...	2870	3250	3600	3360	3810	4220
M80 × 6	4340	977	1040	1740	...	...	...	...	...	...	2600	2860	3600	...	...	...	3600	4080	4510	4210	4770	5290
M90 × 6	5590	1260	1340	2240	...	...	...	...	...	...	...	...	...	...	...	...	4640	5250	5810	5420	6150	6820
M100 × 6	6990	1570	1680	2800	...	...	...	...	...	...	...	...	...	...	...	...	5800	6570	7270	6780	7690	8530

[A] Proof loads and tensile strengths are computed by multiplying the stresses given in Table 3 by the stress area of the thread.

[B] Stress area, mm^2 = 0.7854 (D − 0.9382 P)^2, where D = nominal product size, mm, and P = thread pitch, mm.

[C] Proof load, Method 1, is the length measurement method as described in 3.2.3 of Test Methods F 606. Proof load, Method 2, is the yield strength method as described in 3.2.5 of Test Methods F 606.

[D] For Classes 8.8 and 8.8.3 sizes M16 and smaller are not covered by Specification F 568M. Class 9.8 may be suitable for applications requiring sizes M16 and smaller after consideration of design parameters, application and service environment.

[E] M22 and M27 are standard sizes for high-strength structural bolts only as covered in Specifications A 325M and A 490M.

TABLE 6
TENSION TEST WEDGE ANGLE

Product	Property Class	Nominal Product Diameter, (*D*)	Wedge Angle,*
Hex bolts and screws threaded 1*D* or closer to underside of head	4.6, 4.8, 5.8	through M24	10
		over M24	6
	8.8, 8.8.3, 9.8, 10.9, 10.9.3	through M20	6
		over M20	4
Hex bolts and screws with unthreaded length greater than 1*D*	4.6, 4.8, 5.8, 8.8, 8.8.3, 9.8, 10.9, 10.9.3	through M24	10
		over M24	6
Hex bolts and screws threaded 2*D* or closer to underside of head	12.9	all	4
Hex bolts and screws with unthreaded length greater than 2*D*	12.9	through M20	6
		over M20	4
Hex flange screws	5.8, 9.8, 10.9	all	6
Studs	all	through M20	6
		over M20	4

TABLE 7
PROPERTY CLASS IDENTIFICATION SYMBOLS

Property Class	Identification Symbol			Studs		
	Specification A 325M Bolts	Specification A 490M Bolts	Other Bolts and Screws	M4 and Smaller	M5 to M10 incl.	M12 and Larger
4.6	[A]	[A]	4.6	[A]	[A]	4.6
4.8	[A]	[A]	4.8	[A]	[A]	4.8
5.8	[A]	[A]	5.8	[A]	[A]	5.8
8.8[B]	8S	[A]	8.8	[A]	[A]	8.8
8.8.3	8S3	[A]	8.8.3	[A]	[A]	8.8.3
9.8[B]	[A]	[A]	9.8	[A]	+	9.8
10.9[B]	[A]	10S	10.9	[A]	□	10.9
10.9.3	[A]	10S3	10.9.3	[A]	[A]	10.9.3
12.9	[A]	[A]	12.9	[A]	△	12.9

[A] Not applicable.
[B] Products made of low-carbon martensite steel shall be additionally marked by underlining the property class symbol.

APPENDIXES

(Nonmandatory Information)

X1 CONVERSION GUIDANCE

X1.1 For guidance purposes only, to assist designers and purchasers in the selection of a property class, the following conversion guidance is provided:

X1.1.1 Class 4.6 mechanical properties are approximately equivalent to those of Specification A 307, Grade A.

X1.1.2 Class 8.8 mechanical properties are approximately equivalent to those of Specification A 449, and Specification A 325, Types 1 and 2.

X1.1.3 Class 8.8.3 mechanical properties are approximately equivalent to those of Specification A 325, Type 3.

X1.1.4 Class 9.8 mechanical properties are approximately 9% higher than those of Specification A 449.

X1.1.5 Class 10.9 mechanical properties are approximately equivalent to those of Specification A 354, Grade BD and Specification A 490, Types 1 and 2.

X1.1.6 Class 10.9.3 mechanical properties are approximately equivalent to those of Specification A 490, Type 3.

X1.1.7 Class 12.9 mechanical properties are approximately equal to those of Specification A 574.

X1.2 Class 9.8 is applicable to fasteners of nominal thread diameters M16 and smaller; Class 8.8 is applicable to fasteners larger than M16, except for Specification A 325M bolts where M16 and larger bolt diameters are Class 8.8.

X2. SIGNIFICANCE OF PROPERTY CLASS DESIGNATION

X2.1 Property classes are designated by numbers where increasing numbers generally represent increasing tensile strengths. The designation symbol has the following significance:

X2.1.1 The one or two numerals preceding the first decimal point approximates 1/1000 of the minimum tensile strength in MPa.

X2.1.2 The numeral following the first decimal point approximates 1/10 of the ratio, expressed as a percentage, between minimum yield stress and minimum tensile strength.

X2.1.3 The numeral 3, following the second decimal point, is an indicator that the material has atmospheric corrosion resistance and weathering characteristics comparable to steels covered in Specification A 588/A 588M.

SPECIFICATION FOR FINE GRAINED, WELDABLE STEEL PLATES FOR PRESSURE EQUIPMENT

SA/AS 1548

(Identical with International Specification AS 1548-2008(R2018) with these additional requirements.)

SPECIFICATION FOR FINE GRAINED, WELDABLE STEEL PLATES FOR PRESSURE EQUIPMENT

SA/AS 1548

(Identical with International Specification AS 1548-2008(R2018) with these additional requirements.)

1. Additional Requirements

1.1 *Steelmaking Process:*
The ratio of reduction of thickness from a strandcast slab to plate shall be at least 3.0:1.

1.2 *Marking:*
In addition to the marking requirements of this specification, the prefix, SA/, shall be added ahead of the marking on all products required to be marked by this specification, and to the material identification used on all documentation required by the specification.

1.3 *Chemical Composition:*
The requirements of paras. 7.1.2 and 7.1.3 on heat analysis, and of paras. 7.2.3 and 7.2.4 on product analysis, of SA-20/SA-20M shall apply.

1.4 *Test Reports:*

1.4.1 The designation of this SA/AS specification shall include the edition year.

1.4.2 Copies of the original manufacturer's test report shall be included with any subsequent test report.

2. Appendix

2.1 The appendix "Interchangeability of Strength Grades" does not apply for SA/AS 1548.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of AS 1548 and its references.

SPECIFICATION FOR STRUCTURAL QUALITY STEELS

SA/CSA-G40.21

(23)

(Identical with International Specification CSA-G40.21-2013(R2018) including Update No. 1 (May 2014), with these additional requirements.)

SPECIFICATION FOR STRUCTURAL QUALITY STEELS

SA/CSA-G40.21

(Identical with International Specification CSA-G40.21-13(R2018) with these additional requirements.)

1. Additional Requirements

1.1 *Marking:*

1.1.1 In addition to the marking requirements of this specification, all products are to be identified by this SA/CSA specification designation.

1.1.2 Plates that are required to be heat treated, but have not been so heat treated, shall be marked by the manufacturer or processor with the letter "G" (denoting green) following the required specification mark.

1.1.3 When such plates are subsequently heat treated, they shall be marked by the party that performed the heat treatment, with the letters "MT" (denoting material treated) following the required specification mark.

1.1.4 The heat number and manufacturer's name or brand shall be marked on each plate irrespective of its thickness.

1.1.5 For secured lifts of all sizes of plates $^3/_8$ in. (10 mm) or under in thickness, the manufacturer or processor shall have the option of placing such markings on only the top piece of each lift, or showing such markings on a substantial tag attached to each lift, unless otherwise specified.

1.1.6 The sole use of color code marking to indicate material standard designation and grade, as described in para. 9 of this standard, is not permitted.

1.2 *Controlled Rolling or Normalizing Rolling:*
Controlled rolling or normalizing rolling shall not be used as normalizing procedure.

1.3 *Chemical Composition:*
The requirements of paras. 7.1.2 and 7.1.3 on heat analysis, and of paras. 7.2.3 and 7.2.4 on product analysis, of SA-20/SA-20M shall apply.

1.4 *Test Reports:*
Test reporting shall be in accordance with SA-6/SA-6M.

2. Source

2.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of CSA-G40.21 and its references.

SPECIFICATION FOR HOT ROLLED PRODUCTS OF STRUCTURAL STEELS

Part 2: Technical Delivery Conditions for Non-Alloy Structural Steels

SA/EN 10025-2

(**23**)

(Identical with International Specification EN 10025-2:2019 with these additional requirements.)

SPECIFICATION FOR HOT ROLLED PRODUCTS OF STRUCTURAL STEELS
Part 2: Technical Delivery Conditions for Non-Alloy Structural Steels

SA/EN 10025-2

(Identical with International Specification EN 10025-2:2019 with these additional requirements.)

1. Additional Requirements

1.1 *Marking:*

(a) In addition to the marking requirements of this specification, all products required to be marked and material identification used on all documentation required by this specification are to be identified by this SA/EN specification designation.

(b) Products that have been given the full heat treatment required by para. 6.3 shall be marked by the party performing the heat treatment with the letters designating the applicable heat treatment condition following the stamped steel name or number.

(c) Products that have received a normalizing treatment shall be marked "+N." Products that have received a normalizing rolling treatment shall be marked "+NR" instead of "+N."

(d) Products that are not heat treated but are qualified on the basis of heat treated specimens shall be stamped with letter "G" following the stamped specification designation.

(e) When such products are subsequently heat treated, they shall be marked by the party that performed the heat treatment, as required by *(b)* following the required stamped specification designation.

1.2 *Chemical Composition:*

These materials shall conform to SA-20/SA-20M Table 1, whenever SA-20/SA-20M Table 1 is more restrictive.

1.3 *Resurfacing by Welding:*

If resurfacing by welding is acceptable by agreement with the purchaser the following requirements have to be fulfilled:

(a) Preparation for repair welding shall include inspection to assure complete removal of the defect.

(b) Repairs shall be made utilizing welding procedures qualified in accordance with ASME Section IX and repair welding shall be done by welders or welding operators meeting the qualification requirements of ASME Section IX.

1.4 *Test Reports:*

1.4.1 For all products, a test report shall be furnished; it shall include all elements required in this SA/EN specification.

1.4.2 The designation of this SA/EN specification shall include the edition year.

1.4.3 Copies of the original manufacturer's test report shall be included with any subsequent test report.

2. National Parts

2.1 The National Foreword and the National Annexes, if any, do not apply for SA/EN 10025-2.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of EN 10025-2 and its references.

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SPECIFICATION FOR FLAT PRODUCTS MADE OF STEELS FOR PRESSURE PURPOSES

Part 2: Non-Alloy and Alloy Steels With Specified Elevated Temperature Properties

SA/EN 10028-2

(**23**)

(Identical with International Specification EN 10028-2:2017 with these additional requirements.)

SPECIFICATION FOR FLAT PRODUCTS MADE OF STEELS FOR PRESSURE PURPOSES
Part 2: Non-Alloy and Alloy Steels With Specified Elevated Temperature Properties

SA/EN 10028-2

(Identical with International Specification EN 10028-2:2017 with these additional requirements.)

1. Additional Requirements

1.1 *General Requirements:*
All "see EN 10028-1" shall be read as "shall be according to EN 10028-1."

1.2 *Marking:*
(a) In addition to the marking requirements of this specification, all products required to be marked and material identification used on all documentation required by this specification are to be identified by this SA/EN specification designation.

(b) Plates that have been given the full heat treatment required by para. 8.2.1 or 8.2.2 shall be marked by the party performing the heat treatment with the letters designating the applicable heat treatment condition in Table 3 of EN 10028-2 following the stamped steel name or number.

(c) Plates for which normalizing has been replaced by normalizing rolling as permitted by para. 8.2.2 shall be marked "+NR" instead of "+N."

(d) Plates that are not heat treated but are qualified on the basis of heat treated specimens per para. 8.2.3 shall be stamped with letter "G" following the stamped specification designation.

(e) When such plates are subsequently heat treated, they shall be marked, by the party that performed the heat treatment, as required by (b) above following the required stamped specification designation.

1.3 *Delivery Condition:*
Normalizing shall not be replaced by normalizing rolling for plates of steel Grade 16Mo3.

1.4 *Chemical Composition:*
The requirements of paras. 7.1.2 and 7.1.3 on heat analysis, and of paras. 7.2.3 and 7.2.4 on product analysis, of SA-20/SA-20M shall apply.

1.5 *Tension Tests:*
For quenched and tempered plates one tension test shall be taken from each end of the heat treated plate. The gage length of the tension test specimens shall be taken at least 1*T* from any heat treated edge, where *T* is the thickness of the plate, and shall be at least $\frac{1}{2}$ in. (12.5 mm) from flame cut or heat-affected-zone surfaces.

1.6 *Impact Test Sampling:*
Deviation from the requirement for preparation of test pieces for impact testing in EN 10028-1 shall not be permitted in SA/EN 10028-2.

1.7 *Steelmaking Process:*
The ratio of reduction of thickness from a strand-cast slab to plate shall be at least 3.0:1.

1.8 *Quality:*
All surface imperfections, the removal of which will reduce the plate thickness below its permissible minimum, shall be cause for rejection of the plate; however by agreement with the purchaser, the metal so removed may be replaced with weld metal.

Preparation for repair welding shall include inspection to assure complete removal of the defect.

Repairs shall be made utilizing welding procedures qualified in accordance with ASME Section IX and repair welding shall be done by welders or welding operators meeting the qualification requirements of ASME Section IX.

1.9 *Test Reports:*

1.9.1 The designation of this SA/EN specification shall include the edition year.

1.9.2 Copies of the original manufacturer's test report shall be included with any subsequent test report.

2. National Parts

2.1 The National Foreword and the National Annexes, if any, do not apply for SA/EN 10028-2.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of EN 10028-2 and its references.

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SPECIFICATION FOR FLAT PRODUCTS MADE OF STEELS FOR PRESSURE PURPOSES

Part 3: Weldable Fine Grain Steels, Normalized

SA/EN 10028-3

(23)

(Identical with International Specification EN 10028-3:2017 with these additional requirements.)

SPECIFICATION FOR FLAT PRODUCTS MADE OF STEELS FOR PRESSURE PURPOSES
Part 3: Weldable Fine Grain Steels, Normalized

SA/EN 10028-3

(Identical with International Specification EN 10028-3:2017 with these additional requirements.)

1. Additional Requirements

1.1 *General Requirements:*
All "see EN 10028-1" shall be read as "shall be according to EN 10028-1."

1.2 *Marking:*
(a) In addition to the marking requirements of this specification, all products required to be marked and material identification used on all documentation required by this specification are to be identified by this SA/EN specification designation.

(b) Plates that have been given the full heat treatment required by para. 8.2.1 or 8.2.2 shall be marked by the party performing the heat treatment with the letters designating the applicable heat treatment condition in Table 4 of EN 10028-3 following the stamped steel name or number.

(c) Plates for which normalizing has been replaced by normalizing rolling as permitted by para. 8.2.2 shall be marked "+NR" instead of "+N."

(d) Plates that are not heat treated but are qualified on the basis of heat treated specimens per para. 8.2.3 shall be stamped with letter "G" following the stamped specification designation.

(e) When such plates are subsequently heat treated, they shall be marked, by the party that performed the heat treatment, as required by (b) above following the required stamped specification designation.

1.3 *Chemical Composition:*
The requirements of paras. 7.1.2 and 7.1.3 on heat analysis, and of paras. 7.2.3 and 7.2.4 on product analysis, of SA-20/SA-20M shall apply. In addition, the copper content shall be per SA-20/SA-20M Table 1.

1.4 *Impact Test Sampling:*
Deviation from the requirement for preparation of test pieces for impact testing in EN 10028-1 shall not be permitted in SA/EN 10028-3.

1.5 *Steelmaking Process:*
The ratio of reduction of thickness from a strand-cast slab to plate shall be at least 3.0:1.

1.6 *Quality:*
All surface imperfections, the removal of which will reduce the plate thickness below its permissible minimum, shall be cause for rejection of the plate; however by agreement with the purchaser, the metal so removed may be replaced with weld metal.

Preparation for repair welding shall include inspection to assure complete removal of the defect.

Repairs shall be made utilizing welding procedures qualified in accordance with ASME Section IX and repair welding shall be done by welders or welding operators meeting the qualification requirements of ASME Section IX.

1.7 *Test Reports:*

1.7.1 The designation of this SA/EN specification shall include the edition year.

1.7.2 Copies of the original manufacturer's test report shall be included with any subsequent test report.

2. National Parts

2.1 The National Foreword and the National Annexes, if any, do not apply for SA/EN 10028-3.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of EN 10028-3 and its references.

SPECIFICATION FOR FLAT PRODUCTS MADE OF STEELS FOR PRESSURE PURPOSES

Part 4: Nickel Alloy Steels With Specified Low Temperature Properties

SA/EN 10028-4

(23)

(Identical with International Specification EN 10028-4:2017 with these additional requirements.)

SPECIFICATION FOR FLAT PRODUCTS MADE OF STEELS FOR PRESSURE PURPOSES Part 4: Nickel Alloy Steels With Specified Low Temperature Properties

SA/EN 10028-4

(Identical with International Specification EN 10028-4:2017 with these additional requirements.)

1. Additional Requirements

1.1 *General Requirements:*

All "see EN 10028-1" shall be read as "shall be according to EN 10028-1."

1.2 *Marking:*

(a) In addition to the marking requirements of this specification, all products required to be marked and material identification used on all documentation required by this specification are to be identified by this SA/EN specification designation.

(b) Plates that have been given the full heat treatment required by para. 8.2.2 shall be marked by the party performing the heat treatment with the letters designating the applicable heat treatment condition in Table A.1 of EN 10028-4 following the stamped steel name or number.

(c) Plates that are not heat treated but are qualified on the basis of heat treated specimens per para. 8.2.3 shall be stamped with letter "G" following the stamped specification designation.

(d) When such plates are subsequently heat treated, they shall be marked by the party that performed the heat treatment, as required by (b) above following the required stamped specification designation.

1.3 *Chemical Composition:*

The requirements of paras. 7.1.2 and 7.1.3 on heat analysis, and of paras. 7.2.3 and 7.2.4 on product analysis, of SA-20/SA-20M shall apply.

1.4 *Tension Tests:*

For quenched and tempered plates one tension test shall be taken from each end of the heat treated plate. The gage length of the tension test specimens shall be taken at least 1*T* from any heat treated edge, where *T* is the thickness of the plate, and shall be at least $\frac{1}{2}$ in. (12.5 mm) from flame cut or heat-affected-zone surfaces.

1.5 *Impact Tests:*

1.5.1 *Impact Test Sampling:*

Deviation from the requirement for preparation of test pieces for impact testing in EN 10028-1 shall not be permitted in SA/EN 10028-4.

1.5.2 The impact test specimens shall be taken from a location adjacent to the tension test specimens and shall be at least 1*T* from any heat treated edge.

1.6 *Steelmaking Process:*

The ratio of reduction of thickness from a strand-cast slab to plate shall be at least 3.0:1.

1.7 *Quality:*

1.7.1 *Surface Imperfections*

(a) Shallow imperfections shall be ground to sound metal; the ground area shall be well faired and the thickness of the ground plate shall not be reduced below the minimum thickness permitted.

(b) All surface imperfections, the removal of which reduce the plate thickness below the minimum thickness permitted, shall be cause for rejection of the plate, except that, by agreement with the purchaser, the metal so removed may be replaced with weld metal.

1.7.2 *Repair Welding*

(a) Repair by welding shall be permitted only with the approval of the purchaser

(b) Preparation for repair welding shall include inspection to confirm complete removal of the defect.

(c) Repairs shall be made utilizing welding procedures qualified in accordance with Section IX of the ASME Code and repair welding shall be done by welders or welding operators meeting the requirements of ASME Section IX.

(d) If Charpy impact tests of the plate are required, the welding procedure qualification tests shall also include Charpy impact tests of the weld, heat affected zone, and the plate, and the test results shall be reported to the purchaser.

(e) If the plate is subjected to normalizing, quenching and tempering, hot forming, or post-weld heat treating, the welding procedure qualification test plates and the weld repaired plate shall be subjected to the thermal heat treatment as specified by the purchaser.

(f) In addition, repair welds shall meet the requirements of the construction code specified by the purchaser.

(g) The location and size of the repaired area(s), the welding procedure and welding consumables shall be documented and reported to the purchaser.

1.8 *Test Reports:*

1.8.1 The designation of this SA/EN specification shall include the edition year.

1.8.2 Copies of the original manufacturer's test report shall be included with any subsequent test report.

2. National Parts

2.1 The National Foreword and the National Annexes, if any, do not apply for SA/EN 10028-4.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of EN 10028-4 and its references.

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SPECIFICATION FOR FLAT PRODUCTS MADE OF STEELS FOR PRESSURE PURPOSES

Part 7: Stainless Steels

SA/EN 10028-7

(Identical with International Specification EN 10028-7:2016 with these additional requirements.)

SPECIFICATION FOR FLAT PRODUCTS MADE OF STEELS FOR PRESSURE PURPOSES
Part 7: Stainless Steels

SA/EN 10028-7

(Identical with International Specification EN 10028-7:2016 with these additional requirements.)

1. Additional Requirements

1.1 *Marking:*
In addition to the marking requirements of this specification, all products required to be marked and material identification used on all documentation required by this specification are to be identified by this SA/EN specification designation.

1.2 *Heat Treatment:*
Heat treatment shall be per the Tables of Annex A.

1.3 *Test Reports:*

1.3.1 The designation of this SA/EN specification shall include the edition year.

1.3.2 Copies of the original manufacturer's test report shall be included with any subsequent test report.

2. National Parts

2.1 The National Foreword and the National Annexes, if any, do not apply for SA/EN 10028-7.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of EN 10028-7 and its references.

SPECIFICATION FOR STAINLESS STEELS

Part 2: Technical Delivery Conditions for Sheet/Plate and Strip of Corrosion Resisting Steels for General Purposes

SA/EN 10088-2

(Identical with International Specification EN 10088-2:2014 with these additional requirements.)

SPECIFICATION FOR STAINLESS STEELS Part 2: Technical Delivery Conditions for Sheet/Plate and Strip of Corrosion Resisting Steels for General Purposes

SA/EN 10088-2

(Identical with International Specification EN 10088-2:2014 with these additional requirements.)

1. Additional Requirements

1.1 *Marking:*
In addition to the marking requirements of this specification, all products required to be marked and material identification used on all documentation required by this specification are to be identified by this SA/EN specification designation.

1.2 *Dimensions:*
Cold rolled strip, hot rolled strip and hot rolled plate thickness, shall not be greater than the applicable thickness shown in the tables of mechanical properties at room temperature.

1.3 *Delivery Condition:*
Plates of martensitic Grades X12Cr13, X15Cr13, X20Cr13, and X30Cr13, shall not be delivered in the annealed condition.

1.4 *Resurfacing by Welding:*
If repairs are authorized by the purchaser, the following requirements have to be fulfilled:

(a) Preparation for repair welding shall include inspection to assure complete removal of the defect.

(b) Repairs shall be made utilizing welding procedures qualified in accordance with ASME Section IX and repair welding shall be done by welders or welding operators meeting the qualification requirements of ASME Section IX.

1.5 *Extent of Testing:*
The tensile tests at room temperature for strips and sheets cut from strips (C, H) in rolling width less than 600 mm, shall be performed on one test sample from each coil.

1.6 *Test Reports:*

1.6.1 Results of the mandatory tests marked by “m” in Table 21, second column, shall be reported.

1.6.2 The designation of this SA/EN specification shall include the edition year.

1.6.3 Copies of the original manufacturer’s test report shall be included with any subsequent test report.

2. National Parts

2.1 The National Foreword and the National Annexes, if any, do not apply for SA/EN 10088-2.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of EN 10088-2 and its references.

SPECIFICATION FOR STAINLESS STEEL

Part 3: Technical Delivery Conditions for Semi-Finished Products, Bars, Rods, Wire, Sections, and Bright Products of Corrosion Resisting Steels for General Purposes

SA/EN 10088-3

(Identical with International Specification EN 10088-3:2014 with these additional requirements.)

SPECIFICATION FOR STAINLESS STEEL Part 3: Technical Delivery Conditions for Semi-Finished Products, Bars, Rods, Wire, Sections, and Bright Products of Corrosion Resisting Steels for General Purposes

SA/EN 10088-3

(Identical with International Specification EN 10088-3:2014 with these additional requirements.)

1. Additional Requirements

1.1 *Marking:*
In addition to the marking requirements of this specification, all products required to be marked and material identification used on all documentation required by this specification are to be identified by this SA/EN specification designation.

Products shall be marked by the party performing the heat treatment with the letters designating the applicable heat treatment condition in Tables of Annex A of EN 10088-3 following the marked steel name or number.

Products that are not heat treated but are qualified on the basis of heat treated specimens per para. 6.5.1 shall be marked with letter "G" following the marked specification designation.

1.2 *Dimensions:*

1.2.1 Product thickness or diameter as applicable, shall not be greater than the dimension shown in the tables of mechanical properties at room temperature.

1.2.2 Diameter of bright bars delivered in conditions 2H, 2B, 2G, or 2P, shall be equal to or greater than 5 mm.

1.2.3 Thickness or diameter of bright bars of Grade X2CrNiMoCuN25-6-3 delivered in conditions 2H, 2B, 2G, or 2P, shall be greater than 16 mm.

1.3 *Tests and Inspection:*

1.3.1 *Reports:*

1.3.1.1 A Material Test Report shall be provided and, if required by the referencing Code Section or Purchase Order, a Certificate of Conformance shall be supplied in addition to any test reports or inspection certificates described in para. 7.2. Certified Material Test Reports shall be provided when applicable.

1.3.1.2 Results of the mandatory tests marked by "m" in Table 21, second column, shall be reported.

1.3.1.3 The designation of this SA/EN specification shall include the edition year.

1.3.1.4 Copies of the original manufacturer's test report shall be included with any subsequent test report.

1.3.2 For tension tests, impact tests, hardness tests, and intergranular corrosion tests of round and rectangular cross-section products greater than 1 in. (25 mm), specimens shall be taken at a location corresponding to the $\frac{1}{4}$ T-plane or deeper.

1.4 *Repair by Welding:*
Repair by welding is acceptable only by agreement with the purchaser, and the following additional requirements shall apply:

(a) Preparation for repair welding shall include inspection to assure complete removal of the defect.

(b) Repairs shall be made utilizing welding procedures qualified in accordance with ASME Section IX, and repair welding shall be done by welders or welding operators meeting the qualification requirements of ASME Section IX.

1.5 *Heat Treatment:*
Austenitic stainless steel material shall be supplied in the solution annealed condition.

1.6 *Surface Quality:*
In Table 1 — Maximum depth of acceptable discontinuities for bars, rods and sections, the permissible depth of discontinuities and the maximum % of delivered weight in excess of permissible depth of discontinuities for

rounds and rod in conditions 1U, 1C, 1E, and 1D shall be EN 10221 class A za2 unless specified otherwise at the time of inquiry and order.

2. National Parts

2.1 The National Foreword and the National Annexes, if any, do not apply for SA/EN 10088-3.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of EN 10088-3 and its references.

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SPECIFICATION FOR SEAMLESS STEEL TUBES FOR PRESSURE PURPOSES

Part 2: Technical Delivery Conditions for Non-Alloy and Alloy Steel Tubes With Specified Elevated Temperature Properties

SA/EN 10216-2

(Identical with International Specification EN 10216-2:2013 with these additional requirements.)

SPECIFICATION FOR SEAMLESS STEEL TUBES FOR PRESSURE PURPOSES
Part 2: Technical Delivery Conditions for Non-Alloy and Alloy Steel Tubes With Specified Elevated Temperature Properties

SA/EN 10216-2

(Identical with International Specification EN 10216-2:2013 with these additional requirements.)

1. Additional Requirements

1.1 *Marking:*
In addition to the marking requirements of this specification, all products required to be marked and material identification used on all documentation required by this specification are to be identified by this SA/EN specification designation.

1.2 *Test Reports:*
The designation of this SA/EN specification shall include the edition year.

2. National Parts

2.1 The National Foreword and the National Annexes, if any, do not apply for SA/EN 10216-2.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of EN 10216-2 and its references.

SPECIFICATION FOR WELDED STEEL TUBES FOR PRESSURE PURPOSES

Part 1: Technical Delivery Conditions for Electric Welded and Submerged Arc Welded Non-Alloy Steel Tubes With Specified Room Temperature Properties

SA/EN 10217-1

(Identical with International Specification EN 10217-1:2019 with these additional requirements.)

SPECIFICATION FOR WELDED STEEL TUBES FOR PRESSURE PURPOSES
Part 1: Technical Delivery Conditions for Electric Welded and Submerged Arc Welded Non-Alloy Steel Tubes With Specified Room Temperature Properties

SA/EN 10217-1

(Identical with International Specification EN 10217-1:2019 with these additional requirements.)

1. Additional Requirements

1.1 *Material:*
Tubes shall be made using the HFW process only. The tubes shall not be delivered in the "As welded" condition.

1.2 *Inspection:*
Tubes of Quality TR2 shall be submitted to specific inspection.

1.3 *Marking:*
In addition to the marking requirements of this specification, all products required to be marked and material identification used on all documentation required by this specification are to be identified by this SA/EN specification designation.

1.4 *Resurfacing by Welding:*
Repair welding is not permitted without specific approval by the purchaser. If repairs are authorized by the purchaser, the following requirements have to be fulfilled:

(a) Preparation for repair welding shall include inspection to assure complete removal of the defect.

(b) Repairs shall be made utilizing welding procedures qualified in accordance with ASME Section IX and repair welding shall be done by welders or welding operators meeting the qualification requirements of ASME Section IX.

1.5 *Test Reports:*
The designation of this SA/EN specification shall include the edition year.

2. National Parts

2.1 The National Foreword and the National Annexes, if any, do not apply for SA/EN 10217-1.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of EN 10217-1 and its references.

SPECIFICATION FOR STEEL FORGINGS FOR PRESSURE PURPOSES

Part 2: Ferritic and Martensitic Steels With Specified Elevated Temperature Properties

SA/EN 10222-2

(23)

(Identical with International Specification EN 10222-2:2017 with these additional requirements.)

SPECIFICATION FOR STEEL FORGINGS FOR PRESSURE PURPOSES
Part 2: Ferritic and Martensitic Steels With Specified Elevated Temperature Properties

SA/EN 10222-2

(Identical with International Specification EN 10222-2:2017 with these additional requirements.)

1. Additional Requirements

1.1 *General Requirements:*
All "see EN 10222-1" shall be read as "shall be according to EN 10222-1."

1.2 *Marking:*
In addition to the marking requirements of this specification, the marking on products, and the material identification used on all documentation shall include:
(a) this SA/EN specification designation
(b) the steel grade or number
(c) heat treatment condition as described below
Forgings shall be marked by the party performing the heat treatment with the letters designating the applicable heat treatment condition in Table 1 of EN 10222-2 following the stamped steel name or number.

1.3 *Resurfacing by Welding:*
If resurfacing by welding is acceptable by agreement with the purchaser and in accordance with para. 6.7.2.3 of EN 10222-1 the following requirements have to be fulfilled:
(a) Preparation for repair welding shall include inspection to assure complete removal of the defect.
(b) Repairs shall be made utilizing welding procedures qualified in accordance with ASME Section IX and repair welding shall be done by welders or welding operators meeting the qualification requirements of ASME Section IX.

1.4 *Test Reports:*

1.4.1 In addition to information listed in EN 10222-1, para. 15, test reports shall include:
(a) the purchaser's order number
(b) the heat number

1.4.2 The designation of this SA/EN specification shall include the edition year.

2. National Parts

2.1 The National Foreword and the National Annexes, if any, do not apply for SA/EN 10222-2.

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of EN 10222-2 and its references.

SPECIFICATION FOR STEEL PLATES FOR BOILERS AND PRESSURE VESSELS

SA/GB 713

(Identical with International Specification GB 713-2014 with these additional requirements.)

SPECIFICATION FOR STEEL PLATES FOR BOILERS AND PRESSURE VESSELS

SA/GB 713

(Identical with International Specification GB 713-2014 with these additional requirements.)

1. Additional Requirements

1.1 *Chemical Composition:*
In addition to the chemical composition requirements of this specification, the limits on elements listed in SA-20/SA-20M, Table 1 shall be observed..

1.2 *Marking:*
In addition to the marking requirements of this specification, all products are to be identified by this SA/GB specification designation.

1.3 *Controlled Rolling:*
Controlled rolling shall be as defined in Figure X1.1 of SA-841/SA-841M.

1.4 *Heat Treatment:*
For material Grades Q245R and Q345R, plates over 1.50 in. (40 mm) in thickness shall be normalized.

1.5 *Test Reports:*

1.5.1 The designation of this SA/GB specification shall include the edition year.

1.5.2 The delivery state shall be indicated on the test report.

1.5.3 Copies of the original manufacturer's test report shall be included with any subsequent test report.

2. Source

2.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of GB 713 and its references.

SPECIFICATION FOR HOT ROLLED MEDIUM AND HIGH TENSILE STRUCTURAL STEEL

SA/IS 2062

(23)

(Identical with International Specification IS 2062-2011 (Seventh Revision) as translated and published in the English language by the Bureau of Indian Standards, with these additional requirements.)

SPECIFICATION FOR HOT ROLLED MEDIUM AND HIGH TENSILE STRUCTURAL STEEL

SA/IS 2062

(Identical with International Specification IS 2062-2011 (Seventh Revision), as translated and published in the English language by the Bureau of Indian Standards, with these additional requirements.)

1. Additional Requirements

1.1 *Marking:*

1.1.1 In addition to the marking requirements of this specification, all products are to be identified by this SA/IS specification designation.

The designation of the steel, grade designation, and quality shall be marked and followed by letters designating the applied heat treatment (+AR, +N, or +NR).

1.1.2 The required markings for plates shall be by steel die stamping, paint marking, or by means of permanently affixed labels or tags.

1.2 *Chemical Composition:*

In addition to the chemical requirements of Table 1 and Table 3 of this specification, the limits on elements listed in SA-20/SA-20M shall be observed.

1.3 *Mechanical Properties:*

Note 1 of Table 2 shall not apply to SA/IS 2062.

1.4 *Delivery Conditions:*

The products shall be supplied only in the as-rolled, normalized or normalized-rolled condition. Steel shall be killed by use of not less than 0.02% total aluminum content. Semi-killed steel shall not be used.

1.5 *Repair by Welding:*

Repairs shall be made by utilizing welding procedures qualified in accordance with ASME Section IX, and repair welding shall be done by welders or welding operators meeting the qualification requirements of ASME Section IX.

1.6 *Test Reports:*

1.6.1 For all products, a test report shall be furnished. As a minimum, it shall include the following:

(a) this SA/IS specification designation including the edition year

(b) grade designation and quality to which the product is furnished

(c) delivery condition

(d) heat number, heat analysis, and nominal sizes

(e) the results of all tests required by this SA/IS specification

1.6.2 Copies of the original manufacturer's test report shall be included with any subsequent test report.

2. Source

2.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of IS 2062 and its references.

SPECIFICATION FOR CARBON STEEL PLATES FOR PRESSURE VESSELS FOR INTERMEDIATE AND MODERATE TEMPERATURE SERVICE

SA/JIS G3118

(23)

(Identical with International Specification JIS G3118:2017 as translated and published in the English language by the Japanese Standards Association, with these additional requirements.)

SPECIFICATION FOR CARBON STEEL PLATES FOR PRESSURE VESSELS FOR INTERMEDIATE AND MODERATE TEMPERATURE SERVICE

SA/JIS G3118

(Identical with International Specification JIS G3118:2017, as translated and published in the English language by the Japanese Standards Association, with these additional requirements.)

1. Additional Requirements

1.1 *Marking:*

1.1.1 In addition to the marking requirements of this specification in para. 4.5, all products are to be identified by this SA/JIS specification designation.

1.1.2 Plates that are required to be heat treated per para. 4.2(b), but have not been so heat treated as allowed in para. 4.2(d), shall be marked with the letter "G" following the stamped specification designation.

1.1.3 When such plates are subsequently heat treated, they shall be marked per para. 4.5, by the party that performed the heat treatment, following the required stamped specification designation.

1.1.4 The required markings shall be by paint marking or by steel die stamping.

1.1.5 The required markings shall be in at least one place on each finished plate.

1.2 *Trace Elements:*
The requirements of SA-20/SA-20M shall apply.

1.3 *Plates Produced by TMCP:*
Steel plates subjected to thermo-mechanical controlled processing shall be excluded.

1.4 *Steelmaking Process:*
The ratio of reduction of thickness from a strand-cast slab to plate shall be at least 3.0:1.

1.5 *Test Reports:*

1.5.1 The designation of this SA/JIS specification shall include the edition year.

1.5.2 The heat number, plate identifier of the plate tested, and nominal plate thickness shall be shown on the test report.

1.5.3 Copies of the original manufacturer's test report shall be included with any subsequent test report.

1.6 *Mechanical Properties:*

1.6.1 Tension testing is mandatory. Metric symbol materials (Table 1) shall use the values in Table 5 only.

1.6.2 Note c of Table 5 shall be understood as concerning Test pieces No. 10 for steel plates of thickness over 90 mm.

1.7 *Repair Welding:*
Weld repairs may be performed when permitted by the purchaser. The requirements of SA-20/SA-20M shall apply.

1.8 *Inspection:*
When sulphur print test, or nondestructive test, or impact test is performed in accordance with para. 11, the result shall comply with the acceptance criterion set upon agreement between the purchaser and the manufacturer.

2. Austenitic Grain Size

2.1 “5 or more” in para. 8 shall mean “5 or finer.”

3. Source

3.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of JIS G3118 and its references.

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SPECIFICATION FOR STAINLESS STEEL BARS

SA/JIS G4303

(Identical with International Specification JIS G4303:2012 with these additional requirements.)

SPECIFICATION FOR STAINLESS STEEL BARS

SA/JIS G4303

(Identical with International Specification JIS G4303:2012 with these additional requirements.)

1. Additional Requirements

1.1 *Marking:*
In addition to the marking requirements of this specification in para. 13, all products are to be identified by this SA/JIS specification designation.

1.2 *Dimensions:*
The dimension of austenitic bars shall not be greater than 180 mm. The dimension of austenitic-ferritic, ferritic, martensitic, and precipitation hardening bars shall not be greater than 75 mm.

1.3 *Mechanical Properties:*
The mechanical properties, including proof stress, shall conform to the requirements of the tables of clause "Mechanical Properties."

1.4 *Test Reports:*
A test report shall be furnished. It shall include this SA/JIS specification designation including the edition year and the results of all tests required by this SA/JIS specification.

1.5 *Mechanical Testing:*
Tensile testing and hardness testing are mandatory requirements of this specification.

2. Source

2.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of JIS G4303 and its references.

SPECIFICATION FOR HEAVY-WALLED FERRITIC SPHEROIDAL GRAPHITE IRON CASTINGS FOR LOW TEMPERATURE SERVICE

SA/JIS G5504

(Identical with International Specification JIS G5504:2005 as translated and published in the English language by the Japanese Standards Association, with these additional requirements.)

SPECIFICATION FOR HEAVY-WALLED FERRITIC SPHEROIDAL GRAPHITE IRON CASTINGS FOR LOW TEMPERATURE SERVICE

SA/JIS G5504

(Identical with International Specification JIS G5504:2005, as translated and published in the English language by the Japanese Standards Association, with these additional requirements.)

1. Additional Requirements

1.1 *Marking:*
In addition to the marking requirements of this specification in para. 16, all products are to be identified by this SA/JIS specification designation.

1.2 *Mechanical Properties:*
The mechanical properties, including proof stress, shall conform to the requirements of Table 1.

1.3 *Test Reports:*
A test report shall be furnished containing the results of all tests performed. It shall include this SA/JIS specification designation including the edition year.

1.4. *Repair:*
Castings shall not be repaired by plugging, welding, brazing, impregnation, or any other means.

2. Source

2.1 See Nonmandatory Appendix A for ordering information to obtain an English language copy of JIS G5504 and its references.

MANDATORY APPENDIX I
STANDARD UNITS FOR USE IN EQUATIONS

Table I-1
Standard Units for Use in Equations

Quantity	U.S. Customary Units	SI Units
Linear dimensions (e.g., length, height, thickness, radius, diameter)	inches (in.)	millimeters (mm)
Area	square inches (in.^{2})	square millimeters (mm^2)
Volume	cubic inches (in.^{3})	cubic millimeters (mm^3)
Section modulus	cubic inches (in.^{3})	cubic millimeters (mm^3)
Moment of inertia of section	inches^4 (in.^{4})	millimeters^4 (mm^4)
Mass (weight)	pounds mass (lbm)	kilograms (kg)
Force (load)	pounds force (lbf)	newtons (N)
Bending moment	inch-pounds (in.-lb)	newton-millimeters (N·mm)
Pressure, stress, stress intensity, and modulus of elasticity	pounds per square inch (psi)	megapascals (MPa)
Energy (e.g., Charpy impact values)	foot-pounds (ft-lb)	joules (J)
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)
Absolute temperature	Rankine (°R)	kelvin (K)
Fracture toughness	ksi square root inches (ksi $\sqrt{\text{in.}}$)	MPa square root meters (MPa$\sqrt{\text{m}}$)
Angle	degrees or radians	degrees or radians
Boiler capacity	British thermal units per hour (Btu/hr)	watts (W)

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MANDATORY APPENDIX II
FRAMEWORK OF ASME MATERIAL SPECIFICATIONS

II-100 GENERAL

An ASME material specification is a standard originally published by an external organization, then modified to conform to ASME BPVC requirements. A list of all ASME material specifications is in the "Specification" column of Tables II-200-1 and II-200-2.

II-200 SOURCE STANDARDS

The standards forming the framework of ASME material specifications are produced by organizations from around the world. The source standard from which an ASME material specification was derived is part of the specification's designation, as shown below.

ASME Material Specification Designation	Source Standard
SA-217/SA-271M	ASTM A217/A217M
SA/AS-1548	AS 1548
SA/CSA-G40.21	CSA G40.21
SB-166	ASTM B166
SF-568M	ASTM F568M
SA/EN 10028-2	EN 10028-2
SA/GB 713	GB 713
SA/IS 2062	IS 2062
SA/JIS G3118	JSA-JIS G 3118

The "Latest Adopted" column of Tables II-200-1 and II-200-2 states which edition (revision) of the source standard is the framework for the ASME material specification. The "Description" column explains any changes made to the source standard when it was adopted as an ASME material specification.

II-300 PERMISSIBILITY OF SUPERSEDED EDITIONS FOR ASME CONSTRUCTION

At times, the publishing organization will update its standard and supersede the previous edition. When this occurs, the BPVC II committee may choose to evaluate the update and adopt it as the framework for the ASME material specification.

The Section II committee may also choose to continue to allow for Code construction a previously accepted but now superseded edition. Superseded editions permitted are referenced in the column "All Acceptable Editions" of Tables II-200-1 and II-200-2. Any caveats listed in the "Description" column shall be met.

If no superseded editions are currently permitted for use, then an ellipse (…) will appear in the "All Acceptable Editions" column.

II-400 STRUCTURE OF ASME MATERIAL SPECIFICATIONS

This paragraph gives examples of deciphering from Tables II-200-1 and II-200-2 the structure of ASME material specifications as well as which editions of a source standard are permitted for use. These examples are based on Figure II-400-1. The specifications in the figure are based on editions found in BPVC Section II, Parts A and B, 2021 Edition.

(a) SA-217/SA-217M. The standard adopted was ASTM A217/A217M. The 2007 edition (A217/A217M-07) is the latest adopted. The word "Identical" is listed in the "Description" column; this means that ASME material specification SA-217/SA-217M is identical to ASTM A217/A217M-07. The "All Acceptable Editions" column indicates that revisions 1993 through 2007, inclusive, are permitted for construction.

(b) SA-513. The standard adopted was ASTM A513. The 2000 edition (A513-00) is the latest adopted. The "Description" column indicates that for the ASTM specification to be used as ASME material specification SA-513, its Supplementary Requirements S6 and either S7 or S8 are mandatory. Ellipses (…) are listed under the "All Acceptable Editions" column. This means that only the edition listed under the "Latest Adopted" column — ASTM A513-00 — is permitted for Code construction.

(c) SA/CSA-G40.21. The standard adopted was CSA G40.21. The latest edition adopted is 2013(R2018). This means that the 2018 edition is the latest adopted, and that it is a reapproval of the 2013 edition [(CSA-G40.21-2013 (R2018)]. The ASME material specification was modified to have additional requirements for marking, chemical composition, controlled and normalized rolling, and providing a test report. The only CSA-G40.21 editions permitted for construction are 1992, and 2004 through 2018, inclusive.

(d) SB-166. The standard adopted was ASTM B166, 2011 edition (B166-11). The ASME material specification has been modified to require certification and test report be given to the purchaser; and that the details of N06617's heat treatment are provided on the certification. The B166 editions permitted for construction are 1986 through 2011, inclusive.

(e) SB-516. The standard adopted was ASTM B516, 2014 edition [B516-03(2014)]. The ASME material specification has been modified to require certification and test report be given to the purchaser. Any ASTM B516 specification having a year-date between 1985 and 2014, inclusive, is permitted for construction with an exception to alloy N06025. If alloy N06025 certified to ASTM A516 is to be used, then it can only be certified to a year-date between 1998 and 2014.

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Table II-200-1
Material Specifications Acceptable for ASME Construction

Specification	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA-6/SA-6M	21	Identical General Requirements, Rolled Products	88c through 21
SA-20/SA-20M	20	Identical except for revision in para. 11.5.3. General Requirements, Plates	88 through 20
SA-29/SA-29M	20	Identical General Requirements, Bars	88 through 20
SA-31	14	Identical except that 3.1.7 has been deleted, Note 1 has been revised for ASME and certification is mandatory in 14.	00 through 14
SA-36/SA-36M	19	Identical	88 through 19
SA-47/SA-47M	99(2018)$^{\varepsilon 1}$	Identical except for the deletion of welded repair references in 11.2 and 11.3 and mandatory certification in 14.1.	84 through 99(2018)$^{\varepsilon 1}$
SA-53/SA-53M	20	Identical	10 through 20
SA-105/SA-105M	21	Identical except for addition of Footnote A call out next to vanadium composition limit in Table 1 and deletion of [mm] from the thickness variable (*T*) in Table 3 Note minimum elongation formula.	87a through 21
SA-106/SA-106M	19a	Identical	88a through 19a
SA-134/SA-134M	19	Identical. For products ordered to Section III, Division 1, Supplementary Requirement S1 is mandatory.	85 through 19
SA-135/SA-135M	19	Identical except certification has been made mandatory. The 06, 09, and 09(2014) ASTM editions are acceptable provided the minimum metric hydrostatic pressure is 17200 kPa.	88 through 19
SA-178/SA-178M	95	Identical	89 through 95
SA-179/SA-179M	19	Identical	88a through 19
SA-181/SA-181M	06	Identical	87 through 06
SA-182/SA-182M	21	Identical except for the inclusion of Grade F316Ti in para. 7.3.1, the removal of reduced strength levels for thicker sections of Grade F53 in Table 3, the removal of Grade F53 Classes in Table 3, the removal of Note (G) in Table 3, the increase of minimum yield strength for Grade F60 in Table 3 and clarification of requirements for parts machined from bar or hollow bar in 6.4 and para. 7.2.1 revised to include F12, Classes 1 and 2. *(a)* S32202 (F66) heat treatment range shall be 1,870°F to 1,975°F (1,020°F to 1080°C) for ASTM editions prior to 09a *(b)* S32205 (F60) min YS in Table 3 shall be 70 (485) in all ASTM editions *(c)* S30815 (F45) and S32228 (F56) direct or indirect in-process heat treatment is prohibited for ASTM editions prior to 07 *(d)* K90901 (F91), other acceptable editions are limited to 18 *(e)* K91061 (F911), other acceptable editions are limited to 05 or later	87a through 21
SA-192/SA-192M	17	Identical	88 through 17
SA-193/SA-193M	20	Identical	14 through 20

Table II-200-1
Material Specifications Acceptable for ASME Construction (Cont'd)

Specification	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA-194/SA-194M	22	Identical	14 through 22
SA-203/SA-203M	17	Identical	82 through 17
SA-204/SA-204M	17	Identical	88 through 17
SA-209/SA-209M	03(2017)	Identical	88 through 03(2017)
SA-210/SA-210M	95	Identical except for editorial differences in Table 2	88 through 95
SA-213/SA-213M	22	Identical except for the additional H Grade heat treatment requirements in para. 6.2 and correction of UNS number for Grade T9 in Table 3. For Grade T91, other acceptable editions are limited to 18 and later. For UNS S31035 and UNS K91060, the acceptable edition is limited to 18b.For UNS S31050, other acceptable ASTM editions are limited to 15a and later. For UNS S31002, the ASTM edition is limited to 22.	10 through 22
SA-214/SA-214M	19	Identical	88 through 19
SA-216/SA-216M	07	Identical except for addition of 2.3 and editorial differences in 2.1 and 10.1	84b through 07
SA-217/SA-217M	07	Identical	93 through 07
SA-225/SA-225M	17	Identical	86 through 17
SA-231/SA-231M	96	Identical except that certification requirements in 13.1 are mandatory	...
SA-232/SA-232M	91	Identical	...
SA-234/SA-234M	19	Identical. For Grade WP91, other acceptable ASTM editions are limited to 18 and later. For welded and filler metal products ordered to Section III, Division 1, Supplementary Requirement S4 is mandatory.	82a through 19
SA-240/SA-240M	17	Identical except for UNS S31050, other acceptable ASTM editions are limited to 04 and later. For UNS S32906, other acceptable ASTM editions are limited to $07^{\varepsilon1}$ and later. For UNS S38815, other acceptable ASTM editions are limited to 16 and later. For UNS S32101, other acceptable ASTM editions are limited to -05 and later.	88c through 17
SA-249/SA-249M	18a	Identical except for the deletion of S5, which allows lower mechanical properties, and for Section I only, S9 is mandatory when 100% joint efficiency is required. For UNS S31040, other acceptable ASTM editions are limited to 10a and later.	88b through 18a
SA-250/SA-250M	05(2014)	Identical except that Supplementary Requirement S1 is mandatory when 100% weld joint efficiency is required.	88a through 05(2014)
SA-263	12(2019)	Identical. In cases where cladding is used in the design strength calculations and welding is used to join multiple alloy cladding plates, ASTM editions prior to 12 are not acceptable unless welding was performed by an ASME Certificate Holder.	88 through 12(2019)

Table II-200-1
Material Specifications Acceptable for ASME Construction (Cont'd)

Specification	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA-264	12(2019)	Identical. In cases where cladding is used in the design strength calculations and welding is used to join multiple alloy cladding plates, ASTM editions prior to 12 are not acceptable unless welding was performed by an ASME Certificate Holder.	88 through 12(2019)
SA-265	12(2019)	Identical. In cases where cladding is used in the design strength calculations and welding is used to join multiple alloy cladding plates, ASTM editions prior to 12 are not acceptable unless welding was performed by an ASME Certificate Holder.	88 through 12(2019)
SA-266/SA-266M	21	Identical. ASTM editions 03 through 11 are acceptable provided the term "hubbed flanges" is replaced with "hubbed flat heads" in para. 3.4.	99 through 21
SA-268/SA-268M	20	Identical	88b through 20
SA-276/SA-276M	17	Identical	02 through 17
SA-278/SA-278M	01(2015)	Identical except for an editorial change to 5.1.1 and a change to 16.1 making certification mandatory.	85 through 01(2015)
SA-283/SA-283M	13	Identical	88 through 13
SA-285/SA-285M	17	Identical	82(R87) through 17
SA-299/SA-299M	17	Identical	82(R87) through 17
SA-302/SA-302M	17	Identical. ASTM editions prior to 12 are acceptable provided that any accelerated cooling of plates as permitted in 5.3 is followed by tempering.	82 through 17
SA-307	10	Identical except for the deletion of the term “private label distributor” and “as appropriate” in para. 13.1.1.	00 through 10
SA-311/SA-311M	04(2015)	Identical except for the deletion of 5.1.11, revision of Table 1 footnote A, and editorial change to 5.1.9, and 11.1 revised to make certification mandatory.	90b through 04(2015)
SA-312/SA-312M	18a	Identical except for the revision to para. 6.2 to add "H" grade heat treatment requirements. For UNS S31035, the acceptable ASTM edition is limited to 18a. For UNS S34051, ASTM editions prior to 14b are acceptable provided that the nickel composition in Table 1 is met.	88a through 18a
SA-320/SA-320M	22	Identical	21 through 22
SA-325	10	Identical except for the deletion of the term “private label distributor” in 15.1 and 15.5	86a through 10
SA-333/SA-333M	16	Identical. For Grade 6, acceptable ASTM editions are limited to 11 and later.	94 through 16
SA-334/SA-334M	04a(2016)	Identical	$88^{\varepsilon 1}$ through 04a(2016)
SA-335/SA-335M	18	Identical except for the revision to 9.5 to replace the words "as agreed upon in accordance with Note D in Table 2" with "performed." For Grades 23, 91, and 911, other acceptable ASTM editions are limited to 18.	10b through 18

Table II-200-1
Material Specifications Acceptable for ASME Construction (Cont'd)

Specification	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA-336/SA-336M	18	Identical. ASTM editions prior to 15 are acceptable provided the term "hubbed flanges" is replaced with "hubbed flat heads" in 3.4. For Grade F5a, ASTM editions prior to 15 are acceptable provided the minimum temperature is 1,250°F.	06a through 18
SA-350/SA-350M	02b	Identical except for the deletion of 6.1.2 and 14.1, revision to 14.2.5, and test reports have been made mandatory. SA-350/SA-350M Grade LF2 forgings made to revisions earlier than the 2001 ASME Boiler and Pressure Vessel Code or to ASTM Specification A350/A350M with year dates from 1987 through 1997 are acceptable for either Class 1 or Class 2 applications unless Supplementary Requirement S4 was used to test forgings at a higher test temperature.	87 through 02b
SA-351/SA-351M	$18^{\varepsilon1}$	Identical. For Grades CK3MCuN and CN3MN, acceptable ASTM editions are limited to 13a and later.	86 through $18^{\varepsilon1}$
SA-352/SA-352M	06(2012)	Identical	88 through 06(2012)
SA-353/SA-353M	17	Identical	87 through 17
SA-354	11	Identical except for the deletion of the term “private label distributor” in 15.1 and 15.3.5.	86 through 11
SA-358/SA-358M	19	Identical except for the deletion of 6.3.2.2 for HT-O pipe and 6.3.2.3 for HT-SO pipe. For products ordered to Section III and Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, Supplementary Requirement S8 is mandatory.	88 through 19
SA-369/SA-369M	18	Identical	88 through 18
SA-370	21	Identical Mechanical Testing of Steel Products	77 through 21
SA-372/SA-372M	$20^{\varepsilon1}$	Identical. ASTM editions prior to -$20^{\varepsilon1}$ are acceptable provided that the minimum tensile strength for Class 55 in Table 2 is 585 MPa.	02 through $20^{\varepsilon1}$
SA-376/SA-376M	19	Identical except for the deletion of HT-O option from 5.2.1 and 13.1, and clarification of heat-treatment requirements in 5.2.1.	88 through 19
SA-387/SA-387M	17a	Identical. For Grade 91, acceptable ASTM editions are limited to 11 and later.	88 through 17a
SA-395/SA-395M	99(2018)	Identical	80 through 99(2018)
SA-401/SA-401M	18	Identical	...
SA-403/SA-403M	19a	Identical except for clarified heat treatment requirements in 6.1 and 6.4, the deletion of 5.14 and 5.15, and the deletion of revised tensile requirements for Grades 321 and 321H in Table 5. For H Grades, other acceptable ASTM editions are limited to 02 and later. For Grade S38815, other acceptable ASTM editions are limited to 16 and later. For welded with filler metal products ordered to Section III, Division 1 of the ASME Boiler and Pressure Vessel Code, Supplementary Requirement S3 is mandatory.	86 through 19a

Table II-200-1
Material Specifications Acceptable for ASME Construction (Cont'd)

Specification	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA-409/SA-409M	19	Identical except for clarified heat treatment requirements for H grade stainless steels and S30815 in 5.3.1, deletion of 5.3.2.2 and 5.3.2.3 for the non-heat treated pipe provisions, and the inclusion of a grain size requirement in 5.1.1 for H grade stainless steels and S30815, and mandatory certification in 17. For grade S31727 and S32053, ASTM editions are limited to 08a and later. For S20100, S20153, and S31254, ASTM editions are limited to 13 and later. For S31266, the ASTM edition is limited to 15. For products ordered to Section III, Division 1 or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, Supplementary Requirement S7 is mandatory	01 through 19
SA-414/SA-414M	14(2019)	Identical	10 through 14(2019)
SA-420/SA-420M	19a	Identical. For products welded with filler metal ordered to Section III, Division 1, Supplementary Requirement S1 is mandatory.	85a through 19a
SA-423/SA-423M	19	Identical	89 through 19
SA-426/SA-426M	13	Identical	10 through 13
SA-437/SA-437M	15(2021)	Identical	84b through 15(2021)
SA-439/SA-439M	18	Identical except for repair by welding and plugging is not permitted, and certification made mandatory.	...
SA-449	10	Identical except for requiring all mating fastener components to be coated by the same zinc-coating process in 5.1.4, the removal of reference to bolts in 6.4, and the deletion of the term "private label distributor" in 16.1 and 16.3.2.	87 through 10
SA-450/SA-450M	21	Identical General Requirements for Tubes	88a through 21
SA-451/SA-451M	06(2010)	Identical except for editorial differences in 15.1.	80(R85) through 06(2010)
SA-453/SA-453M	17	Identical	00 through 17
SA-455/SA-455M	12a(2017)	Identical	82(1987) through 12a(2017)
SA-476/SA-476M	00(2018)	Identical except for editorial changes in 4.1.6 and 13.1 to make certification mandatory.	82 through 00(2018)
SA-479/SA-479M	21	Identical. For Grade S32654, ASTM editions are limited to 11 and later.	87b through 21
SA-480/SA-480M	17	Identical General Requirements — Flat Products	88 through 17
SA-484/SA-484M	21	Identical General Requirements Wrought SS Products	87 through 21
SA-487/SA-487M	21	Identical except no welding for Grade 17 per Table 4	...
SA-508/SA-508M	18	Identical except for revision prior to 05b. For these A966/A966M added to 2.1, 3.1, and 7.2.1 revised to allow A966 in revisions prior to $05^{\varepsilon 1}$ reference to Notes 2 and 3 in 6.1.2.2 should be 3 and 4 respectively.	87 through 18
SA-513	00	Identical except that Supplementary Requirements S6 and either S7 or S8 at the manufacturer's option are mandatory.	...
SA-515/SA-515M	17	Identical	82 through 17

Table II-200-1
Material Specifications Acceptable for ASME Construction (Cont'd)

Specification	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA-516/SA-516M	17	Identical. The reference to Footnote B in Table 1 shall apply to the 04, 05, and 05e editions.	86 through 17
SA-517/SA-517M	17	Identical except that Footnote A also applies to Boron in Table 1.	87a $^{\varepsilon 1}$ through 17
SA-522/SA-522M	07	Identical	87 through 07
SA-524/SA-524M	21	Identical except for the deletion of alternate elongation and deletion of SI Units from Table 2 Note on Grade I.	88 through 21
SA-530/SA-530M	18	Identical General Requirements for Pipe	88a through 18
SA-533/SA-533M	16	Identical	87 through 16
SA-537/SA-537M	20	Identical	86 through 20
SA-540/SA-540M	15(2021)	Identical	84a through 15(2021)
SA-541/SA-541M	05(2015)	Identical	...
SA-542/SA-542M	19	Identical	88 through 19
SA-543/SA-543M	09(2014)	Identical	87 through 09(2014)
SA-553/SA-553M	17	Identical	87b through 17
SA-556/SA-556M	90a(1995) $^{\varepsilon 1}$	Identical	88 through 90a(1995) $^{\varepsilon 1}$
SA-562/SA-562M	10	Identical	82(1987) through 10
SA-563	07a(2014)	Identical except for deletion of the term "private label distributor" in paras. 14.7 and 14.9 and editorially corrected title.	84 through 07a(2014)
SA-564/SA-564M	04(2009)	Identical	87b through 04(2009)
SA-568/SA-568M	07a	Identical General Requirements for Steel Sheet	02 through 07a
SA-572/SA-572M	21 $^{\varepsilon 1}$	Identical	01 through 21 $^{\varepsilon 1}$
SA-574	04 $^{\varepsilon 1}$	Identical except that Table 1 on chemical requirements has been deleted and Supplementary Requirement S1 is now mandatory. Paragraphs 6.1 and 6.2 have been revised to refer to Table S1.1 and para. 6.3 has been deleted.	97a through 04 $^{\varepsilon 1}$
SA-587	96(2005)	Identical except for deletion of 1.5.	88 through 96(2005)
SA-592/SA-592M	04(2009)	Identical	85 through 04(2009)
SA-609/SA-609M	91(2007)	Identical Ultrasonic Longitudinal Beam — Castings	83 through 91(2007)
SA-612/SA-612M	12(2019)	Identical	87 through 12(2019)
SA-638/SA-638M	00(2004)	Identical except for an editorial correction in 6.2.	87 through 00(2004)
SA-645/SA-645M	10(2016)	Identical	87(1991) through 10(2016)
SA-649/SA-649M	04	Identical	91a through 04
SA-656/SA-656M	18	Identical	00a through 18
SA-660	96(2010)	Identical	88 through 96(2010)
SA-662/SA-662M	17	Identical	86 through 17

Table II-200-1
Material Specifications Acceptable for ASME Construction (Cont'd)

Specification	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA-666	03	Identical	90 through 03
SA-667/SA-667M	87(2018)	Identical	...
SA-671/SA-671M	19	Identical except for additional requirements that apply as shown in Specification and, for editions prior to 16, certification for designations CF and CJ shall include the appropriate ASTM plate specification grade. For products ordered to Section III, Division 1, Supplementary Requirement S15 is mandatory.	85 through 19
SA-672/SA-672M	19	Identical. For products ordered to Section III, Division 1, Supplementary Requirement S15 is mandatory.	81 through 19
SA-675/SA-675M	03(2009)	Identical except that Supplementary Requirement S7 is mandatory and Grades 65 [450] and 70 [485] have been added to S7. Certification is mandatory.	...
SA-688/SA-688M	15	Identical. For products ordered to Section III, Division 1 of the ASME Boiler and Pressure Vessel Code, Supplementary Requirement S13 is mandatory	88a through 15
SA-691/SA-691M	19	Identical. For products ordered to Section III, Division 1 or the ASME Boiler and Pressure Vessel Code, Supplementary Requirement S13 is mandatory.	85a through 19
SA-693	$02^{\varepsilon1}$	Identical except for aligning the elongation requirements for Gr. XM-16 and correction of the max. hardness for Gr. XM-12 and 630 in Table 5. Also a revision to Note B of Table 1.	88 through $02^{\varepsilon1}$
SA-696	90a(2012)	Identical	85 through 90a(2012)
SA-703/SA-703M	18a	Identical General Requirements for Castings	87b through 18a
SA-705/SA-705M	95(2009)	Identical	87a through 95(2009)
SA-723/SA-723M	10(2015)	Identical. ASTM edition 02 is acceptable except that for Class 2a the minimum elongation shall be 13.5%.	02 through 10(2015)
SA-724/SA-724M	09(2018)	Identical	88 through 09(2018)
SA-727/SA-727M	14(2009)	Identical	02(2007) through 14(2019)
SA-736/SA-736M	17	Identical	88 through 17
SA-737/SA-737M	17	Identical	87(1991) through 17
SA-738/SA-738M	19	Identical	87a through 19
SA-739	90a(2016)	Identical	81a through 90a(2016)
SA-747/SA-747M	04	Identical except for the revision of the mandatory ordering requirements of 4.1.6 and the mandatory use of Supplementary Requirement S15 of SA-781/SA-781M.	86 through 04
SA-748/SA-748M	87(2018)	Identical	...
SA-749/SA-749M	97(2002)	Identical General Requirements for Steel Strip	...
SA-751	21	Identical except for editorial corrections to an element designation in Tables 1 and 2.	89a through 21

Table II-200-1
Material Specifications Acceptable for ASME Construction (Cont'd)

Specification	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA-765/SA-765M	07(2017)	Identical. ASTM editions prior to 04 are acceptable provided the term "hubbed flanges" is replaced with "hubbed flat heads" in S9.	94 through 07(2017)
SA-770/SA-770M	03(2018)	Identical except for editorial correction to Table 2. Tension Testing of Steel Plates	86(1990)$^{\varepsilon 1}$ through 03 (2018)
SA-781/SA-781M	06	Identical Common Requirements for Castings	87a through 06
SA-788/SA-788M	15	Identical. ASTM editions prior to 13 are acceptable, provided the term "hubbed flanges" is replaced with "hubbed flat heads" in S12. General Requirements for Forgings	05c through 15
SA-789/SA-789M	18	Identical	10a through 18
SA-790/SA-790M	19	Identical	10 through 19
SA-803/SA-803M	16	Identical	96 through 16
SA-813/SA-813M	14(2019)	Identical except for the addition of grain size requirements for H grades and S30815, the addition of E112 to section 2, the deletion of heat treat omitted options, and adding a minimum heat treat temperature for S30815.	88a through 14(2019)
SA-814/SA-814M	15(2019)	Identical	88a through 15(2019)
SA-815/SA-815M	10a	Identical except for the deletion of para. 5.9, 5.14 (Class CR fittings), and 5.15.4. *(a)* Paragraphs 5.14 and 5.15 deleted for all editions prior to 10a *(b)* S32202, para. 7.2.3 filler metal with nominal 23.5% Cr, 12.00% Ni is not permitted, minimum HT temperature in Table 2 to be 1,870°F to 1,975°F (1 020°C to 1 080°C) *(c)* S32808, maximum *S* in Table 2 shall be 0.010 in all editions	86 through 10a
SA-832/SA-832M	17	Identical	84(1989) through 17
SA-834	95(2015)	Identical Common Requirements for Iron Castings	84 through 95(2015)
SA-836/SA-836M	14(2020)	Identical	02(2007) through 14(2020)
SA-841/SA-841M	17	Identical	88 through 17
SA-874/SA-874M	98(2018)$^{\varepsilon 1}$	Identical	98(2018)$^{\varepsilon 1}$
SA-905	93	Identical	91 through 93
SA-941	22a	Identical	99b through 22a
SA-960/SA-960M	20	Identical	99b through 20
SA-961/SA-961M	21	Identical except for the editions prior to 13, certification is mandatory.	99 through 21
SA-962/SA-962M	22	Identical	99 through 22
SA-965/SA-965M	21a	Identical	06a through 21a
SA-985/SA-985M	04a	Identical General Requirements, Castings	03 through 04a

Table II-200-1
Material Specifications Acceptable for ASME Construction (Cont'd)

Specification	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA-988/SA-988M	17	Identical except for addition of para. 5.1.6; Supplementary Requirements S19, S20, S21, and S22 are mandatory; correction to S20 to add powder storage requirements.	17
SA-989/SA-989M	18	Identical except for addition of para. 5.1.7; Supplementary Requirements S2, S4, and S5 are mandatory.	18
SA-995/SA-995M	20	Identical except for Grade 6A editions prior to 19 are obsolete.	98(2007) through 20
SA-999/SA-999M	18	Identical except for the editions prior to 04a, para. 6.2.1 on grade substitution of the 04a edition or later applies.	04a through 18
		General Requirements, Pipes	
SA-1008/SA-1008M	01a	Identical except for the addition of 8.1.1.1 on mechanical properties for pressure vessel design.	00 through 01a
SA-1010/SA-1010M	01(2009)	Identical except for an editorial correction to a column heading in Table 2.	...
SA-1011/SA-1011M	06b	Identical	01a through 06b
SA-1016/SA-1016M	17a	Identical	10 through 17a
		General Requirements, Tubes	
SA-1017/SA-1017M	17	Identical. For Grade 122, acceptable editions 07 and later. For Grade 23, acceptable editions 11 and later.	01 through 17
SA-1058	19	Identical	...
SF-568M	98	Identical	93a through 98
		Threaded Metric Fasteners	

NOTE:
(1) The source standards for specifications listed in this table are ASTM standards. ASTM technical committees review the standards under their jurisdiction on a 5-yr cycle. If no changes are needed, then the standard is simply reapproved. At times, editorial errors are discovered within an ASTM standard between the 5-yr review cycle. If the technical committee decides to fix the errors immediately, then the standard will be republished with a superscript epsilon (ε) in the designation. BPVC II Committee has taken the position that a reapproved or editorially corrected edition is technically and substantively identical to the base edition. For example, edition 15(2020), $15^{\varepsilon 1}$, or $15(2020)^{\varepsilon 1}$ is technically and substantively identical to 15. Therefore, for the purposes of ASME construction, a reapproved or editorially corrected edition of an ASTM specification shall be considered acceptable for use, even if the edition is beyond the range listed in this column, provided that its base edition is within range.

Table II-200-2
Material Specifications Acceptable for ASME Construction

(23)

Specifications	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA/AS-1548	2008 (R2018)	Identical except for steelmaking process, marking, chemical composition, and test reports as shown in the specification. Appendix "Interchangeability of Strength Grades" does not apply.	2008
SA/CSA-G40.21	2013 (R2018)	Identical except for marking, chemical composition, controlled and normalized rolling, and test reports as shown in the specification.	2004 through 2013(R2018)
SA/EN 10025-2	2019	Identical except for marking, chemical composition, resurfacing by welding, and test reports as shown in the specification.	...
SA/EN 10028-2	2017	Identical except for general requirements, marking, delivery condition, chemical composition, tension test, impact test sampling, steelmaking process, quality, and test reports as shown in the specification. For Grade 13CrMo4-5, other acceptable editions are limited to 2009 and later. For other acceptable editions prior to 2017, plate thickness shall not be greater than 250 mm.	2003 through 2017
SA/EN 10028-3	2017	Identical except for general requirements, marking, chemical composition, impact test sampling, steelmaking process, quality, and test reports as shown in the specification. For other acceptable editions prior to 2017, plate thickness of Grades P460NH, P460NL1, and P460NL2, shall not be greater than 100 mm.	2003 through 2017
SA/EN 10028-4	2017	Identical except for general requirements, marking, chemical composition, tension, impact tests, steelmaking process, surface imperfections, repair welding, and test reports as shown in the specification.	2003 through 2017
SA/EN 10028-7	2016	Identical except for marking, heat treatment and test reports, as shown in the specification. For the latest adopted edition, heat treatment shall be per the Tables of Annex A; for other acceptable editions prior to 2007, heat treatment shall be per the Tables of Annex B. For other acceptable editions prior to 2016, plate thickness of Grades X2CrNi12 and X6CrNiTi12, shall not be greater than 25 mm.	2000 through 2016
SA/EN 10088-2	2014	Identical except for marking, dimensions, delivery condition, resurfacing by welding, extent of testing, and test reports as shown in the specification.	2005 through 2014
SA/EN 10088-3	2014	Identical except for marking, dimensions, test/inspection documents, repair welding, heat treatment, and surface quality as shown in the specification.	2005 through 2014
SA/EN 10216-2	2013	Identical except for marking and test reports as shown in the specification.	2002+A2:2007 through 2013
SA/EN 10217-1	2019	Identical except for material, inspection, marking, resurfacing by welding, and test reports as shown in the specification.	...
SA/EN 10222-2	2017	Identical except for general requirements, marking, resurfacing by welding, and test reports as shown in the specification.	...
SA/GB 713	2014	Identical except for chemical composition, marking, controlled rolling, heat treatment, and test reports as shown in the specification.	...

Table II-200-2
Material Specifications Acceptable for ASME Construction (Cont'd)

Specifications	Latest Adopted	Description	All Acceptable Editions [Note (1)]
SA/IS 2062	2011	Identical except for chemical composition, marking, mechanical property limits, delivery condition, repair qualification, and test reports as shown in the specification.	…
SA/JIS G3118	2017	Identical except for marking, trace elements, plates produced by TMCP, steelmaking process, test reports, mechanical properties, repair welding, and inspection as shown in the specification. Annex, supplementary quality requirements, does not apply.	2000 through 2017
SA/JIS G4303	2012	Identical except for marking, dimensions, mechanical properties, test reports, and mechanical testing as shown in the specification.	1998 through 2012
SA/JIS G5504	2005	Identical except for marking, mechanical properties, test reports, and repairs as shown in the specification.	…

GENERAL NOTE: The source standards for specifications listed in this table are produced by standards organizations from around the world with the exclusion of ASTM. The date of publication of the European standards considered in this table is the year of approval of the standard by CEN. This date appears in the body of the standard on the page starting with EN; dates appearing on the front page of an XX EN standard (e.g., XX = BS or NF or DIN) correspond only to the date of adoption by each member country.

NOTE:
(1) BPVC II Committee has taken the position that a reapproval is technically and substantively identical to the base edition. Therefore, for the purposes of ASME construction, a reapproval shall be considered acceptable for use, even if the edition is beyond the range listed in this column, provided that its base edition is within range.

Figure II-400-1
Illustrative Table of ASME Material Specifications (for II-400 Explanation Purposes Only)

Material Specifications Acceptable for ASME Construction

Specification	Latest Adopted	Description	All Acceptable Editions
SA-217/SA-217M	07	Identical	93 through 07
SA-513	00	Identical except that Supplementary Requirements S6 and either S7 or S8 at the manufacturer's option are mandatory.	...
SA/CSA-G40.21	2013 (R2018)	Identical except for marking, chemical composition, controlled and normalized rolling, and test reports as shown in the specification.	1992 and 2004 through 2013 (R2018)
SB-166	11	Identical except for the addition of UNS N06617 heat treatment requirements. Certification and test reports have been made mandatory.	86 through 11
SB-516	03(2014)	Identical except that certification and a test report have been made mandatory, and all ASTM editions prior to 98 are obsolete for N06025 only.	85 through 03(2014)

MANDATORY APPENDIX III
GUIDELINES ON MULTIPLE MARKING OF MATERIALS

III-100 BACKGROUND

A common inquiry topic is the permissibility of using material that is identified with two or more specifications (or grades, classes, or types), even if they have different strengths, or even if one of them is not permitted for use in the construction code of application. The Committee has addressed variants of these questions in several interpretations: I-89-11, IIA-92-08, VIII-1-89-269, and VIII-1-89-197.

III-200 GUIDELINES

The construction codes individually define what materials may be used in boilers, vessels, and components constructed in compliance to their rules. If a material meets all of the requirements for a specification for which it is marked, including documentation, if any, and if it meets all requirements for use imposed by the construction code, it may be used. The construction codes, in general, do not address the case of materials marked with more than one specification, grade, class, or type, so these guidelines are offered for clarification.

III-210 ACCEPTABILITY OF MULTIPLE MARKING

Dual or multiple marking is acceptable, as long as the material so marked meets all of the requirements of all the specifications, grades, classes, and types with which it is marked.

All of the measured and controlled attributes of the multiply marked grades or specifications must overlap (e.g., chemistry, mechanical properties, dimensions, and tolerances) and the material so marked must exhibit values that fall within the overlaps. Further, the controlled but unmeasured attributes of the specifications or grades must overlap (e.g., melting practices, heat treatments, and inspection).

Many specifications or grades have significant overlap of chemistry ranges or properties. It is common for material manufacturers to produce materials that satisfy more than one specification, grade, class, or type. Examples are SA-53 and SA-106 (some grades and classes), SA-213 TP304L and TP304, SA-213 TP304 and TP304H, and SA-106 B and C.

III-220 PROHIBITION ON MULTIPLE MARKING

Dual or multiple marking is not acceptable if two or more specifications to which the material is marked have mutually exclusive requirements.

This prohibition includes more than just chemistry and property requirements. One example is SA-515 and SA-516; the former requires melting to coarse grain practice while the latter requires melting to fine grain practice. Another example is SA-213 TP304L and TP304H; the carbon content ranges of these grades have no overlap.

III-230 GRADE SUBSTITUTION

Grade substitution is not permitted. Grade substitution occurs when

(a) the material contains an element (other than nitrogen) that is unspecified for one of the grades marked

(b) the amount of that element present in the material meets the minimum and maximum composition limits for that element in another grade of a specification contained in Section II, Part A or Part B, whether or not it is also so marked

For example, a material meets all of the composition limits for SA-240 304, contains 0.06C and 0.02N, but also contains 0.45% Ti. This material cannot be marked or provided as meeting SA-240 304 because the Ti content meets the requirements of SA-240 321 [which is Ti greater than 5× (C + N) but less than 0.70].

Another material, with identical composition, except 0.35% Ti, may be marked SA-240 304 because the Ti content does not meet the minimum requirement for 321. The Ti content is just a residual.

III-240 MARKING SELECTION

If a material is marked with specifications, grades, classes, or types, it may be used with the allowable stresses, design stress intensities, or ratings appropriate for any of the markings on the material, as long as the material specification, grade, class, and type is permitted by the code of construction governing the boiler, vessel, or component in which the material is to be used. However, once the designer has selected which marking applies (specification, grade, class, type, etc.), the designer must use all the design values appropriate for that selection and may not mix and match values from any other specifications, grades, classes, types, etc., with which the material may be marked.

III-250 OTHER MARKINGS

Any other markings, such as marking of non-ASME or non-ASTM material specifications, have no relevance, even if those markings are for materials explicitly prohibited by the construction code being used. That is, as long as the *one* marking, and the documentation required by the material and by the construction code, shows that it meets all the requirements for use of that material in that construction code, any additional markings are irrelevant.

MANDATORY APPENDIX IV GUIDELINES ON THE APPROVAL OF NEW MATERIALS UNDER THE ASME BOILER AND PRESSURE VESSEL CODE

IV-100 CODE POLICY

It is expected that requests for Code approval will normally be for materials for which there is a recognized national or international specification. It is the policy of the ASME Boiler and Pressure Vessel (BPV) Committee on Materials to approve, for inclusion in the Code Sections, only materials covered by specifications that have been issued by standards-developing organizations such as, but not limited to, American Petroleum Institute (API), American Society for Testing and Materials (ASTM), American Welding Society (AWS), Canadian Standards Association (CSA), European Committee for Standardization (CEN), Japan Industrial Standards (JIS), Standards Association of Australia (SAA), and China Standardization Committee (CSC).

Material specifications of other than national or international organizations, such as those of material producers/suppliers or equipment manufacturers, will not be considered for approval. The Committee will consider only official requests for specifications authorized by the originating standardization body and available in the English language and in U.S. Customary and/or SI/Metric units.

For materials made to a recognized national or international specification other than that of ASTM or AWS, the inquirer shall give notice to the standards-developing organization that a request has been made to ASME for approval of the specification under the ASME Code and should request that the issuing organization grant ASME permission to at least reproduce copies of the specification for Code Committee internal use and, if possible, reprint the specification. For other materials, a request shall be made to ASTM, AWS, or a recognized national or international standardization body to include the material in a specification that can be presented to the BPV Committee on Materials.

It is the policy of the ASME BPV Committee on Materials to consider requests to approve new materials only from boiler, pressure vessel, transport tank, nuclear facility component manufacturers, architect–engineers, or end users. Such requests should be for wrought, cast, or hot isostatically pressed powder materials for which there is a reasonable expectation of use in a boiler, pressure vessel, transport tank, or nuclear facility component constructed to the rules of one of the Sections of this Code. When a grade does exist in a defined wrought product form, a material producer/supplier may request the inclusion of additional wrought product forms or, provided all of the requirements of Table IV-100-1 of this Appendix are met, the inclusion of hot isostatically pressed (HIP) powder metallurgy components of this grade. When a grade does exist in a defined cast product form, a material producer/supplier may request the inclusion of additional cast product forms.

Any qualified organization requesting that an ASME BPV Committee approve a “new” material for use in their Code book should be aware that only the BPV Committee on Materials provides the appropriate design values for the Construction Codes (Sections I, III, IV, VIII, and XII of the BPV Code and B31 Codes).

The design values are calculated in accordance with the appropriate mandatory Code rules. If the inquirer considers the material to be essentially identical to one that has been approved by the BPV Committee on Materials, the inquirer shall so state in its request, and the BPV Committee on Materials shall evaluate that judgment. If the material is not essentially identical to one that has been approved by the BPV Committee on Materials, the inquirer shall provide all of the data cited in these Guidelines. Based on those data, the BPV Committee on Materials will provide the appropriate design values.

Before approval of a new material for inclusion in one of the Sections of the Code, use of this material may be permitted in the form of a Code Case. This Case shall fix at least the conditions of use and the necessary requirements linked to these conditions. It is the policy of the ASME BPV Committee to admit, in this way, material for which full experience on all working parameters has not yet been acquired.

IV-200 APPLICATION

The inquirer shall identify to the BPV Committee the following:

(a) the Section or Sections and Divisions of the Code in which the new material is to be approved

(b) the temperature range of intended application

(c) whether cyclic service is to be considered

(d) whether external pressure is to be considered

The inquirer shall identify all product forms, size ranges, and specifications or specification requirements for the material for which approval is desired. When

Table IV-100-1
Hot Isostatically Pressed Component Requirements for Austenitic Stainless Steels, Austenitic–Ferritic (Duplex) Stainless Steels, Martensitic Stainless Steels, Ferritic Steels, and Nickel Alloys

Category	Requirement
Chemistry	The chemistry requirements of the hot isostatically pressed components shall be identical to those of the corresponding wrought product form.
Mechanical properties	The room-temperature mechanical properties of hot isostatically pressed components shall be identical to those that apply to the corresponding wrought product form.
Heat treatment	The heat-treatment requirements that apply to the hot isostatically pressed components shall be identical to those that apply to the corresponding wrought product form.
Grain size	The grain size requirements that apply to the hot isostatically pressed components shall be identical to those that apply to the corresponding wrought product form.
Control of powder prior to hot isostatic pressing	The maximum allowable powder size shall be 0.020 in. (5 mm) and the powder shall be produced by the gas atomization process.
	Immediately following atomization, the powder shall remain shielded by an inert gas until the powder is below a temperature of 105°F (40°C), to ensure that the detrimental absorption of oxygen and other deleterious contaminants is no longer possible.
	For austenitic stainless steels, duplex stainless steels, martensitic stainless steels, and nickel alloys, powder should be protected during storage to prevent the detrimental pickup of oxygen and other contaminants.
	For ferritic steels, following atomization, powders shall be stored under a positive nitrogen or argon atmosphere or vacuum to minimize potential oxidation or contamination.
Mandatory testing of hot isostatically pressed components	The chemical composition of a sample from one part from each lot of parts shall be determined by the manufacturer. The composition of the sample shall conform to the chemistry requirements of the defined wrought product form.
	The microstructure shall be examined at 20–50X, 100–200X, and 1,000–2,000X. The microstructure shall be reasonably uniform and shall be free of voids, laps, cracks, and porosity. One sample from each production lot shall be examined. The sample shall be taken from the component, stem, protrusion, or test part made from a single powder blend consolidated in the same hot isostatic press, using the same pressure, temperature, and time parameters, and heat treated in the same final heat-treatment charge at the option of the producer, after hot isostatic pressing or after final heat treatment.
	Samples for mechanical testing shall be from the component, stem, protrusion, or test part made from a single powder blend consolidated in the same hot isostatic press, using the same pressure, temperature, and time parameters, and heat-treated in the same final heat-treatment charge.
Material certification requirements	A manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with the applicable specification, and that the test results on representative samples meet specification requirements. A report of the test results shall be furnished.

GENERAL NOTES:
(a) When a grade does exist in a defined wrought product form for alloys other than those cited, an inquirer may request the inclusion of hot isostatically pressed (HIP) components of this grade. However, the Committee may have additional requirements placed on the grade to accept this request.
(b) If the material is to be used at temperatures where the time-dependent performance will determine the allowable stress values, the requirements of Mandatory Appendix IV relative to the provision of data for new materials shall apply.

available, the inquirer shall furnish information describing service experience in the temperature range requested.

IV-300 CHEMICAL COMPOSITION

The inquirer shall recommend to the BPV Committee on Materials whether the chemical composition specified in the reference specification applies or whether restrictions to this composition shall be imposed for the intended application. When coverage by a recognized national or international standardization body has been requested but not yet obtained, the inquirer shall indicate the detailed chemical composition in the inquiry. The inquirer shall explain the reasons for the chemistry and chemistry limits, and their relationship to the metallurgical structure (e.g., influence on precipitates and their morphology, grain size, and phases), heat treatment effect (e.g., strengthening mechanisms and their stability), and mechanical properties. Elements that significantly influence strength, ductility, toughness, weldability, and behavior under service conditions should be identified.

After review of the submitted data, the Committee reserves the right to modify the permitted compositional ranges for key elements so that they more accurately reflect the range of the elements of the submitted test heats.

IV-400 METALLURGICAL STRUCTURE AND HEAT TREATMENT

When applicable for the proposed material, the inquirer shall indicate the intended metallurgical structure(s) to be achieved in order to comply with the mechanical properties requirements and, where applicable, fully describe the heat treatment (including cooling rates) to be applied to achieve this (or these) structure (s), the mechanical properties, and the expected behavior under service conditions.

An explanation for the proposed heat treatment temperature ranges shall be furnished. When such concepts apply, metallurgical transformation curves and information on the transformation points and conditions for appearance of the major phases in the microstructure (e.g., continuous cooling transformation diagram or time–temperature precipitation plots) would be beneficial for the Committee's consideration.

IV-500 MECHANICAL PROPERTIES

Test methods employed for the properties tested shall be those referenced in or by the material specifications, or shall be the appropriate ASTM test methods, recommended practices, or test methods described in accepted international standards. The test methods used shall be indicated in the data package.

It is desired that the data be obtained using material representative of the range of effects of the key variables of composition, thickness, mechanical working, and heat treatment. It is desirable that, when applicable, test data also be provided for the range of heat treatment exposures that may influence properties such as tensile strength, toughness, and stress rupture behavior. After consideration of the submitted data, the Committee reserves the right to modify the specification requirements.

IV-600 DEFINITIONS FOR DATA COLLECTION PURPOSES

casting lot: single production pour from a master heat.

heat: quantity of metal with one chemical composition, produced by a recognized production process from a single primary melt of the metal. Remelted ingot material is not recognized as a separate heat unless it is produced from a melt having a different chemical composition than the other heats.

hot isostatically pressed component lot: a number of parts made from a single powder blend consolidated in the same hot isostatic press using the same pressure, temperature, and time parameters, and heat treated in the same final heat-treatment charge.

powder blend: a homogeneous mixture of powder from one or more heats of the same grade. The term "powder blend" shall be substituted for the term "heat" for hot isostatically pressed powder material in IV-300, IV-700, IV-900, IV-1200, IV-1400, and IV-1800.

wrought lot: quantity of metal made by melting followed by working or by working and heat treatment as a unique batch. Different lots may come from the same heat and may be made into different product forms. Lot definitions are expected to be found in the applicable material specifications.

IV-700 REQUIRED SAMPLING

For all mechanical properties, data shall be provided over the required range of test temperatures from at least three heats of material meeting all of the requirements of the applicable specifications. Data submitted on three heats of one wrought product form for which coverage is requested may be considered to be applicable for all other wrought product forms having the same chemistry.

For wrought materials and especially for those materials whose mechanical properties are enhanced by heat treatment, forming practices, or a combination thereof, and for other materials for which the mechanical properties may be reasonably expected to be thickness dependent, data from one additional lot from material of at least 75% of the maximum thickness for which coverage is requested shall be submitted. If no maximum thickness is given, information shall be provided to support the suitability of the thickness used for the tested samples.

When adoption of cast product forms is requested, data from at least three heats for one of the cast product forms shall be submitted. The cast material shall be considered as a separate material even if its nominal composition is the same or very similar to that of an approved wrought material.

If the hot isostatically pressed powder material meets all of the requirements of Table IV-100-1, it shall be considered the same material as that of the approved wrought material for temperatures approximately 50°F (25°C) below the temperature where time-dependent properties, as defined by the Time-Dependent Properties Notes (T Notes) in the applicable allowable stress table for the approved wrought material, govern.

If the hot isostatically pressed material is to be used at temperatures where the time-dependent properties, as defined by the Time-Dependent Properties Notes (T Notes) in the applicable allowable stress table for the approved wrought material, govern, the requirements of this Appendix relative to the provision of data for new materials shall apply.

If the hot isostatically pressed powder material does not meet all of the requirements of Table IV-100-1, it shall be considered as a separate material to that of the approved wrought material. In this case, the requirements of this Appendix relative to the provision of data for new materials shall apply.

Additional data for other heats tested to a lesser degree than described herein would be beneficial to the Committee's consideration.

IV-800 TIME-INDEPENDENT PROPERTIES

For time-independent properties at and above room temperature, the required data include values of ultimate tensile strength, 0.2% offset yield strength, reduction of area (when specified in the material specification), and elongation. For steels, nickel alloys, cobalt alloys, and aluminum alloys, data shall be provided at room temperature and 100°F (50°C) intervals, beginning at 200°F (100°C) to 100°F (50°C) above the maximum intended use temperature, unless the maximum intended use temperature does not exceed 100°F (40°C). For copper alloys, titanium alloys, and zirconium alloys, data shall be provided at room temperature, 150°F (65°C), and 200°F (100°C), and then at 100°F (50°C) intervals, to 100°F (50°C) above the maximum intended use temperature, unless the maximum intended use temperature does not exceed 100°F (40°C). The test methods shall be as given in ASTM A370, ASTM A1058, ASTM E8, ASTM E21, or other equivalent national or international test standards. In addition, when specified in the material specification, hardness values shall be provided at room temperature and shall be determined as specified in the material specification. Data provided shall be expressed in the units and to the number of significant figures shown in Table IV-800-1. When either the material specification or the applicable construction code (e.g., Section XII) permits or requires that yield strength be determined by other than the 0.2% offset method, those other yield strength values shall also be reported.

IV-900 TIME-DEPENDENT PROPERTIES

If approval is desired for temperatures where time-dependent properties may be expected to control design, time-dependent data, as itemized below, shall be provided, starting at temperatures approximately 50°F (25°C) below the temperature where time-dependent properties may govern and extending at least 100°F (50°C) above the maximum intended use temperature. Exceptions to this rule are permitted, provided the inquirer provides suitable justification for the deviation. The creep–rupture test method shall be in accordance with ASTM E139 or other equivalent national or international test standard.

For time-dependent tests, the interval between successive temperatures shall be chosen such that it permits, in all cases, an accurate estimation of the slope of the stress-rupture curves. For normally stable materials (e.g., solid solution-strengthened materials), test temperatures shall be at intervals of 100°F (50°C) or less. Where there is a possibility of degradation of strength related to metallurgical instability (e.g., for precipitation-strengthened materials), test temperatures shall be at intervals of 50°F (25°C) or less. Data provided shall be expressed in the units and to the number of significant figures shown in Table IV-800-1.

In addition, for certain types of steels or alloys, it may be necessary to choose different temperature intervals in order to adequately reflect the evolution of the properties. In such cases, the interval between successive test temperatures shall be chosen such that rupture lives do not differ by more than a factor of 10 at any given stress for two adjacent temperatures. Data to be reported include stress, temperature, time to rupture, and, when available, either or both elongation and reduction of area. Additional comments regarding post-test specimen appearance (e.g., oxidation, necking, intergranular fracture, etc.), as well as photographs and photomicrographs, may be beneficial for the analysis.

Except as provided further below, the longest rupture time at each test temperature shall be in excess of 10,000 hr for each required heat. At least three additional tests shall be conducted for each required heat at each test temperature, at stresses selected to provide shorter rupture times but at least 500 hr (e.g., 500 hr, 1,400 hr, and 4,000 hr).

Tests of shorter duration than about 500 hr are not desired for long-term stress rupture prediction. Obviously, longer times and additional test data are beneficial. At

Table IV-800-1
ASTM Test Methods and Units for Reporting

ASTM Designation	Title	Property	U.S. Customary Units	U.S. Customary Significant Figures	Metric Units	Metric Significant Figures
A370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products	Tensile strength and yield strength	ksi	3	...	...
A1058	Standard Test Methods for Mechanical Testing of Steel Products—Metric	Tensile strength and yield strength	...	...	MPa	3
D2766	Standard Test Method for Specific Heat of Liquids and Solids	Specific heat [Note (1)]	Btu/lb-°F	3	J/kg-K	3
E8	Standard Test Methods for Tension Testing of Metallic Materials	Tensile strength and yield strength	ksi	3	MPa	3
		Density	lb/in.^{3}	3	kg/m^3	4
E21	Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials	Tensile strength and yield strength	ksi	3	MPa	3
E132	Standard Test Method for Poisson's Ratio at Room Temperature	Poisson's ratio	...	2	...	2
E139	Standard Test Methods for Conducting Creep, Creep–Rupture, and Stress–Rupture Tests of Metallic Materials	Rupture time	hr	5	h	5
E228	Standard Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer	Instantaneous coefficient	(in./in./°F) × 10^{-6}	3	(mm/mm/°C) × 10^{-6}	3
		Mean linear coefficient	(in./in./°F) × 10^{-6}		(mm/mm/°C) × 10^{-6}	
		Linear coefficient	in./100 ft		mm/m	
E289	Standard Test Method for Linear Thermal Expansion of Rigid Solids With Interferometry	Instantaneous coefficient	in./in./°F × 10^{-6}	3	(mm/mm/°C) × 10^{-6}	3
		Mean coefficient	in./in./°F × 10^{-6}		(mm/mm/°C) × 10^{-6}	
		Linear coefficient	in./100 ft		mm/m	
E831	Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis	Instantaneous coefficient	(in./in./°F) × 10^{-6}	3	(mm/mm/°C) × 10^{-6}	3
		Mean linear coefficient	(in./in./°F) × 10^{-6}		(mm/mm/°C) × 10^{-6}	
		Linear coefficient	in./100 ft		mm/m	
E1225	Standard Test Method for Thermal Conductivity of Solids Using the Guarded-Comparative-Longitudinal Heat Flow Technique	Thermal conductivity	Btu/hr-ft-°F	3, except 2 for x < 10	W/m × °C	4, except 3 for x < 100
E1461	Standard Test Method for Thermal Diffusivity by the Flash Method	Thermal diffusivity	ft^2/hr	3	m^2/sec × 10^{-6}	3
		Thermal conductivity	Btu/hr-ft-°F	3, except 2 for x < 10	W/m × °C	4, except 3 for x < 10
E1875	Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio by Sonic Resonance	Modulus of elasticity	psi × 10^6	3	MPa × 10^3	3

NOTE:
(1) Specific heat is not published but may be used to calculate thermal diffusivity from thermal conductivity.

successive temperatures, two or more test stresses should be selected to be preferably identical or in a close range.

Alternative test plans that deviate from the prior description but achieve the overall objective may be considered. This may, in particular, apply to solid solution alloys for which the stability of strength-controlling microstructures is certain.

For new materials for which the expectation of reasonable stability of strength-controlling microstructures is uncertain or suspect, and for extension of allowable stresses of more familiar classes of alloys into much higher temperature applications where such stability might come into question, either creep–rupture data with duration of more than 30,000 hr or equivalent experience in service is required. A Code Case may be approved based on shorter duration test data, but inclusion of the material into one of the sections of the BPV Code may be deferred until longer-term creep–rupture data are available or until sufficient service experience is obtained to provide confidence that extrapolations from the existing database reasonably describe the long-term behavior of the material.

For at least two heats, strain–time plots or minimum creep rate (MCR) data shall be provided for at least two test stresses at each test temperature, including at least one stress for each material resulting in MCR values below 3×10^{-4} %/hr. If it can be conclusively demonstrated that creep rate does not control the design stresses, the creep rate data may be sparse in relation to the above requirement. Creep rate data may be obtained in the course of stress–rupture testing or may be obtained on additional specimens.

IV-1000 LOW-TEMPERATURE PROPERTIES

If use of the material below room temperature is contemplated, data should be provided at appropriate temperatures down to the lowest contemplated use temperature.

IV-1100 TOUGHNESS DATA

Toughness data shall be provided for materials for which Construction Code toughness rules would be expected to apply. The test requirements shall be as required by the requested Construction Code(s). The data shall include test results for the intended lowest service metal temperature and for the range of material thicknesses desired.

IV-1200 STRESS–STRAIN CURVES

If the material is to be used in components that operate under compressive loads (e.g., external pressure), stress–strain plots (tension or compression) shall be furnished for each of the three heats of material at 100°F (50°C) intervals from room temperature up to 100°F (50°C) above the maximum temperature desired.[1] Engineering stress–strain data (stress versus strain) shall be provided in the form of stress–strain plots and digitized data, from which the plots were derived, in tabular form up to 1.2% strain. Digitized data shall be provided at intervals no greater than 0.01% strain. In addition, the minimum yield strength,[2] modulus of elasticity,[3] and proportional limit, for materials where a proportional limit can be identified, shall be reported for each temperature. The stress–strain plots (not load versus extension) shall be determined using a Class B-2 or better-accuracy extensometer as defined in ASTM E83. The plots shall include gridlines with the units marked on the gridlines: for strain, minor gridlines at intervals of 0.01% and major gridlines at 0.1%, up to 1.2% strain; and for stress, minor gridlines at 0.2 ksi (2 MPa) and major gridlines at 2.0 ksi (20 MPa).

IV-1300 FATIGUE DATA

If the material is to be used in cyclic service and the Construction Code in which adoption is desired requires explicit consideration of cyclic behavior, fatigue data for characterized samples shall also be furnished over the range of design temperatures desired, from 10^3 to at least 10^6 cycles.

IV-1400 PHYSICAL PROPERTIES

For at least one heat meeting the requirements of the material specification, the inquirer shall furnish to the Boiler and Pressure Vessel Committee on Materials adequate data necessary to establish values for coefficient of thermal expansion, coefficients of thermal conductivity and diffusivity, modulus of elasticity, Poisson's ratio, and density. Test methods shall be as follows:

(a) ASTM E228, E289, or E831 for thermal expansion coefficients

[1] Since most materials are, in many applications, used in components that operate under compressive loads, the Committee recommends that stress–strain plots as described above should always be included in the data package submitted in support of the application for any new material.

[2] The term *minimum yield strength*, as used here, means the yield strength values that are derived from the analysis of the tensile data required elsewhere in these Guidelines.

[3] Modulus of elasticity values shall be determined by dynamic methods such as ASTM Test Method E1876 (latest edition) or other international equivalent.

(b) ASTM D2766, E1225, and E1461, for thermal conductivity and thermal diffusivity

(c) ASTM E1875 for modulus of elasticity

(d) ASTM E1875 or ASTM E132 for Poisson's ratio

Data from other equivalent national or international test standards shall be acceptable in lieu of those listed above. Instantaneous, mean, and linear coefficients of thermal expansion shall be reported. Data for all physical properties shall be provided at least over the range of temperatures for which the material is to be used. It is recommended that data be collected at temperature intervals not greater than 100°F (50°C). If the material is intended to be used below room temperature, data should be provided for temperatures down to the minimum use temperature. Data provided shall be expressed in the units and to the number of significant figures shown in Table IV-800-1.

IV-1500 DATA REQUIREMENTS FOR WELDS, WELDMENTS, AND WELDABILITY

The following three types of welding information are required for a new base metal for use in welded construction in an ASME BPV Construction Code: data on weldability, data on strength and toughness in the time-independent regime, and data on strength in the time-dependent regime.

The data requirements for weldability and for strength in the time-independent regime are the responsibility of the BPV IX Standards Committee and are to be found in Section II, Part C, Guideline on the Approval of New Welding and Brazing Material Classifications Under the ASME Boiler and Pressure Vessel Code; and in Section IX, Mandatory Appendix J, Guideline for Requesting P-Number Assignments for Base Metals Not Listed in Table QW/QB-422. The requirements for weld metal and weldment toughness data vary with the class of materials and their application, and are to be found in the Construction Codes that have toughness rules — Sections III, VIII, and XII.

Data for welds and weldments for a new base material for use in the time-dependent regime are the responsibility of the BPV II and BPV IX Standards Committees, and particularly of their joint Subgroup on Strength of Weldments. The following welding information shall be provided by the Inquirer, to support the request for a Code Case for, or incorporation of, a new base material for use in elevated temperature service:

(a) When there is one or more AWS, ASME, or equivalent consumable specification and classification suitable for use with the new base material, and when such consumable/process combinations can produce welds and weldments that have both good weldability and as high or higher strengths as the base metal over the range of expected service temperatures, no time-dependent test data is required. Rather, the inquirer shall submit a tabular or graphical comparison of time-dependent allowable stresses for base metals nominally matching the compositions of such welding consumables against the allowable stresses proposed for the new base metal. (Note that since neither ASME nor any other organization publishes allowable stresses for all-weld metal or for weldments, it is necessary to use, in this comparison, the allowable stresses for the base metals equivalent to the welding consumables as a reasonable first approximation.) An example of such a comparison appears in Table IV-1500-1.

(b) When there is no such suitable consumable having an AWS, ASME, or equivalent specification and classification, or when it is necessary or desirable to use a new, perhaps nominally matching, welding consumable, the following information shall be provided to the Committee:

(1) the chemistry ranges for each element specified for the consumable to be used. If the chemistry ranges vary for the consumables to be used for different processes, then the chemistry ranges of the consumables appropriate for each process shall be provided.

(2) creep–rupture data for weldments made with one lot of consumables for each process intended to be used with the new base material

(-a) at temperature intervals not greater than 200°F (100°C)

(-b) over a temperature range spanning the range from the first rational temperature above the temperature at which time-dependent properties control the allowable stresses of the new base material to about 100°F (50°C) above the maximum temperature for which allowable stresses for the base material are requested

(-c) at a minimum of four stresses calculated to produce rupture times of about 1000, 2500, and 4500 hr, and beyond 6000 hr

(-d) the test temperature; stress; rupture time; specimen size and configuration, including weld location; and failure location (base metal, weld metal, or heat affected zone), for each test condition

(-e) the creep–rupture data shall be compared to the scatter bands of data for the base metal

IV-1600 LONG-TERM PROPERTIES STABILITY

For new materials, and particularly for those whose creep–rupture properties are affected by heat treatment or deformation processes or a combination of these, it is important to know the structural stability characteristics and the degree of retention of properties with long-term exposure at temperature. Where particular temperature ranges of service exposure or fabrication heat treatment, cooling rates, and combination of mechanical working and thermal treatments cause significant changes in the microstructure on which the creep–rupture properties depend, these shall be brought to the attention of the BPV Committee.

Table IV-1500-1
Example of a Comparison of Allowable Stresses of Base Metals With Compositions Similar to Those of Selected Welding Consumables and the Proposed New Base Metal

Comparison of Nominal Chemical Compositions, %, and Specified Mechanical Properties of Ni-Base Alloys in Section II, Part B

Grade	Ni	Cr	Fe	Mn	Mo	Co	Al	C	Cu	B	Si	Ti	W	Cb + Ta	Ultimate Tensile Strength, ksi (MPa)	Yield Strength, ksi (MPa)
N06230	Bal. ≈ 53	22	3	0.65	2	5	0.5	0.1	...	...	0.5	...	14	...	110 (760)	45 (310)
N06600	72 min.	15.5	8	0.5	...	...	...	0.1	0.25	...	0.25	...	...	...	80 (550)	35 (240)
N06617	44	22	1.5	0.5	9	12	1.2	0.1	0.25	0.005	0.5	0.4	...	...	95 (665)	35 (240)
N06625	58 min.	21.5	5	0.5	9	1	0.4	0.1	0.4	...	0.5	0.4	...	3.65	120 (827)	60 (414)
N06696	Bal. ≈ 60	30	4	0.2	2	...	...	0.07	2	...	1.5	0.2	...	...	85 (586)	35 (240)

Comparison of Allowable Stresses of Ni-Base Alloys in Section II, Part B (ksi at Temperature, °F, Estimated for N06696)

Grade	P-No.	950	1,000	1,050	1,100	1,150	1,200	1,250	1,300	1,350	1,400	1,450	1,500	1,550	1,600	1,650	1,700	1,750	1,800
N06230	43	20.9	20.9	20.9	20.9	19.0	15.6	12.9	10.6	9.5	6.7	5.3	4.1	2.9	2.1	1.5	1.1	0.70	0.45
N06600	43	10.6	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	...	...	...
N06617	43	21.0	20.9	20.9	20.8	20.7	18.1	14.5	11.2	8.7	6.6	5.1	3.9	3.0	2.3	1.8	1.4	1.1	0.73
N06625	43	26.6	26.4	26.3	26.2	26.1	20.0	15.0	11.6	8.5	6.7	4.9	3.8	2.6	1.9	...	...	...	...
N06696	TBD	17.9	14.1	11.0	8.6	6.7	5.2	4.1	3.2	2.4	1.8	1.4	1.1	0.76	0.59	0.47	0.37	0.29	0.23

Comparison of Allowable Stresses of Ni-Base Alloys in Section II, Part B (MPa at Temperature, °C, Estimated for N06696)

Grade	P-No.	500	550	600	650	700	750	800	850	900	950	1 000
N06230	43	194	194	151	102	75.5	50.4	32.9	18.4	10.2	5.2	2.4
N06600	43	79.7	40.1	19.0	13.8	...	...	...	...	...	...	...
N06617	43	108	106	106	105	81.0	50.4	31.3	19.4	12.3	7.5	...
N06625	43	184	182	178	136	84.3	50.2	30.3	16.5	...	...	...
N06696	TBD	139	87.0	55.6	35.5	22.8	13.9	9.0	4.9	3.2	2.1	1.4

GENERAL NOTE: In this example, the proposed new base metal is N06696.

IV-1700 REQUESTS FOR ADDITIONAL DATA

The Committee may request additional data, including data on properties or material behavior not explicitly treated in the Construction Code for which approval is desired.

IV-1800 NEW MATERIALS CHECKLIST

To assist inquirers desiring Code coverage for new materials, or extending coverage of existing materials, the Committee has developed the following checklist of items that ought to be addressed in each inquiry. While taking into account the intended application of the product, the Committee may require specific information from the inquirer, as shown above for certain material characteristics.

(a) Has a qualified inquirer request been provided?

(b) Has a request either for revision to existing Code requirements or for a Code Case been defined?

(c) Has a letter to ASTM or AWS been submitted requesting coverage of the new material in a specification? Alternatively, is this material already covered by a specification issued by a recognized national or international organization and has an English language version been provided?

(d) Has the Construction Code and, if applicable, a Division, Subsection, or Part been identified?

(e) Have product forms, size range, and the applicable specification(s) been defined?

(f) Has the range (maximum/minimum) of temperature application been defined?

(g) Has the chemistry been submitted and the related requirements been addressed?

(h) Have the metallurgical structure and heat treatment requirements been submitted?

(i) Have mechanical property data been submitted (ultimate tensile strength, yield strength, reduction of area, and elongation at 100°F (50°C) intervals, from room temperature to 100°F (50°C) above the maximum intended use temperature, for three heats of appropriate product forms and sizes?

(j) If requested temperatures of coverage are above those at which time-dependent properties begin to govern design values, have appropriate time-dependent property data for base metal and weldments been submitted?

(k) If higher allowable stresses for material to be used below room temperature are requested, have appropriate mechanical property data below room temperature been submitted?

(l) Have toughness considerations required by the Construction Code been defined and have appropriate data been submitted?

(m) Have stress–strain curves been submitted for the establishment of External Pressure Charts?

(n) If cyclic service considerations are required by the requested Construction Code application, have appropriate fatigue data been submitted?

(o) Have physical properties data (coefficient of thermal expansion, thermal conductivity and diffusivity, modulus of elasticity, Poisson's ratio, and density) been submitted?

(p) Have welding requirements been defined, and weld metal and weldment data been submitted?

(q) Has the influence of fabrication practices on material properties been defined?

IV-1900 REQUIREMENTS FOR RECOGNIZED NATIONAL OR INTERNATIONAL SPECIFICATIONS

Acceptable material specifications will be identified by date or edition. The latest approved edition(s) will be stated in the subtitle of the ASME specification. Eventually, acceptable previous editions will be listed in Section II, Parts A and B. Minimum requirements that shall be contained in a material specification for which acceptance is being requested include such items as the name of the national or international organization, scope, reference documents, process, manufacture, conditions for delivery, heat treatment, chemical and tensile requirements, forming properties, testing specifications and requirements, workmanship, finish, marking, inspection, and rejection.

IV-2000 PUBLICATION OF RECOGNIZED NATIONAL OR INTERNATIONAL SPECIFICATIONS

Specifications for which ASME has been given publishing permission by the originating organization will be published in Section II, Parts A and B. Specifications for which ASME has not been given publishing permission by the originating organization will be referenced on a cover sheet in Section II, Parts A and B. Information on obtaining a copy of those referenced documents will be maintained in those Parts. Additions and exceptions to the material specification will be noted in the subtitle of the specification and in Table II-200-1 or II-200-2 in Section II, Parts A and B.

IV-2100 CEN SPECIFICATIONS

European Standards are adopted by CEN in three official languages (English, French, and German) as an EN standard. After the CEN adoption, to become applicable in a member country of CEN, an EN standard shall be given the status of a national standard. During this process

(a) the text of the EN standard shall remain unaltered and shall be included as adopted by CEN

(b) national forewords and/or annexes may be added to cover specific national practices, but shall not be in contradiction with the EN standard

(c) a prefix XX (e.g., XX = BS for the United Kingdom, NF for France, and DIN for Germany) is added to the designation of the EN standard (e.g., BS EN 10028-1 or NF EN 10028-1)

(d) the date of adoption as a national standard will differ from the date of adoption as an EN standard, and may differ from one country to another

Written or electronic copies can only be obtained from European National Standardization Bodies as XX EN (CEN does not sell standards). Consequently, in order to maintain coherence and homogeneity in the reference system, the mentions in the subtitle of the corresponding ASME specification will only refer to the EN standard number without any prefix and to the year of approval by CEN. It will also be mentioned in the cover sheet that the national parts do not apply for the ASME specification.

NONMANDATORY APPENDIX A
SOURCES OF STANDARDS

This Nonmandatory Appendix provides information for obtaining official English language copies of specifications and their references for which ASME has not been given permission to publish by the originating organization.

Standard Type	Standards Organization	Contact Information
AS	Standards Australia Limited (Standards Association of Australia)	Level 10, The Exchange Centre 20 Bridge Street GPO Box 476 Sydney NSW 2001 Australia Tel: +61 2 9237 6171 Fax: +02 9237 6010 www.standards.org.au
BS	British Standards Institution	389 Chiswick High Road GB-London W4 4AL, Great Britain Tel: +44 20 8996 9000 Fax: + 44 20 8996 7001 12110 Sunset Hills Road, Suite 200 Reston, VA 20190-5902 Tel: 1.800.862.4977 Fax: 703.437.9001 www.bsigroup.com
CSA	Canadian Standards Association	178 Rexdale Blvd. Toronto, Ontario Canada M9W 1R3 Tel: 416-747-4000; (800) 463-6727 www.csa.ca
DIN	Deutsches Institut für Normung e.V.	Burggrafenstrasse 6 10787 Berlin, Germany Tel: + 49 30 2601-0 Fax: + 49 30 2601-1231 www.din.de
EN	Any member of the European Committee for Standardization (CEN)	A list of CEN members can be obtained from www.cenorm.be; alternatively standards may be obtained directly from any of the CEN members listed herein.
GB	China Standardization Committee on Boilers and Pressure Vessels	No. 24 Xiaoguan Street Anwai Chaoyang District Beijing, China 100029 Tel: + 86 10 644 157 59 Fax: + 86 10 644 157 49 sale.gb168.cn/saleagent/Customer_En/Default.aspx
IS	Bureau of Indian Standards	Manak Bhawan 9, Bahadur Shah Zafar Marg New Delhi 110002, India Tel: + 91 11 23230131 Fax: + 91 11 23234062 www.bis.org.in
JIS	Japanese Standards Association	Mita MT Building 3-13-12, Mita, Minato-ku Tokyo, 108-0073 Japan Tel: + 81 3 4231 8500 Fax: + 81 3 4231 8650

Table continued

Standard Type	Standards Organization	Contact Information
NBN	Institut Belge de Normalisation (Belgisch Instituut voor Normalisatie)	Bureau de Normalisation Rue Joseph II 40/6 1070 Brussels, Belgium Tel: +32 2 738 01 11 Fax: +32 2 733 42 64 www.nbn.be
NF	Association Française de Normalisation	11, avenue Francis de Pressensé F-93571 Saint-Denis La Plaine Cedex, France Tel:+33141628000 Fax:+33149179000 www.afnor.org
ÖNORM	Österreichisches Normungsinstitut (Austria)	Heinestraße 38 1020 Wien Austria Tel: +43 1 21 300 - 805 Fax: +43 1 21 300 - 815 www.austrian-standards.at/en/home/

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