American Welding Society
LEARNING

Study Guide: API 1104

Twenty-First Edition

STUDY GUIDE
for
API Standard 1104:
Welding of Pipelines
and Related Facilities
21st Edition

CWI
Seminar

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Study Guide

for

API Standard 1104 Welding of Pipelines and Related Facilities

TWENTY-FIRST EDITION

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Abstract

This study guide contains information on the use of API Standard 1104, Twenty-First Edition, which will assist the student in learning how to use the standard as well as in preparing for code-related examinations. Material is provided for each of the 13 sections of the standard and Annexes A and B. Exercise questions and answers are provided for each section and annex, and additional practice tests are included at the end.

American Welding Society®

EDUCATION

Study Guide for API Standard 1104, Twenty-First Edition

Foreword

AWS Education Services has published this Study Guide for API 1104 to assist quality professionals—inspectors and supervisors—and quality-conscious engineers and managers in reading, understanding, and learning to apply the American Petroleum Institute's (API) Standard 1104, Welding of Pipelines and Related Facilities, Twenty-First Edition. This Study Guide was written specifically for the 21st Edition with Errata 4 and Addendum 2. For other errata or addenda, page numbers may be different.

The API Standard 1104 applies to the welding of piping used in the compression, pumping, and transmission of petroleum products, fuel gases, carbon dioxide, and nitrogen. The standard's purpose is to present methods for the production and inspection of high-quality welds through the use of qualified personnel using approved procedures, materials, and equipment. It applies to new construction and in-service welding and is voluntary.

This API 1104 Study Guide consists of an introduction, 15 sections, each covering the corresponding section or annex of the standard along with exercise questions for each section, and several groups of practice questions with an answer key.

Answering the practice questions serves as a valuable review of the section contents. These questions also illustrate the types of questions you're likely to encounter on the AWS CWI exam.

In addition to explanations of each section of API 1104, in some cases, this Study Guide also provides a commentary or examples to further explain the provision.

As you read this book, open the standard to the corresponding page.

Remembering excerpts from the standard is neither necessary nor desirable. You need not memorize the standard; just learn how to use it.

The American Welding Society appreciates feedback from participants in its education programs. Please send comments or questions to:

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or contact the AWS Education Services Department by email at aws.seminars@aws.org. Additional information on AWS products and services may be found on our website at www.aws.org.

Study Guide Table of Contents

INTRODUCTION: HOW TO USE API 1104

Definition of Documents

All codes, standards, and specifications are conceptually similar, but each has a specific application and purpose. API 1104 is a good example of the concept, so learning to use this standard will help you learn to use others as well.

A CODE is a body of laws arranged systematically for easy reference and use. Because a code has legal status, it is, by definition, mandatory, and it uses words such as shall, will, and must to express requirements and to verify that those requirements are being met. Examples of codes include the AWS D1.1 Structural Welding Code — Steel, the AASHTO/AWS D1.5 Bridge Welding Code, and the ASME B31.1 Power Piping Code.

A STANDARD is established for use as a rule or basis of comparison in measuring quality, quantity, content, relative value, etc. API Standard 1104, Welding of Pipelines and Related Facilities, is an example. So are the AWS A3.0, Standard Welding Terms and Definitions and AWS QC1 Standard for AWS Certification of Welding Inspectors.

A SPECIFICATION is a detailed description of the parts of a whole; a statement or enumeration of particulars, as to actual or required size, quality, performance, terms, etc. Thus, a specification describes all pertinent technical information for a material, product, system, or service, and indicates how to determine that the requirements have been met. Examples include the AWS Filler Metal Specifications A5.1 through A5.36.

A RECOMMENDED PRACTICE is a description of generally accepted industrial methods and techniques. One of the most common examples is ASNT's Recommended Practice No. SNT-TC-1A, ASNT's guideline to personnel qualification and certification in nondestructive examination.

Less Than or Greater Than?

In many codes and standards, including API 1104, the rules vary depending on the size of a part, the intended service, and the manufacturing requirements. Often these rules are differentiated symbolically. Most people know that = means "equal to" but the symbols for "less than" and "greater than" can cause confusion. Here's an easy way to keep them straight:

"<" is the symbol for "less than" and it points to the left. Example: $5 < 9$ indicates that five is less than nine.

">" is the symbol for "greater than" and it points to the right. Example: $9 > 5$ indicates that nine is greater than five.

"≤" is the symbol for "less than or equal to."

"≥" is the symbol for "greater than or equal to."

Other Definitions

Section 3 Terms, Definitions, Acronyms, and Abbreviations presents a list of welding terms and their definitions that adds on to and, in some cases, supersedes those listed in AWS 3.0 Standard Welding Terms and Definitions. Many of the terms defined in Section 3 are specific to API 1104.

The Meaning of Quality

Quality is generally understood to mean measurable conformance to specifications. To establish product quality, purchasers invoke or mandate certain codes, standards, and/or specifications that state the requirements to which the product must conform. Thus, quality professionals must be able to read, understand, and apply the provisions of the governing documents cited in a contract, job specification or purchase order.

For test-taking purposes, to find requirements in a code or standard more quickly, you should attach an index tab to the first page of each section and to significant tables and figures that you will use frequently. In addition, it may be helpful to briefly describe the contents of the section on that tab. API 1104 has 13 sections and two annexes that are included in the scope of the AWS CWI exam. See Study Guide Figure A below.

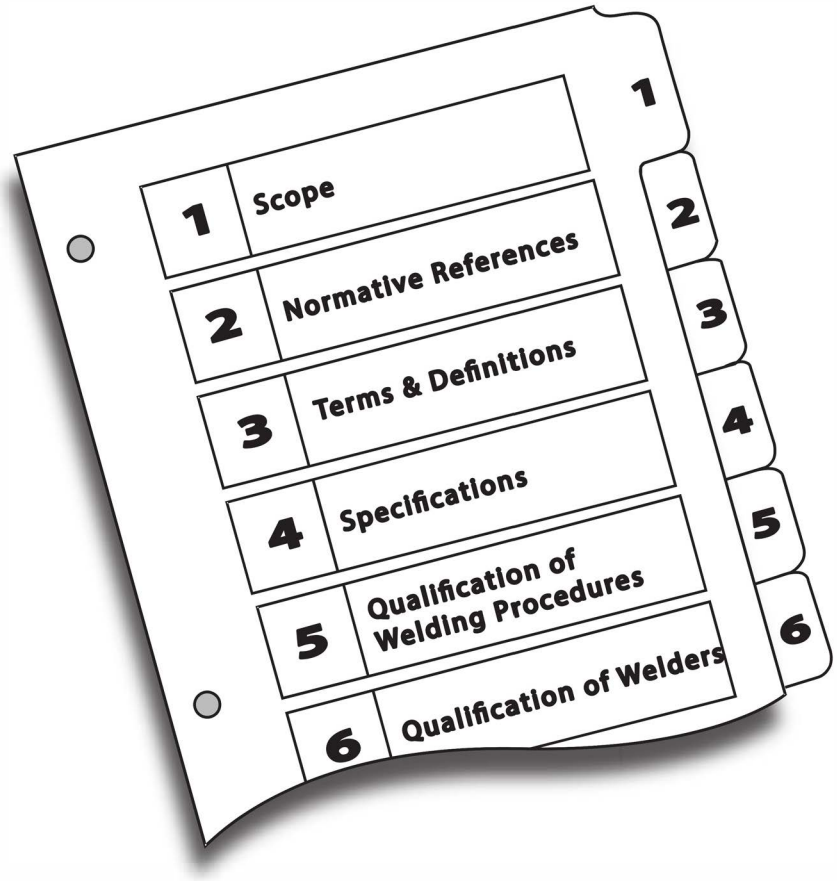

Figure A: Section ID Tabs

Many codes and standards make extensive use of notes, which may be footnotes in tables or figures or general notes incorporated into the text, to explain something or to cover special cases or particular circumstances. Every time you read the provisions of a code or standard, be thorough and pay close attention to any notes.

Carefully review the tables and figures, being attentive to superscripts and their corresponding footnotes, which can modify the application of the information in the table or figure. In many cases, the answer to a given code or standard inquiry will either be modified by the footnote or contained completely within the footnote. If the question does not invoke the conditions of the footnote, the footnote does not apply.

You will see three types of footnotes. They are:

(a) Global or general footnotes—These appear in the title of a figure, list, or table and they influence all provisions from that figure, list, or table. Sometimes general footnotes are located in the footer of a table or figure and are labeled as "NOTE(S)."

(b) Regional footnotes—These appear in the column header or at the end of a row title in a table or at the top of a subsection and influence only that column or row of the table or that specific subsection of text.

(c) Local or specific footnotes—These apply only to the specific item being footnoted.

For example, turn to page 15 in API 1104. Note the small superscript letters that follow certain filler metal Group Numbers in Table 1. Each superscript refers to a local footnote, which changes some aspect of the table's provisions for that specific filler metal in the table.

As you work with a code or standard, be aware of applicable Errata Sheets. Errata are published to correct printing errors. If any exist, mark the changes in the code or standard. Subsequent printings of that code or standard will usually incorporate those corrections.

Typically, codes and standards are revised according to a regular schedule. API generally updates its standards every five years, though up to two additional years may be added to a review cycle. See the Foreword of API 1104 for information on ascertaining the status of the Twenty-First Edition.

Finding Provisions

Codes and standards typically use the multiple decimal numbering system. See Study Guide Figure B below. The first "1" in "1.1.1.2.2" is the chapter or section in which the provision is found. The second "1" is the subsection within Section 1. However, for simplicity, in this Study Guide, any indented reference further than the second (subsection) number will be referred to simply as a "paragraph." For instance, Section 5 is where rules for qualifying welding procedures using manual or semiautomatic welding processes are found. Subsection 5.4 lists the essential variables but "paragraph" 5.4.2.2 addresses base materials.

1.
1.1
    1.1.1- -
    1.1.2- -
1.2
    1.2.1- -
    1.2.2- -
2.

Figure B Multiple Decimal Numbering System

A provision is the specific text contained within a numbered section, subsection, or paragraph of a code or standard.

When you use a code or standard, identify the key term or phrase that best describes the issue or requirement of interest and then locate the provision that best addresses that issue or requirement.

Although you might find a particular provision by paging through the standard, a more systematic approach is to convert the information you seek into a question, then analyze the question to identify key words or phrases. In API 1104, look for those key words or phrases in the table of contents to locate the applicable provisions by section or subsection number. Those numbers are called references. Then locate those references in the text.

Reference Exercise

For the radiographic test method, how long after processing of the developed film shall the images still be interpretable?

Key Words: a) radiographic test method

b) processed, handled, and stored

Check Contents: Section 11 Procedures for NDT on page vi and

Subsection 11.1 Radiographic Test Methods

Look it up: Find reference 11.1.10.4 Image Processing on page 61.

Provision: “When requested by the company, film or other imaging media shall be processed, handled, and stored so that the images are interpretable for at least three years after they are produced.”

API 1104 Contents

API 1104 contains 13 sections and three annexes. They are:

1. Scope

2. Normative References

3. Terms, Definitions, Acronyms, and Abbreviations

4. Specifications

5. Qualification of Welding Procedures with Filler Metal Additions

6. Qualification of Welders

7. Design and Preparation of a Joint for Production Welding

8. Inspection and Testing of Production Welds

9. Acceptance Standards for NDT

10. Repair and Removal of Weld Defects

11. Procedures for NDT

12. Mechanized Welding with Filler Metal Additions

13. Automatic Welding Without Filler Metal Additions

Annex A Alternative Acceptance Standards for Girth Welds

Annex B In-service Welding

Annex C Requests for Interpretation and Request for Revision to the Document

This Study Guide follows the structure of API 1104, except that Annex C will not be discussed. Otherwise, the sections and subsections in this Study Guide correspond to those in API 1104.

The table of contents in API 1104 is titled “Contents” and it begins on page v. It contains:

(a) A list of provisions by section and subsection number and title, e.g.,“3.1 Terms and Definitions.” The page on which a given section or subsection begins is to the right of that section or subsection’s title. For the annexes, only the number of the title page is listed.

(b) A list of figures. A figure is a pictorial or schematic illustration. Figures are listed by number, title, and the page on which they appear in the text. The list of figures begins on page vii.

(c) A list of tables. A table is a systematic arrangement of data, typically in rows and columns. Tables are listed by number, title, and the page on which they appear in the text. The list of tables begins on page viii.

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Section 1

Scope

Section 1: Scope

API 1104 provides a list of eight permitted welding processes. They are listed below:

(a) Shielded metal arc welding (SMAW).
(b) Submerged arc welding (SAW).
(c) Gas tungsten arc welding (GTAW).
(d) Gas metal arc welding (GMAW).
(e) Flux-cored arc welding (FCAW).
(f) Plasma arc welding (PAW).
(g) Oxyacetylene welding (OAW).
(h) Flash butt welding (FW).

API 1104 also states that these processes may be applied using manual, semiautomatic, mechanized, or automatic welding techniques or a combination of these techniques. All of these techniques, except manual welding, are defined in Section 3. Study Guide Table 1.1 indicates which techniques are applicable to the permitted welding processes.

API 1104 covers procedures for various NDT methods and the acceptance standards to be applied to production welds. The NDT methods are listed below, along with their AWS abbreviations:

(a) Radiographic testing (RT).
(b) Magnetic particle testing (MT).
(c) Liquid penetrant testing (PT).
(d) Ultrasonic testing (UT).
(e) Visual testing (VT).

The numerical values stated in API 1104 are given in either U.S. Customary units or metric (SI) units. The U.S. Customary values typically appear first, followed by the SI units in parentheses, but the SI units are approximations of the corresponding U.S. customary units. API 1104 emphasizes that you must use one system or the other and not combine them.

Process	Manual	Semi-automatic	Mechanized	Automatic
Shielded metal arc welding (SMAW)	X			
Submerged arc welding (SAW)		X	X	
Gas tungsten arc welding (GTAW)	X	X	X	X
Gas metal arc welding (GMAW)		X	X	X
Flux-cored arc welding (FCAW)		X	X	X
Plasma arc welding (PAW)	X		X	X
Oxyacetylene welding (OAW)	X			
Flash butt welding (FW)				X

Table 1.1

Processes and Techniques

Exercise Questions

Section 1 Scope

1.1 What topic(s) does API 1104 cover?

A. Gas welding of butt welds
B. Arc welding of fillet and socket welds
C. Welding of carbon and low-alloy steel piping
D. Welding of petroleum pipelines
E. All of the above

1.2 Which testing method(s) is(are) specified in API 1104?

A. Nick break tests
B. Only bend tests for butt welds
C. Radiographic testing only
D. Ultrasonic testing only
E. Both radiographic and ultrasonic testing

1.3 Which welding process(es) is(are) addressed in API 1104?

A. Flash butt
B. Submerged arc
C. Oxyacetylene
D. Gas metal arc
E. All of the above

1.4 API 1104 permits the use of both US customary units and metric (SI) units.

A. True, as long as each system is used independent of the other
B. False
C. True, as long as the inspector places the US customary value in parentheses
D. True, as long as the metric values are used in conjunction with the US Customary values
E. The inspector should use codes published in either SI or US Customary units.

1.5 Welds may be produced by:

A. Fixed welding only
B. Position or roll welding only
C. Position welding, roll welding, or a combination of both
D. Only position welding
E. Only roll welding

1.6 API 1104 covers:

A. New construction
B. In-service welding
C. Structural tubular applications
D. Cyclical applications
E. Both A & B

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Section 2

Normative References

Section 2: Normative References

This section lists the standards, codes, and specifications incorporated by reference throughout the standard. The footnotes provide contact information for the organizations that publish these documents. The address for the American Welding Society, however, is incorrect. The correct address is:

8669 NW 36th Street #130
Miami, Florida 33166-6672

Exercise Questions

Section 2 Normative References

2.1 Which of the referenced documents is used by Annex A for evaluating fracture toughness?

A. ASTM E164
B. API Specification 5L
C. AWS A5.28
D. BS EN ISO 15653
E. None of the above

2.2 Which organization writes most of the NDT specifications cited in API 1104?

A. API
B. ASNT
C. ASTM
D. AWS
E. NACE

2.3 Which organization writes the filler metal specifications referenced in API 1104?

A. AWS
B. ASNT
C. ASTM
D. BSI
E. NACE

2.4 Which organization writes a document on personnel certification in NDT methods that is cited by API 1104?

A. API
B. ASNT
C. AWS
D. BSI
E. NACE

2.5 Which of the following is a specification that lists carbon steel rods for use with the GTAW process?

A. AWS A5.1
B. ASTM E747
C. AWS A5.18
D. ER70S-2
E. AWS A5.29

2.6 Which of the following describes procedures for UT of weldments?

A. AWS A5.28
B. ASTM E164
C. ASNT SNT-TC-1A
D. AWS A5.1
E. BS EN ISO 15653

2.7 Which of the following is a document that provides guidance for selection of metallic materials for oil field equipment when sulfide stress cracking is a concern?

A. NACE MR0175
B. E71T-1
C. E6010
D. ASTM E747
E. AWS A5.18

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Section 3

Terms, Definitions, Acronymns, and Abbreviations

Section 3: Terms, Definitions, Acronyms, and Abbreviations

For the purposes of this standard, the welding terms and definitions in AWS A3.0 Standard Welding Terms and Definitions apply with the additions and modifications listed in subsection 3.1. Terms defined in AWS A3.0 are not defined again here. Additional key terms not defined in Section 3 of the standard or AWS A3.0 are defined below:

butt weld. A nonstandard term for a groove weld in a butt joint.

classification (AWS). The AWS designation that lists rods, electrodes and filler metals according to their chemical composition and operating characteristics. Examples include, for SMAW—E7018, for GMAW—ER70S-6, and for GTAW— EWTh-2.

coupon test report. A form that can be used to record either procedure qualification or welder qualification test results or report on a weld coupon from a production weld. It is sometimes referred to as a "weld test report."

crown surface. A nonstandard term for weld face, usually referring to the final bead placed on the outside of a pipe.

destructive testing. Mechanical testing that destroys a sample or part in the process of measuring a specific material property.

essential variable. A variable that has a significant effect on mechanical properties for procedure qualification or welder/operator skill for performance qualification. In general, if the value for an essential variable is changed to a value outside the range qualified, as defined by the code or standard in question, requalification of the procedure or welder/operator by testing is required. The essential variables for procedure and performance qualification are not the same within any given code or standard. Similarly, the essential variables for procedure or performance qualification are not usually the same from one code or standard to the next.

image quality indicator (IQI). A device used to confirm the resolution sensitivity of radiographic images. This is sometimes referred to as a penetrameter or "penny." See Study Guide Figure 3.1 below.

Figure 3.1—Wire-Type IQI

lineup clamp. An external or internal device used to bring two pipe segments into alignment for pre-weld tacking or for welding.

nick break test. A destructive test used to determine the soundness of weld metal by fracturing the specimen through the weld so the fractured surface of the weld metal can be visually examined for the presence of discontinuities.

pipe nipple. A short length or section of a pipe, usually used for qualifying a procedure or a welder.

shielding atmosphere. A gas envelope surrounding the weld area during welding to prevent or reduce the formation of oxides or other detrimental surface substances and facilitate their removal.

socket weld. A fillet weld joining two pipes or a pipe to a pipe fitting, where one pipe is inserted into the other pipe or into the fitting. See Study Guide Figure 3.2 below.

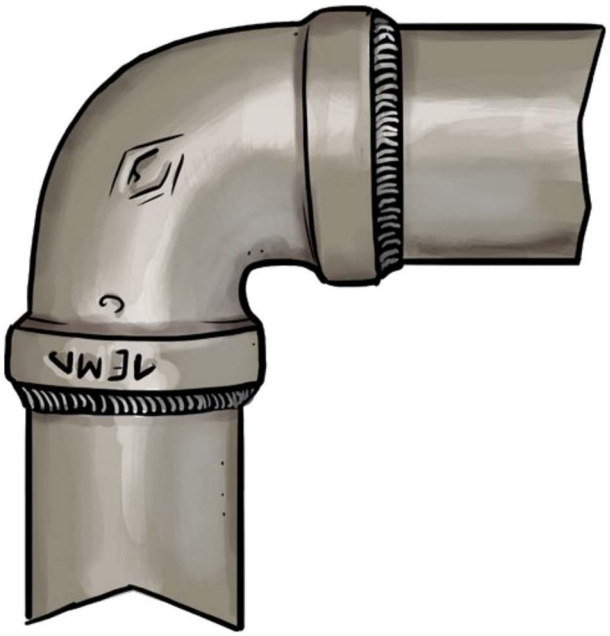

Figure 3.2—Socket Weld

soundness. Relative freedom from imperfections.

soundness testing. Testing done to verify a weldment is free from defects. API 1104 permits the use of bend and nick break destructive tests, as well as radiographic and ultrasonic testing, which are both nondestructive tests.

specification (AWS). An AWS document that lists the rods, electrodes, or filler metals that can be used to weld a given category of base metals with a given category of welding processes. An example is AWS A5.1, Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.

specified minimum tensile strength (SMTS). The minimum ultimate tensile strength, specified by the pipe specification, for any given grade of pipe. For instance, API 5L Grade X52 pipe has a SMTS of 66,000 psi, meaning that a tension test of this pipe will result in an ultimate tensile strength no less than 66,000 psi.

specified minimum yield strength (SMYS). The minimum yield strength, specified by the pipe specification, for any given grade of pipe. For instance, API 5L Grade X52 pipe has a SMYS of 52,000 psi, meaning that a tension test of this pipe will result in a yield strength no less than 52,000 psi.

speed of travel. The rate of welding progression along the weld joint.

tensile strength test. A test in which the specimen is loaded in tension until failure occurs. This is also referred to as a tension test.

trepanning. A process, typically using a hole saw, in which a disc-shaped specimen containing a section of the weld is removed from a pipe weld. The disc is removed so the inspector can evaluate the weld quality and/or the degree of penetration. Trepanning is generally not permitted for production piping applications. See Study Guide Figure 3.3 below.

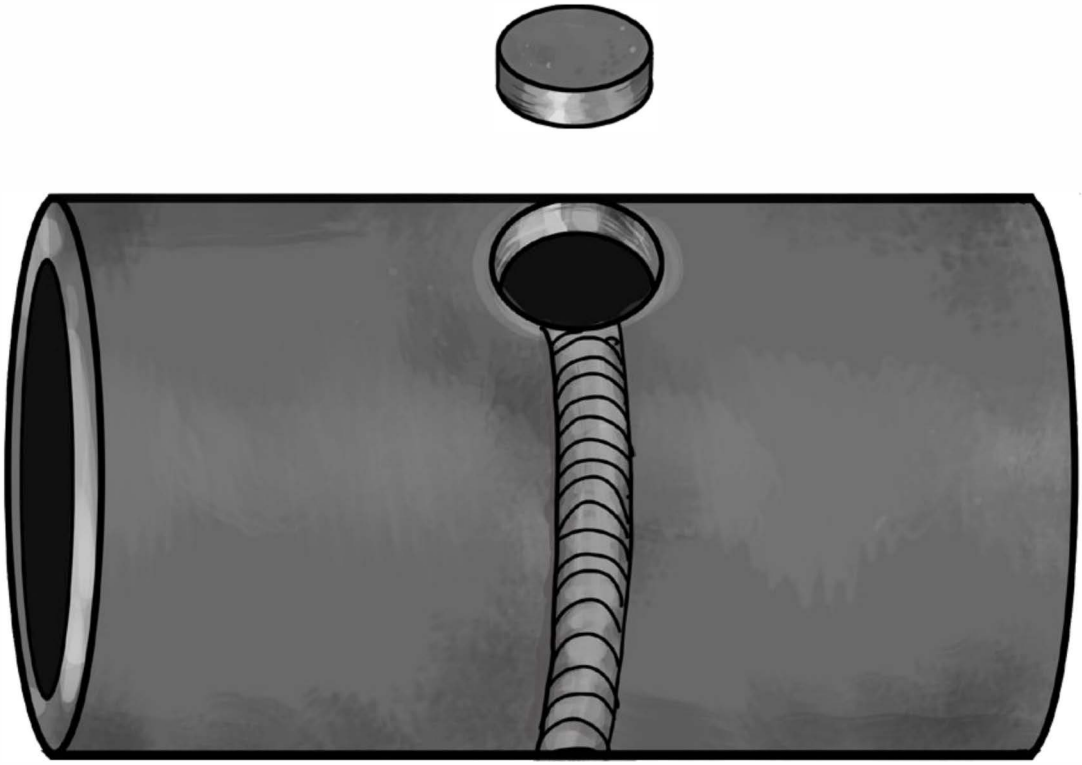

Figure 3.3—Trepanning

yield strength. The point at which a metal's response to the application of a tensile load changes from elastic to plastic.

In some cases, API 1104 uses different terms to refer to the same feature or characteristic. For instance, the terms "discontinuity," "imperfection," "flaw," "irregularity," and "anomaly" are used interchangeably in the text. However, only "imperfection" is defined in paragraph 3.1.11. All of these terms, however, have the same meaning. Similarly, the terms "position" welding and "fixed" welding are used interchangeably, although only "position welding" is defined in paragraph 3.1.17. In addition, the term "porosity" is defined in AWS A3.0 and is used in API 1104, but the term "voids," is used as well; "voids" is not defined in API 1104 but has the same meaning as "porosity." Root face is a standard term defined in AWS A3.0, but API 1104 also uses the nonstandard term "land" to refer to the root face of a weld joint.

Section 3 Terms, Definitions, Acronyms, and Abbreviations

3.1 The term that best describes a detectable irregularity in a weld is?

A. Defect
B. Imperfection
C. Indication
D. Concavity
E. Repair

3.2 API 1104 references which of the following standards for the definition of welding terms?

A. API 5L
B. ASNT's RP SNT-TC-1A
C. AWS A3.0
D. BS EN ISO 7910
E. NACE MR0175

3.3 What welding process application technique uses equipment that controls only the filler metal feed with the advancement of the weld along the joint controlled by the welder?

A. Repair welding
B. Uphill welding
C. Manual welding
D. Semiautomatic welding
E. Automatic welding

3.4 The welding position where the pipe is not rotating during welding is called:

A. Automatic welding
B. Position welding
C. Roll welding
D. Repair welding
E. Semiautomatic welding

3.5 What does the term "roll welding" mean?

A. Welding with an all-position welding electrode
B. Welding is carried out with the pipe assembly rotated while the weld metal is deposited at or near the top dead center
C. Welding with a semiautomatic process
D. Welding with the pipe assembly stationary
E. Welding without a welding procedure

3.6 The term that best describes welding without manual manipulation of the arc other than guiding or tracking and without any manual welding skill requirement is:

A. Mechanized welding
B. Semiautomatic welding
C. Automatic welding
D. Manual welding
E. Orbital welding

3.7 What does the abbreviation "HAZ" mean?

A. Heavily-alloyed zone
B. Heat-altered zone
C. Heat-affected zone
D. High-amperage zone
E. Both B & C

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Section 4

Specifications

Section 4: Specifications

4.1 Equipment

This subsection calls for good judgment, sound engineering, suitable operating practices and attention to safety in the operation of welding equipment. Arc welding equipment shall be operated within the voltage and current ranges specified on the welding procedure specification. Gas welding equipment shall be operated with the flame characteristics and tip sizes given in the qualified WPS.

4.2 Materials

Paragraph 4.2.1 says that pipe and fittings must conform to API or any applicable ASME, ASTM, MSS, or ANSI specifications, but it then further states that materials that comply with the chemical and mechanical properties of any of these specifications are also acceptable, even if they are not manufactured in accordance with the specification. This suggests that the chemical and mechanical properties of any such material must be identified, preferably on the welding procedure specification, when used for an API 1104 application.

Paragraph 4.2.2.1 states that filler metals must conform to one of the listed AWS filler metal specifications. Other filler metals may be used as long as the applicable welding procedures are qualified.

Table 1, in Section 5 on pages 15-16, divides filler metals into nine groups, based on electrode characteristics and the welding processes that use them. It is important to note that the Group Numbers that API 1104 uses are different than the F-Numbers that AWS uses to group filler metals. For instance, the low-hydrogen SMAW electrodes are F-No. 4 electrodes as defined by AWS, but they are Group No. 3 electrodes in API 1104. Table 1 lists:

(a) Group Numbers for filler metals, electrodes, and fluxes.
(b) AWS Specifications.
(c) AWS Classifications for filler metals and electrodes.
(d) AWS Classifications for fluxes.

Group Nos. 1, 2, and 3 electrodes are for SMAW. Group No. 4 electrodes and fluxes are for SAW. Group No. 5 electrodes are for GMAW, GTAW, and PAW. Group No. 6 electrodes are for OFW and Group Nos. 7, 8, and 9 are for FCAW.

Be attentive to the footnotes in Table 1, which modify the requirements for use of certain electrodes, filler metals, or fluxes and may give additional rules.

Paragraph 4.2.2.2 requires protection of filler metals and fluxes from deterioration and excessive changes in moisture, although no definition of “excessive” is provided. Obviously, if the flux coating on an SMAW electrode is damaged, it should not be used because it will not operate properly. Low-hydrogen SMAW electrodes (AWS classifications which end in 5, 6, or 8) must be stored in such a way that their coatings do not absorb excessive moisture from the atmosphere prior to use for welding.

Although it is not specifically required by API 1104, there are recommended good manufacturing practices for the storage and use of low-hydrogen SMAW electrodes in applicable AWS filler metal specifications. These include (a) the storage of these electrodes in a heated, vented oven at a prescribed temperature after removal from their hermetically sealed containers, (b) limited exposure to the atmosphere and (c) recommended minimum baking times and temperatures after atmospheric exposure.

Paragraph 4.2.3.1 addresses the various types of shielding gases used for welding. Inert shielding gases do not react chemically with the weld pool; they work by simply shielding the weld pool from interacting with the gases in the atmosphere. An active gas, however, does interact with either the arc, the weld pool, or in some cases, both. Inert gases include argon and helium. Active gases include carbon dioxide and oxygen. In GMAW, sometimes mixtures of inert and active shielding gases are used. Gases must be relatively pure and dry and the shielding gas or gases to be used shall be qualified in accordance with the applicable essential variable rules for procedure qualification. API 1104 does not reference AWS A5.32 for purity requirements for shielding gases.

Paragraph 4.2.3.2 addresses storage and handling of gases for welding. Gases shall not be field intermixed in their containers and gases of questionable purity or gases from damaged containers shall not be used.

Exercise Questions

Section 4 Specifications

4.1 API 1104 applies to the welding of pipe that conforms to which specifications?

A. AWS A5.28
B. BS EN ISO 1565
C. API specifications
D. ASTM specifications
E. Both C & D

4.2 Filler metals and fluxes in opened containers shall be:

A. Stored in any convenient container
B. Protected from deterioration
C. Kept in the original manufacturers' opened shipping container
D. Stored in ambient air
E. Secured in special plastic bags

4.3 What determines the tip size for gas welding equipment?

A. Manufacturer's instructions
B. Trial and error
C. Qualified welding procedure specification
D. Engineering drawing
E. Pressure of the gas

4.4 Shielding gases used to shield the arc shall never be:

A. Inert
B. Mixed gases
C. Field intermixed in their containers
D. Kept in containers in which they are supplied
E. Both A & B

4.5 Filler metals that are coated shall be protected from:

A. Dust
B. Strong magnetic fields
C. Excessive ultraviolet rays
D. Excessive changes in moisture
E. None of the above

4.6 When is it permissible to use a filler metal not conforming to the specifications listed in API 1104?

A. When approved by the company
B. When approved by the API committee
C. When the WPS involved with its use is qualified
D. Only filler metals whose specifications are listed in Table 1 may be used
E. Only filler metals approved by the engineer may be used

4.7 When is it permissible to use base materials that are not manufactured in accordance with the specifications listed in API 1104?

A. When the material is approved by the engineer
B. When the material has chemical and mechanical properties that comply with an ASTM or an API 5L specification
C. It is not permissible to use a base material that does not have an approved specification number in accordance with Section 4
D. When the WPS involving its use is qualified
E. Both A & D

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Section 5

Qualification of Welding Procedures with Filler Metal Additions

Section 5 Qualification of Welding Procedures with Filler Metal Additions

5.1 Procedure Qualification

AWS A3.0 defines a welding procedure as "the detailed methods and practices involved in the production of a weldment." These methods and practices are communicated to the welder in the form of a document referred to as a welding procedure specification. Some codes and standards refer to a welding procedure specification as a "WPS," but API 1104 does not use that acronym. AWS A3.0 further defines a welding procedure specification as "a document providing the required welding variables for a specific application to assure repeatability by properly trained welders and welding operators." The welding procedure specification should provide meaningful instructions to the welder for the successful completion of a production weldment.

These definitions set the stage for a detailed discussion of welding procedure qualification, which involves:

(a) Qualifying a welding procedure by testing to prove that welds with suitable mechanical properties can be made by the procedure.
(b) Documenting the results of the procedure qualification test.
(c) Establishing conditions under which requalification of the welding procedure by testing is required.

Note that Section 5 covers only manual and semi-automatic welding using filler metal additions; mechanized welding with filler metal additions is addressed in Section 12, while automatic welding without filler metal additions is addressed in Section 13 of the standard.

5.2 Record

Subsection 5.2 requires the company to record the complete details of each procedure qualification and to keep that record as long as the welding procedure specification is in use. The record of the procedure qualification is the record of the pipe grade and wall thickness, as well as all of the other required welding variables used to weld the test coupon; this record also includes the results of the tests (tension, bends, and/or nick breaks) performed. Some codes refer to this document as a procedure qualification record or "PQR," although API 1104 does not use that term. API 1104 provides sample forms for this purpose. Figure 2 on page 11 shows a Sample Coupon Test Report, which can be used to document the results of the procedure qualification test. When the form is used in this manner, the box on the left side of the form, in the middle of the page, labeled "Procedure," should be checked. This form can be referred to as either a "Coupon Test Report" ("CTR") or a "Weld Test Report" ("WTR"), although API 1104 does not use these terms.

Figure 1 on page 10 is a Sample Welding Procedure Specification Form. The contents of this form are dictated by paragraph 5.3.2 of API 1104.

5.3 Welding Procedure Specification and 5.4 Essential Variables

These subsections list the variables and the ranges thereof required to be specified on a welding procedure specification. Paragraph 5.3.2 describes the variables that must be listed on the welding procedure specification and paragraph 5.4.2 identifies which of those variables are essential variables and the ranges permitted on the welding procedure specification for each of those essential variables.

There are some variables that are listed in paragraph 5.3.2 that are not listed in paragraph 5.4.2. Paragraph 5.4.1 states of those variables, "Changes other than those given in 5.4.2 may be made in the

procedure without the need for requalification, provided the welding procedure specification is revised to show the changes." In other words, the variables that are listed in 5.3.2 that are not listed in 5.4.2 are not essential variables and may be changed by a simple editorial revision of the welding procedure specification. However, in all cases, the welder must ALWAYS weld within the ranges of all of the variables specified on the welding procedure specification.

In the discussion that follows, each variable in 5.3.2 will be described, followed by a reference to the corresponding provision in paragraph 5.4.2 *if* it is an essential variable. If it is an essential variable, the range qualification rule from 5.4.2 will be explained. Variables listed in 5.3.2 but not listed in 5.4.2 will be so identified. Some codes and standards refer to these types of variables as "nonessential" variables, but API 1104 does not use that term.

5.3.2.1 Process - States the welding process or processes to be used shall be identified and whether they are manual, semiautomatic, mechanized or automatic.

Paragraph 5.4.2.1 indicates that this is an essential variable.

5.3.2.2 Materials - The materials to which the procedure applies shall be identified by SMYS. The materials may be grouped; but to achieve a "group" qualification, the procedure shall be qualified on the highest SMYS material in that group, resulting in a qualification for that SMYS material and all pipe grades below it in that particular group. SMYS groupings are provided in paragraph 5.4.2.2 as follows:

a) SMYS ≤ 42,000 psi.
b) 42,000 psi < SMYS < 65,000 psi.
c) For pipe having an SMYS of 65,000 psi or greater, each pipe grade shall receive a separate qualification test.

For example, qualification on API 5L Grade X42 pipe would qualify for welding Grades X42, B, A, and X25 pipe. Furthermore, qualification on API 5L Grade X56 pipe would qualify for welding Grades X56, X52, and X46, but not Grade X60 because Grade X60 is a higher SMYS grade than that used for qualification. Qualification on API 5L Grade X70 would only qualify for welding Grade X70 pipe. However, a welding procedure specification for API 5L Grade X70 pipe could be used for welding Grade X70 to Grade X56 pipe (see paragraph 5.4.2.2).

Paragraph 5.4.2.2 indicates that a change in base material, group or SMYS, as applicable, is an essential variable.

5.3.2.3 Diameters and Wall Thicknesses - The welding procedure specification shall specify the range of outside diameters (ODs) and wall thicknesses that may be welded.

API 1104 provides suggested groupings for outside diameters and wall thicknesses in paragraphs 6.2.2 d) and e), respectively. The OD groups are:

(a) OD less than 2.375 inch.
(b) ODs from 2.375 through 12.750 inch.
(c) ODs greater than 12.750 inch.

The wall thickness groups are:

(a) Wall thickness less than 0.188 (3/16) inch.
(b) Wall thicknesses from 0.188 (3/16) inch through 0.750 (3/4) inch.
(c) Wall thicknesses greater than 0.750 (3/4) inch.

Paragraph 5.4.2.5 indicates that a change from one specified wall thickness range to another is an essential variable. Outside diameter is not listed in paragraph 5.4.2, so it is not an essential variable.

5.3.2.4 Joint Design - The welding procedure specification must provide a sketch showing the angle of bevel, the size of the root face, the root opening, as well as the shape and size of fillet welds. If backing material is used, the type shall be identified.

Paragraph 5.4.2.3 states that a major change in joint design is an essential variable, but a minor change in the angle of bevel or the size of the root face is not. These definitions are vague, at best.

5.3.2.5 Filler Metal, Flux, and Number of Beads - The size (diameter) and AWS classification number of the filler metal and flux must be identified. In addition, the number and sequence of beads shall be listed.

This means that the welding procedure should be developed by welding a coupon using the smallest number of beads possible; then, as a result, the welding procedure generated can specify a weld schedule having that number of beads or greater.

Paragraph 5.4.2.6 states that a change from one filler metal Group Number in Table 1 to any other Group Number is an essential variable. It is important to restate here that API 1104 uses a different grouping system for electrodes than the F-Numbers used by AWS and the rest of the welding world. API 1104 uses Group Numbers, which are different than F-Numbers. So an SMAW procedure specification qualified by welding a coupon with an E6010 electrode could list E6010, E6011, E7010, and/or E7011 electrodes because these are all Group No. 1 electrodes. However, an SMAW procedure qualified by welding a coupon with an E7018 electrode could not list E6010 or E7010 or E8010 electrodes because E7018 electrodes are Group No. 3 electrodes while the E6010, E7010, and E8010 electrodes are Group No. 1 and No. 2 electrodes. For Group No. 1 through Group No. 3, any change in suffix designator is an essential variable. Aslo, for any filler metal with a G suffix only, a change in the manufacturer or trade name is an essential variable.

Furthermore, paragraph 5.4.2.6 states that, for welding pipe having an SMYS of 65,000 psi or higher, a change in the electrode classification is an essential variable. So, for welding a Grade X70 pipe with SMAW, a change in electrode classification from E8016 to E8018 requires requalification, even though the specified minimum ultimate tensile strength of the weld deposits made by these two low-hydrogen electrode classifications is the same.

Also, the general note at the bottom of Table 1 states that electrodes, filler metals and fluxes other than those listed can be used, but each would require a separate qualification. This includes commonly used higher-strength SMAW electrode classifications, such as E9015 or E10018.

Filler metal size (diameter) is not listed in paragraph 5.4.2 and, therefore, is not an essential variable.

5.3.2.6 Electrical Characteristics - The type of current used shall be identified. Specify either alternating current (AC) or direct current (DC). For DC, the polarity must be identified as well. Either reverse polarity [electrode positive or (EP)] or straight polarity [electrode negative or (EN)] must be listed. A range of voltage and current values must also be specified for each size and type of electrode or filler metal to be used. Typically, the amperage and voltage ranges should provide reasonable flexibility for the welders while being narrow enough to ensure production of an acceptable weld. The inspector should always verify that these ranges are consistent with the manufacturer's recommendations.

Paragraph 5.4.2.7 states that a change in current type or polarity is an essential variable. However, changes in the voltage and current ranges are not essential variables.

5.3.2.7 Flame Characteristics - For oxyacetylene welding, designate the type of flame being used. Three options exist. They are:

(a) Carburizing (also referred to as a reducing flame), in which an excess of acetylene results in unburned acetylene at the tip of the flame that can deposit carbon on or "carburize" the surface of the base metal.
(b) Oxidizing, in which an excess of oxygen results in unburned oxygen at the tip of the flame that can oxidize the surface of the base metal.
(c) Neutral, in which there is no unburned acetylene or oxygen at the tip of the flame.

Also, the size of the orifice in the torch tip must be specified for each size of rod or wire. The inspector should always verify that tip sizes and gas pressures are within manufacturers' recommendations.

This variable is not listed in paragraph 5.4.2 and, therefore, is not an essential variable.

5.3.2.8 Position - Designate whether the pipe is rolled or fixed during welding (roll or position welding).

Paragraph 5.4.2.4 states that a change from roll to fixed position, or vice versa, is an essential variable.

5.3.2.9 Direction of Welding - Designate whether welding is to be performed in the uphill or downhill direction. Sometimes this is referred to as the "progression" of welding.

Paragraph 5.4.2.9 states that a change in the direction of welding is an essential variable.

5.3.2.10 Time Between Passes - The maximum time between the end of the root bead and the start of the second bead (hot pass) must be specified as well as the maximum time between the completion of the second bead (hot pass) and the start of other beads.

Paragraph 5.4.2.8 states that an increase in the time between the end of the root bead and the start of the hot pass is an essential variable. If the welding procedure is qualified by welding a coupon in which the hot pass is begun 10 minutes after the completion of the root bead, the welding procedure specification should state, "Ten minutes, maximum, permitted between the end of the root bead and the start of the hot pass." Obviously, it could state a length of time shorter than ten minutes may pass between the end of the root bead and the start of the hot pass, but it could NOT state a period of time longer than ten minutes. This is an ingenious way to control the interpass temperature for the hot pass, as generated by the root pass, during field welding.

The time between the completion of the hot pass and the start of other beads is not listed in paragraph 5.4.2, so this is not an essential variable and, although it is required to be listed on the procedure specification, it may be changed to any value by a simple editorial revision of the procedure specification without requalification by testing.

5.3.2.11 Type and Removal of Lineup Clamp - Specify whether a lineup clamp is required, and if so, what type (external or internal) is to be used and how much of the root bead must be deposited before the clamp is released. Typically, a prescribed amount of the joint must be welded before removing the clamp so that the partially welded joint is not subject to undue stress prior to completion of the weld.

This variable is not listed in paragraph 5.4.2 and, therefore, is not an essential variable.

5.3.2.12 Cleaning and/or Grinding - Describe whether hand tools or power tools are to be used when cleaning or grinding are necessary. This applies to pre-weld cleaning, interpass cleaning, and post-weld cleaning.

This variable is not listed in paragraph 5.4.2 and, therefore, is not an essential variable.

5.3.2.13 Preheat and Postweld Heat Treatment (PWHT) - For preheat, specify the minimum required temperature at the start of the weld, the minimum temperature below which preheat is required and the method of preheating required. For PWHT, specify the temperature range, the time at temperature, the method of heating, and the temperatuer contorl methods used to measure the temperature.

Paragraph 5.4.2.13 states that a decrease in the minimum preheat temperature is an essential variable. As a result, if a welding procedure is qualified by welding a test coupon at 70 °F, using this welding procedure specification when the temperature outside is 50 °F would require the welder to heat the joint to 70 °F before welding, regardless of pipe grade.

Paragraph 5.4.2.14 states that the addition of PWHT or a change in the range or values for the time, temperature, or technique specified in the welding procedure specification are all essential variables.

5.3.2.14 Shielding Gas and Flow Rate - The composition of the shielding gas and the range of flow rates permitted shall be specified.

Paragraph 5.4.2.10 states that a change in the nominal composition of the shielding gas is an essential variable. In addition, an increase or decrease in the flow rate of more than 20 % of the nominal value is also an essential variable.

5.3.2.15 Shielding Flux - The type of shielding flux must be specified. This variable only applies to submerged arc welding (SAW).

Paragraph 5.4.2.11 refers the reader to Table 1, footnote a for changes in shielding flux that constitute essential variables. Table 1, footnote a applies to Group No. 4 filler metals, which are those for SAW. This footnote states that any combination of electrode and flux can be used to qualify a welding procedure specification and that the combination is identified by its complete AWS classification, which, by definition in AWS Specifications A5.17, specifies both the flux and the electrode. Only substitutions that have the same AWS classification (for both flux and electrode) can be used without requalification.

So, if the welding procedure was qualified by welding a test coupon using a SAW consumable whose AWS classification was F7A0-EL12, any flux with the “F7A0” designation could be used with that welding procedure specification, whether it was made by the same manufacturer as that used on the test coupon or not. Conversely, the use of a flux whose AWS classification is different from that used during qualification would require requalification of the welding procedure by testing.

5.3.2.16 Speed of Travel - The range for speed of travel for each pass must be specified on the welding procedure specification, but this range is defined by the range(s) of travel speed(s) used on the test coupon used to qualify the welding procedure.

Paragraph 5.4.2.12 states that a change in the range for speed of travel is an essential variable. This means that if the test coupon was welded at 10 inches per minute, only 10 inches per minute can be specified on the welding procedure specification. Fabricators must realize that test coupons for qualifying welding procedures must be welded using a range of travel speeds to allow a range of travel speeds to be permitted on the welding procedure specification.

5.3.2.17 Method of Cooling After Welding – When controlled cooling from the welding operation is used, the welding procedure must specify the method used (e.g., water) and the maximum temperature at which the cooling is applied.

This variable is not listed in paragraph 5.4.2 and, therefore, is not an essential variable.

5.5 Welding of Test Joints - Butt Welds

For qualifying a welding procedure for making butt welds (sometimes referred to as girth or circumferential welds), a butt weld shall be made joining two pieces of pipe. Notice that a butt weld procedure is only qualified for making butt welds. For making fillet or branch connection welds, a separate welding procedure must be qualified.

5.6 Testing of Welded Joints - Butt Welds

Paragraph 5.6.1 gives directions for the preparation of the test coupons. The welded test joint is to be cut into sections, as shown in Figure 3 on page 18. Table 2 on page 19 gives the number of required specimens. Figure 3 and Table 2 should be used in tandem, along with 5.6.1, for procedure qualification testing requirements.

Figure 3 illustrates the locations from which test specimens shall be removed for procedure qualification testing. It contains four pipe illustrations, each representing a different range of pipe diameters. Think of each illustration as a clock face. For pipe diameters greater than 4.5 inches, the pipe is big enough that specimens can be removed from four locations approximately 90 degrees apart: at the two, four, eight, and 10 o'clock positions. At each location, arrows outside the pipes indicate the locations where the required specimens shall be taken. For pipes smaller in diameter than 4.5 inches, there is simply not enough room to remove samples from four locations 90 degrees apart, so the illustrations indicate that the specimens should be removed from the two and eight o'clock locations instead. In no case shall the specimens be removed from the area of the pipe containing the longitudinal (long seam) weld. Footnote a of Table 2 and paragraph 5.6.1 identify that for diameters less than 2.375 in. with wall thickness of 0.500 in. or less, two test welds are required to provide the required number of nick break and root bedn specifimens. The same note of Table 2 and Note 2 of Figure 3 specify that for pipe of 1.315 in. diameter and smaller, one full section tension specimen is tested.

Notice that footnote b of Table 2 states that no tension tests are required for pipe having a SMYS of 42,000 psi or less. For such low-strength pipe, it is not even necessary to determine the tensile strength of the tested coupon – only nick break tests and bend tests are needed.

One other feature to notice about Table 2 is that side bend tests are required in lieu of face and root bend tests when the wall thickness is greater than 0.500 inch. This is because heavier wall pipe can require significantly more force to bend the specimens in the face and root orientation. For thicker pipe, the use of side bend specimens 1/2 inch wide by the wall thickness thick (see Figure 9 on page 24) allows thicker pipe to be more easily tested in a field setting. All welding qualification codes have a thickness above which side bends are permitted in lieu of face and root bends. For ASME Section IX and AWS D1.1, that thickness is 3/8 inch. For API 1104, that thickness is 1/2 inch.

Subsection 5.6 discusses these specimens and tests in deatil, describing the preparation of the specimens, the test methods, and the acceptance criteria for each. The discussion refers the reader to Figures 4 through 9 on pages 20 through 24.

Tensile strength test requirements are given in paragraph 5.6.2. Tension specimens are approximately 9 inches long by about 1 inch wide. They are required to be full-thickness specimens and they may be made to either one of the two configurations shown in Figure 4 on page 20. Note that weld reinforcement is not removed when testing a specimen prepared according to Figure 4 a). However, Figure 4 b) provides an option of removing a full-thickness specimen with a reduced width section, in which case the removal of weld reinforcement is optional.

The specimens shall be broken in any device capable of measuring the load at which failure occurs.

The tensile strength of the weld shall be no less than that specified for the base metal. If the specimen fails in the weld metal, then the fracture surface must also meet the requirements of paragraph 5.6.3.3, which is the criteria for evaluating the fractured surface of a nick break specimen. If the specimen fails in the pipe material and produces a tensile strength not less than 95 % of that specified for the pipe material, the test is acceptable.

Testing of nick break specimens is described in paragraph 5.6.3. The term "nick break" refers to the hacksaw notch or "nick" cut into each edge of each transverse specimen, such that the reduction of the overall cross section of the specimen helps facilitate the fracture. These specimens are to be approximately 9 inches long by about 1 inch wide and are shown in Figure 5 on page 21. The specimens may be broken by any convenient method, which may include pulling them apart using a tension-testing machine or hitting one end with a hammer while holding the other end firm.

Figure 6 on page 22 is a schematic of the exposed surface of such a specimen after breaking and it defines the directions in which discontinuity length, depth and separation are to be measured.

The exposed weld metal surfaces of a nick break specimen must show complete fusion and penetration. The maximum permitted pore size is 1/16 inch and the combined area of all acceptable pores shall not exceed 2 % (1/50th) of the fractured surface area. Slag inclusions shall not exceed 1/32 inch in depth and shall not exceed the lesser of 1/8 inch or one half the specified wall thickness. There shall be at least 1/2 inch separation between the edges of adjacent acceptable slag inclusions.

Root and face bend testing is described in paragraph 5.6.4. These specimens are approximately 9 inches long by roughly 1 inch wide and are shown in Figure 7 on page 22. They may be machine or oxygen cut. A maximum corner radius of 1/8 inch is permitted in order to help prevent corner cracks that could originate from the rough-cut corner rather than from flaws in the weld. In addition, the reinforcement on both the face and root surfaces is required to be removed flush with the surface of the specimen prior to bending in order to maintain smooth and consistent contact with the contour of the plunger. The bend test jig is shown in Figure 8 on page 23, which shows that the radius of the plunger is the same for all pipe grades.

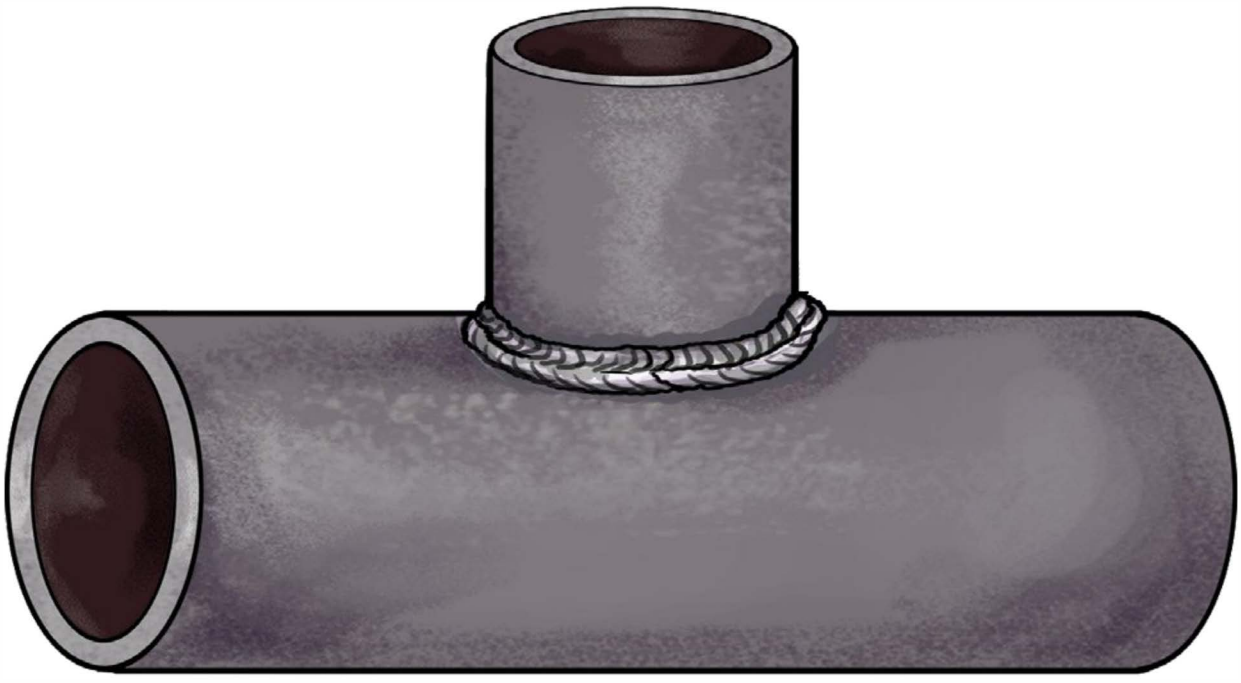

Figure 5.1—Branch Connection Weld

The maximum flaw size permitted on the convex surface of a bend specimen is the lesser of 1/8 inch or one-half the specified wall thickness. Corner cracks that are less than ¼ inch shall not be considered unless they contain obvious weld-related imperfections. In that case, the maximum 1/8 inch flaw size applies.

Side bend testing is described in paragraph 5.6.5. The side bend test is similar to the root and face bend tests, except that the specimens are bent such that one side of these transverse specimens becomes the convex surface instead of the face or root surfaces. The specimens are to be approximately 9 inches long by about 1/2 inch wide and are shown in Figure 9 on page 24. The remainder of the preparation details, the method of testing, and the acceptance criteria are similar to those for face and root bends.

5.7 Welding of Test Joints - Fillet Welds

Figure 10 on page 25 illustrates the two options for qualifying fillet weld procedures. One option is a branch connection weld (see Study Guide Figure 5.1 on the previous page), assembling two pipes in the form of a T; the other is a socket-weld configuration (see Study Guide Figure 5.2 below), where the end of one pipe is inserted into the end of a slightly larger pipe to create a lap joint.

Figure 5.2—Socket Weld

5.8 Testing of Welded Joints - Fillet Welds

Paragraph 5.8.1 describes the details of fillet weld testing. Regardless of the test joint configuration selected, qualification of fillet weld procedures requires four nick break specimens to be removed from the welded coupon at 90° intervals (see Figure 10 on page 25).

Figure 11 on page 25 shows schematics of the nick break specimens. When a branch connection weld is used, two of the four nick break specimens must be removed from the 90° intersection areas, or "crotches," of the joint (shown in the bottom right corner of page 25) and two must be removed from the tangential area (shown in the bottom left corner of page 25). Due to the large amount of reinforcement that can be present in these welds, the cut edges of all four specimens are subject to a flame cut at the weld edge to narrow the specimen width to ensure failure in the weld in addition to the hacksaw cut (nick) made in the weld direction on the weld face. In the nick break specimens removed from the socket

weld, no flame cut is used and the hacksaw cut (nick) in the weld is on the sides of the specimen (not the weld face) and is shown in the top right corner of Figure 11 on page 25.

The specimens should be about 1 inch wide and long enough that they can be gripped to be broken.

As with the butt joints, if the pipe OD is smaller than 2.375 inches, two pipe joints may be needed to obtain the required number of specimens. In this case, two specimens shall be removed from each of the two test welds.

Paragraph 5.8.2 states that the specimens may be broken by any convenient method.

The acceptance criteria for these specimens is given in paragraph 5.8.3 and is exactly the same as that for nick break specimens used to qualify butt weld procedures in paragraph 5.6.3.3.

Exercise Questions

Section 5 Qualification of Welding Procedures with Filler Metal Additions

5.1 API 1104 groups base metals into three groups based on which mechanical property?

A. Specified minimum ultimate tensile strength (SMTS)
B. Specified minimum yield strength (SMYS)
C. Charpy V-Notch impact strength
D. Minimum ductility in a tension test
E. Maximum hardness

5.2 When qualifying a welding procedure on API 5L X46 pipe with an OD less than 4.5 inches and with an SMYS of 46,000 psi, what is the minimum number of tension tests required?

A. 0
B. 1
C. 2
D. 4
E. 8

5.3 When preparing a standard tension specimen for testing as shown in Figure 4 a):

A. Cut a 1/8 inch notch into each edge of the weld
B. Machine or grind all reinforcement smooth
C. Cut a transverse notch into the weld
D. Weld reinforcement should not be removed on either side
E. Bend the specimen in a guided bend jig

5.4. Electrodes in AWS filler metal Specification A5.20 are used for:

A. SMAW
B. SAW
C. FCAW root pass welding only
D. FCAW root and fill passes
E. GMAW with short-circuiting arc transfer

5.5 When performing a nick break test, the width of the exposed area of fracture shall be?

A. 1/2 inch, maximum
B. 3/4 inch, minimum
C. 5/8 inch, exactly
D. 1-1/2 inch, minimum
E. A dimension is not specified

5.6 When welding API 5L Grade X46 pipe to API 5L Grade X65 pipe, which of the following welding procedure specifications may be used?

A. A welding procedure qualified on API 5L Grade X46 pipe
B. A welding procedure qualified on API 5L Grade X65 pipe
C. A welding procedure qualified on API 5L Grade X70 pipe
D. API 1104 has no rules for this
E. Either A or B

5.7 When conducting a procedure qualification on pipe with an OD of 6 inches and a wall thickness of 3/8 inch, the number of tension test(s) required is(are)?

A. Two
B. One
C. None
D. Four
E. None of the above

5.8 When preparing a face or root bend specimen for testing:

A. Weld reinforcement shall be removed from both faces
B. The specimen must be machined
C. The specimen may be oxygen cut
D. Weld reinforcement should not be removed from either face
E. Both A & C

5.9 Electrodes in AWS filler metal Specifications A5.1 and A5.5 are:

A. SMAW electrodes
B. GMAW electrodes
C. Used for root pass welding only
D. Listed in Filler Metal Groups 1 and 3
E. Both A & D

5.10 When performing a nick break test, the exposed area of fracture shall show complete penetration and fusion. The greatest dimension of any single gas pocket shall not exceed:

A. 1/16 inch
B. 1/8 inch
C. 5/8 inch in width
D. 1/2 inch in width
E. Both A & B

5.11 Electrodes for flux-cored arc welding can be found in which AWS specification?

A. AWS A3.0
B. AWS A5.20
C. API 5L
D. ASTM E 164
E. All of the above

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Section 6

Qualification of Welders

Section 6: Qualification of Welders

6.1 General

The purpose of welder qualification is to prove the welder's ability to make sound welds using qualified procedures. Welders must qualify by testing before they perform any production welding. A welder who satisfactorily completes a welding procedure qualification test is also qualified as long as all of the test specimens required by subsection 6.5 are successfully tested. This standards also requires qualification to be conducted in the presence of a representative acceptable to the company.

The essential variables for welder qualification are different than the essential variables for procedure qualification. The essential variables for welder qualification are listed in paragraphs 6.2.2 and 6.3.2 and will be discussed in detail below.

There are two options for qualifying welders: (1) a single qualification and (2) a multiple qualification. The multiple qualification qualifies the welder for the widest range of variables and is generally preferred.

6.2 Single Qualification

Single qualification requires separate qualification tests for fillet and groove welds. Note that a fillet weld qualification will qualify for welding both socket welds and branch connection welds. However, butt welds do not always qualify the welder to make fillet welds in API 1104.

Paragraph 6.2.1 describes the requirements for the single qualification. In this test, the welder qualifying to make butt welds will make a butt weld in either the fixed or rolled position with the axis of the pipe either horizontal, vertical, or inclined from horizontal at an angle of no more than 45 degrees. The welder qualifying to make branch connections or fillet welds will make a branch or socket connection weld in the position and orientation specified by the welding procedure. The test welds shall meet the requirements of subsection 6.4 (visual examination) and either subsection 6.5 (destructive testing) or 6.6 (nondestructive testing for butt welds only).

Paragraph 6.2.2 is entitled "Scope," but it really just lists the essential variables for the single qualification of welders. The welder who has completed the single qualification test must requalify if he changes any variables outside the following ranges:

(a) A change in the welding process or combination of welding processes (with the exception that a welder qualified separatel for each process used in the combination is also qualified to use the processes in combination).
(b) A change in the direction of welding from uphill to downhill or vice versa.
(c) A change in filler metal classification from Group No. 1 or Group No. 2 to any other group or from any Group No. 9 filler metal to a Group No. 1 or Group No. 2 filler metal. Note that this implies that a welder qualified for SMAW may switch between Group No. 1 electrodes (E6010, E6011, E7010 and E7011) and Group No. 2 electrodes (E8010, E8011 and E9010) without having to requalify. However, if a welder qualifies for SMAW using a low-hydrogen electrode (Group No. 3), he must requalify to weld using an E6010 electrode (Group No. 1). In addition, each filler metal classification not listed in Table 1 requires a separate qualification.
(d) A change from one OD group to another (note that OD group was NOT an essential variable for the qualification of welding procedures).
(e) A change from one wall thickness group to another.
(f) A change in position with the following exceptions: a welder who qualifies for fixed (position) welding is also qualified to perform roll welding; a welder who qualifies for making butt welds is also qualified to make lap fillet welds (socket welds), but NOT branch connection welds; a welder who

qualifies by making a butt weld in the fixed position at a 45 ° angle is qualified to make butt welds and lap fillet welds (but NOT branch connection welds) in all positions.

(g) A change in the joint design, such as the deletion of a backing strip or a change in edge preparation from a V bevel (i.e. V groove) to a U bevel (i.e. U groove), although this variable is rather vague.

6.3 Multiple Qualification

A multiple qualification qualifies a welder to weld in all positions, on all wall thicknesses, joint designs, and fittings. However the widest range of pipe diameters qualified depends on the diameters he welded during the test.

Paragraph 6.3.1 describes the requirements for the multiple qualification, which requires the welder to complete two test weld joints. They are:

(a) A butt weld in the fixed position with the axis of the pipe either horizontal or inclined from horizontal at an angle of no more than 45 degrees. The weld shall be made on pipe with a minimum outside diameter of 6.625 inches and a minimum wall thickness of 0.250 inch. The weld is also required to be welded without a backing strip.

The weld must meet the requirements of API 1104 subsection 6.4 (visual examination) and either subsection 6.5 (destructive testing) or 6.6 (nondestructive testing).

(b) A branch-on-pipe connection weld, for which the welder is required to lay out, cut, fit, and weld two pipes of equal diameter together in the form of a T (see Study Guide Figure 5.1). The weld shall be made with the axis of the run pipe horizontal and with the branch connection extending vertically down, such that the weld is made in the overhead position.

In addition to the workmanship requirements of paragraph 6.3.1, four nick break specimens shall be removed from the weld as shown in Figure 10 and they must also meet the nick break test requirements of subsection 5.8.3.

Paragraph 6.3.2 describes the essential variable rules for multiple qualification. A welder who successfully completes the butt weld test on pipe 12.750 inches in diameter or larger and the branch connection weld on pipes 12.750 inch in diameter or larger is qualified to weld in all positions, on all wall thicknesses, joint designs, fittings, and on all pipe diameters. Successful testing on pipes smaller than 12.750 inches in diameter qualifies for welding in all positions, on all wall thicknesses, joint designs, fittings, and on all pipe diameters equal to or less than that on which he tested.

A welder holding a multiple qualification shall be required to be requalified if any of the following are changed:

(a) A change from one welding process to another process or combination of processes (agin with the exception that a welder qualified separatel for each process used in the combination is also qualified to use the processes in combination).

(b) A change in the direction of welding from uphill to downhill or vice versa.

(c) A change in filler metal classification from Group No. 1 or Group No. 2 to any other group or from any Group No. 3 through 9 to Group No. 1 or Group No. 2. Also, a change in filler metal classification not listed in Table 1 to any ohter filler metal or vice versa.

6.4 Visual Examination

Visual examination of the test weld must precede any preparation of samples for mechanical testing. If the visual examination reveals cracks, inadequate penetration, burn-through, or unacceptable amounts of undercut, rejection is automatic and another test weld must be prepared. In addition, an inspector may reject the weldment if it does not present a neat, workman-like appearance. Welds made by semiautomatic (e.g. GMAW) or mechanized (e.g. SAW) processes may be rejected if too much filler wire protrudes into the interior of the pipe (sometimes referred to as "bird's nests" or "whiskers"), although API 1104 offers no definition of what "shall be kept to a minimum" means."

6.5 Destructive Testing

Paragraph 6.5.1 details the testing requirements for butt weld qualifications. Test specimens shall be cut from the test welds at the locations shown in Figure 12 on page 28. The number and type of specimens required are listed in Table 3 on page 30. Figure 12, Table 3, and paragraph 6.5.1 should be used together for determining welder qualification test requirements. The test specimen locations are exactly the same as those required for procedure qualification, shown in Figure 3 on page 18. The number and type of specimens required for welder qualification, however, are slightly different. Table 3 for welder qualification on page 30 is arranged the same as Table 2 for procedure qualification on page 19. The only difference is in the number of specimens required. The similarity of these two tables makes them easy to confuse. Make sure you are referencing the correct table in API 1104: Table 2 on page 19 when welding procedures are being qualified and Table 3 on page 30 when welders are being qualified.

Since smaller pipes have less material from which to remove specimens, for pipes less than 2.375 inches in OD, it may be necessary to weld an additional test joint to obtain the required number of test specimens. Furthermore, for pipe 1.315 inches in OD or less, footnote a of Table 3 on page 30 (and Note 2 of Figure 12 on page 28 and paragraph 6.5.1) provides the option of pulling a single full-section tension test specimen in lieu of performing the required two root bend and nick break tests.

When welders qualify by making butt welds, paragraph 6.5.2 states that the specimens shall be prepared for tensile strength, nick break, and bend tests, as applicable, and the tests shall be performed as described for procedure qualification testing in subsection 5.6. Since the purpose of welder qualification is to determine the welder's ability to deposit sound weld metal, it is not necessary to determine the tensile strength of the tension test specimens. The tension test may even be omitted, in which case the specimens designated for the tension test shall be subjected to the nick break test.

The tensile strength test requirements for welder qualification are detailed in paragraph 6.5.3. This test is really just a weld metal soundness test. If any of the reduced-section specimens or the full-section specimen fails in the weld or at the junction of the weld and the base metal, the fractured surface must meet the soundness requirements of paragraph 5.6.3.3, which is the acceptance criteria for the fractured surface of a nick break specimen. If the specimen fails in the parent material, the weld metal is considered to be acceptable.

Paragraph 6.5.4 gives the requirements for the nick break tests for welder qualification and states that these specimens must meet the same acceptance criteria as those for procedure qualification. See paragraph 5.6.3.3.

The requirements for the bend tests for welder qualification are given in paragraph 6.5.5, which references the same acceptance criteria as those for procedure qualification in paragraphs 5.6.4.3 or 5.6.5.3, as applicable. However, there are two exceptions: Welds in high-strength pipe may crack or break before they bend to a full U shape. In that case, the specimen is acceptable as long as the exposed surfaces meet the requirements for nick break tests as given in paragraph 5.6.3.3. The other

exception is that the company may permit the testing of an additional bend specimen removed from the same test weld to replace a failed bend specimen if, in their opinion, the failure was not representative of the weld. The welder shall be disqualified if this additional specimen fails.

Paragraph 6.5.6 requires that fillet welds be tested using nick break specimens, as shown in Figure 10 on page 25. Four specimens shall be removed from locations approximately 90 degrees apart to qualify each welder.

Paragraph 6.5.7 gives the instructions for cutting, preparing, and testing the nick break specimens for welder qualification. When specimens are removed from a complete circumferential test weld, subsection 5.8 and Figures 10 and 11 on page 25 apply. If the test weld consists of multiple pipe segments (weldments), each segment must supply the same number of specimens. The acceptance criteria for each specimen is given in paragraph 5.8.3.

6.6 Nondestructive Testing (NDT) – Butt Welds Only

At the company's option, the qualification butt weld may be examined by radiographic testing or automatic ultrasonic testing instead of mechanical testing and meet the requirements in 9.3 or 9.6, respectively. It is not permitted to use NDT methods to purposely locate sound areas or defective areas and subsequently making tests of such areas to qualify or disqualify a welder. Be aware that jurisdictional limitations may override API 1104 and, in doing so, may restrict the use of NDT methods in lieu of mechanical testing for welder qualification.

6.7 Retesting

If a welder fails a test but the company and the welder's representatives mutually agree that the welder wasn't at fault, the welder may be given a second chance to qualify. If the welder fails the second time, the welder must submit proof of additional welder training that is acceptable to the company before taking the test for a third time.

6.8 Records

A record that documents the test results for each welder shall be maintained. Furthermore, a list of welders and the procedures for which they are qualified shall also be maintained. If the abilities of a welder come into question, the welder may be required to requalify.

Exercise Questions

Section 6 Qualification of Welders

6.1 For a welder holding a single qualification, which of the following changes would require requalification?

A. A change from vertical uphill to vertical downhill
B. A change in filler metal from Group 1 to Group 3
C. A change from one welding process to another
D. A change from a V bevel to a U bevel joint preparation
E. All of the above

6.2 During visual examination of the welder's qualification test weld, which of the following applies?

A. The weld shall be free from cracks
B. The weld shall be free from inadequate penetration
C. The weld shall be free from burn-through
D. The weld must have a neat, workman-like appearance
E. All of the above

6.3 For multiple qualification, a welder shall be required to:

A. Make a butt weld in the fixed position
B. Lay out, cut, fit and weld a branch-on-pipe connection in which the specified diameters of the run and branch pipes are equal
C. Join pipes greater than 4.5 inches in outside diameter
D. Weld in the 6G position only
E. Both A & B

6.4 During visual examination of a qualification test coupon welded with mechanized or semiautomatic welding, filler wire protruding into the inside of the pipe:

A. Is not permitted
B. Shall not exceed 1/16 inch
C. Shall not exceed 1/8 inch
D. Shall be kept to a minimum
E. Both B & C apply

6.5 For a welder qualification on 0.500 inch thick wall pipe 6 inches in OD, the type and number of destructive test specimens required are?

A. 2 tensiles, 2 nick break tests and 2 side bends
B. 2 tensiles, 2 nick break tests and 2 face bends
C. 2 tensiles, 2 nick break tests and 2 root bends
D. 4 tensiles, 4 nick break tests and 4 side bends
E. 4 tensiles, 4 nick break tests, 2 root bends and 2 face bends

6.6 During visual examination of a branch-on-pipe connection qualification test weld, the finished weld:

A. Shall exhibit a neat, workman-like appearance
B. Shall exhibit no undercut
C. May have undercut up to 1/32 inch deep for the entire length of the weld
D. Shall be free from cracks
E. Shall meet both A & D

6.7 For a butt weld qualification, how many root bend specimens are required to qualify a welder on pipe with an OD of 8 inches and a wall thickness of 5/8 inch?

A. None
B. 1
C. 2
D. 3
E. 4

6.8 For a butt weld qualification, what are the type and number of test specimens required to qualify a welder on pipe with an OD of 8 inches and a wall thickness of 5/8 inch?

A. 2 nick break tests and 2 side bends
B. 2 tensiles, 2 face bends, and 2 root bends
C. 2 tensiles, 2 nick break tests and 2 face bends
D. 2 tensiles, 2 nick break tests and 2 root bends
E. 2 tensiles, 2 nick break tests and 2 side bends

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Section 7

Design and Preparation of a Joint for Production Welding

Section 7: Design and Preparation of a Joint for Production Welding

The purpose of Section 7 is to establish requirements for production welding.

7.1 General

Production welding shall be performed only by qualified welders using qualified welding procedures. This paragraph identifies the cleanliness requirements for the surfaces to be welded. Further, any base material or handling conditions (e.g. lamination, tears, etc) that might adversely affect welding are prohibited.

7.2 Alignment

Ideally, the abutting ends of adjoining pipe lengths should align with little or no axial misalignment. In practice, this is unlikely, so API 1104 suggests a maximum of no more than 1/8 inch of offset (high-low) between adjoining pipe lengths of the same wall thickness. Larger variations are acceptable if the pipe meets the ovality (maximum and minimum diameter) requirements in the applicable material (or purchase) specifications and the offset is distributed evenly around the outside of the joint. API 1104 suggests that hammering on pipes to obtain proper lineup be kept to a minimum.

7.3 Use of Lineup Clamp for Butt Welds

In production and fabrication, the use of a clamping device or fixture is a common practice to help bring adjoining pipe lengths into proper alignment. If external clamps are to be removed before completion of the root bead, at least half of the root bead must be in place, uniformly distributed around the joint. If internal clamps are to be used and removing them before completion of the root bead would permit movement of the pipe or result in undue stress on the unfilled joint, the internal clamps shall remain until the root pass is completed. When it is permissible to remove any clamp prior to the completion of the root bead, the completed portions of the root bead must be in approximately equal segments spaced approximately evenly around the joint.

7.4 Bevel

Bevels placed on pipe ends by the pipe manufacturer, referred to as “mill bevels,” must meet the requirements of the welding procedure specification. Pipe ends may be beveled in the field by any machine tool or machine oxygen cutting. The company, however, must approve the use of manual oxygen cutting. The dimensions of these manual bevels must also conform to those specified in the applicable welding procedure specification.

7.5 Weather Conditions

Welding shall not be done when the weather conditions, such as airborne moisture, winds, or blowing sands, pose a significant threat to the quality of the completed weld. Responsibility for determining how or whether to conduct welding operations lies with the company.

7.6 Clearance

For pipe welded above ground, the working clearance around the joint should be at least 16 inches in all directions. For pipe welded in a trench, the cavity beneath the pipe, sometimes referred to as the “bell hole,” shall be large enough to give the welder or welders adequate working space, but no minimum dimension is specified.

7.7 Cleaning Between Beads

Slag and scale shall be removed from each pass in a multi-pass weld using tools as specified in the welding procedure specification. High spots in beads deposited by semiautomatic or mechanized welding processes shall be removed by grinding to prevent contact between the filler metal and/or electrode and the weld deposit during welding. In addition, surface porosity clusters and bead starts shall be removed by grinding on semiautomatic and mechanized welds.

This requirement to remove slag from weld beads does not address the black "glass deposits" sometimes seen at the ripples of carbon steel weld beads deposited with GMAW. These deposits are black silicon oxide deposits whose black color comes from the manganese and iron in the base metal. Since they do not come from the flux used in flux-shielded processes, they are technically not slag. As a result, these are only required to be removed when specifically requested by the company.

7.8 Position Welding

and

7.9 Roll Welding

For position (or "fixed") welding, the pipes shall be secured against movement and the welders shall have adequate space to work. At the company's option, roll welding may be used, provided the pipe is adequately supported to prevent sag.

API 1104 has established a target weld profile for all pipe welds, regardless of whether they are welded in the fixed or rolled position. Face reinforcement should be no more than 1/16 inch and the face of the completed weld should be about 1/8 inch wider than the width of the original groove. Note that this profile is a target, not a requirement. It is commonly referred to as "nickel-wide and dime-high." In no case, however, shall the crown surface of the weld fall below the outside surface of the pipe. For both position and roll welding, the number of filler and finish eads shall allow the completed weld a substantially uniform cross section around the entire circumference

In position welding, two beads shall not be started in the same location. Instead, the starts and stops of a multipass weld should be located so that they do not coincide to avoid the creation of high-stress areas by multiplying the residual stresses associated with weld terminations. This applies to welds made in the fixed position, but not those made by roll welding.

7.10 Identification of Welds

Each welder shall identify his welds in a manner prescribed by the company.

7.11 Preheat and PWHT

Preheat and PWHT shall be conducted as specified by the welding procedure specification.

Exercise Questions

Section 7 Design and Preparation of a Joint for Production Welding

7.1 Who shall decide if weather conditions are suitable for production welding?

A. The project engineer
B. The company
C. The welding supervisor
D. The contractor
E. The welder

7.2 For production welds made in the fixed position, the face reinforcement should not exceed:

A. The thickness of the pipe wall
B. The amount of pipe offset
C. 1/16 inch
D. 1/32 inch
E. 1/8 inch

7.3 When pipe is welded above ground, the working clearance around the pipe should not be less than?

A. 32 inches
B. 24 inches
C. 18 inches
D. 16 inches
E. 8 inches

7.4 Which of the following are acceptable means for welders to identify their production welds?

A. Stenciling their identification symbol adjacent to the weld
B. Recording their identification symbol on a weld map
C. Writing their identification symbol adjacent to the weld using a permanent marker
D. Recording their identification on a traveler
E. Any of the above methods when prescribed by the company

7.5 Pipe ends of the same specified wall thickness should not be offset by more than:

A. 1/16 inch
B. 1/32 inch
C. 1/8 inch
D. 1/4 inch
E. No offset is permitted

7.6 Under what conditions may roll welding be used?

A. When the pipe is secured against movement
B. When pipe diameter exceeds 12 ¾ inches
C. When the company permits
D. When alignment is maintained with skids or a structural framework
E. Both C & D

7.7 When is the removal of surface porosity clusters, bead starts, and high points required before welding?

A. When using semiautomatic or mechanized welding processes
B. When using manual and semiautomatic processes
C. When welding API 5L Grade X70 pipe
D. When the temperature is below 32 °F
E. All of the above

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Section 8

Inspection and Testing of Production Welds

Section 8: Inspection and Testing of Production Welds

8.1 Rights of Inspection

The company shall determine whether inspection will be nondestructive or destructive, whether the inspection will occur during or after welding, and the frequency of inspections.

8.2 Methods of Inspection

NDT will usually be radiographic testing, but may be any method specified by the company. The acceptance criteria will be that found in either Section 9 or, at the company's option, Annex A. The company has the right to accept or reject any weld that doesn't meet the requirements for the method by which it was inspected. Welders who make welds that fail to meet production acceptance criteria may be, but do not have to be, disqualified from further work.

Operators of NDT equipment may be required to demonstrate the inspection procedure's ability to detect defects and the operator's ability to interpret the indications given by the equipment. This is particularly important for highly sophisticated techniques like phased array - UT and time-of-flight UT. Trepanning methods of testing shall not be used.

8.3 Qualification of Inspection Personnel

Welding inspection personnel shall be qualified by experience and training for the inspection task they perform. Those qualifications shall be acceptable to the company. Documentation of the qualifications shall be maintained by the company and shall address:

(a) Education and experience.
(b) Training.
(c) Results of any qualification examinations.

8.4 Certification of NDT Personnel

The certification of nondestructive testing personnel must be to the American Society for Nondestructive Testing's (ASNT's) Recommended Practice (RP) No. SNT-TC-1A, ASNT's Central Certification Program (ACCP) or any other nationally recognized program with company approval. Only Level II or III personnel are permitted to interpret test results.

A record of certified NDT personnel shall be maintained by the company. All levels of NDT personnel shall be recertified at intervals no greater than five years or sooner if required by the company or if a question arises about their competence.

Vision examinations are required for all NDT personnel.

The near-distance visual acuity requirement is the ability to read a Jaeger Number 1 test chart or equivalent at a distance of no less than 12 inches, documented by a test administered at least annually.

The color contrast requirement is the ability to differentiate between the colors used in the NDT method, documented by a test administered at least every five years.

Exercise Questions

Section 8 Inspection and Testing of Production Welds

8.1 Who determines the frequency of inspections?

A. The welder
B. The chief inspector
C. The QC Manager
D. The company
E. The contractor

8.2 Documentation of inspection personnel qualifications shall include which of the following?

A. Records of education and experience
B. Evidence of training
C. Results of qualification exams
D. All of the above
E. Only A & B

8.3 How often shall Levels I and II NDT personnel be recertified?

A. Every six months
B. Every year
C. At least every two years
D. At least every three years
E. At least every five years

8.4 Who determines the inspection method to be used?

A. The welder
B. The inspector
C. The QC Manager
D. The company
E. None of the above

8.5 Which of the following testing methods may not be used?

A. Visual testing
B. Radiographic testing
C. Trepanning
D. Penetrant testing
E. Ultrasonic testing

8.6 Nondestructive testing personnel shall be qualified in accordance with which of the following?

A. ASNT SNT-TC-1A or ACCP
B. ASME Section V
C. ASTM E165
D. Any other recognized national certification program that is acceptable to the company
E. Either A or D

8.7 How often must Level III NDT personnel be recertified?

A. At least every year
B. At least every two years
C. At least every three years
D. At least every four years
E. At least every five years

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Section 9

Acceptance Standards for NDT

Section 9: Acceptance Standards for NDT

9.1 General

This section presents acceptance standards for imperfections found by radiographic, magnetic particle, liquid penetrant, ultrasonic, and visual testing. NDT shall not be used to select welds that are to be destructively tested for welder qualification.

9.2 Rights of Rejection

The acceptance criteria presented in this Section are based primarily on discontinuity length, given the fact that NDT methods, other than ultrasonic testing, can offer no information about a discontinuity's depth into the weld. For this reason, the company retains the right to reject any weld that meets the limitations specified in this Section if, in their opinion, the depth of any acceptable discontinuity could be detrimental to the weld.

Section 9 defines each discontinuity and, for radiographic testing, clarifies the definition with a figure which shows a schematic. For each discontinuity, this section then provides acceptance criteria, which are typically expressed as both a limit on the size of any single indication as well as a limit on the total length of acceptable discontinuities per weld length. To be acceptable, welds must meet the criteria for each discontinuity as well as for the total accumulated flaws per weld as described in paragraph 9.3.12.

Rather than repeat the verbiage in Section 9, this part of the Study Guide will simply point the reader to the applicable paragraphs for the criteria for each discontinuity.

9.3 Radiographic Testing

Paragraph 9.3.1 provides the acceptance criteria for inadequate penetration without high-low, referred to as IP. The schematic is shown in Figure 13 on page 35.

Paragraph 9.3.2 provides the acceptance criteria for inadequate penetration due to high-low, referred to as IPD. This condition exists when the inadequate penetration is associated with misalignment of the pipe. The schematic is shown in Figure 14 on page 36.

Paragraph 9.3.3 provides the acceptance criteria for inadequate cross penetration, referred to as ICP. This discontinuity can only exist in welds made from both the inside and outside of the pipe. A schematic of this is shown in Figure 15 on page 36.

Paragraph 9.3.4 provides the acceptance criteria for incomplete fusion, referred to as IF. API 1104's definition of this limits it to incomplete fusion that is open to the surface. A schematic of this is shown in Figure 16 on page 36.

Unlike many other welding standards, API 1104 identifies two categories of incomplete fusion, based on whether it is open to the surface or not. While paragraph 9.3.4 addresses incomplete fusion open to the surface (IF), paragraph 9.3.5 provides criteria for incomplete fusion when it is not open to the surface. This type of incomplete fusion, said to be the result of a "cold lap," is referred to as IFD. A schematic of this is shown in Figure 17 on page 37.

Paragraph 9.3.6 provides the acceptance criteria for internal concavity, referred to as IC. A schematic of this is shown in Figure 18 on page 37. These criteria are stated in terms of the density of the radiographic image on radiographic film. Simply stated, this criterion permits any length of internal concavity as long as the weld thickness is no less than the thinner of the two pipe wall thicknesses being

joined. When the minimum wall thickness has been violated, the criteria for burn-through in paragraph 9.3.7 apply instead.

Paragraph 9.3.7 addresses burn-through, referred to as BT. No schematic for this discontinuity is provided. Paragraph 9.3.7.1 defines it and the acceptance criteria are provided for pipe having a specified OD of 2.375 inches and greater in paragraph 9.3.7.2 and for pipe having a specified OD less than 2.375 inches in paragraph 9.3.7.3.

Paragraph 9.3.8 addresses slag inclusions and defines two categories – elongated slag inclusions, referred to as ESIs, and isolated slag inclusions, referred to as ISIs. No schematic is provided for these discontinuities. ESIs are typically linear, separated by approximately the width of the root bead, and usually located between the root bead and the hot pass. ISIs have an irregular shape and may appear anywhere in the weld. The acceptance criteria for slag inclusions are located in paragraph 9.3.8.2 for pipe having a specified OD of 2.375 inches and greater and in paragraph 9.3.8.3 for pipe having a specified OD less than 2.375 inches. The note on page 38 is an exception to the acceptance criteria and specifies that ESIs separated by approximately the width of the root bead are to be considered a single ESI unless the width of either one exceeds 1/32 inch, in which case the two indications are to be considered separately as ESIs.

Paragraph 9.3.9 addresses porosity and defines it in paragraph 9.3.9.1. Acceptance criteria are specified based on the types of porosity. Criteria for individual or scattered porosity are given in paragraph 9.3.9.2. Criteria for cluster porosity, referred to as CP, are given in paragraph 9.3.9.3, which only applies to the final or cover (cap) passes. For CP in other than the finish pass, the criteria in 9.3.9.2 apply. Criteria for hollow bead porosity, referred to as HB, are given in paragraph 9.3.9.4.

Paragraph 9.3.10 provides the acceptance criteria for cracks. Cracks (previously referred to as 'C') are prohibited, except for shallow crater cracks or star cracks 5/32 inch in length or less. These cracks are acceptable and it is worth noting that API 1104 is probably the only construction code that explicitly permits cracks of any size. The note at the bottom of this paragraph defines these shallow crater cracks or star cracks as the cracks at the terminations of welds due to shrinkage. These shrinkage cracks are basically solidification cracks that occur when the welding arc is terminated suddenly while the weld puddle surface is still flat. Solidification and further shrinkage causes the weld surface to become concave and pull away from the center, leaving cracks. These cracks, however, can be easily prevented with proper welding techniques.

Paragraph 9.3.11 addresses undercutting, which is divided into two categories depending on whether it is on the outside surface of the pipe, referred to as EU, or whether it is on the inside of the pipe, referred to as IU. The acceptance criteria here provide limits for the length of undercut when it is discovered using radiography. However, the depth of undercut is just as important, if not more so, than the length. As a result, the note sends the reader to subsection 9.7 for undercut criteria when the undercut is accessible for visual and mechanical measurement, i.e., accessible for depth measurement. Subsection 9.7 on page 46 sends the reader to Table 4 also on page 46 for the permissible lengths of undercut as a function of depth.

Paragraph 9.3.12 provides acceptance criteria for the sum of all acceptable indications in a single weld, referred to as the accumulation of imperfections (previously referred to as 'AI'). In addition to the acceptance criteria for each individual discontinuity as provided in paragraphs 9.3.1 through 9.3.11, the sum of the lengths of all of the different acceptable flaws, excluding IPD, EU, and IU, in any given weld may not exceed the limits given in this paragraph.

Paragraph 9.3.13 requires that base metal (pipe or fitting) discontinuities discovered during radiography of the welds be reported to the company for disposition.

9.4 Magnetic Particle Testing

Paragraph 9.4.1 states that not all indications produced by magnetic particle testing (MT) are the result of weld imperfections. The examiner must be able to distinguish between indications produced by magnetic and metallurgical variations and those produced by imperfections. Indications produced by magnetic and metallurgical variations are to be considered nonrelevant. In addition, indications having a maximum dimension of no more than 1/16 inch are also considered to be nonrelevant unless proven otherwise.

After that, all relevant indications are then considered to be the result of weld imperfections and they are divided into two categories, depending on their aspect ratio. Those whose length is more than three times their width are referred to as linear indications. Those having a length three times their width or less are rounded indications.

Paragraph 9.4.2 provides the acceptance criteria for linear indications and refers the reader to paragraphs 9.3.9.2 (individual or scattered porosity) and 9.3.9.3 (cluster porosity) for the acceptance criteria for rounded indications.

Paragraph 9.4.3 addresses flaws found in base material during MT of a weld and requires that these be reported to the company for disposition.

9.5 Liquid Penetrant Testing

The requirements for liquid penetrant testing (PT) are exactly the same as those stated above for MT.

9.6 Ultrasonic Testing

Paragraph 9.6.1.1 emphasizes that the indications produced by ultrasonic testing (UT) are not necessarily defects. The difference between relevant indications, which are those that result from weld imperfections, and nonrelevant indications, which are the result of changes in the weld geometry, reinforcement profiles, internal chamfering, or other geometric issues must be understood.

Paragraph 9.6.1.2 classifies relevant indications as linear when their longest dimension is parallel to the direction of welding.

Paragraph 9.6.1.3 classifies relevant indications as transverse when their longest dimension is across the direction of welding.

Paragraph 9.6.1.4 classifies three-dimensional indications as volumetric.

Paragraph 9.6.2 provides acceptance criteria for indications found by UT based on the definitions in the following paragraphs:

(a) 9.6.2.2 for linear surface (LS) indications.
(b) 9.6.2.3 for linear buried (LB) indications.
(c) 9.6.2.4 for transverse (T) indications.
(d) 9.6.2.5 for volumetric cluster (VC) indications.
(e) 9.6.2.6 for volumetric individual (VI) indications.
(f) 9.6.2.7 for volumetric root (VR) indications and.
(g) 9.6.2.8 for the accumulation of relevant indications.

Paragraph 9.6.3 addresses imperfections in the base metal found during UT of welds and, similar to RT, MT, and PT, requires disposition of these flaws by the company.

9.7 Visual Acceptance Standards for Undercutting

Paragraph 9.7.1 reminds the reader that these criteria supplement, but do not replace, VT acceptance criteria found elsewhere in the Standard.

Paragraph 9.7.2 refers the reader to Table 4 on page 46 for acceptance criteria for undercut when visual and mechanical means can be used to determine depth. The table states, for instance, that there is no limit on the length of undercut in a weld if it is no deeper than the lesser of 1/64 inch or 6 % of the wall thickness. As undercut becomes deeper, the length permitted decreases.

Exercise Questions

Section 9 Acceptance Standards for NDT

9.1 Incomplete fusion (IF) shall be considered a defect when the length of an individual indication exceeds:

A. 1/8 inch
B. 25% of the wall thickness
C. 1/4 inch
D. 1 inch
E. No incomplete fusion is permitted

9.2 Porosity is:

A. Defined as gas trapped by the solidifying weld metal
B. Generally a spherical indication
C. Considered a defect if a single pore is larger than 1/8 inch
D. Categorized as individual, scattered, or hollow bead
E. All of the above

9.3 Which of the following applies to elongated slag inclusions (ESIs)?

A. They are nonmetallic solids trapped in the weld metal
B. They are typically broken slag lines
C. They are usually found at the fusion zone
D. They are nonmetallic solids trapped between the weld metal and base metal
E. All of the above

9.4 What discontinuity is defined as a portion of the root bead where excessive penetration has caused the weld puddle to be blown into the pipe?

A. Porosity
B. Nonmetallic solids in the base metal
C. Undercut
D. Burn-through
E. Underfill

9.5 Which of the following is(are) true about crater cracks?

A. They are caused by vibrations during welding
B. They are the result of weld metal contractions during solidification
C. They are caused by inclusions
D. They are the result of poor welding technique
E. Both B & D

9.6 The maximum width of an isolated slag inclusion (ISI) in a weld on a pipe whose OD is 6.625 inches is:

A. 1/16 inch
B. 1/8 inch
C. 1/2 inch
D. 1/4 of the weld width
E. Both B & D

9.7 The maximum acceptable length of a crater crack is:

A. 1/8 inch
B. 5/32 inch
C. No cracks are allowed
D. 1/2 of the weld width
E. Craters in welds cannot crack

9.8 When using ultrasonic testing, linear buried (LB) indications within the weld are unacceptable if they:

A. Exceed 2 inches in aggregate length in any continuous 12 inch length of weld
B. Exceed 5/32 inch
C. Have an aggregate length that exceeds 8 percent of the weld length
D. Have an aggregate length that exceeds 6 percent of the weld length
E. Both A & C

9.9 During visual inspection, undercut is found on the face surface of a ½ inch thick wall pipe weld. The undercut mechanically measures 1/64 inch deep and is approximately 6 inches long. The undercut is:

A. Not acceptable
B. Required to be evaluated by radiographic inspection
C. Unacceptable because it exceeds 2 inches in length
D. Acceptable
E. Undercut cannot be produced on the face of a weld

9.10 Where liquid penetrant testing is concerned, a linear indication is an indication whose:

A. Length is more than three times its width
B. Length is less than three times its width
C. Length is greater than 5/32 inch
D. Width is equal to its length
E. Length is less than its width

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Section 10

Repair and Removal of Weld Defects

Section 10: Repair and Removal of Weld Defects

10.1 General

Paragraph 10.1 states that weld defects may be identified at any time.

10.2 Authorization for Repair

Paragraph 10.2.1 states that company authorization is required for crack repairs, back weld repairs, and double repairs. Company authorization is not required for any repair that does not require the application of heat or weld metal, such as grinding or filing.

Paragraph 10.2.2 gives the conditions under which company-authorized repairs can be made to cracked welds. In general, if the length to be repaired is less than 8 % of the weld length, repair is permitted if a qualified repair procedure is used.

Paragraph 10.2.3 addresses repair of defects other than cracks and states that these defects in the root, filler, and finish beads may be repaired with prior company authorization. A qualified repair procedure is required for repair welds when using a welding process, method of application, or filler metal different than that used for the original weld, or when repairs are made in a previously repaired area, or when required by the company.

Paragraph 10.2.4 permits the use of grinding to remove defects in the reinforcement of root beads and cover passes, as long as contour, minimum wall and weld thickness requirements are not violated.

Paragraph 10.2.5 permits the repair of back welds as long as a qualified repair welding procedure is used and the company permits the repair.

Paragraph 10.2.6 requires prior company authorization for double repairs. Further repair of a double repair is only permitted with company authorization and when the repair procedure to be used has been qualified by replicating the number of thermal cycles that the pipe will have seen after the repair.

Paragraph 10.2.7 places limits on the lengths of repairs. For pipe having a specified OD of 2.375 inch and greater, the limit on the length of repairs shall be established by the company. For pipe having a specified OD less than 2.375 inch, all repairs require prior company authorization.

Paragraph 10.2.8 establishes a minimum required repair length of 2 inches unless the company authorizes a shorter repair.

10.3 Repair Procedure

This section provides detailed requirements for qualifying repair welding procedures. Repairs are categorized as full-thickness repairs, internal partial-thickness repairs, external partial-thickness repairs, cover pass repairs, or back weld repairs and the type and number of test specimens required for each type of repair procedure are given in Table 5 on page 49, with detailed instructions in paragraph 10.3.3. The tests required are fewer in number to, and different than, the tests required to qualify a butt weld procedure in Table 2. This table adds macrosections and hardness tests for all of the repair procedures but Charpy impact specimens are only required if the original production welding procedure was qualified with Charpy impact tests and when specified by the company.

Paragraph 10.3.4 lists the information required to be on a repair welding procedure and includes:

(a) Location and method for exploration of the defect.
(b) Method of defect removal and subsequent inspection for verification of removal.
(c) Requirements for preheat and interpass temperature.
(d) Welding processes and all of the other specification information required in paragraph 5.3.2.
(e) Requirements for interpass NDT, if applicable.
(f) Methods for filler metal control or storage, including electrodes, fluxes, and/or shielding gases when hydrogen control is recommended by the manufacturer.
(g) Repair type and procedure limitations.
(h) Time dley before final inspection, when required.

Paragraph 10.3.5 adds three new essential variables to the list in paragraph 5.4.2: (1) the location of excavation in paragraph 10.3.5.2, (2) type of repair in paragraph 10.3.5.3, and (3) the preheat and interpass temperature in paragraph 10.3.5.4

Paragraph 10.3.6 addresses the welding of the test joint and specifies a minimum length of 8 inches. In addition, multiple repair procedures may be qualified in a single test joint.

Paragraph 10.3.7 addresses the testing of the weld joints and provides specific requirements for visual examination and the hardness tests to be conducted on the macrosections. Hardness tests are required for both the deposited weld metal and the heat-affected zones of the macrosections at the locations specified in Figures 21 through 26 on pages 51 through 53, depending on the type of repair. Hardness tests shall be conducted per ASTM E384 using a Vickers indenter and a 10 kg load. Maximum hardness values shall not exceed those listed in Table 6 on page 54, but the company can specify other maximum hardness values if they choose to do so. When hardness testing is required, chemical analysis is also necessary to determine the carbon equivalent of the base metal.

Charpy impact testing shall also be performed when the production welding procedure was qualified by Charpy impact tests and shall be performed at locations specified by the company. The company shall specify the minimum design temperature at which the specimens shall be tested and the minimum required absorbed energy for those tests.

10.4 Repair Welder Qualification

This subsection lists the rules for qualifying welders who perform repair welds. Welders performing repair welds must have an existing qualification to subsections 6.2 or 6.3 in addition to the requirements in this subsection. The welder must then make an additional qualification weld using the applicable repair welding procedure and the number and type of test specimens required are provided in Table 7 on page 54 for the specific type of repair welding procedure.

Paragraph 10.4.3 gives the changes in essential variables that would require requalification of repair welders. They are:

(a) Any change from one repair type to another except qualification on a full-thickness repair qualifies all partial-thickness repairs.
(b) A change in filler metal groups as defined in Table 1.
(c) An increase in depth of the repair area greater than twice that deposited in the qualification weldment.
(d) A change in position from that for which the repair welder has already qualified.

10.5 Supervision

Repair welds shall be made under the supervision of an individual experienced in repairs who is acceptable to the company. Inspection of repairs and the qualification of those conducting the inspections shall be as specified by the company. Repairs shall be documented and the records maintained by the company.

10.6 Acceptance Criteria

Repaired areas shall be inspected by and evaluated in accordance with the same NDT methods and acceptance criteria as used for the original weld. NDT of a repair weld must include the entire length of the repair plus the greater of 2 inches or 10 % of the repaired length on both ends of the repair.

Section 10 Repair and Removal of Weld Defects

10.1 Upon visual detection of a weld crack, what should the inspector do?

A. Authorize an immediate repair weld
B. Have it removed from the line unless permitted by 9.3.10
C. Submit it for additional nondestructive testing
D. Contact the company representative for repair authorization
E. Either B or D, depending on the length and type of crack

10.2 Repaired welds shall:

A. Meet the standards of acceptability of Section 9
B. Be examined by the company representative
C. Be submitted for radiographic inspection
D. Be ground smooth with a minimum of metal removal
E. Be inspected by a Level III inspector

10.3 Which of the following are required in a weld repair procedure?

A. Method of defect removal
B. Preheat requirements
C. All of the procedure specification information contained in paragraph 5.3.2
D. The welding process or processes
E. All of the above

10.4 Under which of the following conditions could rejectable porosity be repaired by welding?

A. With prior company authorization if it is in the root bead
B. With prior company authorization if it is in a filler bead
C. With prior company authorization if it is in the cover pass
D. All of the above
E. Porosity may not be repaired

10.5 Cracked welds may be repaired by welding provided which of the following criteria is/are met?

A. The length of the crack is less than 8% of the weld length
B. The weld is made by a qualified welder
C. A qualified weld repair procedure is used
D. All of the above
E. Both B & C

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Section 11

Procedures for Nondestructive Testing (NDT)

Section 11 Procedures for Nondestructive Testing (NDT)

Written procedures are required for all NDT procedures.

11.1 Radiographic Test Methods

Paragraph 11.1.1 addresses requirements for radiographic examination of welds using film or other media. It describes the film characteristics (appropriate density, clarity, and contrast) necessary to produce the requisite images. Images produced by other systems shall have the necessary sensitivity to clearly define the essential wire diameter of the proper image quality indicator (IQI), sometimes referred to as a "penetrameter."

All image quality requirements apply equally to images produced by x-rays or gamma rays. Paragraph11.1.2 reiterates the fact that written procedures are required and refers the reader to paragraphs 11.1.2.2 for the details to be addressed in procedures for film radiography and to paragraph 11.1.2.3 for the details to be addressed in procedures for techniques that use other imaging media.

Paragraph 11.1.3 addresses exposure geometry, which is the relationship between the radiation source, the part being inspected, and the film or other medium. Three exposure geometries are defined. Single wall exposure/single wall viewing (SWE/SWV) is an exposure where the radiographic source is centered inside the pipe with the film on the outside of the pipe so that, at all locations on the film, the radiation goes through a single wall thickness before it reaches and exposes the film and the film only shows one wall thickness. When the radiographic source is outside the pipe, but no more than ½ inch from the weld surface, and the film is on the opposite side of the pipe, three exposures separated by 120 degrees are required to examine all 360 degrees of the weld. This is referred to as double wall exposure/ single wall viewing or DWE/SWV, in which radiation passes through two pipe wall thicknesses before it reaches and exposes the film, but only the film-side portion of the wall thickness is visible on the film and can be read for evaluation of the weld. This is also sometimes referred to as a "contact shot." When the radiographic source is outside the pipe and more than 1/2 inch from the weld surface, at least four exposures 90 degrees apart are required to examine all 360 degrees of the weld. This is also referred to as DWE/SWV. However, for pipe having diameters of 3-1/2 inches or less, a double wall exposure/ double wall viewing (DWE/DWV) technique may be used, in which the source is offset from the plane of the weld so that the weld appears as an ellipse on the film. In this case, two exposures separated by 90 degrees are required, as a minimum, for the evaluation of the full 360 degrees of the weld.

Paragraph 11.1.4 introduces image quality indicators (IQIs) and gives basic information about their characteristics and use. IQIs shall be either the ASTM E747 wire type or the ISO 19232-1 wire type. The wires shall be "radiographically similar" to the pipe and weld material being examined, meaning that they must have the same or very nearly identical density to that of the materials being examined. The company will decide which IQI type is to be used.

The "essential" wire diameter is the smallest wire that must be seen clearly across the area of interest on the film. Since the wires are placed across the weld, the area of interest is, obviously, the weld. The essential wire diameter is specified, based on weld thickness, in Table 8 on page 58 for ASTM E747 wire-type IQIs and in Table 9 on page 59 for ISO 19232-1 wire-type IQIs. Note that the essential wire diameter is based on weld thickness, not just nominal wall thickness, so this means that the thickness to be used in these tables is the nominal wall thickness plus weld reinforcement on both the outside and inside of the pipe weld. At the company's option, smaller wire diameter IQIs may be used, as long as the minimum required sensitivity is obtained.

The details of IQIs to be used are addressed in paragraph 11.1.5. The ASTM E747 wire-type IQI has six wires while the ISO 19232-1 wire-type IQI has seven wires, both of which arrange the wires in order of increasing diameter. These tools are used to ensure the radiographic technique's minimum sensitivity, which is usually the ability to resolve any indication whose maximum dimension is 2 % of the weld thickness or greater.

Placement of IQIs is described in paragraph 11.1.6. Wire-type IQIs are typically placed on top of the weld with the wires transverse to the weld. The location (source side vs. film side) is a function of the exposure geometry. When a weld is radiographed in a single exposure with the radiation source inside of the pipe (SWE/SWV), a minimum of four IQIs, equally spaced around the outside of the pipe, is required. For DWE/DWV procedures, a single IQI on the source side of the pipe is required. For DWE/SWV and SWE/SWV procedures requiring multiple exposures or films to cover all 360 degrees of the weld and where the length of film to be interpeted exceeds five inches, two IQIs located on the film side are required.

When placing IQIs across the weld is impractical due to weld reinforcement or profile, the IQI may be placed on a separate block of similar material, also called a "shim," is used to elevate the IQI to a height level with the top of the weld reinforcement.

Paragraph 11.1.7 limits the interpretation of radiographic images of production welds to Level II or Level III radiographers. Radiographers are required to report all defects to the company unless the company specifically requires all imperfections to be reported. The radiographers shall state whether the welds meet the requirements of Section 9 of API 1104, but the company shall determine the final disposition of the welds.

Paragraph 11.1.8 requires that lead letters, numbers, or markers be placed on the weldment to identify the radiographic image relative to the weld. This will allow the defects identified on the film to be located on the weld so that repairs can be accurately located.

Improper storage of unexposed film can render it unsuitable for use. Paragraph 11.1.9 recognizes this hazard and requires unexposed film to be stored in a clean, dry place and it also explains the characteristics of damaged film.

All film must exhibit the same level of quantitative blackening, referred to as "transmitted density," when exposed to the same intensity of radiation. This transmitted density can be limited by pre-exposure fog on the unexposed film. There is a limit to the amount of pre-exposure fog permitted on unexposed film. For transparent-based film, the pre-exposure fog cannot exceed 0.30 H & D transmitted density; for opaque-based film, this pre-exposure fog can be no more than 0.50 H & D reflected density, where "H & D" is the Hurter-Driffield method of defining the quantitative blackening of film.

Paragraph 11.1.10 gives the film quality requirements for the areas of interest for developed film. Except for small areas on the film corresponding to irregular weld configurations, the transmitted H & D density of transparent-based film shall be between 1.8 and 4.0, inclusive; the reflected H & D density of opaque-based film shall be between 0.5 and 1.5, inclusive. Paragraph 11.1.10.4 states that, when requested by the company, the film or other imaging media must be processed, handled, and stored so that the images are interpretable for at least three years after they are produced.

11.2 Magnetic Particle Test Method

A procedure for magnetic particle testing (MT) must be written, qualified by demonstration, and accepted by the company prior to use. The MT procedure must comply with ASTM E709, Standard Guide for Magnetic Particle Testing.

11.3 Liquid Penetrant Test Method

A procedure for liquid penetrant testing (PT) must be written, qualified by demonstration, and accepted by the company prior to use. The PT procedure must comply with ASTM E165, Standard Test Method for Liquid Penetrant Examination.

11.4 Ultrasonic Test Methods

A detailed procedure must be developed, qualified by demonstration, and agreed upon by the contractor and company. The use of ultrasonic testing (UT) shall be at the option of the company. The pipe being inspected with UT must be uncoated and the inspector should be aware of surface conditions that can interfere with scanning. Pipe seams should be ground flush.

Paragraph 11.4.2 describes the elements required to be addressed in the written procedures for ultrasonic testing of welds. This includes calibration requirements.

Paragraph 11.4.3 states that only NDT Level III UT personnel are permitted to develop application techniques and prepare and approve the procedures. However, both Level II and Level III UT personnel are permitted to calibrate equipment and interpret the test results. Similarly, both Level II and III UT personnel are permitted to perform the tests and evaluate the results per the acceptance criteria.

The company has the right to require personnel to demonstrate their ability to perform to the requirements of the procedure as described in paragraph 11.4.4.

Paragraph 11.4.4 requires that the UT procedure as well as the system/equipment to be used must be demonstrated and this demonstration must be accepted by the company. This demonstration must also be documented in a report which must address the following:

(a) Welds containing defects and acceptable discontinuities must be prepared from actual production material using a qualified welding procedure.
(b) Radiographs shall be made of the welds and the results documented.
(c) The UT procedure shall be applied to the welds and the results documented and compared with the radiographs.
(d) Differences in detection results shall be documented. Destructive testing will usually be necessary to confirm the results or document discrepancies. This, however, is at the option of the company.
(e) The use of the UT procedure on production welds is then based on the capability of the method/systems to:

1) Circumferentially locate,
2) Size for length,
3) Determine the depth from the OD surface, and
4) Axially locate (across the weld cross-section) the discontinuities/defects in the test welds.

Paragraph 11.4.5 requires the sensitivity of the UT process and equipment to meet minimum requirements. This is accomplished by applying the procedure to known reference standards and specifying the minimum magnitude (screen height) of return echoes produced by standard geometric conditions. The reference block used for this is shown in Figure 27 on page 64. The block must be made by introducing a standard N10 notch, as shown in the figure, into a sample of the pipe material to be inspected. The highest point of the distance-amplitude-corrected (DAC) or time-corrected gain (TCG) echo produced by this notch shall not be less than 80 % of the full screen height on the UT display. Adjusting the equipment to meet this requirement will ensure proper calibration. Requirements for the sensitivity of the automated UT procedure follow a similar approach, except that flat-bottomed holes

must be machined into a sample of the pipe to be inspected, in addition to the N10 notches.

Paragraph 11.4.6 requires that parent material be screened for flaws that may interfere with the weld inspection. Before ultrasonic testing of a completed pipe weld is begun, a compression wave test must be conducted on both sides of the weld to locate any reflectors in the parent material that may interfere with the weld inspection. Once the parent material is determined to be sound or any reflectors in the parent metal are located and documented, the weld may be inspected.

Paragraph 11.4.7 identifies the reference scanning sensitivity and screen height requirements for manual compression wave and automatic testing of the parent material and the scanning and evaluation sensitivities for the manual and automated testing of welds. Determination of the reference sensitivity for the parent material and inspection of the weld must be performed and documented independently.

Paragraph 11.4.8 requires UT technicians to report only defects, unless the company specifically requires that all indications (evaluation level and above) be reported.

Paragraph 11.4.9 specifies that the UT report shall list the weld number, datum location, length, depth from the OD surface, and the defect classification (linear, transverse, or volumetric) for each reported indication.

Exercise Questions

Section 11 Procedures for Nondestructive Testing (NDT)

11.1 Prior to radiography of any production weld, the radiographic procedure should be established and agreed upon by whom?

A. The inspector and the welder
B. The company and the radiographer
C. The company and the welder
D. The company and the CWI
E. The company and the radiographic contractor

11.2 NDT Level III UT personnel:

A. Are permitted to calibrate equipment
B. Are permitted to interpret test results
C. May be required to demonstrate their capabilities to perform to the requirements of the qualified procedure for the company representative
D. Shall develop the application technique and approve the testing procedure
E. All of the above

11.3 Using the ISO 19232-1 wire type IQI, the smallest wire required to be visible on the radiograph of a full penetration weld in a pipe having a weld thickness of 0.432 inch is identified by what number?

A. 10
B. 11
C. 12
D. 15
E. 17

11.4 Using the ASTM E747 wire type IQI, the essential wire diameter required to be visible on the radiograph of a weld in a pipe with a weld thickness of 0.550 inch is:

A. 0.008 inch
B. 0.010 inch
C. 0.013 inch
D. 0.016 inch
E. 0.020 inch

11.5 What conditions must be considered when using ultrasonic testing on in-service welds?

A. The scope of use for ultrasonic testing is at the option of the inspector
B. Pipe seams are not required to be ground flush
C. Results may vary from unit to unit
D. Surface imperfections can interfere with its use
E. Surfaces must be coated prior to testing

11.6 During radiographic examination of a weld, the image of the essential wire shall:

A. Be parallel to the weld direction
B. Be visible next to the weld
C. Appear clearly across the entire area of interest
D. Be selected by the radiographic contractor
E. Wire type image quality indicators are not permitted by API 1104

11.7 Who shall interpret the radiographic images of production welds?

A. Level I radiographer
B. Level I or Level II radiographers
C. The welding inspector
D. Level II or Level III radiographers
E. The company representative

11.8 When using an ISO wire type IQI, what is the essential wire diameter required to be visible on the radiograph of a pipe weld whose weld thickness is 0.750 inch?

A. 0.013 inch
B. 0.020 inch
C. 0.016 inch
D. 0.025 inch
E. 0.010 inch

11.9 The procedure to be used for ultrasonic testing must:

A. Be demonstrated by the contractor to prove the application of the procedure and system
B. Be proven on welds containing defects and acceptable imperfections produced by approved welding procedures on actual production pipe material
C. Be proven to be as accurate as radiographs made of the demonstration welds
D. Be documented by detailing the differences between the radiographic and ultrasonic examination of the demonstration welds
E. Meet all of these requirements

11.10 DWE/SWV is an acronym for which of the following ?

A. Double-wall exposure for single-wall viewing
B. Double-wall exposure for double-wall viewing
C. Single-wall exposure for single-wall viewing
D. Double-wall exposure on shielded weld V grooves
E. Double-weld exposure for single welded viewing

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Section 12

Mechanized Welding with Filler Metal Additions

Section 12: Mechanized Welding with Filler Metal Additions

Section 12 provides the rules for qualifying welding procedures and personnel for mechanized welding with filler metal additions. It further addresses production welding along with inspection and NDT of production welds.

12.1 Acceptable Processes

Mechanized welding shall be performed using one or more of the following processes:

(a) Submerged arc welding (SAW).
(b) Gas metal arc welding (GMAW).
(c) Gas tungsten arc welding (GTAW).
(d) Flux cored arc welding (FCAW) with or without external shielding gas.
(e) Plasma arc welding (PAW).
(f) Any of the above processes combined with a manual or semiautomatic process.

12.2 Procedure Qualification

The rules in Section 12 are basically identical to those in Section 5 with a few additions and exceptions. Only the differences from Section 5 will be discussed here.

The quality of test welds shall be determined by both destructive testing and nondestructive testing and shall meet the requirements of subsection 5.6, except that nick break tests are not required, and Section 9. The use of nondestructive testing is in addition to the destructive tests required in Section 5.

12.3 Record

Identical to Section 5, this subsection refers the reader to Figures 1 and 2 on pages 10 and 11 for recommended forms that can be used to document a welding procedure specification and the record of the procedure qualification test coupon, respectively. The record of the procedure qualification must be maintained as long as the welding procedure specification is in use.

12.4 Welding Procedure Specification

Subsection 12.4 lists the variables required to be recorded on a welding procedure specification for mechanized welding. The list is the same as that in subsection 5.3, with the following additions and exceptions:

(a) This section does not provide suggested groupings for diameters or wall thicknesses.
(b) Paragraph 12.4.2.1 requires the welding procedure specification to include a description of the equipment to be used.
(c) Paragraph 12.4.2.4 requires that the welding machine used for each bead be recorded on the welding procedure specification.
(d) Flame characteristics are not listed in subsection 12.4 because oxyfuel welding cannot be mechanized.
(e) The minimum percentage of root bead welding that must be completed before a lineup clamp can be removed is not listed in paragraph 12.4.2.11.
(f) Paragraph 12.4.2.12 includes the requirements for joint end and interpass cleaning, but does

not require that the type of cleaning tools (power or hand) be specified on the welding procedure specification.

(g) Paragraphs 12.4.2.13 and 12.4.2.14 require the width of material to be heated during preheat and PWHT to be specified on the welding procedure specification.

(h) Paragraph 12.4.2.19 requires the welding procedure specification to list any other important factors necessary to produce a good weld and gives examples.

12.5 Essential Variables

Subsection 12.5 lists the essential variables for the qualification of welding procedures using mechanized welding processes. This list is essentially the same as that in subsection 5.4 with the following additions and exceptions:

(a) Paragraph 12.5.2.3 adds that any change to the root spacing, root face or angle of bevel to a value not specified on the welding procedure specification is an essential variable.

(b) Paragraph 12.5.2.4 adds that any change in wall thickness beyond the range listed in the welding procedure specification is an essential variable.

(c) Paragraph 12.5.2.5 adds that any change in specified pipe OD beyond the range listed in the welding procedure specification is an essential variable.

(d) Paragraph 12.5.2.7 adds that a change in the size of the filler metal wire is an essential variable.

(e) Change in welding position is NOT an essential variable.

(f) Paragraph 12.5.2.10 specifies that a change in the range of flow rates established for the shielding gas is an essential variable (whereas subsection 5.4 addresses a specific percentage change).

(g) Paragraph 12.5.2.16 adds that, for plasma arc welding, any change in the orifice gas nominal composition or change in the orifice diameter is an essential variable.

12.6 Qualification of Welding Equipment and Operators

This subsection lists the essential variables and the tests required to qualify the welding operators.

Paragraph 12.6.1 provides the general rules applicable to welding operator qualification. Similar to Section 6, welding operators shall be qualified by welding a test coupon which shall be tested either by destructive methods or nondestructive methods, or both, and shall meet the requirements of subsection 6.4 (visual examination) and either 6.5 (mechanical testing) or 6.6 (radiographic testing), except that nick break tests are not required. When required, tensile strength tests may NOT be omitted in lieu of nick break tests. In addition, welding operators shall be qualified on the type of equipment to be used in production welding.

Paragraph 12.6.2 lists the essential variables for welding operator qualification. They are:

(a) A change from one welding process, mode of transfer, polarity, or method of application to another.

(b) A change in the direction of welding from vertical uphill to downhill or vice versa.

(c) A change in the filler metal type (solid wire, metal cored, flux cored, etc.).

(d) A change from one specified OD group to another where the OD groups are defined as:

1) OD less than 12.75 inches.

2) OD equal to or greater than 12.75 inches.

(e) An increase in wall thickness over that welded during the qualification test.

(f) A change in position from that qualified (a change from rolled to fixed or a change from vertical to horizontal). A welding operator who qualifies in the fixed position shall also be qualified to perform welds in the rolled position.

(g) A change in welding bug manufacturer or model.
(h) A change in the method of applying the root bead (e.g., external root versus internal root).
(i) A major change in joint design (e.g. from a V-groove to a U-groove) or any change beyond the range established for root spacing, root face or angle of bevel.
(j) At the option of the company, welding operators whose work is limited to specific passes in a multipass butt weld may qualify by depositing only those passes in a joint, with other passes necessary to complete the joint being welded by others.

12.7 Records of Qualified Operators

A record shall be made of the tests and results required by subsection 12.6. A form similar to that shown in Figure 2 on page 11 should be used, but any form is suitable as long as it records all of the required information. A list of qualified operators and the procedures for which they are qualified shall be maintained. An operator may be required to requalify if a question arises about his competence.

12.8 Inspection and Testing of Production Welds

Production welds shall be inspected and tested in accordance with Section 8.

12.9 Acceptance Standards for NDT

Acceptance criteria for production welds shall be those found in Section 9 or, at the company's option, Annex A.

12.10 Repair and Removal of Defects

Repair and removal of defects shall be in accordance with Section 10.

12.11 Radiographic Testing

Radiographic testing procedures shall be in accordance with subsection 11.1.

12.12 Ultrasonic Testing

Ultrasonic testing procedures shall be in accordance with subsection 11.4.

Exercise Questions

Section 12 Mechanized Welding with Filler Metal Additions

12.1 For the qualification of mechanized pipe welding procedures, the use of a lineup clamp:

A. Is required
B. Must be of the internal type
C. Must be of the external type
D. Is required and cannot be removed until the entire weld is completed
E. Must be specified in the procedure

12.2 Which of the following is not an essential variable for a welding procedure specification for mechanized welding processes?

A. Pipe wall thickness
B. Direction of welding
C. Postweld cleaning
D. Welding process
E. Pipe diameter

12.3 Radiographic testing of welds made by mechanized processes shall be in accordance with:

A. Subsection 6.4
B. Subsection 11.1
C. Subsection 13.9
D. Paragraph 9.3.10
E. Section 8

12.4 On a welding procedure specification for mechanized welding, the travel speed:

A. Does not need to be recorded
B. Need not be addressed if current and voltage are recorded
C. May be changed at the discretion of the welding operator
D. Must be recorded for each pass
E. Both A & C

12.5 Which of the following is <u>not</u> an essential variable for the qualification of mechanized welding procedure specifications?

A. A change from V groove to U groove
B. A change from a 1/8 inch diameter filler wire to a 1/16 inch diameter filler wire
C. An increase in the time between the end of the fill passes and the start of the cap pass
D. An increase in the range of gas flow rates
E. A change in the plasma gas orifice diameter

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Section 13

Automatic Welding Without Filler Metal Additions

Section 13: Automatic Welding Without Filler Metal Additions

13.1 Acceptable Processes

Section 13 addresses the welding of pipe using automatic welding without filler metal additions. It applies to only one welding process: the flash butt welding process.

13.2 Procedure Qualification

Subsection 13.2 requires at least two test welds to be made, followed by radiographic testing prior to destructive testing using tension, nick break, and side bend tests. If the required tests are acceptable, the welding variables at which these two test welds are made will establish the maximum and minimum values permitted for welding voltage, welding current, axial speed, time intervals in the weld cycle, and upset stroke on the resulting welding procedure.

Table 10 on page 75 lists the type and number of test specimens required for procedure qualification. The number of specimens depends on the outside diameter of the pipe, with larger diameter pipe requiring more specimens, as shown in Figures 30, 31, and 32 on pages 73 and 74.

Paragraph 13.2.3.2 addresses the tension tests required. The preparation, testing, and acceptance criteria are the same as previously described in Section 5.

Paragraph 13.2.3.3 addresses the nick break tests required. Since flash butt welding is typically used on large diameter, heavy-wall pipe, wider nick break specimens are used. These are 2-inches wide as opposed to the 1-inch wide specimens required in Sections 5 and 12. Figure 33 on page 76 shows a schematic of these 2-inch wide specimens. These specimens have, in addition to the 1/8 inch deep notch on each edge of the specimen, a 1/16 inch, max., deep notch on the top and bottom of the weld bead. In order to locate the notch on the bond line, however, the edges of the nick break specimen must be polished and macroetched to reveal the bond line.

Other than that, the preparation and testing for nick break tests are the same as previously described in Section 5. The acceptance criteria, however, are slightly different from those required in Section 5.

Paragraph 13.2.3.4 addresses the side bend tests required. Since flash butt welding is typically used on large diameter, heavy-wall (greater than ½ inch thick) pipe, no face and root bend tests are used – only side bend tests. The preparation, testing, and acceptance criteria are the same as previously described for side bend tests in Section 5.

13.3 Record

The details of each procedure shall include all of the data specified in subsection 13.4. The record of the qualification shall show the results of the qualification tests and shall be retained as long as the procedure is in use.

13.4 Welding Procedure Specification

This paragraph lists the variables required to be recorded on a welding procedure specification. They are:

(a) The welding process.
(b) The pipe material.
(c) The pipe wall thickness and OD.
(d) The preparation of the pipe, grinding of the pipe seam, and cleaning of the pipe ends.

(e) The welding position.
(f) Preheat.
(g) Cleaning and inspection of electrical contact shoes.
(h) Permitted range of welding voltage.
(i) Permitted range of welding current.
(j) Permitted range of axial speed.
(k) Permitted range of time intervals in the weld cycle.
(l) Permitted range of upset stroke.
(m) Time delay before removal of clamps.
(n) Method of removing internal flash.
(o) Method of removing external flash.
(p) PWHT time, temperature, measurement techniques, and cooling rate requirements.

13.5 Essential Variables

This paragraph lists the essential variables for the qualification of welding procedure specifications. They are:

(a) A change in the pipe material.
(b) A change in the specified pipe wall thickness or OD.
(c) A change in the pipe preparation dimensions.
(d) A change in the welding position.
(e) A change in the requirements for preheating.
(f) A change in voltage to a value outside the range listed on the welding procedure specification.
(g) A change in current to a value outside the range listed on the welding procedure specification.
(h) A change in the axial speed to a value outside the range listed on the welding procedure specification.
(i) A change in the time intervals in the weld cycle to a value outside the range listed on the welding procedure specification.
(j) A change in the upset stroke distance to a value outside the range listed on the welding procedure specification.
(k) A change in PWHT conditions.

13.6 Qualification of Equipment and Operators

Each welding operator must qualify by welding a test coupon that meets all of the test requirements imposed by subsection 13.2, in other words, the same tests as required for qualifying a welding procedure.

13.7 Records of Qualified Operators

A record shall be made of the tests and results required by subsection 13.6. A form similar to that shown in Figure 2 on page 11 should be used, but any form is suitable as long as it records all of the required information. A list of qualified operators and the procedures for which they are qualified shall be maintained. An operator may be required to requalify if a question arises about his competence.

13.8 Quality Assurance of Production Welds

The company has the right to inspect all welds using nondestructive means, by removing welds and subjecting them to destructive tests, or both. The frequency of any of these tests shall be at the

discretion of the company.

Paragraph 13.8.2 states that production welds can be rejected if the welding voltage, current, axial speed, cycle time, or upset stroke variables recorded during the weld are outside the ranges specified on the welding procedure specification. Welds can be rejected either during the welding process or after welding has been completed. Rejected welds must be removed from the line.

Paragraph 13.8.3 states that production welds can also be rejected based on the results of nondestructive testing, including visual examination, in accordance with the requirements of subsection 13.9.

Paragraph 13.8.4 establishes limits for interanal and external reinforcement. Internal (ID) reinforcement shall not exceed 1/16 inch and outside (OD) reinforcement shall not exceed 1/8 inch. Values in excess of these require rejection of the weld; however, if it is possible to remove the flash from the weld initially, it should also be possible to remove any reinforcement in excess of these limits to render the weld acceptable.

Paragraph 13.8.5 requires each flash butt weld to be subjected to an austenitizing heat treatment, meaning PWHT at a temperature above the upper transformation temperature, also referred to as the Ac_3. This is the temperature above which the ferrite-to-austenite transformation is complete. This heat treatment must be followed by controlled cooling or still-air cooling. Any deviation in time at temperature, maximum temperature, or cooling rate beyond those specified in the welding procedure specification shall require reheat treatment.

13.9 Acceptance Standards for NDT

Paragraph 13.9.1 states that the acceptance criteria in paragraph 13.9.2 apply to flaws found by radiography or by any other nondestructive test method, including visual examination.

Paragraph 13.9.2 establishes limits for isolated slag inclusion (ISIs) and allows a small amount. However, cracks, incomplete fusion, and porosity in a flash butt weld are all cause for rejection, regardless of size or length.

13.10 Repair and Removal of Defects

Subsection 13.10 establishes the rules for repair and removal of defects.

Paragraph 13.10.1 states that defects that are open to the surface may be repaired by grinding, if the pipe's minimum wall is not violated. Other defects may be removed by grinding, chipping, or gouging (or a combinatoin of these), followed by a repair weld in accordance with Section 10. All repair welds must be approved by the company.

Paragraph 13.10.2 states that porosity found in a flash butt weld cannot be repaired; therefore, a flash butt weld containing porosity is rejected and must be removed from the line. However, porosity found in a repaired area (welded with a different process) of a flash butt weld shall be acceptable if it does not exceed the limits established in paragraphs 9.3.9.2 for individual or scattered porosity or 9.3.9.3 for cluster porosity.

13.11 Radiographic Procedure

Subsection 13.11 states that radiography of flash butt welds shall be performed in accordance with the rules described in subsection 11.1.

Exercise Questions

Section 13 Automatic Welding Without Filler Metal Additions

13.1 How many test specimens are required for qualifying a flash butt welding procedure?

A. 24 total for 19 inch OD pipe
B. 32 total for 29 inch OD pipe
C. 40 total for 32 inch OD pipe
D. 4 tensile strength specimens are required for all sizes
E. All of the above are correct

13.2 Which of the following is <u>not</u> an essential variable for the qualification of a flash butt welding procedure?

A. Welding position
B. Axial speed tolerances
C. Pipe material
D. Filler metal
E. Pipe wall thickness

13.3 All flash butt welds are required to be postweld heat treated. This heat treatment must meet which of the following requirements?

A. The heat treatment must be above the A_{C3} temperature
B. The heat treatment must be followed by controlled cooling or still air cooling to room temperature
C. The heat treatment must be documented using a strip chart recorder
D. The weld must be reheat treated if there are any deviations outside the ranges specified for time or temperature in the welding procedure specification
E. All of the above

13.4 Which of the following methods may be used to repair a flash butt weld?

A. Grinding
B. Chipping
C. Gouging
D. Welding
E. All of the above

13.5 Flash butt welds shall be examined radiographically:

A. Immediately after welding
B. After flash removal and postweld heat treatment
C. Before final heat treatment
D. After mechanical testing
E. Not less than 24 hours after the weld has cooled to room temperature

13.6 When evaluating the fracture surface of a nick break specimen that was removed from a flash butt qualification weld, the maximum size slag inclusion allowed is:

A. 1/2 inch in length
B. 1/32 inch in depth
C. 1/2 inch in width
D. 1/8 inch in length or width
E. Both A & C

13.7 Procedure qualification tests for a flash butt weld are being performed on a pipe that has an OD of 20 inches. How many and what type of test specimens are required?

A. 4 tensile tests, 4 two-inch nick break tests, 4 face bend tests and 4 root bend tests
B. 4 tensile tests, 16 two-inch nick break tests and 4 side bend tests
C. 4 tensile tests, 32 two-inch nick break tests and 4 side bend tests
D. 4 tensile tests, 24 two-inch nick break tests and 4 side bend tests
E. 4 tensile tests, 16 standard nick break tests and 4 side bend tests

13.8 For the qualification of flash butt welding procedure specifications, all of the following are essential variables except:

A. A change in welding position
B. A change in welding current tolerance
C. A change in pipe material
D. A change from 1/2 inch thick wall pipe to 1 inch thick wall pipe
E. A change in power source

13.9 A single ISI in a flash butt production weld shall not exceed:

A. 3/8 inch in length
B. 1/2 inch
C. 1/8 inch in length
D. 1/16 inch in length
E. ISIs are not allowed

13.10 What is the maximum weld reinforcement permitted on the OD of a flash butt production weld?

A. 1/16 inch
B. Unlimited
C. 1/32 inch
D. 1/8 inch
E. It must be determined by testing

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Annex A

Alternative Acceptance Standards for Girth Welds

Annex A: Alternative Acceptance Standards for Girth Welds

A.1 General

The acceptance criteria for welds in Section 9 are based on the length of defects and are typically conservative. Annex A offers an alternative way to determine acceptance criteria by means of fracture mechanics analysis and fitness for purpose considerations (alternatively called engineering critical assessment for ECA). These alternative acceptance criteria permit larger imperfections, but require additional testing. These alternative criteria apply only under the following conditions:

(a) Circumferential (girth) welds between pipes of equal specified wall thickness.
(b) NDT performed for essentially all welds.
(c) No gross weld strength undermatching.
(d) Maximum axial design stress no greater than the SMYS.
(e) Maximum axial design strain no greater than 0.5%.
(f) Welds in pump and compressor stations, repair welds, fittings, and valves in the main line are excluded.

A.2 Stress Analysis

In order to use Annex A, a stress analysis must be performed to determine the maximum axial design stress anticipated during construction, installation, and operation. This analysis must include consideration of potential dynamic loads on girth welds, such as loads from closure of check valves. Paragraph A2.2.2 addresses environmental effects on fatigue, such as CO_2 and H_2S. Paragraph A2.3 addresses sustained-load cracking and includes stress corrosion cracking, failures that have occurred, and reference to NACE MR0175.

A.3 Welding Procedure

Qualification of welding procedures to be used with this annex shall be in accordance with Section 5 or 12, with the additional mechanical property testing in accordance with A.3.4. The essential variables for welding procedures to be used with this annex, however, are very different and have more restricted qualification ranges than those listed in Section 5 or 12. They are listed below:

(a) A change in the welding process, mode of arc transfer, or method of application.
(b) A change in the grade, source/mill, raw material processing facility, pipe manufacturing facility, pipe manufacturing process, or compositional limits, including any significant increase in the carbon equivalent.
(c) A major change in joint design.
(d) A change in position from rolled to fixed, or vice versa, or from vertical to horizontal, or vice versa.
(e) A change in the specified qualified wall thickness of more than +/- 0.125 inch.
(f) A change in the size, type, heat/lot number, or manufacturer of the filler metal and flux.
(g) An increase in the time between the completion of the root bead and the start of the second bead.
(h) A change in welding progression (from uphill to downhill or vice versa).
(i) A change from one shielding gas or mixture to another.
(j) A change in the nominal qualified flow rate of more than +/-10%.
(k) A change in the shielding flux, including a change in the manufacturer.
(l) A change in the type of current (AC or DC) or polarity.
(m) A change in the preheat temperature requirements.
(n) A decrease in the interpass temperature or an increase of 45 °F or more in the interpass temperature.
(o) A change in the post-weld heat treatment requirements.

(p) An increase in the specified pipe OD of more than 50% from that qualified or a decrease in the specified pipe OD of more than 25% from that qualified.
(q) A change in the heat input of more than +/-10% from that qualified for each pass.

Paragraph A.3.3 provides conditions under which multiple pipe sources may be qualified.

Paragraph A.3.4 lists the mechanical property tests required for procedure qualification. The tension test specimen geometry shown in Figure A.1 is the same as that required in Figure 4 b) in Section 5. The acceptance criteria for tension tests are similar to that in Section 5, except that failures in the base metal may be acceptable if the observed tensile strength is no less than 95 % of the SMTS of the pipe material and additional test requirements are met.

Charpy V-notch impact testing of both the weld metal and the heat-affected zone is also required. Six specimens are required from each of the 12, 6, and 3 or 9 o'clock positions, for a total of 18 specimens per procedure. For each location in the weldment, three specimens shall have the notch located in the coarse-grained heat-affected zone and three shall have the notch located on the weld centerline. All specimens shall be tested at the lowest design temperature. The average absorbed energy for each set of three specimens shall be no less than 30 ft-lbs and the minimum absorbed energy for each set of three specimens shall be no less than 22 ft-lbs. These criteria apply to both full-sized and subsized specimens.

Fracture toughness testing of the weld and heat-affected zone in accordance with BS EN ISO 15653 is required as well. The location and orientation of the crack-tip opening displacement (CTOD) specimens required for this test are shown in Figures A.3 and A.4 on page 88. Both the weld and the heat-affected zone must be tested. Two specimens are required from each of the 12, 6, and 3 or 9 o'clock positions, for a total of six specimens per procedure. For each location in the weldment, fatigue precracks shall be located in the center of the weld and in the coarse-grained heat affected zone. All specimens shall be tested at the lowest design temperature in accordance with BS EN ISO 15653. The qualification criteria in paragraph 12.4 of BS EN ISO 15653 shall be met. The minimum CTOD value of all six specimens must be greater than 0.002 inch to use this annex.

A.4 Qualification of Welders

Welders must be qualified in accordance with Section 6. For mechanized welding, the welding operators must be qualified in accordance with subsection 12.6.

A.5 Inspection and Acceptable Limits

To locate imperfections, whether planar or rounded, use inspection methods capable of determining an imperfection's length, height and depth. This will typically require the use of ultrasonic testing. Regardless of the NDT method employed, its accuracy must first be established (see paragraph 11.4.4).

Paragraph A.5.1.2 addresses three options for an engineer to determine the maximum acceptable planar imperfection size. Option 1 is described in paragarph A.5.1.3 along with an example to show the interaction of pipe diameter and wall thickness, CTOD, axial strain, and calculation allowance for inspection error.

Planar imperfections have sharp ends that can easily propagate to failure in the presence of a transverse tensile stress, particularly if the stress is cyclic in nature. These flaws are the most critical type in any pressurized pipe. Paragraph A.5.1.6 states that the height of imperfections that are indicative of stacked weld bead starts and stops shall not exceed the lesser of ¼ inch or 50% of the wall thickness.

Volumetric imperfections, addressed in paragraph A.5.2, are not as critical as planar imperfections because they do not have sharp ends. Buried volumetric imperfections, such as slag or porosity, contained in high-toughness material are less likely to cause a catastrophic failure than are planar imperfections. These buried volumetric imperfections can be treated conservatively (like they are planar and more dangerous) or by the simplified method of Table A.4 on page 99. In this table, limits are given for the height or width and length, for both porosity and slag, for pipe of a given wall thickness, t.

Paragraph A.5.3 addresses arc burns, which typically result from inadvertent arc strikes or improper grounding. The acceptance criteria for unrepaired arc burns are given in Table A.5 on page 100. Arc burns that contain cracks visible to the eye or on conventional radiographs are not covered by this annex and shall be repaired or removed.

When multiple imperfections exist in close proximity, they may behave as one. Figure A.11 on page 101 provides criteria for determining whether one imperfection will interact with another to create a more serious condition. If a repair is indicated, any interacting imperfections shall be repaired in accordance with A.7.

A.6 Record

The type, location, and dimensions of all accepted imperfections must be recorded. This information must be stored with radiographs or other pipeline inspection records.

A.7 Repairs

Imperfections that violate the rules of this annex shall be repaired or removed according to Sections 9 and 10.

A.8 Nomenclature

Subsection A.8 defines the terms and variables used in this annex.

Exercise Questions

Annex A Alternative Acceptance Standards for Girth Welds

A1. External exposure of buried pipe to carbonates and nitrates in the soil has been shown to produce:

A. A few cases of axial cracking
B. Many cases of circumferential cracking
C. Axial cracking due to circumferential stress
D. Axial cracking due to axial stress
E. Both A & C

A2. Using the simplified method of Table A.4, the acceptance limit for buried slag in a girth weld is:

A. The lesser of t/4 or 0.25 inch in width and the lesser of t/4 or 0.25 inch in length
B. The lesser of t/4 or 0.25 inch in width and 0.25 inch in length
C. The lesser of t/4 or 0.25 inch in width and t/4 in length
D. The lesser of t/4 or 0.25 inch in width and 4t in length
E. t/4 in width and 2t in length

A3. The maximum depth permitted for an unrepaired arc burn in Annex A is:

A. 1/64 inch
B. 1/32 inch
C. 1/16 inch
D. 3/32 inch
E. 1/8 inch

A4. Which of the following is used to determine the maximum axial design stress for a pipeline?

A. A visual weld inspection
B. A stress analysis
C. A tensile test
D. A nick break test
E. A chemical analysis

A5. Which of the following mechanical tests is required for the qualification of welding procedures when the use of the alternative girth weld acceptance criteria in Annex A is authorized by the company?

A. The CTOD fracture toughness test
B. The CVN toughness test
C. The guided bend test
D. The tension test
E. All of the above

A6. How many options are available in Annex A for the determination of acceptance limits for planar imperfections?

A. 2
B. 3
C. 4
D. 5
E. 6

A7. What is the primary purpose of Annex A?

A. To define the procedure for CTOD and Charpy V Notch impact testing
B. To delineate between circumferential and axial stresses in pipelines
C. To define the effect of various anomalies on the suitability of the whole weld for a specific service
D. To permit the use of fracture mechanics analysis and fitness for purpose criteria in establishing a more conservative acceptance criteria
E. To provide pipe size and strength specifications for use in service

A8. Annex A requires welders to be qualified:

A. Each month
B. By radiographic testing
C. In accordance with Section 6 of API 1104
D. By Charpy V-Notch impact testing
E. In the presence of state regulators

A9. Typically, validated fitness-for-purpose criteria provide for:

A. Higher tensile and yield strength values
B. More generous acceptance criteria for imperfections
C. CVN acceptance criteria
D. Larger flaw sizes for girth weld procedure and welder qualification test specimens
E. All of the above

A10. Qualification of welding procedures to be used with Annex A shall be in accordance with:

A. Sections 5 and 6
B. Section 6 or 12
C. Section 5 or 12
D. Section 5 or 12, with the additional mechanical property testing in accordance with A.3.4
E. None of the above

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Annex B

In-service Welding

Annex B: In-service Welding

B.1 General

This annex provides welding practices for making repairs to and installing appurtenances on piping systems that are in service. Of particular importance are the welds that melt into the carrier pipe since they cool at an accelerated rate due to the quenching effect of the fluid flowing through the carrier pipe. The welds that melt into the carrier pipe are either fillet welds or branch connection welds. Fillet welds are used to join the ends of encirclement sleeves to the carrier pipe. These fillet welds are also referred to as "sleeve welds" and "circumferential welds." Groove welds are used to join split sleeves using longitudinal welds, but these, unlike sleeve welds and branch connection welds, do not melt into the carrier pipe.

Welding attachments onto in-service pipelines poses two major risks: (1) burning through the pipe wall and (2) hydrogen cracking. Burning through the pipe wall is unlikely when the wall thickness is 0.250 inch or greater, although many companies successfully weld onto thinner wall pipe with regularity. Although Annex B explains how to prevent both of these problems, the major focus of Annex B is on the prevention of hydrogen cracking.

For hydrogen cracking to occur, three conditions must be satisfied simultaneously: (1) hydrogen in the weld, (2) a crack susceptible microstructure and (3) a tensile stress acting on the weld. Conversely, to prevent hydrogen cracking, one of these must be reduced or eliminated. Since these welds are made on pipelines that have been in service, hydrogen is always present and cannot be reduced to sufficient levels. In addition, residual tensile stresses are present in every weld due to the inherent shrinkage resulting from solidification and subsequent cooling from high temperatures. As a result, the primary technique used to prevent hydrogen cracking in in-service welds is the prevention of a crack-sensitive microstructure. To make matters worse, in-service welds are made onto pipe carrying flowing fluids which accelerate the cooling rate and, therefore, promote the formation of crack-sensitive phases in steels, particularly martensite. Because of this combination of factors, the most effective approach for preventing hydrogen cracking in in-service welds is the use of a welding procedure that has a high enough heat input to overcome the quenching effects of the fluid flowing through the carrier pipe. As an alternative, temper bead welding sequences are also effective at producing multi-pass welds in which the heat-affected zone in the carrier pipe has a tempered microstructure, known to be more resistant to hydrogen cracking.

B.2 Qualification of In-service Welding Procedures

This subsection lists the essential variables and tests required to qualify in-service welding procedures.

Paragraph B.2.1 refers the reader to Section 5 for the basic requirements for qualifying welding procedures for making fillet welds and states that the requirements and exceptions in this annex will then be added on to those requirements.

Paragraph B.2.2 lists the additional information required to be addressed on the procedure specification. One of these variables is the carbon equivalent of the carrier pipe to be welded. For determining the carbon equivalent, the following equation is provided:

$$CE_{IIW} = \%C + \%Mn/6 + (\%Cu + \%Ni)/15 + (\%Cr + \%Mo + \%V)/5$$

Also included here is the provision that carbon equivalents may be grouped for the purposes of procedure qualification, as will be discussed shortly.

The pipeline operating conditions must also be addressed on the procedure specification. This can be addressed by specifying the fluid type and its flow rate. Again, conditions may be grouped.

For procedures designed to overcome the quenching effect of the flowing contents by using a sufficiently high heat input, the heat input range should be specified. The minimum value of this range should be that used to weld the procedure qualification coupon. Heat input is given in the Note as Heat Input = Amps x Volts x 60 / Travel Speed.

For procedures designed to overcome the quenching effect of the flowing contents by using a temper bead sequence, the weld deposition sequence, including bead size and overlap, should be specified. The required heat input range for each temper bead layer should also be specified on a temper bead procedure specification.

Paragraph B.2.3 lists additions and changes to the essential variable rules specified in Section 5. For in-service welds, specified minimum yield strength is no longer an essential variable, meaning that in-service welding procedures are valid for all pipe grades. However, since hydrogen cracking is more likely on pipe materials having greater hardenability (as measured by the carbon equivalent), an increase in the carbon equivalent over that used to qualify the procedure is now an essential variable. So, for in-service welds, the MTR of the carrier pipe to be welded should be available so that the carbon equivalent can be calculated from the listed composition. When the in-service welding procedure is qualified, the carrier pipe used in the test coupon should have a carbon equivalent no less than that of the production carrier pipe. Ideally, the carrier pipe used for the qualification test should have a very high carbon equivalent. In that case, the in-service welding procedure would be qualified for a large range of carbon equivalents, up to and including that used in the qualification test weld.

For in-service fillet and branch welds, pipe wall thickness is no longer an essential variable, so these procedures are qualified for all wall thicknesses; however, the note in paragraph B.2.3.1.3 provides an exception, which states that, for weld deposit repairs, the welding procedure is qualified only for wall thicknesses equal to or greater than that used in the qualification test.

Finally, for in-service welds, pipeline operating conditions are an important essential variable, with an increase in the severity of the conditions being cause for requalification. So, the procedure should be qualified under the most severe quenching conditions. This can be accomplished by making the test weld on the water canister set up at a 45 ° angle as shown in Figure B.2 on page 105. By implication, this variable rule also suggests that the use of a heat input value less than that used to qualify a “heat-input procedure” is also an essential variable and would require requalification of the procedure. By the same logic, paragraph B.2.3.1.4 states that, for a temper bead procedure, a change in the deposition sequence or the bead spacing (or overlap) from that qualified is also an essential variable and would require requalification of the procedure.

Paragraph B.2.4 addresses the welding of the test joints and refers to Figure B.2 on page 105 showing the carrier pipe coupon filled with flowing water with the sleeve being welded to it using fillet welds or branch connection welds as appropriate. This condition has been shown to produce thermal conditions more severe than typical in-service welding applications. Therefore, a procedure qualified under this condition qualifies for all in-service conditions.

Paragraph B.2.5 addresses the testing of the welded joints. In general, in-service welds that melt into the carrier pipe, including repairs to weld depositions, will be tested using the nick break tests described in subsection 5.8, except that the test locations are shown in Figures B.3 and B.4 on pages 107 and 108, respectively, and the number of specimens required is specified in Table B.1 on page 109. The additional tests required in this table are macrosection tests, detailed in paragraph B.2.5.4, and face bend tests, detailed in paragraph B.2.5.5, and both are described below.

Longitudinal seam welds of full-encirclement sleeves should be tested with the tension tests, bend tests and nick break specimens required in subsection 5.6, as a function of sleeve wall thickness and diameter. Branch and sleeve welds should be tested with the nick break tests in Section 5.8 plus the additional required tests in B.2.5.1.

Paragraph B.2.5.4 gives details about the macrosection tests to be removed from in-service branch and sleeve welds. These are shown schematically in Figure B.5 on page 109. They may be machine cut or oxygen cut oversized. When they are oxygen cut, the oxygen-cut surface must be machined by a non-thermal process to remove at least ¼ inch from the side to be examined. These weld cross sections shall then be ground, polished, etched with a suitable etchant and examined visually without dye penetrants and with little or no magnification (typically at 10X or less).

Two of the four macroetch specimens for branch and sleeve welds and both of the specimens for weld deposition repair shall be examined by hardness testing in accordance with ASTM E384. At least five indentations shall be made in the coarse-grained HAZ at the toe of each weld cross section using a Vickers indenter and a 10 kg load to determine the maximum hardness.

Paragraph B.2.5.4.4 gives the requirements for visual examination of each macroetch specimen:

(a) The weld should show complete fusion at the root of the joint.
(b) The weld must be free from cracks.
(c) The legs of the fillet welds must meet the requirements of the procedure specification.
(d) The fillet weld surface (convexity and concavity) must be flat within +/- 1/16 inch.
(e) The undercut depth should not exceed the lesser of 1/32 inch or 12.5% of the pipe wall thickness.
(f) Heat-affected zone (HAZ) hardness values over 350 HV should be evaluated to determine the risk of hydrogen cracking

Paragraph B.2.5.5 describes the face bend specimens that are required. Specific specimens may be cut for these tests or the remaining portion of the nick break specimens can be used. Both options are shown in Figure B.6 on page 110. They may be machine cut or oxygen cut oversized. When they are oxygen cut, they must be machined by a nonthermal process to remove at least 1/8 inch from each side. When remnants of the sleeve or branch welds are used, the sleeve and branch welds must be removed to, but not below, the surface of the sleeve. Undercut should not be removed.

Paragraph B.2.5.5.2 addresses the method of bending the specimens. This is identical to the requirements in paragraph 5.6.4.2 except that the specimens shall not be tested sooner than 24 hours after welding.

The acceptance criteria for these bend specimens is exactly the same as that found in paragraph 5.6.4.

B.3 In-service Welder Qualification

Paragraph B.3.1 requires welders performing in-service welding to qualify by making a single qualification test weld in accordance with subsection 6.2 using the specific procedure (heat input or temper bead) used to overcome the quenching effects of the fluid flowing through the pipeline. A welder with only that qualification is qualified for in-service welding in accordance with the essential variable limits of subsection 6.2. However, this annex modifies those qualification ranges as explained in the next few paragraphs.

If that qualification test is welded on pipe less than 12.750 inches in OD, the welder is qualified for

diameters up to and including the diameter on which he tested. If that qualification test is welded on pipe 12.750 inches in OD or larger, the welder is qualified to weld all pipe diameters.

A welder who meets both the multiple qualification requirements of subsection 6.3 and the additional qualification test of this annex is qualified as an in-service branch or sleeve welder in accordance with the essential variable rules of subsection 6.3. Welders who perform weld deposition repairs are limited based on the positions in which they perform the test welds.

Paragraph B.3.2 states that the qualification test required by this annex should be welded on a coupon that simulates the ability of the flowing contents to remove heat from the pipe during welding. Similar to the weld coupon required for the procedure qualification test, filling the carrier pipe with flowing water during welding should produce conditions equal to or more severe than typical in-service conditions. Welders qualified on such a coupon are therefore qualified for all typical in-service applications. The coupon should also be welded following either the heat input, temper bead, or weld deposition repair welding procedure, as applicable.

Paragraph B.3.3 requires the test coupon to meet the visual inspection requirements of subsection 6.4 and the mechanical testing requirements of subsection 6.5. For longitudinal seam welds in full encirclement sleeves, the type and number of test specimens required for welder qualification are listed in Table B.2 on page 111.

Paragraph B.3.4 requires that records of these qualifications be maintained.

B.4 Suggested In-service Welding Practices

When making actual in-service welds, the requirements of Section 7 apply, except for the alternative or additional requirements of subsection B.4. Paragraph B.4.1 reminds the reader that safety is the primary concern when welding onto these in-service lines. Factors such as operating pressure, flow conditions, and minimum wall thickness in the area to be welded should be considered. Ultrasonic testing of the pipe wall in the area to be welded is commonly used to determine minimum wall thickness and/or to verify that there are no laminations in the pipe wall that could compromise in-service weld quality or pressure integrity. Additional safety precautions can be found in API's Recommended Practice 2201.

Paragraph B.4.2 addresses important alignment and fit-up issues. For saddle and sleeve welds, the gap between the sleeve and the carrier pipe should be minimized to permit easy fusion of the carrier pipe. Weld metal build-up on the carrier pipe is one way to minimize any gap that might be present. Clamping devices are recommended. For longitudinal butt welds of full encirclement sleeves, the root opening should be sufficient to permit full penetration. Use of a mild steel back-up strip or suitable tape may be necessary to prevent penetration into the carrier pipe.

Recommended welding sequences, sleeve designs and geometries are provided in paragraph B.4.3 and shown graphically in Figures B.7 through B.12 on pages 112 through 115. For full encirclement sleeves requiring circumferential fillet welds, the longitudinal seams should be completed before beginning the sleeve welds to minimize the residual stresses on the sleeve welds. When making the circumferential fillet welds, one sleeve weld should be completely welded before beginning the other. Regardless of the type of fitting used, the welding sequence should always be chosen to minimize residual stresses. Heat input limits and/or temper bead sizes and locations as specified in the welding procedure must be followed.

Paragraph B.4.4 recommends that in-service beads should be deposited in the circumferential direction when possible.

B.5 Inspection and Testing of In-service Welds

In-service welds must meet the acceptance criteria of Section 8 except for the additional or alternative requirements in subsection B.5. Since hydrogen cracking is the primary weld quality concern and most hydrogen cracks are located under the weld bead and do not break the surface, the inspection method must be able to detect underbead and toe cracks. A combination of magnetic particle and ultrasonic testing is recommended for inspecting sleeve-to-saddle and branch-to-carrier pipe welds. Radiographic testing is not a good candidate for detecting these types of cracks.

Since it takes time for hydrogen trapped in the weld to diffuse to the coarse-grained region of the HAZ to cause the cracking, it is important to establish a suitable delay time after welding prior to inspection to ensure that inspection is conducted after the cracking has had adequate time to develop.

B.6 Standards of Acceptability: NDT (Including Visual)

The standards of acceptability in Section 9 apply to imperfections located in in-service welds. For weld deposition repair, the weld length is defined as the maximum weld length in the direction in which the flaw is oriented.

B.7 Repair and Removal of Defects

The requirements in Section 10 apply to the repair and removal of defects found in in-service welds. In addition, care should be taken to ensure that excavation of the defect does not reduce the wall thickness of the pipe to less than that required to contain the pipe's operating pressure.

Exercise Questions

Annex B In-service Welding

B1. The two main concerns with welding on in-service pipelines are:

A. Burn-through and hydrogen cracking
B. Weld cooling rates and the weld sequence
C. Yield strength of the pipe and fittings
D. Tensile strength of the pipe and the weld sequence
E. Joint fit-up and the weld sequence

B2. For in-service welds on a full-encirclement fitting:

A. The circumferential welds should be completed before beginning the longitudinal seams
B. The circumferential welds need not be made
C. The longitudinal seams should be completed before beginning the circumferential welds
D. The weld sequencing is not important
E. The circumferential welds at the ends of the fitting should be welded simultaneously

B3. All welders performing repair work should be familiar with the safety precautions associated with cutting and welding on piping that contains or has contained crude petroleum, petroleum products, or fuel gases. Additional guidance can be found in:

A. AWS/ANSI Z49.1
B. API's RP 2201
C. API's RP 1570
D. AWS A3.0
E. API 510

B4. For the qualification testing of in-service branch and sleeve weld procedures, each macrosection test specimen:

A. Should be ground on both sides to at least a 600 grit finish and etched
B. Should be ground on both sides to at least a 300 grit finish and etched
C. Should be ground on at least one face to at least a 600 grit finish and etched
D. Should be ground on at least one face to at least a 300 grit finish and etched
E. Shall be machine cut

B5. For in-service welder qualification for longitudinal seam welds on pipe with a 0.375 inch wall thickness, the type and number of test specimens required are:

A. One tensile test, one nick break test and two side bends
B. Two tensile tests, two nick break tests and two side bends
C. Two tensile tests, two nick break tests, two root bends and two face bends
D. One tensile test, one nick break test, one root bend and one face bend
E. Two tensile tests and four side bends

B6. For the qualification of in-service fillet weld procedures, specified minimum yield strength (SMYS) is:

A. An essential variable
B. Not an essential variable
C. An essential variable if both pipe and fitting yield strengths are less than or equal to 42 ksi
D. An essential variable if both pipe and fitting yield strengths are greater than 42 ksi but less than 65 ksi
E. Considered an essential variable if both pipe and fitting yield strengths are greater than 65 ksi

B7. When the maximum allowable heat input to avoid burning through is insufficient to provide adequate protection against hydrogen cracking, an alternative precaution that can be used is:

A. A temper bead deposition sequence
B. An increase in travel speed
C. To decrease the voltage
D. To decrease the amperage
E. An increase in cooling rate

B8. When qualifying the welding procedure for in-service welding, the face bend specimens from branch and sleeve welds should not be tested:

A. Less than 24 hours after welding
B. More than 24 hours after welding
C. Less than 48 hours after welding
D. More than 48 hours after welding
E. When the temperature of the specimen exceeds 125 °F

B9. For hydrogen cracking to occur, how many conditions must be satisfied simultaneously?

A. 2
B. 3
C. 5
D. 8
E. 10

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Practice Tests

Mini-Tests 1 - 4,
Full-Length Practice Test,
Answer Grids,
and Answer Keys

Mini-Test 1

1.1 During welder qualification, when destructive testing pipe with a diameter less than or equal to 1.315 inches:

A. Radiography must be used
B. The entire pipe must be used for bend testing
C. One full-section tensile specimen may be substituted for the root-bend and nick-break specimens
D. Pipe of this diameter may not be destructively testing
E. None of the above

1.2 When selecting butt-weld specimens for a welder qualification test, the specimen locations may be rotated, provided they are equally spaced around the pipe; however, specimens shall not include the longitudinal weld.

A. True
B. False
C. The welder may select any location for the samples
D. The inspector may select any location for the samples
E. Not enough information given

1.3 Welding inspection personnel shall be qualified by:

A. The American Welding Society
B. The American Society for Nondestructive Testing
C. The American Petroleum Institute
D. The American Society of Mechanical Engineers
E. Experience and training for the specified inspection task they perform

1.4 A welding procedure test is being performed on 3 inch schedule 80 pipe (0.300" wall). What is the total number of specimens required for testing?

A. 4
B. 6
C. 8
D. 12
E. 16

1.5 When a radiographic source is centered inside the pipe for exposing a butt weld:

A. Three exposures are adequate for the radiographic testing of the completed weld
B. Two exposures are adequate for the radiographic testing of the completed weld
C. One exposure is adequate for the radiographic testomg of the completed weld (SWE/SWV)
D. Double film must be loaded in the film cassette
E. Lead screens must be used

1.6 NDT operators may, by API 1104, be required to:

A. Pass the AWS CWI exam
B. Only pass the ASNT Level I exam for all test method interpretations
C. Be recertified if any question arises about their ability
D. Demonstrate at least two different methods of NDT
E. Demonstrate at least three different methods of NDT

1.7 Testing of weld repairs requires:

A. All repairs be reradiographed
B. All repairs be ultrasonically tested
C. All repairs be magnetic particle tested
D. The repaired areas be inspected by the same methods previously used
E. All repairs be marked by a CWI

1.8 When found by NDT, inadequate penetration due to high-low (IPD) shall be unacceptable when:

A. The length of an individual IPD indication exceeds 1 inch
B. The length of an individual IPD indication exceeds 2 inches
C. The aggregate length of IPD indications exceeds 3 inches in any continuous 12 inch weld length
D. A and C above
E. B and C above

1.9 Cracks in welds may be repaired provided the following criteria are met:

A. The length of the crack is less than 8% of the weld length
B. The crater crack must be ground smooth
C. A qualified repair welding procedure is used
D. A and C above
E. B and C above

1.10 When a weld is radiographed using a DWE/DWV procedure:

A. One IQI is placed on the source side and across the weld
B. The IQI image must not be superimposed on the weld image
C. Wire-type IQIs cannot be used for DWE/DWV radiography
D. Two IQIs must be used, one on the source side and one on the film side
E. A and B above

1.11 The only API-approved method for testing a nick-break specimen is breaking it in a tensile machine.

A. True
B. False
C. True, but the exposed area of the fracture must be at least ¾ inch
D. True, but the exposed area of the fracture must be no more than ¾ inch
E. API does not require a nick-break test

1.12 Inadequate penetration without high-low (IP) found by NDT shall be unacceptable when:

A. The aggregate length of IP indications exceeds 3 inches in any continuous 12 in length of weld
B. The aggregate length of IP indications exceeds 2 inches in any continuous 12 in length of weld
C. The aggregate length of IP indications exceeds 1 inch in any continuous 12 in length of weld
D. The aggregate length of IP indications exceeds 1/2 inch in any continuous 12 in length of weld
E. The aggregate length of IP indications exceeds 1/4 inch in any continuous 12 in length of weld

1.13 If the weld thickness range radiographed is greater than 0.375 in but equal to or less than 0.500 in, what essential wire diameter is required for an ISO wire-type IQI?

A. 0.008 in
B. 0.010 in
C. 0.013 in
D. 0.016 in
E. 0.020 in

1.14 The bend test shall be considered acceptable if:

A. There are no cracks or other defects
B. The bent sample does not break into several pieces
C. The defects in the weld or fusion zone do not exceed 1/16 inch in any direction
D. The defects in the weld or fusion zone do not exceed 3/32 inch in any direction
E. The defects in the weld or fusion zone do not exceed 1/8 inch or one-half the nominal wall thickness, whichever is smaller, in any direction

1.15 Film or other imaging media shall be processed, handled, and stored so that the images are interpretable for at least 3 years after they are produced:

A. Is a requirement of API 1104
B. Is generally accepted to be the best practice
C. Is a very good thing to do
D. Only when requested by the company
E. As in accordance with AWS D1.1

1.16 A record of certified nondestructive testing personnel shall be kept by the company. Level I and Level II NDT personnel shall be recertified at least every:

A. Year
B. 2 years
C. 3 years
D. 4 years
E. 5 years

1.17 Automatic welding without filler metal additions shall be done using:

A. GTAW
B. OFW
C. The flash butt welding process
D. SMAW
E. None of the above

1.18 A shielding gas shall be used with which of the following specifications:

A. AWS A5.18
B. AWS A5.20
C. All electrodes in Group 4
D. All electrodes in Group 5
E. Both A and D

1.19 Welding may be done by which of the following processes:

A. SAW
B. SMAW
C. GTAW
D. GMAW
E. All of the above

1.20 Each welding operator who performs mechanized welding shall be qualified by producing an acceptable weld using the qualified welding procedure.

A. True
B. False
C. Mechanized welding is not permitted in API 1104
D. B anc C above
E. It depends on the welding process used

1.21 Which of the following represents a change in essential variables for welder qualification?

A. A change in the base material
B. A change in welding position from fixed to rolled
C. A change in the vertical direction of welding
D. A change in the shielding gas or a major change in shielding gas flow rate
E. All of the above

1.22 When using Appendix A as an alternative to the main body of API 1104, environmental effects on fatigue may be associated with:

A. Stress intensity
B. Imperfection size
C. Cycles of loading
D. Concentrations of CO_2 or H_2S
E. All of the above

1.23 Appendix A uses the term 'planar imperfection' to describe which of the following types of flaws:

A. Linear porosity
B. Elongated slag inclusions
C. Cluster porosity
D. Incomplete fusion
E. Piping porosity

1.24 When performing in-service welding per Appendix B, hydrogen cracking is of great concern. This condition may be caused by:

A. Excessive heat
B. Welding on thin-walled pipe
C. Rapid cooling of the HAZ
D. Hydrogen present in the weld
E. Both C and D are correct

1.25 When welding an in-service welding procedure qualification test, what material flowing through the pipe creates the greatest quench or most severe thermal effect on the test joint?

A. Water
B. Natural gas
C. Compressed air
D. Oil
E. Nitrogen

Mini-Test 2

2.1 In order for an individual indication of ICP to be considered a defect, its' length has to exceed::

A. 8% of weld length
B. 1/4 in
C. 2 in
D. 3 in
E. 1.6 mm

2.2 While examining the exposed surface of a nick-break specimen you measure a fisheye to be 1/16 in deep and 5/32 in length. The nick break specimen:

A. Fails
B. Fails only for weld procedures containing filler-metal additions
C. Is acceptable only if there is a 1/2 in separation between it and adjacent slag
D. Is acceptable regardless of its size
E. Fail for GMAW-S only

2.3 For multiple qualification of a welder on a full-size branch-on-pipe connection the weld shall be made with the run-pipe axis:

A. Extending vertically downward
B. Externding vertically upward
C. In the flat position
D. In the 6GR position
E. In the horizontal position

2.4 When the pipe is welded above ground, the working clearance around the pipe at the weld should not be less than:

A. 14 in
B. 16 in
C. The diameter of the pipe
D. Twice the diameter of the pipe
E. Diameter of the pipe plus electrode length

2.5 When a repaired weld is radiographed:

A. An additional IQI shall be placed across each repaired area
B. Two IQIs shall be within 1 in of each end of the film length
C. One IQI shall be within 1 in of the end of the film length to be interpreted
D. Two IQIs shall be placed perpendicular to the weld
E. The IQI shall be placed on the source side

2.6 For automatic welding without filler metal additions, the outside diameter weld reinforcement shall not exceed:

A. 1/32 in
B. 1/16 in
C. 3/32 in
D. 1/8 in
E. All welds shall be flush with the pipe

2.7 For welder qualification, tensile tests:

A. Must be calculated to the tensile strength of the coupon
B. May be omitted
C. Must be prepared and the test shall be performed as described in Section 5.8
D. Must be removed from each segment of the pipe
E. Are performed only when the wall thickness exceeds 0.500 in.

2.8 Volumetric individual indications shall be considered defects when the maximum dimension exceeds:

A. 1/2 in
B. 1/4 in width
C. 8% of weld length
D. 1/4 in length
E. 1/8 in

2.9 As a minimum, each completed flash butt weld shall be heated after welding to a temperature above the:

A. Ac1 temperature
B. Ac3 temperature
C. Lower critical temperature
D. AcM temperature
E. Ar1 temperature

2.10 The total accumulation of relevant indications found during UT are a defect when:

A. The individual length of any one exceeds 4 in (100 mm)
B. There are no criteria
C. The aggregage length of indications above the evaluation level exceeds 8% of the weld length
D. The aggregate length of indications above the evaluation level exceeds 16% of the weld length
E. None of the above

2.11 When qualifying a procedure for fillet welds, the number of test specimens is:

A. 1
B. 2
C. 4
D. 6
E. 8

2.12 All welders performing repair work should be familiar with the safety precautions associated with cutting and welding on piping that contains or has contained crude petroleum, petroleum products, or fuel gasses. Additional guidance can be found in:

A. AWS Z.49
B. API RP 2201
C. API RP 1570
D. AWS A3.0
E. API 510

2.13 For pipe with an outside diameter greater than or equal to 2.375 in, isolated slag inclusions (ISI) found by NDT shall be unacceptable when:

A. The aggregate length of ISI indications exceeds 4 inches in any continuous 12 in weld length
B. The aggregate length of ISI indications exceeds 3 inches in any continuous 12 in weld length
C. The aggregate length of ISI indications exceeds 2 inches in any continuous 12 in weld length
D. The aggregate length of ISI indications exceeds 1 inch in any continuous 12 in weld length
E. The aggregate length of ISI indications exceeds 1/2 inch in any continuous 12 in weld length

2.14 SWE/SWV is the abbreviation for:

A. Swage welded and extruded/swage welded and visually inspected
B. Side wall examined/side wall visually inspected
C. Single-wall extruded/single-wall visually expected
D. Single-wall exposure/single-wall viewing
E. Stud welded end/stud welded visual

2.15 Which of the following types of defects may be repaired with prior company authorization?

A. Defects other than cracks in the root
B. Defects other than cracks in the filler bead
C. Excessive undercut in the cover pass
D. Porosity in the cover pass
E. A and B above

2.16 To test fillet-welded joints for qualification of a welding procedure:

A. At least 4 specimens shall be prepared
B. The specimens may be machine cut or oxygen cut
C. The specimens shall be air cooled to ambient temperature before testing
D. The specimens should be at least 1 in wide
E. All of the above

2.17 Any length of internal concavity (IC) found by NDT is acceptable provided:

A. The density of the radiographic image of the IC does not exceed that of the thinnest adjacent base metal
B. The density of the radiographic image of the IC must exceed that of the thinnest adjacent base metal
C. IC is never acceptable
D. Ultrasonic inspection must be used to find internal concavity
E. None of the above

2.18 Parallel elongated slag inclusion (ESI) indications separated by approximately the width of the root bead shall be considered a single indication unless the width of either of the indications exceeds 1/16 in.

A. True
B. False
C. True if no other indications exist
D. True if SMAW was used for welding
E. API does not address elongated slag inclusions

2.19 When mechanized or semiautomatic welding is used, which of the following shall be removed by grinding before welding over them?

A. Surface porosity clusters
B. Bead starts
C. High points
D. All of the above
E. None of the above

2.20 For procedure qualification, the exposed surfaces of each nick-break test specimen shall show:

A. No slag inclusions over 1/4 in
B. At least 3/4 in sound weld metal between inclusions
C. Complete penetration and fusion
D. The tensile strength of the sample
E. None of the above

2.21 Lineup clamps shall be used for butt welds in accordance with the procedure specification. When it is permissible to remove the lineup clamp before the root bead is completed:

A. The completed part of the bead shall be in approximately equal segments spaced approximately equally around the circumference of the joint
B. The completed part of the bead shall be removed and rewelded after removing the clamp
C. The completed part of the bead shall be peened before removing the clamp
D. The completed part of the bead shall be at least 4 inches long for all pipe sizes
E. None of the above

2.22 When performing an in-service weld, 'burning through' is considered a greater possibility when the pipe wall is:

A. Preheated
B. Made from a crack-susceptible alloy
C. Thin
D. all of the above
E. Both A and C are correct

2.23 When using alternative acceptance standards for girth welds, the term 'imperfection' refers to a:

A. Defect
B. Flaw
C. Discontinuity
D. All of the above
E. Both B and C are correct

2.24 When using alternative acceptance criteria for girth welds, which of the following is needed to determine the limits of imperfections for Option 1 application?

A. Pipe diameter and thickness
B. Qualified minimum CTOD
C. Maximum applied axial strain
D. Calculated allowance for inspection error
E. All of the above

2.25 The essential variables (changes requiring requalification) for in-service welding procedures qualified per Appendix B include:

A. A decrease in yield strength
B. An increase in pipe wall thickness
C. Weld bead sequence
D. Both A and B are correct
E. All of the above

Mini-Test 3

3.1 For pipe ends of the same nominal wall thickness, the alignment offset shall not exceed:

A. 1/4 in
B. 3/16 in
C. 1/32 in
D. 1/8 in unless it is due to dimensional variations of the pipe within the purchase specification, in which case it shall be equally distributed around the circumference of the pipe.
E. None of the above

3.2 Undercutting adjacent to the final bead on the outside of production pipe welds shall:

A. Not be permitted
B. Not be more than 1/32 in or 12.5% of the pipe wall thickness, whichever is smaller
C. Not be more than 1/8 in or 6% of the pipe wall thickness, whichever is smaller
D. Always be acceptable if the inspector does not see it
E. Transverse undercut shall be no more than 0.010 in

3.3 Pipe shall be welded by:

A. Qualified welders
B. Pipeline welders
C. Welders using qualified procedures
D. A and C above
E. Qualified and certified welders

3.4 Hollow-bead porosity (HB) found by NDT shall be unacceptable when:

A. The length of an individual indication of HB exceeds 1 in
B. The length of an individual indication of HB exceeds 7/8 in
C. The length of an individual indication of HB exceeds 3/4 in
D. The length of an individual indication of HB exceeds 1/2 in
E. The length of an individual indication of HB exceeds 1/4 in

3.5 Cracks may be repaired provided a qualified repair welding procedure is used and the length of the crack is:

A. More than 6% of the weld length
B. More than 8% of the weld length
C. More than 10% of the weld length
D. More than 12.5% of the weld length
E. None of the above

3.6 IQIs shall be placed across the weld except:

A. When using hole-type IQIs
B. When using wire-type IQIs
C. When placed on heat shields, if demonstrated during procedure qualification
D. On DWE/DWV procedures
E. On DWE/SWV procedures

3.7 A detailed written procedure for magnetic particle inspection shall be established that meets the requirements of:

A. ASTM E142
B. ASTM E709
C. ASNT SNT-TC-1A
D. ASTM E164
E. ASTM E747

3.8 The exposed surfaces of each fillet-weld-break specimen shall show:

A. No slag inclusions greater than 1/4 in
B. At least 3/4 in sound metal between adjacent inclusions
C. Complete penetration and fusion
D. The tensile strength of the specimen
E. No porosity greater than 1/4 in diameter

3.9 When qualifying a test procedure using the ultrasonic test method:

A. Only the pulse-echo technique shall be used
B. No details of the temperature are necessary
C. Radiographs shall be made of the welds
D. Only Level 1 personnel shall calibrate the equipment
E. Only compression waves shall be used

3.10 Field beveling of pipe by manual oxygen cutting is acceptable if authorized by the company

A. True
B. False
C. This statement is true only if the cutting operator is certified by API
D. This statement is true only if the cutting operator is a certified welder
E. Both C and D above

3.11 API 1104 applies to the welding of pipe and fittings that conform to:

A. API Specification 5L
B. API Specification 620
C. AWS Specification A5.19
D. Applicable ASTM specifications
E. A and D above

3.12 A welder who successfully completes the qualification in Section 6.2.1 on 8 in, schedule 40 pipe (0.322 in wall) must be requalified if:

A. The welding process is changed from SMAW to GMAW
B. The welding direction is changed from horizontal left progression to horizontal right progression
C. There is a change in filler metal classification from Group 1 or 2 to Group 3
D. The welder must weld on 6 in, schedule 40 (0.280 in wall) pipe
E. A and C above

3.13 The essential wire diameter of the IQI to be used in radiographic inspection is based on:

A. The thickness of the weld
B. The flange rating of the piping system
C. The type of radiographic film used
D. The curie strength of the radiographic source used
E. It does not make any difference what size IQI is used

3.14 The acronym TCG stands for:

A. Time Conditions Gradient (method of defining quantitative darkening of film)
B. Temperature Cooling Gauge (for measurement of grain refinement)
C. Temporary Code Guidelines (allows leeway within API 1104 before next edition is published)
D. Time-Corrected Gain (ultrasonic testing sensitivity reference)
E. Tungsten Capacitive Gas (modified form of GTA welding)

3.15 For procedure specification of fillet welds:

A. Only the size of the fillet weld will be shown
B. Both the shape and size of the weld shall be shown
C. The amount or degree of penetration must be shown
D. The type of fillet weld must be designated
E. None of the above

3.16 For mechanized welding, which of the following statements is true?

A. Flux cored arc welding without external shielding gas may not be used
B. Qualified procedures need not be recorded
C. The welding position may change from roll or position welding without requalification
D. None of the above
E. All of the above

3.17 The aggregate length of ISIs in any continuous 12 in length of flash butt weld shall not exceed:

A. 3/8 in
B. 13 mm
C. 1/8 in
D. 1/16 in
E. None of the above

3.18 Procedure qualification for a flash butt weld is being performed on a pipe that has an outside diameter of 26 in. What is the total number of specimens that must be tested?:

A. 16
B. 24
C. 40
D. 32
E. 28

3.19 Wire-type IQIs shall conform to the requirements of ISO 19232-1 or:

A. ASTM E737
B. RTFM E737
C. ASTM E747
D. ASTM E 152
E. AWS E747

3.20 Shallow crater cracks or star cracks are the result of:

A. Weld metal contraction during solidification
B. Pipe movement before weld metal has solidified
C. Insufficient travel speed
D. Poor tack welds during fit up
E. Not enough tack welds used during fit up

3.21 When re-examining an indication found with the liquid penetrant test, the surface:

A. May be ground
B. Shall never be ground to remove an indication found in a PT test
C. Must be examined with another NDT method capable of detecting the indication type
D. A and C above
E. Shall be sanded with #320 grit paper

3.22 Root bead segments used in connection with external clamps should be uniformly spaced around the circumference of the pipe and shall have an aggregate length of at least:

A. Six percent of the pipe circumference
B. Twenty-five percent of the pipe circumference
C. One third of the pipe circumference
D. One half of the pipe circumference
E. One fourth of the pipe circumference

3.23 For in-service weld procedure qualification, which of the following cannot be performed sooner than 24 hours after welding of the test coupon?

A. Visual inspection
B. Tension testing
C. Hardness testing
D. Face bend testing
E. All of the above

3.24 In Appendix A, the CTOD test is used to determine the fracture toughness of:

A. The weld
B. The HAZ
C. Both A and B are correct
D. Materials prior to welding
E. None of the above is correct

3.25 In-service welding procedures qualified per Appendix B require which of the following in order to avoid hydrogen cracking?

A. Pipeline operating conditions
B. The determination of the base metal carbon equivalent
C. Weld deposition sequence
D. All of the above
E. Both A and C are correct.

Mini-Test 4

4.1 The minimum distance between the source or focal spot and the source side of the object being radiographed shall be determined by the following formula: D=St/k. For material which has a thickness less than or equal to 2.0 in, k is:

A. 50.8 mm
B. 0.02 in
C. 2 in
D. 0.61 mm
E. Both B and D above

4.2 Incomplete fusion due to cold lap (IFD) is defined as:

A. Weld metal that exhibits roll-over which is observable at the joint root
B. Weld metal not melted to the parent metal found at the joint face
C. A discontinuity between two adjacent weld beads or between the weld metal and base metal that is not open to the surface
D. A discontinuity resulting from weld starts made with insufficiently preheated electrodes
E. A reduction in cross-sectional area along the toe of the weld

4.3 When qualifying a welding procedure, the maximum time between the completion of the root bead and the start of the second bead:

A. Shall not exceed one minute
B. Shall not exceed 30 minutes
C. Shall not exceed eight hours, unless preheat is maintained
D. Shall not exceed the time necessary for the welder qualified to the root pass to exchange positions with the welder qualified for the fill or cover pass(es), but never to exceed 30 minutes
E. Shall be designated

4.4 Standard tensile strength test specimens shall be:

A. 7 in long and 1 ½ in wide
B. 6 in long and 1 ½ in wide
C. Approximately 9 in long and approximately 1 in wide
D. Approximately 7 in long and approximately 1 ½ in wide
E. Specimen length shall be equal to the diameter of the pipe and width equal to twice the wall thickness

4.5 When testing parent metal using ultrasonic testing, the manual compression wave technique shall be performed with the second backwall echo from the reference standard adjusted to at least:

A. 50% of full screen height
B. 60% of full screen height
C. 70% of full screen height
D. 80% of full screen height
E. The compression wave technique is not acceptable for parent metal testing

4.6 Hammering of pipe to obtain proper lineup:

A. Shall not be permitted
B. Shall be approved by the inspector
C. May not cause indentations deeper than 1/32 in measured from the pipe surface
D. Should be kept to a minimum
E. Is allowed only if pipe out of roundness exceeds 50% of pipe diameter

4.7 When preparing a nick-break test specimen, the depth of the notch shall be approximately:

A. 1/8 in
B. 5% of wall thickness
C. Approximately 25 mm
D. A or B above, whichever is less
E. B and C above

4.8 Arc welding with equipment that controls only the filler metal feed with the progression of welding manually controlled best describes:

A. Roll welding
B. Automatic welding
C. Position welding
D. Mechanized welding
E. Semiautomatic welding

4.9 Typical volumetric indications may be caused by:

A. Internal concavity
B. Burn-through
C. Isolated slag inclusions
D. Porosity
E. All of the above

4.10 In order to determine the full skip distance, refracted angle and attenuation in the material to be inspected:

A. Snell's Law must be used
B. A transfer technique must be used
C. A longitudinal wave must be used
D. Acoustic impedance mismatch must be calculated
E. A dual element transducer must be used

4.11 Automated ultrasonic weld testing should be performed at a scanning sensitivity of 80% of screen height reference sensitivity plus:

A. 6 dB minimum
B. 6 dB when using the scattered radiation technique
C. 4 dB when using the pulse-echo technique
D. At least the calculated transmission depth
E. 50 dB of DAC/TAC screen height

4.12 For pipe with an outside diameter less than 2.375 in, slag inclusions shall be considered a defect should:

A. The aggregate length of ESI and ISI indications exceed 8% of the weld length
B. The width of an ESI indication exceed 1/64 in
C. The aggregate length of ISI indications exceeds 2 in
D. The size of an individual ESI exceeds 25% of the wall thickness
E. Parallel ISI be separated by the length of the root bead

4.13 When radiography is used, the proper weld and any imperfections must be quickly and accurately located. This is accomplished by using:

A. Lead number
B. Lead letters
C. Markers
D. Any of the above
E. A and B above

4.14 When previous nick-break testing experience indicated that failures through the pipe can be expected when testing mechanized welds, the external reinforcement:

A. May be notched more than 1/8 in
B. May be notched transverse 1/8 in deep measured from the original weld surface
C. May be notched 1/16 in on each side at the center of the weld
D. May be notched transverse 1/16 in deep measured from the original weld surface
E. Transverse notches may never be used on a nick-break test specimen

4.15 As a minimum, the procedure for radiography using imaging media other than film shall include all of the following except:

A. The image storage system used
B. Intensifying screens
C. Exposure conditions
D. Radiation source
E. Heat shields

4.16 All position welds shall be made with the parts to be joined:

A. Rolled to maintain welding at or near the top of the pipe
B. Uniform and crown raised 1/8 in above the parent metal
C. Using an adequate number of roller dollies to prevent sag
D. Cleaned with power tools only
E. Secured against movement

4.17 A welder who has successfully completed the butt-weld qualification test described in 6.3.1 on pipe with a diameter greater than or equal to 12.750 in and a full-size branch-connection weld on pipe with a diameter greater than or equal to 12.750 in shall be qualified to weld:

A. In all positions
B. On all wall thicknesses
C. On all joint designs
D. All of the above
E. A and B above

4.18 The frequency of inspection shall be as specified by:

A. The inspector
B. The nondestructive test technician
C. The company
D. The CWI
E. The welding supervisor

4.19 A subsurface imperfection between the first inside pass and the first outside pass that is caused by inadequately penetrating the vertical land faces is referred to as:

A. Incomplete fusions
B. Wagon tracks
C. Internal concavity
D. Incomplete penetration
E. Inadequate cross penetration

4.20 When preparing side-bend test specimens for pipe wall thickness greater than 0.500 in:

A. The weld reinforcement shall be removed from both faces flush with the surface
B. The external reinforcement may be notched
C. The external reinforcement should not be removed on either side of the specimen
D. The specimen shall be approximately 1 in wide
E. None of the above

4.21 A welding operator may be required to requalify if:

A. They have not welded in the past 6 months
B. They have not used the same class of welding unit in the past 12 months
C. A question arises about their competence
D. A and C above
E. B and C above

4.22 When using a welding procedure for mechanized welding with filler metal additions, which of the following is an essential variable requiring requalification?

A. A change in the time of day
B. A change in the size of the filler metal wire
C. A change in welders
D. A change in the number of welders
E. C and D above

4.23 When establishing distance, refracted angle, and velocity, the UT technician should adjust the amplitude on the oscilloscope to at least:

A. 50% of DAC
B. 50% of full screen height
C. 70% of full screen height
D. One half the surface distance
E. 80% of full screen height

4.24 When using alternative acceptance standards for girth welds, the tensile strength test required for procedure qualification shall:

A. Meet the requirements of Section 12
B. Fail in the weld metal
C. Be a circular specimen
D. Meet the requirements of Sections 5 or 12, as applicable
E. None of the above is correct

4.25 The required number and type of in-service procedure test specimens are found in Table B-1. Which type requires additional hardness tests?

A. Tensile tests
B. Macro tests
C. Root bend tests
D. Nick break tests
E. Side bend tests

Full-Length Practice Test

1. Automatic welding without filler metal additions shall be done using:

A. GTAW
B. OFW
C. The flash butt welding process
D. SMAW
E. none of the above

2. Atmospheres for shielding an arc may consist of:

A. Inert gases, active gases, or mixtures of inert and active gases
B. Inert gases only
C. Active gases only
D. Any welding gas
E. None of the above

3. For the qualification of welders, specimens shall be prepared for tensile strength, nick break, and bend tests. When tensile strength tests are omitted:

A. The welder is not qualified
B. The weld must be replaced
C. This is not covered in API 1104
D. Tensile strength specimens shall be subject to the nick break test
E. Extra face bend specimens must be tested

4. For pipe ends of the same nominal wall thickness, the maximum permitted offset is:

A. 1/4 inch
B. 1/8 inch
C. 1/32 inch
D. 1/16 inch
E. None of the above

5. For an acceptable procedure qualification, the exposed surfaces of each nick break specimen shall show:

A. No slag inclusions over 1/4 inch in length
B. At least 3/4 inch of sound weld metal between acceptable inclusions
C. Complete penetration and fusion
D. The tensile strength of the sample
E. None of the above

6. Lineup clamps shall be used for butt welds in accordance with the procedure specification. When it is permissible to remove a lineup clamp before the root bead is completed:

A. The completed part of the bead shall be in approximately equal segments spaced approximately equally around the circumference of the joint.
B. The completed part of the bead shall be removed and rewelded after removing the clamp.
C. The completed part of the bead shall be peened before removing the clamp.
D. The completed part of the bead shall be at least 4 inches long for all pipe sizes.
E. none of the above

7. During welder qualification, when destructively testing pipe with a diameter less than or equal to 1.315 inch:

A. Radiography must be used
B. The entire pipe must be used for bend testing
C. One full-section tensile specimen may be substituted for the root bend and nick break specimens.
D. Pipe of this diameter may not be destructively tested
E. None of the above

8. When pipe is welded above ground, the working clearance around the pipe at the weld should be at least:

A. 12 inches
B. 16 inches
C. 20 inches
D. 24 inches
E. 30 inches

9. What is the primary purpose of Annex A?

A. To define the procedure for CTOD and Charpy V Notch testing
B. To delineate between the circumferential and axial stress
C. To define the effect of various anomalies on the suitability of the whole weld for a specific service, which may allow more generous allowable imperfection lengths
D. To describe the use of fracture mechanics analysis and fitness criteria in establishing a more strict imperfection allowance
E. To provide pipe size and strength specifications for use in pipeline service

10. When mechanized or semiautomatic welding is used, which of the following shall be removed by grinding before welding over them?

A. Surface porosity clusters
B. Bead starts
C. High points
D. All of the above
E. None of the above

11. Undercutting adjacent to the final bead on the outside of production pipe welds shall:

A. Not be permitted
B. Not be more than 1/32 inch or 12.5% of the pipe wall thickness, whichever is smaller
C. Not be more than 1/64 inch or 6% of the pipe wall thickness, whichever is smaller
D. Not be less than 1/64 inch or 6% of the pipe wall thickness, whichever is smaller
E. None of the above

12. Welding inspection personnel shall be qualified by:

A. The American Welding Society
B. The American Society for Nondestructive Testing
C. The American Petroleum Institute
D. The American Society of Mechanical Engineers
E. Experience and training acceptable to the company for the specified inspection task they perform

13. Welding may be done by which of the following processes:

A. SAW
B. SMAW
C. GTAW
D. GMAW
E. Any of the above

14. Inadequate penetration without high-low (IP) found by RT shall be unacceptable when:

A. The aggregate length of IP indications exceeds 3 inches in any continuous 12-inch length of weld
B. The aggregate length of IP indications exceeds 2 inches in any continuous 12-inch length of weld
C. The aggregate length of IP indications exceeds 1 inch in any continuous 12-inch length of weld
D. The aggregate length of IP indications exceeds 1/2 inch in any continuous 12-inch length of weld
E. The aggregate length of IP indications exceeds 1/4 inch in any continuous 12-inch length of weld

15. Incomplete fusion due to cold lap (IFD) is defined as:

A. Weld metal not melted in the joint root
B. A surface imperfection between weld metal and base metal that is open to the surface
C. An imperfection between two adjacent weld beads or between the weld metal and base metal that is not open to the surface
D. A discontinuity along the weld toe
E. Both B and C are correct

16. Under what conditions is field beveling of pipe ends by manual oxygen cutting acceptable?

A. When authorized by the company
B. If the beveled ends are reasonably smooth and uniform
C. If the beveled end dimensions are in accordance with the WPS
D. All of the above
E. None of the above

17. Any length of internal concavity (IC) found by RT is acceptable provided:

A. The density of the radiographic image of the IC does not exceed that of the thinnest adjacent base metal
B. The density of the radiographic image of the IC must exceed that of the thinnest adjacent base metal
C. IC is never acceptable.
D. Ultrasonic testing does not reveal the IC
E. None of the above

18. Parallel elongated slag inclusion (ESI) indications separated by approximately the width of the root bead shall be considered a single indication unless the width of either of the indications exceeds 1/16 inch.

A. True
B. False
C. True if no other indications exist
D. True if SMAW was used for the welding
E. None of the above

19. A manual welding procedure is being qualified by welding a 3 inch schedule 80 API 5L Grade X42 pipe (3 ½ inch OD by 0.300 inch thick wall) coupon. What is the total number of specimens required for this qualification?

A. 4
B. 6
C. 8
D. 12
E. 16

20. Hollow-bead porosity (HB) found by RT shall be unacceptable when:

A. The length of an individual indication of HB exceeds 1 inch
B. The length of an individual indication of HB exceeds 7/8 inch
C. The length of an individual indication of HB exceeds 3/4 inch
D. The length of an individual indication of HB exceeds 1/2 inch
E. The length of an individual indication of HB exceeds 1/4 inch

21. NDT personnel may be required to:

A. Pass the AWS CWI exam
B. Only pass the ASNT Level I exam for any test method
C. Be recertified if any question arises about their ability
D. Demonstrate at least two different methods of NDT
E. Demonstrate at least three different methods of NDT

22. Which of the following types of defects require prior company authorization before repair?

A. Cracks
B. Porosity in a back weld
C. Porosity in the finish bead
D. Incomplete fusion due to cold lap (IFD)
E. All the above

23. Which of the following applies to the tests required for the qualification of a welding procedure for making fillet welds?

A. At least 4 specimens shall be prepared
B. The specimens may be machine cut or oxygen cut
C. The specimens shall be air cooled to ambient temperature before testing
D. The specimens should be at least 1 inch wide
E. All of the above

24. Which of the following applies to the NDT of weld repairs ?

A. All repairs shall be radiographed
B. All repairs shall be ultrasonically tested
C. All repairs shall be magnetic particle tested
D. The repaired areas shall be inspected by the same means used to identify the original defect
E. None of the above

25. The use of the alternative acceptance standards for girth welds in Annex A is authorized by the company and the required stress analysis has been performed. The welding procedure used was qualified in accordance with Section 5 and the additional requirements of Annex A. Ultrasonic testing of a 2-inch thick pipe weld reveals a buried volumetric flaw identified as slag. The indication has a height of 1/4 inch and a length of 8 inches. Is it acceptable?

A. Yes
B. No

26. Cracks in welds may be repaired provided the following criteria are met:

A. The total length of the crack is less than 8% of the weld length
B. The repair must be authorized by the company
C. A qualified repair welding procedure is used
D. All of the above
E. Both B and C

27. For pipe with an outside diameter greater than or equal to 2.375 inches, isolated slag inclusions (ISI) found by RT shall be unacceptable when:

A. The aggregate length of ISI indications exceeds 4 inches in any continuous 12-inch weld length
B. The aggregate length of ISI indications exceeds 3 inches in any continuous 12-inch weld length
C. The aggregate length of ISI indications exceeds 2 inches in any continuous 12-inch weld length
D. The aggregate length of ISI indications exceeds 1 inch in any continuous 12-inch weld length
E. The aggregate length of ISI indications exceeds 1/2 inch in any continuous 12-inch weld length

28. SWE/SWV is the abbreviation for:

A. Swage welded and extruded/swage welded and visually inspected
B. Side-wall examined/side-wall visually inspected
C. Single-wall extruded/single-wall visually inspected
D. Single-wall exposure/single-wall viewing
E. None of the above

29. The essential wire diameter for an ASTM E747 IQI to be used in radiographic testing is based on:

A. The thickness of the weld
B. The thickness of the pipe wall
C. The type of radiographic film used
D. The curie strength of the radiographic source used
E. None of the above

30. What essential wire diameter is required when using the ISO wire type IQI for the radiographic testing of a full penetration weld with 1/16 inch reinforcement in a steel pipe with a 1 inch thick wall?

A. 0.013 inch
B. 0.016 inch
C. 0.020 inch
D. 0.025 inch
E. None of the above

31. When removing test specimens from a butt weld coupon used for a welder qualification, under what conditions may the specimen locations be rotated?

A. Never
B. When they are equally spaced around the pipe
C. When they do not include the longitudinal weld
D. B and C are correct
E. Anytime with the approval of the inspector

32. API 1104 applies to the welding of pipe and fittings that conform to:

A. API Specification 5L
B. API Specification 620
C. AWS Specification A5.19
D. Applicable ASTM specifications
E. A and D above

33. What essential wire diameter(s) may be used with an ASTM E747 wire type IQI for the radiographic testing of a full penetration weld with 1/32 inch reinforcement in a steel pipe with a 0.500 inch thick wall?

A. 0.013 inch may be used provided the required sensitivity is obtained
B. 0.016 inch
C. 0.020 inch
D. 0.025 inch may be used provided the required sensitivity is obtained
E. Both A and B

34. Pipe shall be welded by:

A. Qualified welders
B. Pipeline welders
C. Using qualified procedures
D. A and C above
E. None of the above

35. By what method(s) shall a nick break specimen be tested?

A. By breaking it in a tensile testing machine
B. By supporting the ends and striking the center with a hammer until it breaks
C. By supporting one end and striking the other end with a hammer until it breaks
D. By supporting the ends and bending in a guided bend fixture
E. Any of the above

36. For the radiographic testing of a pipe weld whose thickness is 0.425 inch, what is the identity of the essential wire diameter required when using the ISO wire type IQI?

A. 13
B. 12
C. 11
D. 10
E. 9

37. The bend test shall be considered acceptable if:

A. Cracks that originate on the outer radius of the bend along the edge do not exceed 1/2 inch
B. The bend specimen does not break into several pieces
C. The imperfections in the weld or fusion zone do not exceed 1/16 inch in any direction
D. The imperfections in the weld or fusion zone do not exceed 3/32 inch in any direction
E. The imperfections in the weld or fusion zone do not exceed 1/8 inch or one-half the nominal wall thickness, whichever is smaller, in any direction

38. In qualifying welding procedures for in-service welding, what are the two welding techniques for which qualification rules are given for overcoming the quenching effects of the fluid flowing through the pipe?

A. Use of sufficiently low heat input and temper bead welding
B. Use of sufficiently high heat input and post-weld heat treatment
C. Use of sufficiently high heat input and temper bead welding
D. The use of GMAW and spraying water on the weld immediately after welding
E. The use of sufficiently low heat input and post-weld heat treatment

39. A record of certified nondestructive testing personnel shall be kept by the company. Level III NDT personnel shall be recertified at least every:

A. Year
B. 2 years
C. 3 years
D. 4 years
E. 5 years

40. Mechanized welding shall be done using which of the following processes?

A. SAW
B. GMAW
C. GTAW
D. FCAW with or without external shielding
E. Any of the above

41. When a radiographic source is centered inside the pipe for exposing a butt weld:

A. Three exposures are adequate for the radiographic testing of the completed weld.
B. Two exposures are adequate for the radiographic testing of the completed weld.
C. One exposure is adequate for the radiographic testing of the completed weld (SWE/SWV).
D. Double film must be loaded in the film cassette
E. None of the above

42. Which of the following is not true for the qualification of welding operators who perform mechanized welding?

A. Each operator must be qualified.
B. Each test weld shall be tested by destructive and/or nondestructive methods.
C. Nick-break tests are required.
D. The test weld shall be made using a qualified procedure.
E. None of the above

43. A welder who successfully completes the single qualification requirements of Section 6 on 8 inch schedule 40 pipe (0.322 inch thick wall) must be requalified if:

A. The welding process is changed from SMAW to GMAW
B. The welder changes the welding direction from horizontal left to horizontal right
C. There is a change in filler metal classification from Group 1 or 2 to Group 3
D. The welder welds on 6 inch schedule 40 (0.280 inch thick wall) pipe
E. A and C above

44. Which of the following is true regarding the essential variables for the qualification of in-service welding procedures?

A. Pipe wall thickness is an essential variable for fillet welds.
B. SMYS is an essential variable for fillet welds.
C. For temper bead welding procedures, a change in the bead spacing beyond the limits in the procedure specification is an essential variable.
D. All of the above
E. None of the above

45. Which of the following are essential variables for the qualification of a welding procedure for a manual welding process like SMAW?

A. A change in the pipe material group
B. A change in the welding position
C. A change in the direction of welding from uphill to downhill
D. A change from one shielding gas to another
E. All of the above

46. Which of the following are essential variables for the qualification of welding procedures when the company authorizes the use of the alternative acceptance standards for girth welds in Annex A?

A. A change in the pipe manufacturing facility
B. A change in the heat of filler metal within an AWS classification
C. A change in the manufacturer of the filler metal
D. A decrease in the specified pipe OD of more than 25 % of the nominal OD qualified
E. All of the above

47. The face bend test specimens required for the qualification of in-service welding procedures should not be tested:

A. Less than 24 hours after welding
B. More than 24 hours after welding
C. Less than 48 hours after welding
D. More than 48 hours after welding
E. When the temperature of the specimens exceeds 1250 °F

48. The acronym TCG represents:

A. Time Conditions Gradient (method of defining quantitative blackening of film)
B. Temperature Cooling Gauge (transformation of grains)
C. Temporary Code Guidelines (allows flexibility in the application of API 1104)
D. Time Corrected Gain (ultrasonic testing sensitivity reference)
E. Tungsten Capacious Gas (form of GTAW)

49. The aggregate length of ISIs in any continuous 12-inch length of a flash butt weld shall not exceed:

A. 3/8 inch
B. 1/2 inch
C. 1/8 inch
D. 1/16 inch
E. None of the above

50. A flash butt welding procedure is being qualified by making a test weld on a pipe having an outside diameter of 26 inches. What is the total number of test specimens required for this qualification?

A. 16
B. 24
C. 40
D. 32
E. 28

51. The main focus of Annex B is:

A. To provide safety guidelines for in-service welds
B. To provide alternate acceptance criteria for girth welds
C. To prevent hydrogen cracking in in-service welds
D. To promote hydrogen cracking in in-service welds
E. To restrict in-service welds to pipe diameters of 6 5/8 inches and less

52. During ultrasonic testing of parent material , manual compression wave shall be performed with the second backwall echo from the reference standard adjusted to at least:

A. 50% of full screen height
B. 60% of full screen height
C. 70% of full screen height
D. 80% of full screen height
E. Compression waves cannot be used for testing of parent material

53. Arc welding with equipment that controls only the filler metal feed while the advancement of the weld along the joint is manually controlled is defined as:

A. Roll welding
B. Automatic welding
C. Position welding
D. Mechanized welding
E. Semiautomatic welding

54. For in-service welds, which NDT method(s) have been shown to be effective at detecting hydrogen cracks at the toe of sleeve-to-carrier pipe welds?

A. RT and/or PT
B. RT and/or MT
C. UT and/or PT
D. UT and/or MT
E. none of the above – hydrogen cracking can only be detected using PRT

55. When preparing root bend test specimens:

A. The weld reinforcement shall be removed from both faces and made flush with the surface of the specimen
B. The external reinforcement may be notched
C. The weld reinforcement should not be removed on either side of the specimen
D. The specimen shall be approximately 1 inch wide
E. Both A and D

56. Which of the following tests are required for the qualification of welding procedures when the company authorizes the use of the alternate acceptance standards for girth welds in Annex A?

A. Hardness tests
B. Tension tests
C. Crack-tip opening displacement (CTOD) tests
D. Charpy V-notch impact tests
E. B, C and D

57. For the qualification of in-service welding procedures for making sleeve welds, how many macro test specimens should be prepared for hardness testing?

A. 1
B. 2
C. 3
D. 4
E. 5

58. All position welds shall be made with the parts to be joined:

A. Rolled to maintain welding at or near the top of the pipe
B. Perfectly aligned with no offset between surfaces
C. Using an adequate number of roller dollies to prevent sag
D. Cleaned with power tools only
E. Secured against movement

59. In the application of the alternative acceptance standards for girth welds in Annex A, the stress analysis required must consider the cyclic stress, referred to as "fatigue," that results from pressure changes in the pipeline over time. The effects of environment on fatigue crack growth external to the pipe at girth welds are normally mitigated by:

A. An increase of H_2S
B. External coating
C. An increase in CO_2
D. Cathodic protection
E. Both B and D above

60. For in-service welding, the type and number of tests required for the qualification of a welding procedure for a branch weld on pipe with a wall thickness of 0.719 inch are:

A. 2 tensile tests, 2 root bends, and 2 face bends
B. 2 tensile tests, 2 nick break tests, and 4 side bends
C. 2 nick break tests and 4 face bends
D. 4 nick break tests and 4 side bends
E. 4 nick break tests, 4 face bends, and 4 macro tests

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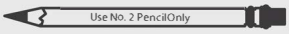
IMPORTANT



MAKE HEAVY ***DARK*** MARKS

EXAMPLE ⊏A⊐ ⊏B⊐ ⊏C⊐ ⊏D⊐ ⊏E⊐

ERASE ***COMPLETELY*** TO CHANGE

DATE _____

NUMBER CORRECT _____

NUMBER INCORRECT _____

PERCENTAGE _____

DATE _____

NUMBER CORRECT _____

NUMBER INCORRECT _____

PERCENTAGE _____

Mini-Test 1

1	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
2	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
3	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
4	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
5	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
6	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
7	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
8	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
9	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
10	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
11	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
12	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
13	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
14	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
15	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
16	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
17	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
18	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
19	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
20	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
21	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
22	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
23	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
24	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
25	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐

Mini-Test 2

1	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
2	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
3	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
4	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
5	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
6	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
7	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
8	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
9	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
10	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
11	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
12	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
13	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
14	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
15	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
16	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
17	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
18	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
19	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
20	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
21	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
22	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
23	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
24	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
25	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐

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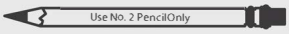
IMPORTANT



MAKE HEAVY ***DARK*** MARKS

EXAMPLE ⊏A⊐ ⊏B⊐ ⊏C⊐ ⊏D⊐ ⊏E⊐

ERASE ***COMPLETELY*** TO CHANGE

DATE _____

NUMBER CORRECT _____

NUMBER INCORRECT _____

PERCENTAGE _____

DATE _____

NUMBER CORRECT _____

NUMBER INCORRECT _____

PERCENTAGE _____

Mini-Test 3

1	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
2	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
3	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
4	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
5	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
6	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
7	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
8	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
9	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
10	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
11	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
12	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
13	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
14	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
15	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
16	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
17	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
18	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
19	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
20	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
21	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
22	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
23	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
24	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
25	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐

Mini-Test 4

1	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
2	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
3	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
4	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
5	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
6	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
7	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
8	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
9	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
10	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
11	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
12	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
13	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
14	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
15	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
16	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
17	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
18	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
19	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
20	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
21	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
22	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
23	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
24	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
25	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐

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DATE _____

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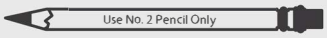
NUMBER INCORRECT _____

PERCENTAGE _____

IMPORTANT



MAKE HEAVY ***DARK*** MARKS

EXAMPLE ⊏A⊐ ⊏B⊐ ⊏C⊐ ⊏D⊐ ⊏E⊐

ERASE ***COMPLETELY*** TO CHANGE

Full-Length Exam

1	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
2	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
3	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
4	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
5	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
6	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
7	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
8	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
9	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
10	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
11	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
12	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
13	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
14	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
15	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
16	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
17	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
18	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
19	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
20	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
21	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
22	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
23	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
24	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
25	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
26	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
27	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
28	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
29	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
30	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
31	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
32	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
33	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
34	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
35	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
36	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
37	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
38	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
39	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
40	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
41	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
42	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
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44	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
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48	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
49	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
50	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
51	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
52	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
53	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
54	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
55	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
56	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
57	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
58	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
59	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐
60	⊏A⊐	⊏B⊐	⊏C⊐	⊏D⊐	⊏E⊐

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Answers & References for Chapter/Section Questions

Section 1			
Question	Answer	API 21st Reference	API 21st Page
1.1	E	1	1
1.2	E	1	1
1.3	E	1	1
1.4	A	1	1
1.5	C	1	1
1.6	E	1	1

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Question	Answer	API 21st Reference	API 21st Page
2.1	D	2 A3.4.3.1	1,2,87
2.2	C	2	1,2
2.3	A	2	1,2
2.4	B	2	1,2
2.5	C	2	1,2
2.6	B	2	1,2
2.7	A	2	1,2

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3.1	B	3.1.11	3
3.2	C	3.1	2
3.3	D	3.1.28	5
3.4	B	3.1.17	4
3.5	B	3.1.26	5
3.6	C	3.1.1	2
3.7	C	3.2	6

Answers & References for Chapter/ Questions

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4.2	B	4.2.2.2	9
4.3	C	4.1	8
4.4	C	4.2.3.2	9
4.5	D	4.2.2.2	9
4.6	C	4.2.2.1	8
4.7	B	4.2.1	8

Section 5			
Question	Answer	API 21st Reference	API 21st Page
5.1	B	5.4.2.2	13
5.2	B	5.6.1 & Table 2 Note b	17,19
5.3	D	5.6.2.1.a & Fig 4a	17,20
5.4	C	Table 1 (note d)	15-16
5.5	B	5.6.3.2 & Fig. 5	19,21
5.6	B	5.4.2.2	13-14
5.7	A	5.6.1 & Table 2	17,19
5.8	E	5.6.4.1 & Fig. 7	20,22
5.9	E	Table 1	15
5.10	A	5.6.3.3	19
5.11	B	Table 1	15-16

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Question	Answer	API 21st Reference	API 21st Page
6.1	E	6.2.2	26,27
6.2	E	6.4	29
6.3	E	6.3.1	27
6.4	D	6.4	29
6.5	C	6.5.1 & Table 3	29,30
6.6	E	6.4	29
6.7	A	6.5.1 & Table 3	29,30
6.8	E	6.5.1 & Table 3	29,30

Answers & References for Chapter/Section Questions

Section 7			
Question	Answer	API 21st Reference	API 21st Page
7.1	B	7.5	32
7.2	C	7.8.2	33
7.3	D	7.6	32
7.4	E	7.10	33
7.5	C	7.2	32
7.6	E	7.9	33
7.7	A	7.7	32

Section 8			
Question	Answer	API 21st Reference	API 21st Page
8.1	D	8.1	33
8.2	D	8.3	34
8.3	E	8.4.2	34
8.4	D	8.2	33
8.5	C	8.2	34
8.6	E	8.4.1	34
8.7	E	8.4.2	34

Section 9			
Question	Answer	API 21st Reference	API 21st Page
9.1	D	9.3.4	36
9.2	E	9.3.9.1-9.3.9.4	39-40
9.3	E	9.3.8.1	38
9.4	D	9.3.7.1	37
9.5	E	9.3.10	41-42
9.6	B	9.3.8.2(e)	39
9.7	B	9.3.10(b)	41
9.8	E	9.6.2.3	45
9.9	D	9.3.11 & Note, 9.7.2 & Table 4	42,46
9.10	A	9.5.1(b)	43

Answers & References for Chapter/Section Questions

Section 10			
Question	Answer	API 21st Reference	API 21st Page
10.1	E	10.2.2	46-47
10.2	A	10.6	55
10.3	E	10.3.4	49
10.4	D	10.2.3	47
10.5	D	10.2.2 & 10.4.1	46,53

Section 11			
Question	Answer	API 21st Reference	API 21st Page
11.1	E	11.1.1	55-56
11.2	E	11.4.3	63
11.3	B	11.1.5 & Table 9	58,59
11.4	D	11.1.5 & Table 8	58
11.5	D	11.4.1	61
11.6	C	11.1.5	58
11.7	D	11.1.7	59
11.8	C	11.1.5 & Table 9	58,59
11.9	E	11.4.4	63
11.10	A	11.1.2.2(d)	56

Section 12			
Question	Answer	API 21st Reference	API 21st Page
12.1	E	12.4.2.11	68
12.2	C	12.5.2	69-71
12.3	B	12.11	72
12.4	D	12.4.2.17	68
12.5	C	12.5.2	69-71

Answers & References for Chapter/Section Questions

Section 13			
Question	**Answer**	**API 21st Reference**	**API 21st Page**
13.1	E	13.2.3.1 & Table 10	73,75
13.2	D	13.5	76-77
13.3	E	13.8.5	79
13.4	E	13.10.1	79
13.5	B	13.8.3	78
13.6	D	13.2.3.3.3	75
13.7	B	13.2.3.1 & Table 10	73,75
13.8	E	13.5.2	77
13.9	C	13.9.2	79
13.10	D	13.8.4	78

Annex A			
Question	**Answer**	**API 21st Reference**	**API 21st Page**
A1	E	A.2.3	82
A2	D	A.5.2 & Table A.4	99
A3	C	A.5.3 & Table A.5	99,100
A4	B	A.2.1	81
A5	E	A.3.1 & A.3.4	83, 85-89
A6	B	A.1 & A.5.1.2	80,90
A7	C	A.1	80
A8	C	A.4	90
A9	B	A.1, Para. 1	80
A10	D	A.3.1	83

Annex B			
Question	**Answer**	**API 21st Reference**	**API 21st Page**
B1	A	B.1, Para. 2	102
B2	C	B.4.3	112
B3	B	B.4.1	111
B4	C	B.2.5.4.1	106
B5	D	B.3.3 & Table B.2	111
B6	B	B.2.3.1.1	104
B7	A	B.1, Para. 4	102
B8	A	B.2.5.5.2	109
B9	B	B.1, Para. 4	102

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Answers & References for MiniTests

Mini-Test 1			
Question	**Answer**	**API 21st Reference**	**API 21st Page**
MT1.1	C	6.5.1	29
MT1.2	A	Fig. 12, Note 1	28
MT1.3	E	8.3	34
MT1.4	A	Table 2	19
MT1.5	C	11.1.3.1	57
MT1.6	C	8.4.2	34
MT1.7	D	10.6	55
MT1.8	E	9.3.2	35
MT1.9	D	10.2.2	46-47
MT1.10	A	11.1.6.1	59
MT1.11	B	5.6.3.2	19
MT1.12	C	9.3.1.b	35
MT1.13	C	Table 9	59
MT1.14	E	5.6.4.3	21-22
MT1.15	D	11.1.10.4	61
MT1.16	E	8.4.2	34
MT1.17	C	13.1	72
MT1.18	E	Table 1, Note b	15-16
MT1.19	E	1 Paragraph 1	1
MT1.20	A	12.6.1	71
MT1.21	C	6.2.2	26-27
MT1.22	E	Paragraph A.2.2.2	82
MT1.23	D	Paragraph A.5.1	90
MT1.24	E	B.1 Paragraphs 2, 4	102
MT1.25	A	Paragraph B.2.4.1, Note	105

Answers & References for MiniTests

Mini-Test 2			
Question	Answer	API 21st Reference	API 21st Page
MT2.1	C	9.3.3	36
MT2.2	D	5.6.3.3	19-20
MT2.3	E	6.3.1 Paragraph 3	27
MT2.4	B	7.6	32
MT2.5	A	11.1.6.1.a (last sentence)	59
MT2.6	D	13.8.4	78
MT2.7	B	6.5.2	30
MT2.8	E	9.6.2.6	45
MT2.9	B	13.8.5	79
MT2.10	C	9.6.2.8	45
MT2.11	C	5.8.1 (at least 4)	24
MT2.12	B	B.4.1 Paragraph 2	111
MT2.13	E	9.3.8.2 d)	38
MT2.14	D	11.1.2.2.d	56
MT2.15	E	10.2.3	47
MT2.16	E	5.8.1	24
MT2.17	A	9.3.6	37
MT2.18	B	9.3.8.2 note	38
MT2.19	D	7.7 Paragraph 2	32
MT2.20	C	5.6.3.3	19-20
MT2.21	A	7.3	32
MT2.22	E	B.1 Paragraph 3	102
MT2.23	E	A.1 Paragraph 6	80
MT2.24	E	Paragraph A.5.1.3	94
MT2.25	C	Paragraph B.2.3.1	104

Answers & References for MiniTests

Mini-Test 3			
Question	Answer	API 21st Reference	API 21st Page
MT3.1	D	7.2	32
MT3.2	B	Table 4 and 9.7.2	46
MT3.3	D	7.1	31
MT3.4	D	9.3.9.4 a)	40
MT3.5	E	10.2.2	46
MT3.6	C	11.1.6.1c)	59
MT3.7	B	11.2 Paragraph 1	61
MT3.8	C	5.8.3	24
MT3.9	C	11.4.4 b)	63
MT3.10	A	7.4.2	32
MT3.11	E	2, 4.2.1	1, 8
MT3.12	E	6.2.2	26-27
MT3.13	A	11.1.5	58
MT3.14	D	3.2; 11.4.5	7, 63
MT3.15	B	5.3.2.4	12
MT3.16	D	12.1; 12.3; 12.4.2	66-67
MT3.17	B	13.9.2	79
MT3.18	D	Table 10	75
MT3.19	C	11.1.4	58
MT3.20	A	9.3.10 Note	42
MT3.21	A	9.5.1 a)	43
MT3.22	D	7.3	32
MT3.23	D	Paragraph B.2.5.5.2	109
MT3.24	C	Paragraph A.3.4.3.3	88
MT3.25	D	B.2.2.1	103-104

Answers & References for MiniTests

Mini-Test 4			
Question	Answer	API 21st Reference	API 21st Page
MT4.1	B	11.1.3.1 Paragraph 4	57-58
MT4.2	C	9.3.5	37
MT4.3	E	5.3.2.10	12
MT4.4	C	5.6.2.1, Figure 4a)	17,20
MT4.5	D	11.4.7.1	65
MT4.6	D	7.2	32
MT4.7	A	5.6.3.1	19
MT4.8	E	3.1.28	5
MT4.9	E	9.6.1.4	44
MT4.10	B	11.4.5 Paragraph 4	65
MT4.11	C	11.4.7.3	66
MT4.12	A	9.3.8.3	39
MT4.13	D	11.1.8	60
MT4.14	D	5.6.3.1	19
MT4.15	B	11.1.2.3	57
MT4.16	E	3.1.17	4
MT4.17	D	6.3.2	29
MT4.18	C	8.1	33
MT4.19	E	9.3.3	36
MT4.20	A	5.6.5.2; Figure 9	23,24
MT4.21	C	12.7	72
MT4.22	B	12.5.2	70
MT4.23	E	11.4.5	63-65
MT4.24	E	A.3.4.1.2	85,86
MT4.25	B	Paragraph B.2.5.4.3, Table B.1	106, 109

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Answers & References for Full-Length Practice Test

Full-Length Practice Test			
Question	Answer	API 21st Reference	API 21st Page
FL1	C	13.1	72
FL2	A	4.2.3.1	9
FL3	D	6.5.2	30
FL4	B	7.2	32
FL5	C	5.6.3.3	19
FL6	A	7.3	32
FL7	C	6.5.1	29
FL8	B	7.6	32
FL9	C	A.1	80
FL10	D	7.7	32
FL11	B	9.3.11 Note; 9.7.2; Table 4	41,46
FL12	E	8.3	34
FL13	E	1	1
FL14	C	9.3.1 b)	35
FL15	C	9.3.5	37
FL16	D	7.4.2	32
FL17	A	9.3.6	37
FL18	B	9.3.8.2 Note	38-39
FL19	A	5.6.1, Table 2 Note b	17,19
FL20	D	9.3.9.4 a)	40

Answers & References for Full-Length Practice Test

Full-Length Practice Test			
Question	**Answer**	**API 21st Reference**	**API 21st Page**
FL21	C	8.4.2	34
FL22	E	10.2.1; 10.2.3	46-47
FL23	E	5.8.1	24
FL24	D	10.6	55
FL25	A	A.5.2 & Table A.4	99
FL26	D	10.2.2 a) & c)	46
FL27	E	9.3.8.2 d)	38
FL28	D	11.1.2.2 d)	56
FL29	A	11.1.5; Table 8	58
FL30	D	11.1.5; Table 9	57-58
FL31	D	6.5.1; Figure 12 Note 1	29,28
FL32	D	4.2.1 a) & c)	8
FL33	E	11.1.5; Table 8	58
FL34	D	7.1	31
FL35	E	5.6.3.2	19
FL36	C	11.1.5; Table 9	58-59
FL37	E	5.6.4.3	21
FL38	C	B.2.2.1.3 & B.2.2.1.4	104
FL39	E	8.4.2	34
FL40	E	12.1	66

Answers & References for Full-Length Practice Test

Full-Length Practice			
Question	Answer	API 21st Reference	API 21st Page
FL41	C	11.1.3.1	57
FL42	C	12.6.1	71
FL43	E	6.2.2 a) & c)	26,27
FL44	C	B.2.3.1.1; B.2.3.1.3; B.2.3.1.4	104
FL45	E	5.4.2.2; 5.4.2.4; 5.4.2.9; 5.4.2.10	13-16
FL46	E	A.3.2 b) 4), f) & p)	83-85
FL47	A	B.2.5.5.2	109
FL48	D	3.2	7
FL49	B	13.9.2	79
FL50	D	13.2.3.1 & Table 10	73,75
FL51	C	B.1	102
FL52	D	11.4.7.1	65
FL53	E	3.1.28	5
FL54	D	B.5 Note	115
FL55	E	5.6.4.1 & Figure 7 Note	20-22
FL56	E	A.3.4.1.1; A.3.4.2 & A.3.4.3.3	85-88
FL57	B	B.2.5.4.3	106
FL58	E	7.8.1	33
FL59	E	A.2.2.2	82
FL60	E	B.2.5.1 & Table B.1	106,109

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