

Approval Date: October 11, 2005

*Code Cases will remain available for use until annulled
by the applicable Standards Committee.***Case 2235-9****Use of Ultrasonic Examination in Lieu of Radiography
Section I; Section VIII, Divisions 1 and 2; and
Section XII**

Inquiry: Under what conditions and limitations may an ultrasonic examination be used in lieu of radiography, when radiography is required in accordance with Section I, para. PW-11; Section VIII, Division 1, para. UW-11(a); Section VIII, Division 2, Table AF-241.1; and Section XII, TE-230.1?

Reply: It is the opinion of the Committee that all welds in material $\frac{1}{2}$ in. (13 mm) or greater in thickness in pressure vessels and power boilers may be examined using the ultrasonic (UT) method in lieu of the radiography (RT) method, provided that all of the following requirements are met:

(a) The ultrasonic examination area shall include the volume of the weld, plus 2 in. (50 mm) on each side of the weld for material thickness greater than 8 in. (200 mm). For material thickness 8 in. (200 mm) or less, the ultrasonic examination area shall include the volume of the weld, plus the lesser of 1 in. (25 mm) or t on each side of the weld. Alternatively, examination volume may be reduced to include the actual heat affected zone (HAZ) plus $\frac{1}{4}$ in. (6 mm) of base material beyond the heat affected zone on each side of the weld, provided the following requirements are met:

(1) The extent of the weld HAZ is measured and documented during the weld qualification process.

(2) The ultrasonic (UT) transducer positioning and scanning device is controlled using a reference mark (paint or low stress stamp adjacent to the weld) to ensure that the actual HAZ plus an additional $\frac{1}{4}$ in. (6 mm) of base metal is examined.

(b) A documented examination strategy or scan plan shall be provided showing transducer placement, movement, and component coverage that provides a standardized and repeatable methodology for weld acceptance. The scan plan shall also include ultrasonic beam angle used, beam directions with respect to weld centerline, and vessel volume examined for each weld. The documentation shall be made available to the Owner/User upon request.

(c) The ultrasonic examination shall be performed in accordance with a written procedure conforming to the requirements of Section V, Article 4.¹ The procedure shall have been demonstrated to perform acceptably on a qualification block(s). The qualification block(s) shall be prepared by welding or the hot isostatic process (HIP) and shall contain a minimum of three flaws, oriented to simulate flaws parallel to the production weld's fusion line as follows:

(1) one surface flaw on the side of the block representing the vessel OD surface

(2) one surface flaw on the side of the block representing the vessel ID surface

(3) one subsurface flaw

(4) If the block can be flipped during UT examination, then one flaw may represent both the ID and OD surfaces. Thus only two flaws may be required.

Flaw size shall be no larger than the flaw in Table 1, 2, or 3 for the thickness to be examined. Acceptable performance is defined as response from the maximum allowable flaw and other flaws of interest demonstrated to exceed the reference level. Alternatively, for techniques that do not use amplitude recording levels, acceptable performance is defined as demonstrating that all imaged flaws with recorded lengths, including the maximum allowable flaws, have an indicated length equal to or greater than the actual length of the flaws in the qualification block.

(d) The ultrasonic examination shall be performed using a device employing automatic computer based data acquisition. The initial straight beam material examination (T-472 of Section V, Article 4) for reflectors that could interfere with the angle beam examination shall be performed (1) manually, (2) as part of a previous manufacturing process, or (3) during the automatic UT examination provided detection of these reflectors is demonstrated [subpara. (c)].

¹ Sectorial scans (S-scans) with phased arrays may be used for the examination of welds, provided they are demonstrated satisfactorily in accordance with para. (c). S-scans provide a fan beam from a single emission point, which covers part or all of the weld, depending on transducer size, joint geometry, and section thickness. While S-scans can demonstrate good detectability from side drilled holes, because they are omnidirectional reflectors, the beams can be misoriented for planar reflectors (e.g., lack of fusion and cracks). This is particularly true for thicker sections, and it is recommended that multiple linear passes with S-scans be utilized for components greater than 1 in. (25 mm) thick. An adequate number of flaws should be used in the demonstration block to ensure detectability for the entire weld volume.

The Committee's function is to establish rules of safety, relating only to pressure integrity, governing the construction of boilers, pressure vessels, transport tanks and nuclear components, and inservice inspection for pressure integrity of nuclear components and transport tanks, and to interpret these rules when questions arise regarding their intent. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks and nuclear components, and the inservice inspection of nuclear components and transport tanks. The user of the Code should refer to other pertinent codes, standards, laws, regulations or other relevant documents.

TABLE 1
FLAW ACCEPTANCE CRITERIA FOR $\frac{1}{2}$ in. (13 mm) TO
LESS THAN 1 in. (25 mm) THICK WELD

	a/t	ℓ
Surface flaw	≤ 0.087	≤ 0.25 in. (6.4 mm)
Subsurface flaw	≤ 0.143	≤ 0.25 in. (6.4 mm)

GENERAL NOTES:

- (a) t = the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet weld shall be included in t .
- (b) A subsurface indication shall be considered as a surface flaw if the separation (S in Fig. 1) of the indication from the nearest surface of the component is equal to or less than half the through dimension ($2d$ in Fig. 1, sketch [b]) of the subsurface indication.

(e) Data is recorded in unprocessed form. A complete data set with no gating, filtering, or thresholding for response from examination volume in para. (a) above shall be included in the data record.

(f) Personnel performing and evaluating UT examinations shall be qualified and certified in accordance with their employer's written practice. ASNT SNT-TC-1A or

CP-189 shall be used as a guideline. Only Level II or III personnel shall analyze the data or interpret the results.

(g) Contractor qualification records of certified personnel shall be approved by the Certificate Holder and maintained by their employer.

(h) In addition, personnel who acquire and analyze UT data shall be trained using the equipment in (d) above, and participate in the demonstration of (c) above.

(i) Data analysis and acceptance criteria shall be as follows:

(1) *Data Analysis Criteria.* Reflectors exceeding the limits in either (a) or (b) below, as applicable, shall be investigated to determine whether the indication originates from a flow or is a geometric indication in accordance with para. (i)(2) below. When a reflector is determined to be a flaw, it shall be evaluated for acceptance in accordance with para. (i)(4), Flaw Evaluation and Acceptance Criteria.

(a) For amplitude-based techniques, the location, amplitude, and extent of all reflectors that produce a response greater than 20% of the reference level shall be investigated.

(b) For nonamplitude-based techniques, the location and extent of all images that have an indicated length

TABLE 2
FLAW ACCEPTANCE CRITERIA FOR 1 in. (25 mm) TO 12 in. (300 mm) THICK WELD

Aspect Ratio, a/ℓ	1 in. (25 mm) $\leq t \leq 2\frac{1}{2}$ in. (64 mm) [Note (1)]		4 in. (100 mm) $\leq t \leq 12$ in. (300 mm) [Note (1)]	
	Surface Flaw, a/t	Subsurface Flaw, a/t	Surface Flaw, a/t	Subsurface Flaw, a/t
0.00	0.031	0.034	0.019	0.020
0.05	0.033	0.038	0.020	0.022
0.10	0.036	0.043	0.022	0.025
0.15	0.041	0.049	0.025	0.029
0.20	0.047	0.057	0.028	0.033
0.25	0.055	0.066	0.033	0.038
0.30	0.064	0.078	0.038	0.044
0.35	0.074	0.090	0.044	0.051
0.40	0.083	0.105	0.050	0.058
0.45	0.085	0.123	0.051	0.067
0.50	0.087	0.143	0.052	0.076

GENERAL NOTES:

- (a) t = thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet weld shall be included in t .
- (b) A subsurface indication shall be considered as a surface flaw if separation (S in Fig. 1) of the indication from the nearest surface of the component is equal to or less than half the through thickness dimension ($2d$ in Fig. 1, sketch [b]) of the subsurface indication.
- (c) If the acceptance criteria in this table results in a flaw length, ℓ , less than 0.25 in. (6.4 mm), a value of 0.25 in. (6.4 mm) may be used.

NOTE:

- (1) For intermediate flaw aspect ratio a/ℓ and thickness t ($2\frac{1}{2}$ in. [64 mm] $< t < 4$ in. [100 mm]) linear interpolation is permissible.

TABLE 3
FLAW ACCEPTANCE CRITERIA FOR LARGER THAN 12 in. (300 mm) THICK WELD

Aspect Ratio, a/ℓ	Surface Flaw, a		Subsurface Flaw, a	
	in.	mm	in.	mm
0.00	0.228	5.79	0.240	6.10
0.05	0.240	6.10	0.264	6.71
0.10	0.264	6.71	0.300	7.62
0.15	0.300	7.62	0.348	8.84
0.20	0.336	8.53	0.396	10.1
0.25	0.396	10.1	0.456	11.6
0.30	0.456	11.6	0.528	13.4
0.35	0.528	13.4	0.612	15.5
0.40	0.612	15.5	0.696	17.7
0.45	0.618	15.7	0.804	20.4
0.50	0.624	15.9	0.912	23.6

GENERAL NOTES:

- (a) For intermediate flaw aspect ratio, a/ℓ linear interpolation is permissible.
- (b) t = the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet weld shall be included in t .
- (c) A subsurface indication shall be considered as a surface flaw if separation (S in Fig. 1) of the indication from the nearest surface of the component is equal to or less than half the through thickness dimension ($2d$ in Fig. 1, sketch [b]) of the subsurface indication.

greater than the limits in (1), (2), or (3) below, as applicable, shall be investigated.

(1) For welds in material equal to or less than $1\frac{1}{2}$ in. (38 mm) thick at the weld, images with indicated lengths greater than 0.150 in. (3.8 mm) shall be investigated.

(2) For welds in material greater than $1\frac{1}{2}$ in. (38 mm) thick but less than 4 in. (100 mm) thick at the weld, images with indicated lengths greater than 0.200 in. (5 mm) shall be investigated.

(3) For welds in material greater than 4 in. (100 mm) thick at the weld, images with indicated lengths greater than $0.05t$ or 0.75 in. (19 mm), whichever is smaller, shall be investigated (t = nominal material thickness adjacent to the weld).

(2) *Geometric*. Ultrasonic indications of geometric and metallurgical origin shall be classified as follows:

(a) Indications that are determined to originate from the surface configurations (such as weld reinforcement or root geometry) or variations in metallurgical structure of materials (such as cladding to base metal interface) may be classified as geometric indications, and

(1) need not be characterized or sized in accordance with (i)(3) below;

(2) need not be compared to allowable flaw acceptance criteria of Table 1, 2, or 3;

(3) the maximum indication amplitude and location shall be recorded, for example: internal attachments, 200% DAC maximum amplitude, one (1) in. (25 mm)

above the weld centerline, on the inside surface, from 90 to 95 deg.

(b) The following steps shall be taken to classify an indication as geometric:

(1) Interpret the area containing the reflector in accordance with the applicable examination procedure;

(2) Plot and verify the reflector coordinates, provide a cross-sectional display showing the reflector position and surface discontinuity such as root or counterbore; and

(3) Review fabrication or weld prep drawings.

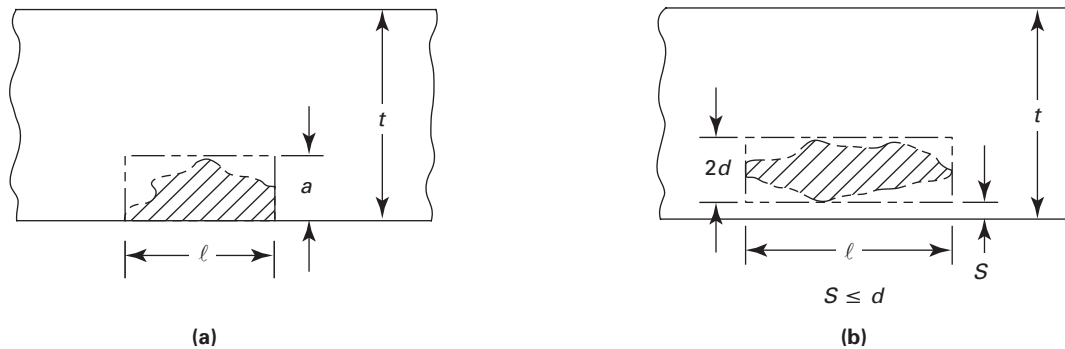
(c) Alternatively, other NDE methods or techniques may be applied to classify an indication as geometric (e.g., alternative UT beam angles, radiography, ID and/or OD profiling).

(3) *Flaw Sizing*. Flaws shall be sized in accordance with a procedure demonstrated to size similar flaws at similar material depths. Alternatively, a flaw may be sized by a supplemental manual technique so long as it has been qualified by the demonstration above. The dimensions of the flaw shall be determined by the rectangle that fully contains the area of the flaw. (Refer to Figs. 1–5.)

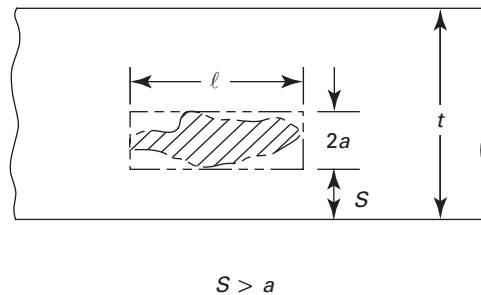
(a) The length (l) of the flaw shall be drawn parallel to the inside pressure-retaining surface of the component.

(b) The depth of the flaw shall be drawn normal to the inside pressure retaining surface and shall be denoted as “a” for a surface flaw or “2a” for a subsurface flaw.

FIG. 1 SINGLE INDICATIONS



Surface Indications



(c) Subsurface Indications

(4) *Flaw Evaluation and Acceptance Criteria.* Flaws shall be evaluated for acceptance using the applicable criteria of Table 1, 2, or 3 and with the following additional requirements:

(a) *Surface Connected Flaws.* Flaws identified as surface flaws during the UT examination may or may not be surface connected. Therefore, unless the UT data analysis confirms that that flaw is not surface connected, it shall be considered surface connected or a flaw open to the surface, and is unacceptable unless a surface examination is performed in accordance with (1), (2), or (3) below. If the flaw is surface connected, the requirements above still apply; however, in no case shall the flaw exceed the acceptance criteria in the applicable Construction Code for the method employed.

Acceptable surface examination techniques are:

(1) Magnetic particle examination (MT) in accordance with Appendix 6 of Section VIII, Division 1; Appendix 9-1 of Section VIII, Division 2; Appendix A-260 of Section I as applicable; or Appendix V of Section XII, or

(2) Liquid penetrant examination (PT) in accordance with Appendix 8 of Section VIII, Division 1; Appendix 9-2 of Section VIII, Division 2; Appendix A-270 of

Section I as applicable; or Appendix VI of Section XII, or

(3) Eddy current examination (ET) in accordance with Supplement I of this Case. All relevant ET indications that are open to the surface are unacceptable regardless of length.

(b) *Multiple Flaws*

(1) Discontinuous flaws shall be considered a singular planar flaw if the distance between adjacent flaws is equal to or less than S as shown in Fig. 2.

(2) Discontinuous flaws that are oriented primarily in parallel planes shall be considered a singular planar flaw if the distance between the adjacent planes is equal to or less than $\frac{1}{2}$ in. (13 mm). (Refer to Fig. 3.)

(3) Discontinuous flaws that are coplanar and nonaligned in the through-wall thickness direction of the component shall be considered a singular planar flaw if the distance between adjacent flaws is equal to or less than S as shown in Fig. 4.

(4) Discontinuous flaws that are coplanar in the through-wall direction within two parallel planes $\frac{1}{2}$ in. (13 mm) apart (i.e., normal to the pressure-retaining surface of the component) are unacceptable if the additive flaw depth dimension of the flaws exceeds those shown in Fig. 5.

FIG. 2 MULTIPLE PLANAR FLAWS ORIENTED IN PLANE NORMAL TO PRESSURE RETAINING SURFACE

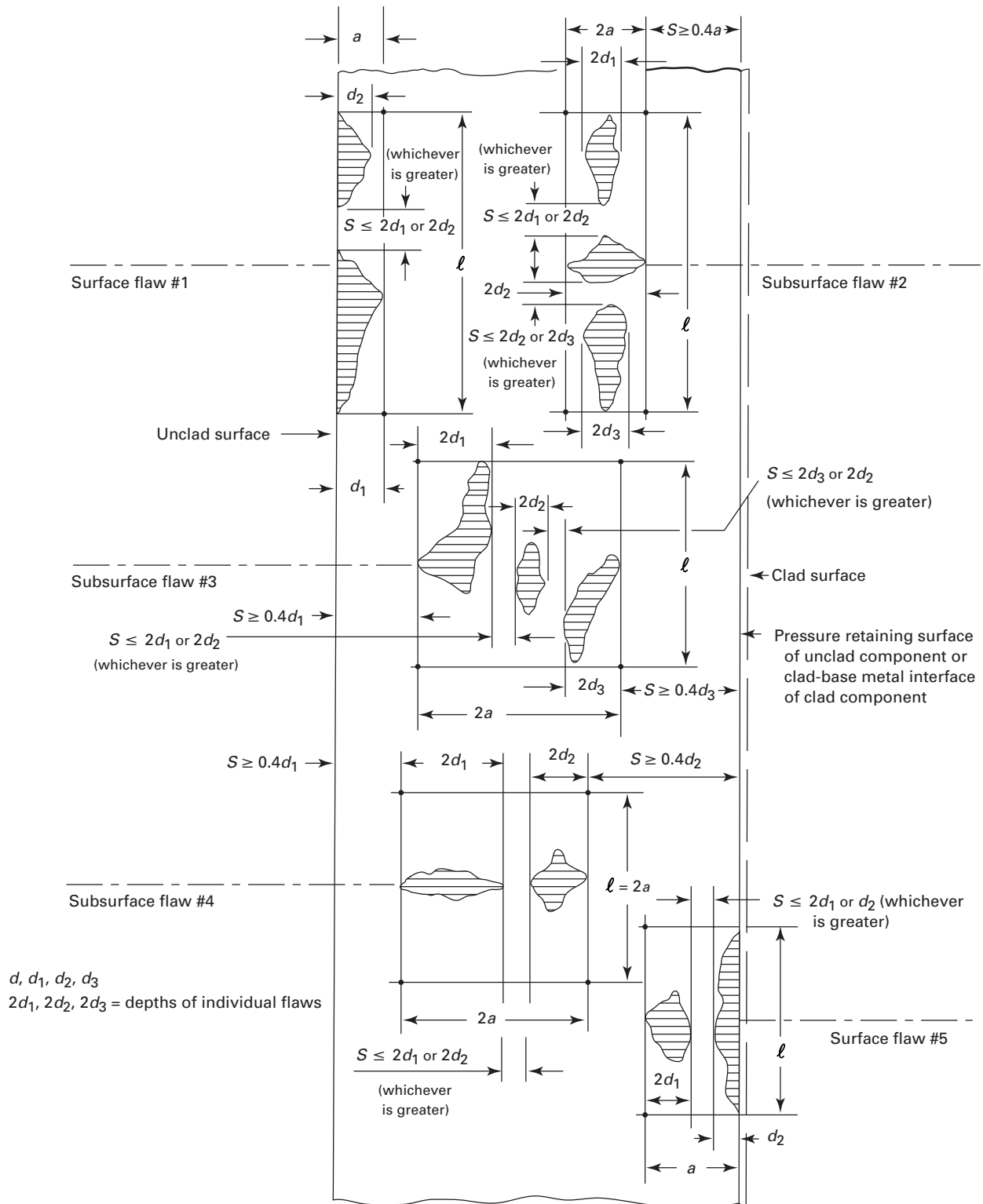
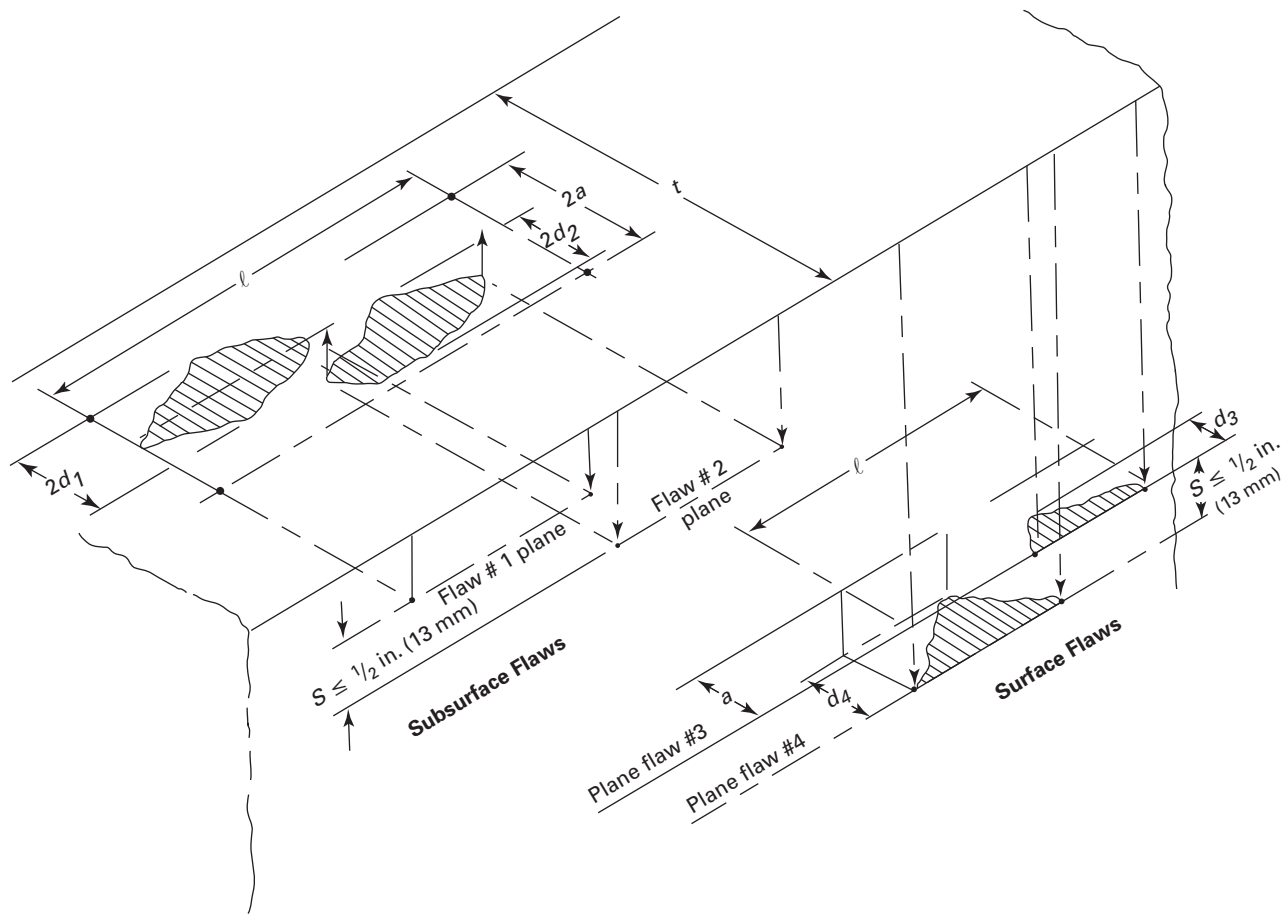


FIG. 3



(c) *Subsurface Flaws.* Flaw length (l) shall not exceed $4t$.

(j) The final data package shall be reviewed by a UT Level III individual. The review shall include:

- (1) the ultrasonic data record
- (2) data interpretations

(3) flaw evaluations/characterizations performed by another qualified Level II or III individual. The data review may be performed by another individual from the same organization.

Alternatively, the review may be achieved by arranging for a data acquisition and initial interpretation by a Level II individual qualified in accordance with paras. (f) and (h) above, and a final interpretation and evaluation shall be performed by a Level III individual qualified similarly. The Level III individual shall have been qualified in accordance with para. (f) above, including a practical examination on flawed specimens.

(k) The nameplate shall be marked under the Code Symbol stamp by applying UT, to indicate ultrasonic examination of welded seams required to be inspected in accordance with Section I; Section VIII, Division 1 or 2; or Section XII.

(l) This Case number shall be shown on the Manufacturer's Data Report, and the extent of the UT examination shall be noted.

SUPPLEMENT I: EDDY CURRENT SURFACE EXAMINATION PROCEDURE REQUIREMENTS

(a) *Procedure Requirements.* A written procedure shall be provided containing a statement of scope that specifically defines the limits of procedure applicability (e.g., material specification, grade, type, or class). The procedure shall reference a technique specification, delineating the essential variables, qualified in accordance with the requirements below.

(b) *Procedure Specifications*

(1) The eddy current procedure shall specify the following regarding data acquisition:

(a) instrument or system, including manufacturer's name and model

FIG. 4 NONALIGNED COPLANAR FLAWS IN PLANE NORMAL TO PRESSURE RETAINING SURFACE (ILLUSTRATIVE FLAW CONFIGURATIONS)

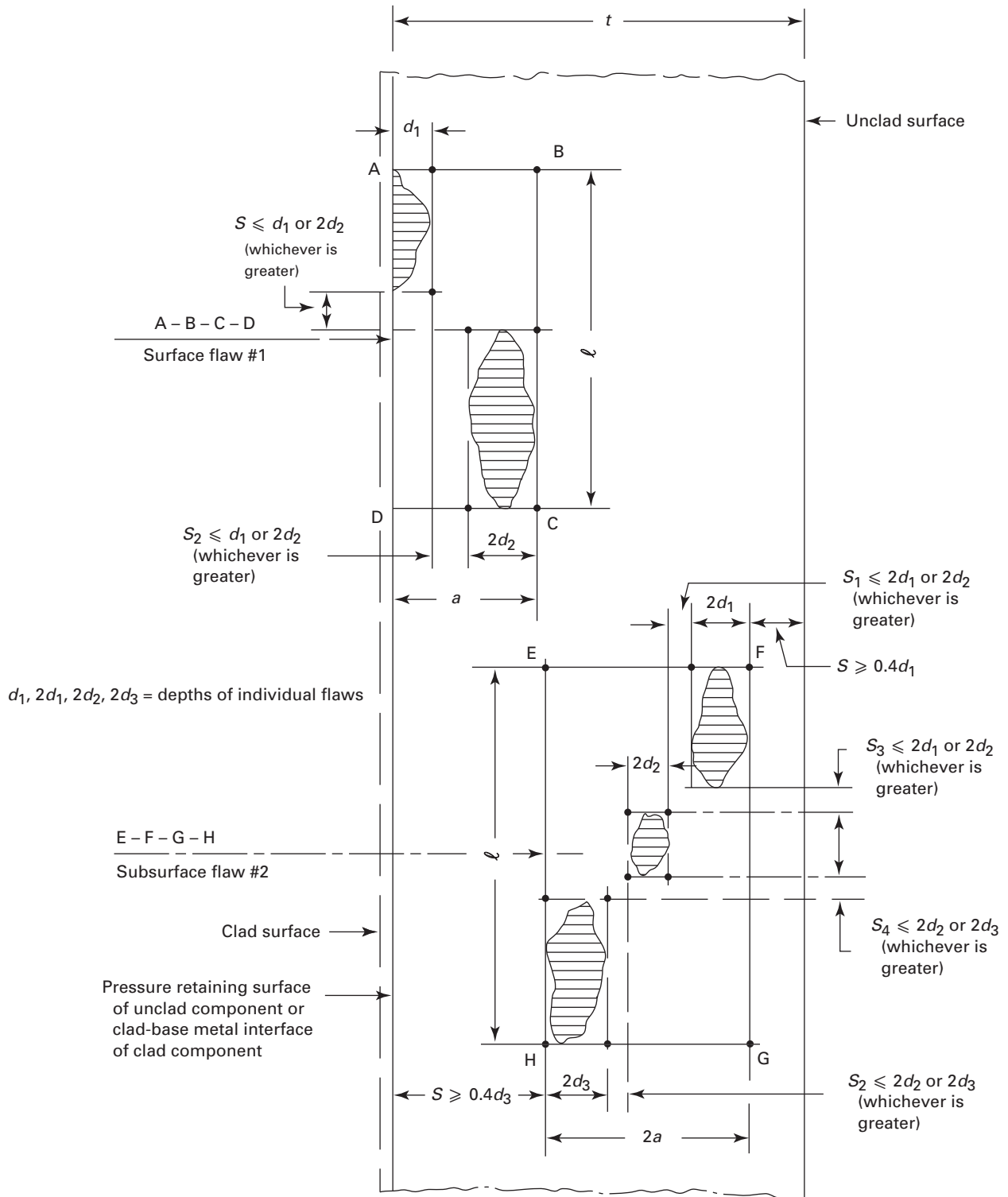
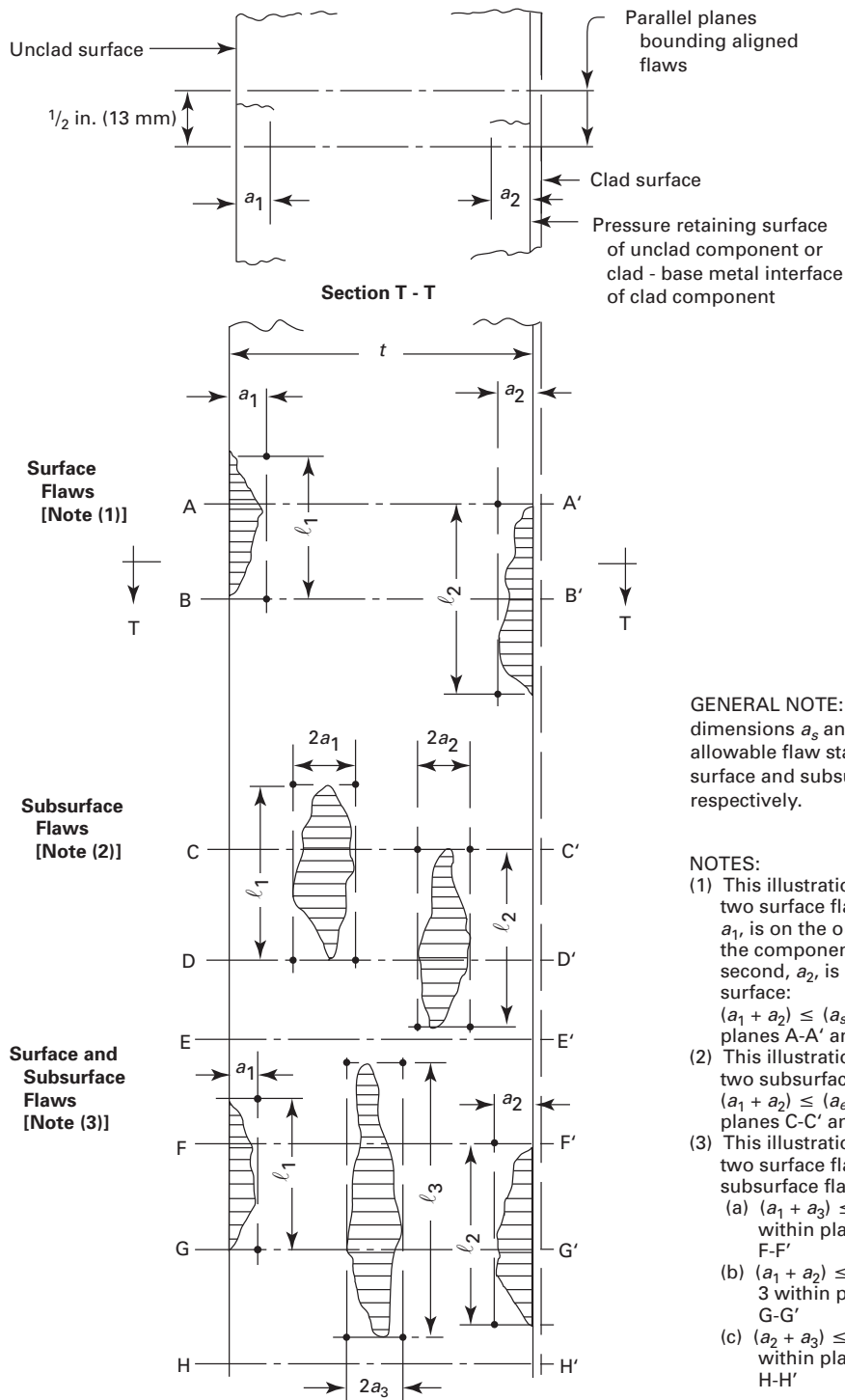


FIG. 5 MULTIPLE ALIGNED PLANAR FLAWS



- (b) size and type of probe, including manufacturer's name and part number
- (c) analog cable type and length
- (d) examination frequencies, or minimum and maximum range, as applicable
- (e) coil excitation mode (e.g., absolute or differential)
- (f) minimum data to be recorded
- (g) method of data recording
- (h) minimum digitizing rate (samples per inch) or maximum scanning speed (for analog systems), as applicable
- (i) scan pattern, when applicable (e.g., helical pitch and direction, rectilinear rotation, length, scan index, or overlap)

- (j) magnetic bias technique, when applicable

- (k) material type

- (l) coating type and thickness, when applicable

(2) The eddy current procedure shall define the following regarding data analysis:

- (a) method of calibration (e.g., phase angle or amplitude adjustments)

- (b) channel and frequencies used for analysis

- (c) extent or area of the component evaluated

- (d) data review requirements (e.g., secondary data review, computer screening)

- (e) reporting requirements (i.e., signal-to-noise threshold, voltage threshold, flaw depth threshold)

- (f) methods of identifying flaw indications and distinguishing them from nonrelevant indications, such as indications from probe lift-off or conductivity and permeability changes in weld material

- (g) manufacturer and model of eddy current data analysis equipment, as applicable

- (h) manufacturer, title, and version of data analysis software, as applicable

(3) The procedure shall address requirements for system calibration. Calibration requirements include those actions required to ensure that the sensitivity and accuracy of the signal amplitude and time outputs of the examination system, whether displayed, recorded, or automatically processed, are repeatable and correct. Any process of calibrating the system is acceptable; a description of the calibration process shall be included in the procedure.

(4) Data acquisition and analysis procedures may be combined or separate, provided the above requirements are met.

(c) Personnel Requirements

(1) Personnel performing data acquisition shall have received specific training and shall be qualified by examination, in accordance with the employer's written practice, in the operation of the equipment, applicable techniques, and recording of examination results.

(2) Personnel performing analysis of data shall have received additional specific training in the data analysis techniques used in the procedure qualification and shall successfully complete the procedure qualification described below.

(3) American Society of Nondestructive Testing (ASNT) standards SNT-TC-1A or CP 189 shall be used as a guideline.

(4) Personnel qualifications may be combined provided all requirements are met.

(d) Procedure Qualification

(1) Data sets for detection and sizing shall meet requirements shown below.

(2) The eddy current procedure and equipment shall be considered qualified upon successful completion of the procedure qualification.

(3) *Essential Variables.* An essential variable is a procedure, software, or hardware item that, if changed, could result in erroneous examination results. Further, any item that could decrease the signal to noise ratio to less than 2:1 shall be considered an essential variable.

(4) Any two procedures with the same essential variables are considered equivalent. Equipment with essential variables that vary within the demonstrated ranges identified in the Data Acquisition Procedure Specification shall be considered equivalent. When the procedure allows more than one value or range for an essential variable, the qualification test shall be repeated at the minimum and maximum value for each essential variable with all other variables remaining at their nominal values. Changing essential variables may be accomplished during successive procedure qualifications involving different personnel; each data analyst need not demonstrate qualification over the entire range of every essential variable.

(e) Qualification Requirements

(1) Specimens to be used in the qualification test shall meet the requirements listed herein unless a set of test specimens is designed to accommodate specific limitations stated in the scope of the examination procedure (e.g., surface roughness or contour limitations). The same specimens may be used to demonstrate both detection and sizing qualification. For examination of vessels with coated surfaces, Section V, Article 8 shall apply.

(2) Specimens shall be fabricated from the same base material nominal composition (UNS Number) and heat treatment (e.g., solution annealed, precipitation hardened, solution heat treated and aged) as those to be examined.

(3) Specimen surface roughness and contour shall be generally representative of the surface roughness and contour of the component surface to be examined. The examination surface curvature need not be simulated if the ratio of the component diameter to the coil diameter exceeds 20:1.

(4) Welding shall be performed with the same filler material AWS classification, and postweld heat treatment (e.g., as welded, solution annealed, stress relieved) as the welds to be examined.

(5) *Defect Conditions*

(a) The qualification flaws shall be cracks or notches.

(b) The length of cracks or notches open to the surface shall not exceed 0.125 in. (3.2 mm).

(c) The maximum depth of a crack or compressed notch shall be 0.040 in. (1.02 mm).

(d) Machined notches shall have a maximum width of 0.010 in. (0.25 mm) and a maximum depth of 0.020 in. (0.51 mm).

(6) *Demonstration Specimens.* The demonstration specimen shall include one crack or notch at each of the following locations:

(a) on the weld

(b) in the heat affected zone

(c) at the fusion line of the weld

(d) in the base material

(7) *Procedure Qualification Acceptance Criteria.* All flaws in each of the four identified areas shall be detected with a minimum 2:1 signal-to-noise ratio at the maximum digitization rate (for digital systems) or maximum scanning speed (for analog systems) permitted by the procedure.

(f) *Evaluation of Eddy Current Results.* Eddy current results are evaluated in accordance with the procedure described in para. (b)(2) above. For this Case, ET is used to simply confirm that a UT flaw is in fact, surface connected. If a UT flaw is determined by ET to be surface connected it shall comply with Acceptance Standards in para. (g) below.

(g) *Acceptance Standards.* These acceptance standards apply unless other more restrictive standards are specified for specific materials or applications within the Construction Code. All surfaces examined shall be free of relevant ET surface flaw indications.