Designation: A 609/A 609M – 91 (Reapproved 2002)

Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof[1]

This standard is issued under the fixed designation A 609/A 609M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice[2] covers the standards and procedures for the pulse-echo ultrasonic examination of heat-treated carbon, low-alloy, and martensitic stainless steel castings by the longitudinal-beam technique.

1.2 This practice is to be used whenever the inquiry, contract, order, or specification states that castings are to be subjected to ultrasonic examination in accordance with Practice A 609/A 609M.

1.3 This practice contains two procedures for ultrasonic inspection of carbon, low-alloy, and martensitic stainless steel castings; that is, Procedure A and Procedure B. Procedure A is the original A 609/A 609M practice and requires calibration using a series of test blocks containing flat bottomed holes. It also provides supplementary requirements for angle beam testing. Procedure B requires calibration using a back wall reflection from a series of solid calibration blocks.

NOTE 1—Ultrasonic examination and radiography are not directly comparable. This examination technique is intended to complement Guide E 94 in the detection of discontinuities.

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

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 217/A217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service[3]

E 94 Guide for Radiographic Examination[4]

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Examination Instruments and Systems Without the Use of Electronic Measurement Instruments[4]

2.2 *Other Document:*

SNT-TC-1A Recommended Practice for Non-Destructive Testing Personnel Qualification and Certification[5]

3. Ordering Information

3.1 The inquiry and order should specify which procedure is to be used. If a procedure is not specified, Procedure A shall be used.

3.2 *Procedure A—Flat-Bottomed Hole Calibration Procedure*:

3.2.1 When this practice is to be applied to an inquiry, contract, or order, the purchaser shall furnish the following information:

3.2.1.1 Quality levels for the entire casting or portions thereof,

3.2.1.2 Sections of castings requiring longitudinal-beam examination,

3.2.1.3 Sections of castings requiring dual element examination,

3.2.1.4 Sections of castings requiring supplementary examination, using the angle-beam procedure described in Supplementary Requirement S1 in order to achieve more complete examination, and

3.2.1.5 Any requirements additional to the provisions of this practice.

3.3 *Procedure B: Back-Wall Reflection Calibration Procedure*—When this procedure is to be applied to an inquiry, contract, or order, the purchaser shall designate the quality levels for the entire casting or applicable portions.

[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Dec. 15, 1991. Published July 1992. Originally published as A 609 – 70. Last previous edition A 609/A 609M – 90.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-609 of Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from American Society for Nondestructive Testing, P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518.

PROCEDURE A—FLAT-BOTTOMED HOLE CALIBRATION PROCEDURE

4. Apparatus

4.1 *Electronic Apparatus*:

4.1.1 An ultrasonic, pulsed, reflection type of instrument that is capable of generating, receiving, and amplifying frequencies of at least 1 to 5 MHz.

4.1.2 The ultrasonic instrument shall provide linear presentation (within ±5 %) for at least 75 % of the screen height (sweep line to top of screen). Linearity shall be determined in accordance with Practice E 317 or equivalent electronic means.

4.1.3 The electronic apparatus shall contain a signal attenuator or calibrated gain control that shall be accurate over its useful range to ±10 % of the nominal attenuation or gain ratio to allow measurement of signals beyond the linear range of the instrument.

4.2 *Search Units*:

4.2.1 *Longitudinal Wave*, internally grounded, having a ½ to 1⅛ in. [13 to 28 mm] diameter or 1-in. [25-mm] square piezo-electric elements. Based on the signals-to-noise ratio of the response pattern of the casting, a frequency in the range from 1 to 5 MHz shall be used. The background noise shall not exceed 25 % of the distance amplitude correction curve (DAC). Transducers shall be utilized at their rated frequencies.

4.2.2 *Dual-Element*, 5-MHz, ½ by 1-in. [13 by 25-mm], 12° included angle search units are recommended for sections 1 in. [25 mm] and under.

4.2.3 Other frequencies and sizes of search units may be used for evaluating and pinpointing indications.

4.3 *Reference Blocks*:

4.3.1 Reference blocks containing flat-bottom holes shall be used to establish test sensitivity in accordance with 8.2.

4.3.2 Reference blocks shall be made from cast steels that give an acoustic response similar to the castings being examined.

4.3.3 The design of reference blocks shall be in accordance with Fig. 1, and the basic set shall consist of those blocks listed in Table 1. When section thicknesses over 15 in. [380-mm] are to be inspected, an additional block of the maximum test thickness shall be made to supplement the basic set.

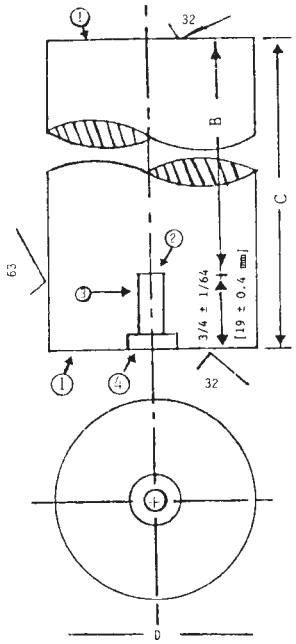
4.3.4 Machined blocks with 3⁄32-in. [2.4-mm] diameter flat-bottom holes at depths from the entry surface of ⅛ in. [3 mm], ½ in. [13 mm], or ½ *t* and ¾ in. [19 mm], or ¾ *t* (where *t* = thickness of the block) shall be used to establish the DAC for the dual-element search units (see Fig. 2).

4.3.5 Each reference block shall be permanently identified along the side of the block indicating the material and the block identification.

4.4 *Couplant*—A suitable couplant having good wetting characteristics shall be used between the search unit and examination surface. The same couplant shall be used for calibrations and examinations.

5. Personnel Requirements

5.1 The manufacturer shall be responsible for assigning qualified personnel to perform ultrasonic examination in conformance with the requirements of this practice.



NOTE 1—Opposite ends of reference block shall be flat and parallel within 0.001 in. [0.025 mm].

NOTE 2—Bottom of flat-bottom hole shall be flat within 0.002-in. [0.051 mm] and the finished diameter shall be ¼ + 0.002 in. [6.4 + 0.050].

NOTE 3—Hole shall be straight and perpendicular to entry surface within 0°, 30 min and located within 1⁄32 in. [0.80 mm] of longitudinal axis.

NOTE 4—Counter bore shall be ½ in. [15.0 mm] diameter by ⅛ in. [5 mm] deep.

FIG. 1 Ultrasonic Standard Reference Block

TABLE 1 Dimensions and Identification of Reference Blocks in the Basic Set (See Fig. 1)

Hole Diameter in 1⁄64ths, in. [mm]	Metal Distance *(B)*, in.[A] [mm]	Overall Length *(C)*, in. [mm]	Width or Diameter *(D)*, min, in. [mm]	Block Identification Number
16 [6.4]	1 [25]	1¾ [45]	2 [50]	16-0100
16 [6.4]	2 [50]	2¾ [70]	2 [50]	16-0200
16 [6.4]	3 [75]	3¾ [95]	2 [50]	16-0300
16 [6.4]	6 [150]	6¾ [170]	3 [75]	16-0600
16 [6.4]	10 [255]	10¾ [275]	4 [100]	16-1000
16 [6.4]	B	B + ¾ [B + 20]	5 [125]	16-B00[B]

[A] Tolerance ±⅛ in. [3 mm].

[B] Additional supplemental blocks for testing thickness greater than 10 in. [250 mm], see 4.3.3.

5.2 Personnel performing ultrasonic examinations in accordance with this practice shall be familiar with the following:

5.2.1 Ultrasonic terminology,

5.2.2 Instrument calibration,

5.2.3 Effect of transducer material, size, frequency, and mode on test results,

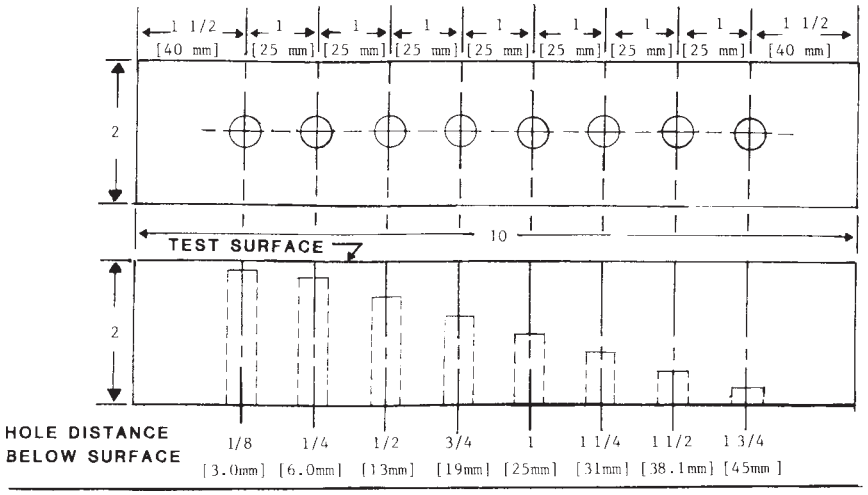
5.2.4 Effect of material structure (grain size, cleanliness, etc.) on test results,

5.2.5 Effect of test distance on test results,

5.2.6 Effect of nonlinearity on test results,

5.2.7 Effect of thickness and orientation of discontinuities on test results, and

5.2.8 Effect of surface roughness on test results.



NOTE 1—Entrant surface shall be 250 µin. [6.3 µm] or finer.

NOTE 2— The 3⁄32-in. [2.4 mm] flat-bottom hole must be flat within 0.002 in. [0.05 mm]. Diameter must be within +0.005 in. [0.13 mm] of the required diameter. Hole axis must be perpendicular to the block and within an angle of 0°, 30 min.

NOTE 3—Hole shall be plugged following checking for ultrasonic response.

in.	[mm]	in.	[mm]
⅛	[3]	1¼	[32]
¼	[6]	1½	[38]
½	[13]	1¾	[44]
¾	[19.0]	2	[50]
1	[25]	10	[254]

FIG. 2 Ultrasonic Standard Reference Block for Dual-Search Unit Calibration

5.3 A qualification record (see Note 2) of personnel considered suitable by the manufacturer to perform examinations in accordance with this practice shall be available upon request.

NOTE 2—SNT-TC-1A, Ultrasonic Testing Method, provides a recommended procedure for qualifying personnel. Other personnel qualification requirement documents may by used when agreed upon between the purchaser and the supplier.

6. Casting Conditions

6.1 Castings shall receive at least an austenitizing heat treatment before being ultrasonically examined.

6.2 Test surfaces of castings shall be free of material that will interfere with the ultrasonic examination. They may be as cast, blasted, ground, or machined.

6.3 The ultrasonic examination shall be conducted prior to machining that prevents an effective examination of the casting.

7. Test Conditions

7.1 To assure complete coverage of the specified casting section, each pass of the search unit shall overlap by at least 10 % of the width of the transducer.

7.2 The rate of scanning shall not exceed 6 in./s [150 mm/s].

7.3 The ultrasonic beam shall be introduced perpendicular to the examination surface.

8. Procedure

8.1 Adjust the instrument controls to position the first back reflection for the thickness to be tested at least one half of the distance across the cathode ray tube.

8.2 Using the set of reference blocks spanning the thickness of the casting being inspected, mark the flat-bottom hole indication height for each of the applicable blocks on the cathode ray tube shield. Draw a curve through these marks on the screen or on suitable graph paper. The maximum signal amplitude for the test blocks used shall peak at approximately three-fourths of the screen height above the sweep by use of the attenuator. This curve shall be referred to as the 100 % distance amplitude correction (DAC) curve. If the attenuation of ultrasound in the casting thickness being examined is such that the system's dynamic range is exceeded, segmented DAC curves are permitted.

8.3 The casting examination surface will normally be rougher than that of the test blocks; consequently, employ a transfer mechanism to provide approximate compensation. In order to accomplish this, first select a region of the casting that has parallel walls and a surface condition representative of the rest of the casting as a transfer point. Next, select the test block whose overall length, *C* (Fig. 1), most closely matches the reflection amplitude through the block length. Place the search unit on the casting at the transfer point and adjust the instrument gain until the back reflection amplitude through the casting matches that through the test block. Using this transfer technique, the examination sensitivity in the casting may be expected to be within ±30 % or less of that given by the test blocks.

8.4 Do not change those instrument controls and the test frequency set during calibration, except the attenuator, or calibrated gain control, during acceptance examination of a

given thickness of the casting. Make a periodic calibration during the inspection by checking the amplitude of response from the ¼-in. [6.4-mm] diameter flat-bottom hole in the test block utilized for the transfer.

NOTE 3—The attenuator or calibrated gain control may be used to change the signal amplitude during examination to permit small amplitude signals to be more readily detected. Signal evaluation is made by returning the attenuator or calibrated gain control to its original setting.

8.5 During examination of areas of the casting having parallel walls, recheck areas showing 75 % or greater loss of back reflection to determine whether loss of back reflection is due to poor contact, insufficient couplant, misoriented discontinuity, etc. If the reason for loss of back reflection is not evident, consider the area questionable and further investigate.

9. Report

9.1 The manufacturer's report of final ultrasonic examination shall contain the following data and shall be furnished to the purchaser:

9.1.1 The total number, location, amplitude, and area when possible to delineate boundaries by monitoring the movement of the center of the search unit of all indications equal to or greater than 100 % of the DAC,

9.1.2 Questionable areas from 8.5 that, upon further investigation, are determined to be caused by discontinuities,

9.1.3 The examination frequency, type of instrument, types of search units employed, couplant, manufacturer's identifying numbers, purchaser's order number, and data and authorized signature, and

9.1.4 A sketch showing the physical outline of the casting, including dimensions of all areas not inspected due to geometric configuration, with the location and sizes of all indications in accordance with 9.1.1 and 9.1.2.

10. Acceptance Standards

10.1 This practice is intended for application to castings with a wide variety of sizes, shapes, compositions, melting processes, foundry practices, and applications. Therefore, it is impractical to specify an ultrasonic quality level that would be universally applicable to such a diversity of products. Ultrasonic acceptance or rejection criteria for individual castings should be based on a realistic appraisal of service requirements and the quality that can normally be obtained in production of the particular type of casting.

10.2 Acceptance quality levels shall be established between the purchaser and the manufacturer on the basis of one or more of the following criteria:

10.2.1 No indication equal to or greater than the DAC over an area specified for the applicable quality level of Table 2.

10.2.2 No reduction of back reflection of 75 % or greater that has been determined to be caused by a discontinuity over an area specified for the applicable quality level of Table 2.

10.2.3 Indications producing a continuous response equal to or greater than the DAC with a dimension exceeding the maximum length shown for the applicable quality level shall be unacceptable.

10.2.4 Other criteria agreed upon between the purchaser and the manufacturer.

TABLE 2 Rejection Level

NOTE 1—The areas in the table refer to the surface area on the casting over which a continuous indication exceeding the amplitude reference line or a continuous loss of back reflection of 75 % or greater is maintained.

NOTE 2— Areas shall be measured from the center of the search unit.

NOTE 3—In certain castings, because of very long test distances or curvature of the test surface, the casting surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting; in such cases a graphic plot that incorporates a consideration of beam spread should be used for realistic evaluation of the discontinuity.

Ultrasonic Testing Quality Level	Area, $in.^2$[cm^2] (see 10.2.1 and 10.2.2)	Length, max, in. [mm]
1	0.8 [5]	1.5 [40]
2	1.5 [10]	2.2 [55]
3	3 [20]	3.0 [75]
4	5 [30]	3.9 [100]
5	8 [50]	4.8 [120]
6	12 [80]	6.0 [150]
7	16 [100]	6.9 [175]

10.3 Other means may be used to establish the validity of a rejection based on ultrasonic inspection.

NOTE 4—The areas for the ultrasonic quality levels in Table 2 of Practice A 609/A 609M refer to the surface area on the casting over which a continuous indication exceeding the DAC is maintained.

NOTE 5—Areas are to be measured from dimensions of the movement of the search unit by outlining locations where the amplitude of the indication is 100 % of the DAC or where the back reflection is reduced by 75 %, using the center of the search unit as a reference point to establish the outline of the indication area.

NOTE 6—In certain castings, because of very long metal path distances or curvature of the examination surfaces, the surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting; in such cases, other criteria that incorporate a consideration of beam angles or beam spread must be used for realistic evaluation of the discontinuity.

PROCEDURE B—BACK-WALL REFLECTION CALIBRATION PROCEDURE

11. Apparatus

11.1 Apparatus shall be kept on a regular six month maintenance cycle during which, as a minimum requirement, the vertical and horizontal linearities, sensitivity, and resolution shall be established in accordance with the requirements of Practice E 317.

11.2 *Search Units*—Ceramic element transducers not exceeding 1.25 in. [32 mm] diameter or 1 $in.^2$ [645 mm^2] shall be used.

11.3 *Search Units Facing*—A soft urethane membrane or neoprene sheet, approximately 0.025 in. [0.64 mm] thick, may be used to improve coupling and minimize transducer wear caused by casting surface roughness.

11.4 *Calibration/Testing*—The same system, including the urethane membrane, used for calibration shall be used to inspect the casting.

11.5 *Other Inspections*—Other frequencies and type search units may be used for obtaining additional information and pinpointing of individual indications.

11.6 *Couplant*—A suitable liquid couplant, such as clean SAE 30 motor oil or similar commercial ultrasonic couplant, shall be used to couple the search unit to the test surface. Other couplants may be used when agreed upon between the purchaser and supplier.

11.7 *Reference Standards*—Reference standards in accordance with Fig. 3 shall be used to calibrate the instrument for inspecting machined and cast surfaces. Reference standards shall be flaw free and machined within tolerances indicated.

12. Ultrasonic Instrument

12.1 *Type*—Pulsed ultrasonic reflection instrument capable of generating, receiving, and amplifying frequencies of 1 MHz to 5 MHz shall be used for testing.

12.2 *Voltage*—Line voltage shall be suitably regulated by constant voltage equipment and metal housing must be grounded to prevent electric shock.

12.3 *Linearity*—The instrument must provide a linear presentation (within ±5 %) of at least 1.5 in. [40 mm] sweep to peak (S/P).

12.4 *Calibrated Gain Control of Attenuator*—The instrument shall contain a calibrated gain control or signal attenuator (accurate within ±10 %) which will allow indications beyond the linear range of the instrument to be measured.

12.5 *Time-Corrected Gain*—The instrument shall be equipped to compensate for signal decay with distance. A method should be available to equalize signal response at different depths.

13. Qualification

13.1 The requirements for pre-production qualification are as follows:

13.1.1 *Personnel*—The personnel qualification requirements of SNT-TC-1A are applicable. Other personnel qualification requirement documents may be used when agreed upon between the purchaser and the supplier. Records of all personnel shall be available to customers upon request.

13.1.2 *Equipment*—The equipment shall be capable of meeting the requirements in Section 12.

14. Preparation

14.1 *Time of Inspection*—The final ultrasonic acceptance inspection shall be performed after at least an austenitizing heat treatment and preferably after machining. In order to avoid time loss in production, acceptance inspection of cast surfaces may be done prior to machining. Machined surfaces shall be acceptance inspected as soon as possible after machining. Repair welds may be inspected before the postweld heat treatment.

14.2 *Surface Finish*:

14.2.1 *Machined Surfaces*—Machined surfaces subject to ultrasonic inspection shall have a finish that will produce an ultrasonic response equivalent to that obtained from a 250 µin. [6.3 µm] surface. The surface finish shall also permit adequate movement of search units along the surface.

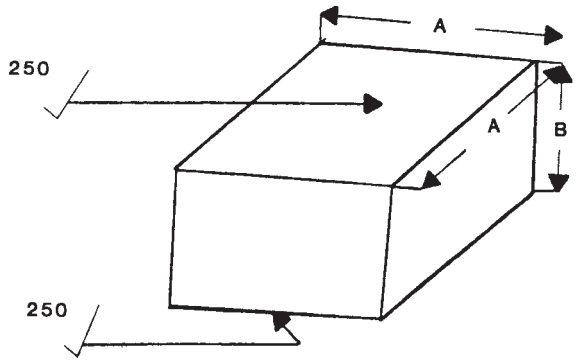
14.2.2 *Casting Surfaces*—Casting surfaces to be ultrasonically inspected shall be suitable for the intended type and quality level (Table 3 and Table 4) of inspection as judged acceptable by a qualified individual as specified in 13.1.1.

14.2.3 *Surface Condition*—All surfaces to be inspected shall be free of scale, machining or grinding particles, excessive paint thickness, dirt, or other foreign matter that may interfere with the inspection.

14.3 *Position of Casting*—The casting shall be positioned such that the inspector has free access to the back wall for the purpose of verifying change in contour.

15. Calibration

15.1 *Calibration Blocks*—Determine the thickness of the material to be ultrasonically inspected. For material thickness of 3 in. [75 mm] or less, use the series of 3 blocks, ½, 2, 5 in. [13, 50, 125 mm] (Fig. 3, B dimension) for calibration. For a



Dimensions, in. [mm]		Material
2 [50]	½ [13]	Specification A 217/A 217M,
2 [50]	2 [50]	Grade WC6 or acoustically similar within ±20 % or 2 dB.
3 [75]	5 [125]	
6 [150]	10 [250]	

Tolerance

All sides to be flat within 0.0002 in. [0.01 mm] and parallel with 0.001 in. [0.03 mm].

FIG. 3 Calibration Blocks

TABLE 3 Acceptance Criteria for Single Isolated Indications

NOTE 1—The area measured by movement of the center of the transducer over the casting surface.

NOTE 2—O = outer wall ⅓, or inner wall ⅓.
C = mid wall ⅓.
E = entire wall.

Quality Level	Maximum Non-Linear Indication, Area, in.^{2}[cm^2]	Position of Indication
1	0	E
2	1 [6]	E
3	1 [6]	O
	2 [13]	C
4	3 [19]	E
5	3 [19]	O
	5 [32]	C
6	5 [32]	E
7	5 [32]	O
	7 [45]	C
8	7 [45]	E
9	7 [45]	O
	9 [58]	C
10	9 [58]	E
11	9 [58]	O
	11 [71]	C

TABLE 4 Acceptance Criteria for Clustered Indications

Quality Level	Cumulative Area of Indications, in.^{2}[cm^2]^{A,B}	Minimum Area in Which Indications Must be Dispersed, in.^{2}[cm^2]^C
1	0	0
2–3	2 [13]	36 [232]
4–5	4 [26]	36 [232]
6–7	6 [39]	36 [232]
8–9	8 [52]	36 [232]
10–11	10 [64]	36 [232]

^{A} Regardless of wall location, that is midwall ⅓, innermost ⅓, or outermost ⅓.

^{B} Each indication that equals or exceeds the 0.5-in. [18 mm] reference line shall be traced to the position where the indication is equal to 0.25 in. [6 mm]. The area of the location, for the purpose of this evaluation, shall be considered the area that is confined within the outline established by the center of the transducer during tracing of the flaw as required. Whenever no discernible surface tracing is possible, each indication which equals or exceeds the 0.5 in. reference amplitude shall be considered 0.15 in.^{2} [1 cm^2] (three times the area of the ¼ diameter [6 mm] flat bottomed hole to compensate for reflectivity degradation of natural flaw) for the cumulative area estimates.

^{C} The indications within a cluster with the cumulative areas traced shall be dispersed in a minimum surface area of the casting equal to 36 in.^{2} [230 cm^2]. If the cumulative areas traced are confined with a smaller area of distribution, the area shall be repair welded to the extent necessary to meet the applicable quality level.

material thickness greater than 3 in., use the series of 3 blocks, 2, 5, 10 in. [50, 125, 250 mm] (Fig. 3, B dimension) for calibration.

15.2 *Calibration of Search Units*—For the thickness of material to be inspected, as determined in 15.1, use the following search units:

15.2.1 For materials 3 in. [75 mm] or less in thickness, use a 2¼ MHz, ½ in. [13 mm] diameter search unit.

15.2.2 For material greater than 3 in. [75 mm] in thickness, use a 2¼ MHz, 1 in. [25 mm] diameter search unit.

15.3 *Calibration Procedure*:

15.3.1 Set the frequency selector as required. Set the reject control in the "OFF" position.

15.3.2 Position the search unit on the entrant surface of the block that completely encompasses the metal thickness to be inspected (Fig. 3) and adjust the sweep control such that the back reflection signal appears approximately, but not more than three-quarters along the sweep line from the initial pulse signal.

15.3.3 Position the search unit on the entrant surface of the smallest block of the series of 3 blocks selected for calibration and adjust the gain until the back reflection signal height (amplitude) is 1.5 in. [40 mm] sweep to peak (S/P). Draw a line on the cathode-ray screen (CRT), parallel to the sweep line, through the peak of the 1.5 in. (S/P) amplitude.

15.3.4 Position the search unit on the entrant surface of the largest block of the series of 3 blocks selected for calibration, and adjust the distance amplitude control to provide a back reflection signal height of 1.5 in. [40 mm] (S/P).

15.3.5 Position the search unit on the entrant surface of the intermediate calibration block of the series of 3 blocks being used for calibration and confirm that the back reflection signal height is approximately 1.5 in. [40 mm] (S/P). If it is not, obtain the best compromise between this block and the largest block of the series of 3 blocks being used for calibration.

15.3.6 Draw a line on the cathode ray tube screen parallel to the sweep line at 0.5 in. [13 mm] (S/P) amplitude. This will be the reference line for reporting discontinuity amplitudes.

15.3.7 For tests on *machined surfaces*, position the search unit on a machined surface of casting where the walls are reasonably parallel and adjust the gain of the instrument until the back reflection signal height is 1.5 in. [40 mm] (S/P). Increase the inspection sensitivity by a factor of three times (10 dB gain) with the calibrated attenuator. Surfaces that do not meet the requirements of 14.2.1 shall be inspected as specified in 15.3.8.

15.3.8 For inspections on *cast surfaces*, position the search unit on the casting to be inspected at a location where the walls are reasonably parallel and smooth (inside and outside diameter) and the surface condition is representative of the surface being inspected. Adjust the gain of the instrument until the back reflection signal height is 1.5 in. [40 mm] (S/P). Increase the inspection sensitivity by a factor of six times (16 dB) by use of the calibrated control or attenuator. A significant change in surface finish requires a compensating adjustment to the gain.

15.3.8.1 Rejectable indications on as-cast surfaces may be reevaluated by surface preparation to 250 µin. [6.3 µm] finish or better, and re-inspected in accordance with 15.3.7 of this practice.

15.3.8.2 It should be noted that some instruments are equipped with decibel calibrated gain controls, in which case the decibel required to increase the sensitivity must be added. Other instruments have decibel calibrated attenuators, in which case the required decibel must be removed. Still other instruments do not have calibrated gains or attenuators. They require external attenuators.

16. Scanning

16.1 *Grid Pattern*—The surface of the casting shall be laid out in a 12 by 12 in. [300 by 300 mm] or any similar grid pattern for guidance in scanning. Grid numbers shall be stenciled on the casting for record purposes and for grid area identity. The stenciled grid number shall appear in the upper right hand corner of the grid. When grids are laid out on the casting surface and they encompass different quality levels, each specific area shall be evaluated in accordance with the requirements of the specific quality level designated for that area.

16.2 *Overlap*—Scan over the surface allowing 10 % minimum overlap of the working diameters of the search unit.

16.3 *Inspection Requirements*—All surfaces specified for ultrasonic (UT) shall be completely inspected from both sides, whenever both sides are accessible. The same search unit used for calibration shall be used to inspect the casting.

17. Additional Transducer Evaluation

17.1 Additional information regarding any ultrasonic indication may be obtained through the use of other frequency, type, and size search unit.

18. Acceptance Criteria

18.1 *Rejectable Conditions*—The locations of all indications having amplitudes greater than the 0.5 in. [13 mm] line

given in 15.3.6, when amplitude three times (machined surfaces) or six times (cast surfaces) shall be marked on the casting surface. The boundary limits of the indication shall be determined by marking a sufficient number of marks on the casting surfaces where the ultrasonic signal equals one half the reference amplitude, 0.25 in. [6 mm]. To completely delineate the indication, draw a line around the outer boundary of the center of the number of marks to form the indication area. Draw a rectangle or other regular shape through the indication in order to form a polygon from which the area may be easily computed. It is not necessary that the ultrasonic signal exceed the amplitude reference line over the entire area. At some locations within the limits of the indication, the signal may be less than the reference line, but nevertheless still present such that it may be judged as a continuous, signal indication. Rejectable conditions are as follows and when any of the conditions listed below are found, the indications shall be removed and repair welded to the applicable process specification.

18.2 *Linear Indications*—A linear indication is defined as one having a length equal to or greater than three times its width. An amplitude of ½ in. [13 mm], such as would result from tears or stringer type slag inclusion, shall be removed.

18.3 *Non-Linear Indications*:

18.3.1 *Isolated Indications*—Isolated indications shall not exceed the limits of the quality level designated by the customer's purchase order listed in Table 3. An isolated indication may be defined as one for which the distance between it and an adjacent indication is greater than the longest dimension of the larger of the adjacent indications.

18.3.2 *Clustered Indications*—Clustered indications shall be defined as two or more indications that are confined in a 1 in. [25 mm] cube. Clustered indications shall not exceed the limits of the quality level designated by the customer purchase order in Table 4. Where the distance between indications is less than the lowest dimension of the largest indication in the group, the cluster shall be repair welded.

18.3.3 The distance between two clusters must be greater than the lowest dimension of the largest indication in either cluster. If they are not, the cluster having the largest single indication shall be removed.

18.3.4 All indications, regardless of their surface areas as indicated by transducer movement on the casting surface and regardless of the quality level required, shall not have a through wall distance greater than ⅓ *T*, where *T* is the wall thickness in the area containing the indication.

18.3.5 Repair welding of cluster-type indications need only be the extent necessary to meet the applicable quality level for that particular area. All other types of rejectable indications shall be completely removed.

18.3.6 Repair welds of castings shall meet the quality level designated for that particular area of the casting.

18.3.7 Any location that has a 75 % or greater loss in back reflection and exceeds the area of the applicable quality level, and whose indication amplitudes may or may not exceed the 0.5 in. [13 mm] rejection line, shall be rejected unless the reason for the loss in back reflection can be resolved as not being caused by an indication. If gain is added and back echo is achieved without indication percent amplitude exceeding the 0.5 in. [13 mm] rejection line, the area should be accepted.

19. Records

19.1 *Stenciling*—Each casting shall be permanently stenciled to locate inspection zones or grid pattern for ease in locating areas where rejectable indications were observed.

19.2 *Sketch*—A report showing the exact depth and surface location in relation to the stencil numbers shall be made for each rejectable indicator found during each inspection.

19.2.1 The sketch shall also include, but not be limited to, the following:

19.2.1.1 Part identification numbers,

19.2.1.2 Purchase order numbers,

19.2.1.3 Type and size of supplemental transducers used,

19.2.1.4 Name of inspector, and

19.2.1.5 Date of inspection.

20. Product Marking

20.1 Any rejectable areas (those indications exceeding the limits of Section 19) shall be marked on the casting as the inspection progresses. The point of marking shall be the center of the search unit.

21. Keywords

21.1 carbon and low-alloy steel; castings; martensitic stainless steel; ultrasonic

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall be applied only when agreed upon between the purchaser and the supplier to achieve an effective examination of a critical casting area that cannot be effectively examined using a longitudinal beam as a result of casting design or possible discontinuity orientation.

S1. Angle Beam Examination of Steel Castings

S1.1 *Equipment:*

S1.1.1 *Examination Instrument*—Examination shall be conducted with an ultrasonic, pulsed-reflection type of system generating frequencies of at least 0.4 to 5 MHz. Properties of the electronic apparatus shall be the same as those specified in 4.1.

S1.1.2 *Search Units*—Angle-beam search units shall produce an angle beam in steel in the range from 30 to 75° inclusive, measured to the perpendicular of the entry surface of the casting being examined. It is preferred that search units shall have frequency of 0.4 to 5 MHz.

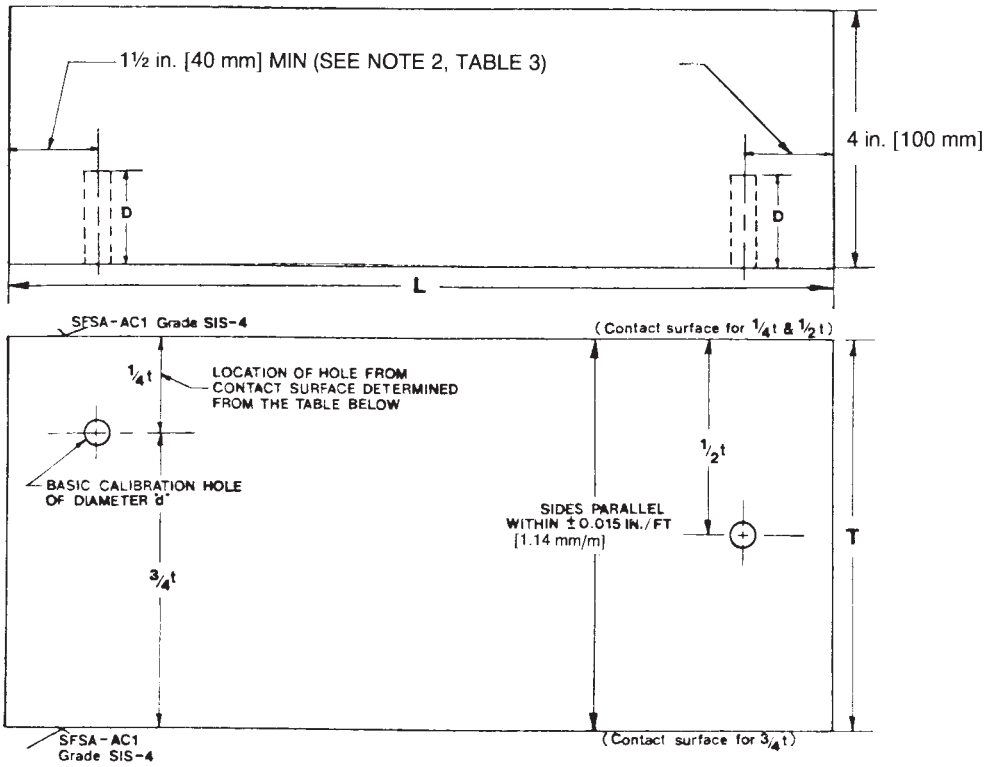
S1.1.3 *Calibration Blocks*—A set of blocks, as shown in Fig. S1.1, with as cast surface equivalent to SCRATA Comparator A3[6] and of a thickness comparable to the sections being examined with side-drilled holes at ¼ *t*, ½ *t*, and ¾ *t* (where *t* = thickness of the block) shall be used to establish an amplitude reference line (ARL).

S1.2 *Calibration of Equipment:*

S1.2.1 Construct the distance amplitude correction curve by utilizing the responses from the side-drilled holes in the basic calibration block for angle beam examination as shown in Fig. S1.1 and Table S1.1.

S1.2.1.1 Resolve and mark the amplitudes of the ¼ *t* and ½ *t* side-drilled holes from the same surface. The side-drilled

[6] Available from Steel Founders Society of America, 205 Park Ave., Barrington, IL 60010-4332.



L = length of block determined by the angle of search unit and the vee-path used,
T = thickness of basic calibration block (see Table S1.1),
D = depth of side-drilled hole (see Table S1.1),
d = diameter of side-drilled hole (see Table S1.1),
t = nominal production material thickness.

FIG. S1.1 Basic Calibration Block for Angle Beam Examination

TABLE S1.1 Dimensions of Calibration Blocks for Angle– Beam Examination

NOTE 1—Dimensions of Calibration Blocks for Angle-Beam Examination For each increase in thickness of 2 in. [50 mm], or a fraction thereof, the hole diameter shall increase 1/16 in. [1.6mm].

NOTE 2—For block sizes over 3 in. [75 mm] in thickness, *T*, the distance from the hole to the end of the block shall be ½ *T*, min, to prevent coincident reflections from the hole and the corner. Block fabricated with a 2-in. [50-mm] minimum dimension need not be modified if the corner and hole indications can be easily resolved.

Nominal Production Material Thickness *(t)*, in. [mm]	Basic Calibration Block Thickness *(T)*, in. [mm]	Hole Diameter *(d)*, in 1.002 [mm ± 0.05]	Minimum Depth *(D)*, in. [mm]
Up to 1 [25] incl.	1 [25] or *t*	3/32 [2.4]	1½ [40]
Over 1 to 2 [25–50]	2 [50] or *t*	⅛ [3.2]	1½ [40]
Over 2 to 4 [50–100]	4 [100] or *t*	3/16 [4.8]	1½ [40]
Over 4 to 6 [100–150]	6 [150] or *t*	¼ [6.3]	1½ [40]
Over 6 to 8 [150–200]	8 [200] or *t*	5/16 [7.9]	1½ [40]
Over 8 to 10 [200–250]	10 [250] or *t*	⅜ [9.5]	1½ [40]
Over 10 [250]	*t*	See Note 1	1½ [40]

hole used for the ¼ *t* amplitude may be used to establish the ¾ *t* amplitude from the opposite surface or a separate hole may be used.

S1.2.1.2 Connect the ¼ *t*, ½ *t*, and ¾ *t* amplitudes to establish the applicable DAC.

S1.2.2 The basic calibration blocks shall be made of material that is acoustically similar to the casting being examined.

S1.2.3 Do not use basic calibration blocks with as cast surface equivalent to SCRATA Comparator A3 to examine castings with surface rougher than SCRATA Comparator A3. Use a machined calibration block for machined surfaces.

S1.2.4 The search unit and all instrument control settings remain unchanged except the attenuator or calibrated gain control.

S1.2.4.1 The attenuator or calibrated gain control may be used to change the signal amplitude during examination to permit small amplitude signals to be more readily detected. Signal evaluation is made by returning the attenuator or calibrated gain control to its original setting.

S1.3 *Data Reporting*—The supplier's report of final ultrasonic examination shall contain the following data:

S1.3.1 The total number, location, amplitude, and area of all indications equal to or greater than 100 % of the distance amplitude curve.

S1.3.2 The examination frequency, type of instrument, type, and size of search units employed, couplant, transfer method, examination operator, supplier's identifying numbers, purchase order number, date, and authorized signature.

S1.3.3 A sketch showing the physical outline of the casting, including dimensions of all areas not examined due to geometric configuration, with the location of all indications in accordance with S1.3.1.

S1.4 *Acceptance Standards*—Acceptance quality levels shall be established between the purchaser and the manufacturer on the basis of one or more of the following criteria:

S1.4.1 No indication equal to or greater than the DAC over an area specified for the applicable quality level of Table 2.

S1.4.2 Other criteria agreed upon between the purchaser and the manufacturer.