Designation: A745/A745M – 20

Standard Practice for Ultrasonic Examination of Austenitic Steel Forgings[1]

This standard is issued under the fixed designation A745/A745M; 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 straight and angle beam contact, pulse-echo ultrasonic examination of austenitic steel forgings produced in accordance with Practice A388/A388M and Specifications A965/A965M and A1049/A1049M.

1.2 Ultrasonic examination of nonmagnetic retaining ring forgings should be made to Practice A531/A531M rather than this practice.

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

1.4 This practice is expressed in inch-pound and SI units; however, unless the purchase order or contract specifies the applicable "M" specification designation (SI units), the inch-pound units shall apply. The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the practice, the SI units are shown in brackets. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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

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

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

A531/A531M Practice for Ultrasonic Examination of Turbine-Generator Steel Retaining Rings

A788/A788M Specification for Steel Forgings, General Requirements

A965/A965M Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts

A1049/A1049M Specification for Stainless Steel Forgings, Ferritic/Austenitic (Duplex), for Pressure Vessels and Related Components

E317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments

E428 Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing (Withdrawn 2019)[4]

2.2 *ASME Code:*[5]

ASME Boiler and Pressure Vessel Code

2.3 *American Society for Nondestructive Testing Document:*[6]

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification

3. Ordering Information

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

3.1.1 Quality level of examination (see Section 12).

3.1.2 Additional requirements to this practice.

[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 A01.06 on Steel Forgings and Billets.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-745/SA-745M in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The last approved version of this historical standard is referenced on www.astm.org.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[6] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

***A Summary of Changes section appears at the end of this standard**

3.1.3 Applicability of supplementary requirements (see Supplementary Requirements section).

3.1.4 Supplementary requirements, if any.

3.2 When specified, the manufacturer shall submit an examination procedure for purchaser approval that shall include, but not be limited to, a sketch of the configuration as presented for ultrasonic examination showing the surfaces to be scanned, scanning directions, notch locations and sizes (if applicable), extent of coverage (if applicable), and an instruction listing calibration and inspection details and stage of manufacture.

4. Apparatus

4.1 *Electronic Apparatus*—A pulse-echo instrument permitting inspection frequencies of 1 MHz, 2.25 MHz, and 5 MHz is required. The accuracy of discontinuity amplitude analysis using this practice involves a knowledge of the true operating frequency of the complete inspection system. One of the best ways to obtain the desired accuracy is by use of a tuned pulser and narrow band amplifier of known frequency response, with either a broadband transducer, or a narrow-band tuned transducer of known and matching frequency.

4.1.1 *Apparatus Qualification and Calibration*—Basic qualification of the ultrasonic test instrument shall be performed at intervals not to exceed 12 months or whenever maintenance is performed that affects the equipment function. The date of the last calibration and the date of the next required calibration shall be displayed on the test equipment.

4.1.2 The horizontal linearity shall be checked on a distance calibration bar using the multiple order technique (see Practice E317). The horizontal linearity shall be ±2 % of the metal path.

4.1.3 The accuracy of the linearity shall be checked by ultrasonically verifying the thickness of the component in at least one location beyond the near field of the transducer. If necessary, minor adjustments for differences in the ultrasonic velocities between the calibration bar and the forging shall then be made.

4.2 *Amplifier*—The amplifier and display shall provide linear response within ±2 %, up to 100 % of full screen height.

4.2.1 *Amplifier Calibration*—An amplifier vertical linearity check shall be made prior to performing the test by observing a multiple order pattern from a calibration block using a 2.25 MHz transducer (see Practice E317). The first back reflection shall be set at 100 % of full screen height. The higher order back reflections, 10 % and higher in amplitude, shall also be positioned on the screen and their amplitudes noted. The first back reflection shall be reduced to 50 % and then 25 % of full screen height. The amplitudes of the higher order back reflections shall be noted at each step. The vertical linearity will be considered acceptable if the signal heights of the higher order reflections decrease in proportion to the decrease set for the first back reflection. The maximum acceptable error for the decrease of the higher order reflections is the greater of ±5 % of the expected back reflection height or ±2 % of full screen height.

4.3 *Signal Attenuator*—The instrument shall contain a calibrated gain control or signal attenuator that meets the requirements of Practice E317 (in each case, accurate within ±5 %) that will allow indications beyond the linear range of the instrument to be measured. It is recommended that these controls permit signal adjustments up to 25 to 1 (28 dB).

4.4 *Search Units:*

4.4.1 The maximum nominal active area of 1½ in.^{2} [970 mm^2] with ½ in. [13 mm] minimum to 1⅛ in. [30 mm] maximum dimensions or ¾ in. [20 mm] diameter minimum dimension shall be used for straight-beam scanning.

4.4.2 Angle-beam scanning transducers shall have a nominal active area of ½ in. to 1 in.^{2} [325 mm to 650 mm^2]. The search unit used for angle-beam examination shall produce a beam angle of 30 to 70° in the material.

4.4.3 Other search units, including frequencies other than those listed in Section 8, may be used for evaluating and pinpointing indications of discontinuities.

4.5 *Couplant*—A suitable couplant having good wetting characteristics shall be used between the transducer and the examination surface. The same couplant shall be used for calibration and examination.

4.6 *Reference Blocks:*

4.6.1 All ultrasonic standard reference blocks shall be in accordance with the general guidelines of Practice E428. However, absolute conformance to Practice E428 is not mandatory due to the nature of the material covered by this practice.

4.6.2 The reference block grain size, as measured by the relative acoustic penetrability of the reference blocks, should be reasonably similar to the forging under examination. However, it must be recognized that large austenitic forgings vary considerably in acoustic penetrability throughout their volume due to variations in grain size and structure. Reference blocks should be chosen that reasonably approximate the average penetrability of the forging under examination. Supplementary blocks of coarser or finer grain may be used for evaluation of indications as covered in Section 11.

4.6.3 As an alternative method, where practicable, the appropriate size of reference hole (or holes) or notches may be placed in representative areas of the forging for calibration and examination purposes when removed by subsequent machining. When holes or notches are not removed by subsequent machining, the purchaser must approve the location of holes or notches.

5. Personnel Requirements

5.1 Personnel performing the ultrasonic examinations to this practice shall be qualified and certified in accordance with a written procedure conforming to Recommended Practice No. SNT-TC-1A or another national standard that is acceptable to both the purchaser and the supplier.

6. Forging Conditions

6.1 Forgings shall be ultrasonically examined after heat treating.

6.2 The surfaces of the forging to be examined shall be free of extraneous material such as loose scale, paint, dirt, etc.

6.3 The surface roughness of scanning surfaces shall not exceed 250 µin. [6 µm] unless otherwise stated in the order or contract where the definition for surface finish is as per Specification A788/A788M.

6.4 The forgings shall be machined to a simple configuration, that is, rectangular or parallel or concentric surfaces where complete volumetric coverage can be obtained.

6.5 In certain cases, such as with contour forged parts, it may be impractical to assure 100 % volumetric coverage. Such forgings shall be examined to the maximum extent possible. A procedure indicating the extent of examination coverage shall be submitted for the purchaser's approval (see 3.2).

7. Procedure

7.1 Perform the ultrasonic examination after heat treatment when the forging is machined to the ultrasonic configuration but prior to drilling holes, cutting keyways, tapers, grooves, or machining sections to final contour.

7.2 To ensure complete coverage of the forging volume when scanning, index the search unit with at least 15 % overlap with each pass.

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

7.4 Scan all regions of the forging in at least two perpendicular directions to the maximum extent possible.

7.5 Scan disk and disk-type forgings using a straight beam from at least one flat face and radially from the circumference when practicable. For the purposes of this practice, a disk is a cylindrical shape where the diameter dimension exceeds the height dimension. Disk-type forgings made as upset-forged "pancakes" shall be classified as disks for inspection purposes although at the time of inspection, the part may have a center hole, counterturned steps, or other detail configuration.

7.6 Scan cylindrical sections, ring and hollow forgings from the entire external surface (sides or circumference), using the straight-beam technique, and scan the forging in the axial direction to the extent possible. When the length divided by the diameter ratio (slenderness ratio) exceeds 6 to 1 (or axial length exceeds 24 in. [600 mm]), scan axially from both end surfaces to the extent possible. If axial penetration is not possible due to attenuation, angle-beam examination directed axially may be substituted in place of axial straight beam. Examine ring and hollow forgings having an outside-diameter to inside-diameter ratio of less than 2 to 1 and a wall thickness less than 8 in. [200 mm] by angle-beam techniques from the outside diameter or inside diameter, or both, using full node or half-node technique (see 10.1.2 and 10.1.3) as necessary to achieve either 100 % volumetric coverage or the extent of coverage defined by an approved procedure (see 3.2).

7.7 If electronic circuitry is used for ultrasonic examination, the manufacturer's instructions for the specific instrument shall be required. This is achieved by the use of electronic circuitry referred to as time variable amplifier gain, typically called distance amplitude correction (DAC), distance echo correction (DEC), time varying gain (TVG), time-corrected gain (TCG), or sensitivity time control (STC). If circuitry is used that normalizes the amplitude of each reflector, such as TCG, the reflector with the lowest response shall be set at 80 % FSH.

8. Examination Frequency

8.1 Perform all ultrasonic examination at the highest frequency practicable (as specified in 8.1.1, 8.1.2, or 8.1.3) that will adequately penetrate the forging thickness and resolve the applicable reference standard. Include in the ultrasonic examination report the examination frequency used. Determine the test frequency at the time of actual examination by the following guidelines:

8.1.1 The nominal test frequency shall be 2.25 MHz. Use of this frequency will generally be restricted due to attenuation.

8.1.2 One megahertz is acceptable and will be the frequency generally applicable.

8.1.3 When necessary, due to attenuation, 0.5 MHz examination frequency may be used. The purchaser may request notification before this lower frequency is employed.

8.1.4 In the event that adequate penetration of certain regions is not possible even at 0.5 MHz, alternative nondestructive examination methods (such as radiography) may be employed to ensure the soundness of the forging by agreement between the purchaser and the manufacturer.

9. Straight-Beam Examination

9.1 *Method of Calibration:*

9.1.1 Perform calibration for straight-beam examination on the flat-bottom hole size determined by the applicable quality level (see Section 12).

9.1.2 Determine the calibration method by the test metal distance involved.

9.1.2.1 Thicknesses up to 6 in. [150 mm] may be examined using either the single-block or the distance-amplitude curve calibration method.

(a) Single-Block Method—Establish the test sensitivity on the reference standard representing the forging thickness. Drill flat-bottom holes normal to the examining surface, to midsection in material up to 1.5 in. [40 mm] in thickness and at least 0.75 in. [20 mm] in depth but no deeper than midsection in thicknesses from 1.5 in. to 6 in. [40 mm to 150 mm]. Make evaluations of indications at the estimated discontinuity depth at which they are observed using supplementary reference standards, if necessary.

(b) Distance-Amplitude-Curve Correction Method—Establish the test sensitivity on the reference standard whose metal travel distance represents the greater metal travel distance of the part under examination, within ±1 in. [25 mm].

9.1.2.2 Examine thicknesses from 6 in. to 24 in. [150 mm to 600 mm] using the distance-amplitude calibration method. Calibration to ½ thickness test metal distance may be used provided examinations from two opposing surfaces are made.

9.1.2.3 For metal travel distances over 24 in. [600 mm], perform one of the following examinations:

(a) Perform a back-reflection examination from at least one surface to QL-5 (see 12.1.1) or to a purchaser-approved procedure (see 3.2).

(b) On hollow-round forgings with wall thicknesses less than 8 in. [200 mm], perform an axial angle-beam scan in place

of the straight-beam scan from the end surfaces. Calibration for this scan may be established on the existing axial notches required for the circumferential scan or on transverse oriented notches installed specifically for axial angle beam.

9.2 *Calibration Procedure*—Over an indication-free area of the forging and with the proper test frequency, adjust the instrument controls to obtain a back reflection, and then adjust the controls to bring the signal to 100 % full screen height (FSH) or maximum vertical linearity of the instrument. The adjusted instrument sensitivity display shall be the primary calibration reference for both the single-block and multiple-block calibration methods. If, at this gain setting, the amplitude response from the flat-bottom hole in the longest calibration block is not equal to or greater than 20 % FSH, adjust the instrument gain further to obtain a 20 % FSH minimum response. To complete the distance-amplitude correction curve, determine the remaining points defining the shape of the curve at this adjusted gain setting and mark the curve on the shield of the display, plot on a graph, or by use of electronic circuitry. At least three blocks shall be used with test metal distances of 3 in. [75 mm], ½ *T*, and *T*, where *T* equals the thickness of the area being inspected. However, the distance between any of the test blocks shall be 1½ in. [40 mm] minimum. If indications closer than 3 in. [75 mm] from the initial pulse must be evaluated, an additional block with 1½ in. [40 mm] test metal distance shall be used. This is the fixed reference against which all indications shall be evaluated at the maximum obtainable response at whatever depth the indications are observed. This will constitute an acceptable examination if there are no indications exceeding the acceptance limits. In large forgings, it is expected that a portion of the distance-amplitude curve will be above the vertical linearity limits of the instrument. If an indication appears in this area, readjust the instrument through the use of a calibrated gain control or through recalibration to the initial calibration level to bring the appropriate portion of the presentation on screen for evaluation of that specific area.

NOTE 1—When flat surfaced reference block calibration is used for examination of forgings with surface curvature, compensation for curvature shall be made and the method for curvature correction shall be a matter of agreement between the producer and the purchaser. For diameters 80 in. [2000 mm] and over, no correction factor is required.

10. Angle-Beam Examination

10.1 Ring and hollow round forgings, as defined in 7.6, shall be angle-beam examined from their outer periphery in both circumferential directions employing the following method of calibration:

10.1.1 Notches of 1.25 in. [30 mm] maximum surface length, with the length perpendicular to sound propagation; depth based on quality level (Section12), either rectangular with a width not greater than twice its depth or 60° minimum to 75° maximum included angle, located in the forging so as to produce no interference with each other, shall be used as calibration standards.

10.1.2 Determine the response from the inside and outside diameter calibration notches with the search unit positioned to produce the maximum response from each notch. Adjust the sensitivity of the ultrasonic equipment so that the indication from the notch at the greatest test metal distance is at least 20 % FSH. Draw a straight line or use electronic circuitry connecting the peaks of the responses obtained from the inside and outside diameter notches. This shall be the primary reference line. This procedure is considered full node calibration.

10.1.3 In the event that a response of at least 20 % cannot be obtained from both the inside and outside diameter notches, calibrate from both the outer periphery (the outside diameter surface) and the inside diameter surface. Adjust the sensitivity of the ultrasonic equipment so that the indication from the notch in the opposite surface is at least 20 % FSH in magnitude. This procedure is considered half-node calibration. Axial angle beam may be substituted for straight beam from the end surfaces, when specified.

NOTE 2—Long cylinders or cylinders with small inside diameters are difficult to examine from the inside diameter surface. Normally, neither inside diameters smaller than 18 in. [450 mm] nor long cylinders exceeding 36 in. [900 mm] in length are scanned from the inside diameter surface.

11. Evaluation of Material

11.1 Coarse-grained austenitic materials frequently display baseline noise, particularly when an examination is performed at high sensitivities. For this reason, it is important to critically scrutinize reportable and rejectable indications to determine whether they result from defects or grain structure. It is desirable to have several sets of calibration blocks with varying degrees of grain coarseness so that the attenuation of the defective area can be reasonably matched with a test block for a more accurate minimum defect size estimation. Due to the normal wide variation in attenuation throughout a given large austenitic forging, it is permissible to evaluate rejectable indications on the basis of alternative calibration blocks that compare more reasonably in attenuation to the defect area. It is also permissible to insert reference holes into representative areas of the forging itself, with the approval of the purchaser, to be used for calibration and evaluation of indications. Loss of back reflection results not only from internal discontinuities but also from coarse or nonuniform grain structures, variations in coupling, nonparallel reflecting surfaces, and other factors that must be considered before concluding that loss of back reflection resulted from discontinuities.

12. Quality Levels for Acceptance

12.1 One of the following quality levels may be specified by the purchaser:

12.1.1 *Straight Beam:*

12.1.1.1 Material producing an indication response whose maximized amplitude equals or exceeds 100 % of the primary reference or distance-amplitude correction curve at the estimated discontinuity depth shall be considered unacceptable.

(a) QL-1—A distance-amplitude curve shall be based upon the amplitude response from No. 8 flat-bottom hole (⅜₆₄ in. [3 mm]).

(b) QL-2—A distance-amplitude curve shall be based upon the amplitude response from No. 16 flat-bottom hole ¹⁶⁄₆₄ in. [6 mm]).