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Used in USNRC-RDT standards

Standard Practice for Ultrasonic Examination of Steel Forgings[1]

This standard is issued under the fixed designation A388/A388M; 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 examination procedures for the contact, pulse-echo ultrasonic examination of steel forgings by the straight and angle-beam techniques. The straight beam techniques include utilization of the DGS (Distance Gain-Size) method. See Appendix X3.

1.2 This practice is to be used whenever the inquiry, contract, order, or specification states that forgings are to be subject to ultrasonic examination in accordance with Practice A388/A388M.

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

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

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

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

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A469/A469M Specification for Vacuum-Treated Steel Forgings for Generator Rotors

A745/A745M Practice for Ultrasonic Examination of Austenitic Steel Forgings

A788/A788M Specification for Steel Forgings, General Requirements

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

E1065/E1065M Practice for Evaluating Characteristics of Ultrasonic Search Units

2.2 *Other Documents:*

ASME Boiler and Pressure Vessel Code[4]

Recommended Practice for Nondestructive Personnel Qualification and Certification SNT-TC-1A, (1988 or later)[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *indication levels (clusters), n*—five or more indications in a volume representing a 2 in. [50 mm] or smaller cube in the forging.

3.1.2 *individual indications, n*—single indications showing a decrease in amplitude as the search unit is moved in any direction from the position of maximum amplitude and which are too small to be considered traveling or planar.

[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-388/SA-388M 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] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] 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 *planar indications, n*—indications shall be considered continuous over a plane if they have a major axis greater than 1 in. [25 mm] or twice the major dimension of the transducer, whichever is greater, and do not travel.

3.1.4 *traveling indications, n*—indications whose leading edge moves a distance equivalent to 1 in. [25 mm] or more of metal depth with movement of the transducer over the surface of the forging.

4. Significance and Use

4.1 This practice shall be used when ultrasonic inspection is required by the order or specification for inspection purposes where the acceptance of the forging is based on limitations of the number, amplitude, or location of discontinuities, or a combination thereof, which give rise to ultrasonic indications.

4.2 The ultrasonic quality level shall be clearly stated as order requirements.

5. Ordering Information

5.1 When this practice is to be applied to an inquiry, contract, or order, the purchaser shall so state and shall also furnish the following information:

5.1.1 Designation number (including year date),

5.1.2 Method of establishing the sensitivity in accordance with 9.2.2 and 9.3.3 (DGS (Distance Gain Size), Vee- or rectangular-notch),

5.1.2.1 The diameter and test metal distance of the flat-bottom hole and the material of the reference block in accordance with 9.2.2.2,

5.1.3 Quality level for the entire forging or portions thereof in accordance with 12.3, and

5.1.4 Any options in accordance with 1.5, 6.4, 6.5, 7.1, 8.1, 8.2, 9.1.11, 10.1, 10.2, and 12.2.

6. Apparatus

6.1 *Electronic Apparatus*—An ultrasonic, pulsed, reflection type of instrument shall be used for this examination. The system shall have a minimum capability for examining at frequencies from 1 to 5 MHz. On examining austenitic stainless forgings the system shall have the capabilities for examining at frequencies down to 0.4 MHz.

6.1.1 *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.

6.1.2 The ultrasonic instrument shall provide linear presentation (within 5 %) for at least 75 % of the screen height (sweep line to top of screen). The 5 % linearity referred to is descriptive of the screen presentation of amplitude. Instrument linearity shall be verified in accordance with the intent of Practice E317. Any set of blocks processed in accordance with Practice E317 or E428 may be used to establish the specified ±5 % instrument linearity.

6.1.3 The electronic apparatus shall contain an attenuator (accurate over its useful range to ±10 % (+1 dB) of the amplitude ratio) which will allow measurement of indications beyond the linear range of the instrument.

6.2 *Search Units,* having a transducer with a maximum active area of 1 in.^{2} [650 mm^2] with ½ in. [13 mm] minimum to 1⅛ in. [30 mm] maximum dimensions shall be used for straight-beam scanning (see 9.2); and search units having a transducer with ½ in. [13 mm] minimum to 1 in. [25 mm] maximum dimensions shall be used for angle-beam scanning (see 9.3).

6.2.1 *Transducers* shall be utilized at their rated frequencies.

6.2.2 Other transducers may be used for evaluating and pinpointing indications.

6.3 *Couplants,* having good wetting characteristics such as SAE No. 20 or No. 30 motor oil, glycerin, pine oil, or water shall be used. Couplants may not be comparable to one another and the same couplant shall be used for calibration and examination.

6.4 *Reference Blocks,* containing flat-bottom holes may be used for calibration of equipment in accordance with 6.1.2 and may be used to establish recording levels for straight-beam examination when so specified by the order or contract.

6.5 *DGS Scales,* matched to the ultrasonic test unit and transducer to be utilized, may be used to establish recording levels for straight or angle beam examination, when so specified by the order or contract. The DGS scale range must be selected to include the full thickness cross-section of the forging to be examined. An example of a DGS overlay is found in Appendix X3.

6.5.1 As an alternative to using DGS overlays, an ultrasonic instrument having DGS software, integral decibel gain or attenuator controls in combination with a specifically paired transducer and DGS diagram may be used to evaluate ultrasonic indications.

7. Personnel Requirements

7.1 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 (1988 or later) or another national standard that is acceptable to both the purchaser and the supplier.

8. Preparation of Forging for Ultrasonic Examination

8.1 Unless otherwise specified in the order or contract, the forging shall be machined to provide cylindrical surfaces for radial examination in the case of round forgings; the ends of the forgings shall be machined perpendicular to the axis of the forging for the axial examination. Faces of disk and rectangular forgings shall be machined flat and parallel to one another.

8.2 The surface roughness of exterior finishes shall not exceed 250 µin. [6 µm] where the definition for surface finish is as per Specification A788/A788M unless otherwise shown on the forging drawing or stated in the order or the contract.

8.3 The surfaces of the forging to be examined shall be free of extraneous material such as loose scale, paint, dirt, and so forth.

9. Procedure

9.1 *General:*

9.1.1 As far as practicable, subject the entire volume of the forging to ultrasonic examination. Because of radii at change of sections and other local configurations, it may be impossible to examine some sections of a forging.

9.1.2 Perform the ultrasonic examination after heat treatment for mechanical properties (exclusive of stress-relief treatments) but prior to drilling holes, cutting keyways, tapers, grooves, or machining sections to contour. If the configuration of the forging required for the treatment for mechanical properties prohibits a subsequent complete examination of the forging, it shall be permissible to examine prior to treatment for mechanical properties. In such cases, reexamine the forging ultrasonically as completely as possible after heat treatment.

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

9.1.4 For manual scanning, do not exceed a scanning rate of 6 in./s [150 mm/s].

9.1.5 For automated scanning, adjust scanning speed or instrument repetition rate, or both, to permit detection of the smallest discontinuities referenced in the specification and to allow the recording or signaling device to function. At no time shall the scanning speed exceed the speed at which an acceptable calibration was made.

9.1.6 If possible, scan all sections of forgings in two perpendicular directions.

9.1.7 Scan disk forgings using a straight beam technique from at least one flat face and radially from the circumference, whenever practicable.

9.1.8 Scan cylindrical sections and hollow forgings radially using a straight-beam technique. When practicable, also examine the forging in the axial direction.

9.1.9 In addition, examine hollow forgings by angle-beam technique from the outside diameter surface as required in 9.3.1.

9.1.10 In rechecking or reevaluation by manufacturer or purchaser, use comparable equipment, search units, frequency, and couplant.

9.1.11 Forgings may be examined either stationary or while rotating in a lathe or on rollers. If not specified by the purchaser, either method may be used at the manufacturer's option.

9.2 *Straight-Beam Examination:*

9.2.1 For straight-beam examination use a nominal 2¼ MHz search unit whenever practicable; however, 1 MHz is the preferred frequency for coarse grained austenitic materials and long testing distances. In many instances on examining coarse grained austenitic materials it may be necessary to use a frequency of 0.4 MHz. Other frequencies may be used if desirable for better resolution, penetrability, or detectability of flaws.

9.2.2 Establish the instrument sensitivity by either the reflection, reference-block technique, or DGS method (see Appendix X3 for an explanation of the DGS method).

9.2.2.1 *Back-Reflection Technique (Back-Reflection Calibration Applicable to Forgings with Parallel Entry and Back Surfaces)*—Use the back reflection from the opposite side of the part as a calibration standard to set the sensitivity for the test. The two surfaces (entry surface and the reflecting surface) must be parallel to each other. Place the transducer in an area of the forging, when possible, so that the geometry will not have an effect on the beam spread. Increase the gain to obtain a 75 % full screen height back reflection, increase the gain by up to an additional 20 dB (10:1). If no indications are present (indication free) return the gain to the original dB setting of the 75 % full screen height (1:1), this will be the reference level. Scanning should be done at a level greater than the reference level, such as 6 dB (2:1). During the scanning, the back reflection shall be monitored for any significant loss of amplitude not attributed to the geometry. Carry out the evaluation of discontinuities with the gain control set at the reference level (75 % full screen height). Recalibration is required for significant changes in section thickness or diameter.

NOTE 1—High sensitivity levels are not usually employed when inspecting austenitic steel forgings due to attendant high level of "noise" or "hash" caused by coarse grain structure.

9.2.2.2 *Reference-Block Calibration*—The test surface roughness on the calibration standard shall be comparable to, but no better than, the item to be examined. Adjust the instrument controls to obtain the required signal amplitude from the flat-bottom hole in the specified reference block. Utilize the attenuator in order to set up on amplitudes larger than the vertical linearity of the instrument. In those cases, remove the attenuation prior to scanning the forging.

NOTE 2—When flat-surfaced reference block calibration is specified, adjust the amplitude of indication from the reference block or blocks to compensate for examination surface curvature (an example is given in Appendix X1).

9.2.2.3 *DGS Calibration*—Prior to use, verify that the DGS overlay or electronic DGS curve matches the transducer size and frequency. Accuracy of the overlay can be verified by reference blocks and procedures outlined in Practice E317. Overlays are to be serialized to match the ultrasonic transducer and pulse echo testing system that they are to be utilized with. Instruments with electronic DGS must use the specified ultrasonic transducer for that electronic curve.

(1) Electronic DGS—Modern test instruments with DGS software are particularly easy to calibrate. Most ultrasonic test instruments with DGS software have 13 standard probes and corresponding DGS diagrams stored in the instrument. There are also custom settings by which the operator may program their own data sets. The operator may choose from flat bottomed hole, side drilled hole or back reflection to use for calibration. The instructions from the test instruments operator's manual for DGS calibration must be followed to properly calibrate the instrument. Operator errors are largely excluded due to the display of on screen messages.

(2) Upon input of all necessary parameters for the flaw evaluation, the corresponding curve will be electronically displayed on the instrument screen. This method of calibration may be used for longitudinal (single and dual) and shear wave examination.

9.2.2.4 Choose the appropriate DGS scale for the cross-sectional thickness of the forging to be examined. Insert the overlay over the CRT screen, ensuring the DGS scale base line

coincides with the sweep line of the CRT screen. Place the probe on the forging, adjust the gain to make the first back-wall echo appear clearly on CRT screen. Using the Delay and Sweep control, shift the screen pattern so that the leading edge of the initial pulse is on zero of the DGS scale and the back-wall echo is on the DGS scale value corresponding to the thickness of the forging. Adjust the gain so the forging back-wall echo matches the height of the DGS reference slope within ±1 Db. Once adjusted, increase the gain by the Db shown on the DGS scale for the reference slope. Instrument is now calibrated and flaw sizes that can be reliably detected can be directly read from the CRT screen. These flaw sizes are the equivalent flat bottom reflector that can be used as a reference point.

NOTE 3—The above can be utilized on all solid forgings. Cylindrical hollow forgings, and drilled or bored forgings must be corrected to compensate for attenuation due to the central hole (see Appendix X4).

9.2.3 *Recalibration*—Any change in the search unit, couplant, instrument setting, or scanning speed from that used for calibration shall require recalibration. Perform a calibration check at least once every 8 h shift. When a loss of 15 % or greater in the gain level is indicated, reestablish the required calibration and reexamine all of the material examined in the preceding calibration period. When an increase of 15 % or greater in the gain level is indicated, reevaluate all recorded indications.

9.2.4 During the examination of the forging, monitor the back reflection for any significant reduction in amplitude. Reduction in back-reflection amplitude may indicate not only the presence of a discontinuity but also poor coupling of the search unit with the surface of the forging, nonparallel back-reflection surface, or local variations of attenuation in the forging. Recheck any areas causing loss of back reflection.

9.3 *Angle-Beam Examination—Rings and Hollow Forgings:*

9.3.1 Perform the examination from the circumference of rings and hollow forgings that have an axial length greater than 2 in. [50 mm] and an outside to inside diameter ratio of less than 2.0 to 1.

9.3.2 Use a 1 MHz, 45° angle-beam search unit unless thickness, OD/ID ratio, or other geometric configuration results in failure to achieve calibration. Other frequencies may be used if desirable for better resolution, penetrability, or detectability of flaws. For angle-beam inspection of hollow forgings up to 2.0 to 1 ratio, provide the transducer with a wedge or shoe that will result in the beam mode and angle required by the size and shape of the cross section under examination.

9.3.3 *Calibration for Angle-Beam Examination:*

9.3.3.1 *Calibration with a Physical Notch*—Calibrate the instrument for the angle-beam examination to obtain an indication amplitude of approximately 75 % full-screen height from a rectangular or a 60° V-notch on inside diameter (ID) in the axial direction and parallel to the axis of the forging. A separate calibration standard may be used; however, it shall have the same nominal composition, heat treatment, and thickness as the forging it represents. The test surface finish on the calibration standard shall be comparable but no better than the item to be examined. Where a group of identical forgings is made, one of these forgings may be used as the separate calibration standard. Cut the ID notch depth to 3 % maximum of the thickness or ¼ in. [6 mm], whichever is smaller, and its length approximately 1 in. [25 mm]. Thickness is defined as the thickness of the forging to be examined at the time of examination. At the same instrument setting, obtain a reflection from a similar OD notch. Draw a line through the peaks of the first reflections obtained from the ID and OD notches. This shall be the amplitude reference line. It is preferable to have the notches in excess metal or test metal when possible. When the OD notch cannot be detected when examining the OD surface, perform the examination when practicable (some ID's may be too small to permit examination), as indicated above from both the OD and ID surfaces. Utilize the ID notch when inspecting from the OD, and the OD notch when inspecting from the ID. Curve wedges or shoes may be used when necessary and practicable.

9.3.3.2 *Electronic DGS Calibration for Angle Beam*—Prior to use verify that the electronic DGS curve matches the transducer size and frequency. Accuracy of the curve can be verified by reference blocks and procedures outlined in Practice E317. Angle beam calibration can be established by use of flat bottom holes, side drilled holes, notches or the back reflection. Separate test blocks may be employed provided they are machined with a reflecting surface. Square-, U- or V-shaped notches, side drilled or flat bottom holes maybe machined into the test block for this purpose. For the back reflection calibration a concave curved surface such as contained on an IIW, K1, or V1 test block may be used.

9.3.4 Perform the examination by scanning over the entire surface area circumferentially in both the clockwise and counter-clockwise directions from the OD surface. Examine forgings, which cannot be examined axially using a straight beam, in both axial directions with an angle-beam search unit. For axial scanning, use rectangular or 60° V-notches on the ID and OD for the calibration. These notches shall be perpendicular to the axis of the forging and the same dimensions as the axial notch.

10. Recording

10.1 *Straight-Beam Examination*—Record the following indications as information for the purchaser. These recordable indications do not constitute a rejectable condition unless negotiated as such in the purchase order or contract.

10.1.1 For individual indications, report:

10.1.1.1 In the back-reflection technique, individual indications equal to or exceeding 10 % of a nominal back reflection from an adjacent area free from indications, and

10.1.1.2 In the reference-block or DGS technique, indications equal to or exceeding 100 % of the reference amplitude.

10.1.2 For indications that are planar, traveling, or clustered, determine the location of the edges and the major and minor axes using the half-amplitude (6 dB drop) technique and report:

10.1.2.1 The variation in depth or planar area, or both, of traveling indications,

10.1.2.2 The length of major and minor axes of planar indications, and