Designation: A418/A418M – 15

Standard Practice for Ultrasonic Examination of Turbine and Generator Steel Rotor Forgings[1]

This standard is issued under the fixed designation A418/A418M; 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 for ultrasonic examination covers turbine and generator steel rotor forgings covered by Specifications A469/A469M, A470/A470M, A768/A768M, and A940/A940M. This standard shall be used for contact testing only.

1.2 This practice describes a basic procedure of ultrasonically inspecting turbine and generator rotor forgings. It does not restrict the use of other ultrasonic methods such as reference block calibrations when required by the applicable procurement documents nor is it intended to restrict the use of new and improved ultrasonic test equipment and methods as they are developed.

1.3 This practice is intended to provide a means of inspecting cylindrical forgings so that the inspection sensitivity at the forging center line or bore surface is constant, independent of the forging or bore diameter. To this end, inspection sensitivity multiplication factors have been computed from theoretical analysis, with experimental verification. These are plotted in Fig. 1 (bored rotors) and Fig. 2 (solid rotors), for a true inspection frequency of 2.25 MHz, and an acoustic velocity of 2.30×10^5 in./s [5.85×10^5 cm/s]. Means of converting to other sensitivity levels are provided in Fig. 3. (Sensitivity multiplication factors for other frequencies may be derived in accordance with X1.1 and X1.2 of Appendix X1.)

1.4 Considerable verification data for this method have been generated which indicate that even under controlled conditions very significant uncertainties may exist in estimating natural discontinuities in terms of minimum equivalent size flat-bottom holes. The possibility exists that the estimated minimum areas of natural discontinuities in terms of minimum areas of the comparison flat-bottom holes may differ by 20 dB (factor of 10) in terms of actual areas of natural discontinuities. This magnitude of inaccuracy does not apply to all results but should be recognized as a possibility. Rigid control of the actual frequency used, the coil bandpass width if tuned instruments are used, and so forth, tend to reduce the overall inaccuracy which is apt to develop.

1.5 This practice for inspection applies to solid cylindrical forgings having outer diameters of not less than 2.5 in. [64 mm] nor greater than 100 in. [2540 mm]. It also applies to cylindrical forgings with concentric cylindrical bores having wall thicknesses of 2.5 [64 mm] in. or greater, within the same outer diameter limits as for solid cylinders. For solid sections less than 15 in. [380 mm] in diameter and for bored cylinders of less than 7.5 in. [190 mm] wall thickness the transducer used for the inspection will be different than the transducer used for larger sections.

1.6 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.

1.7 This practice is expressed in both inch-pound units and in 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 may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.8 *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 The reference is to the latest issue of these designations that appear in the *Annual Book of ASTM Standards* or are available as separate reprints. It shall also apply to product specifications, which may be issued when specifically referenced therein.

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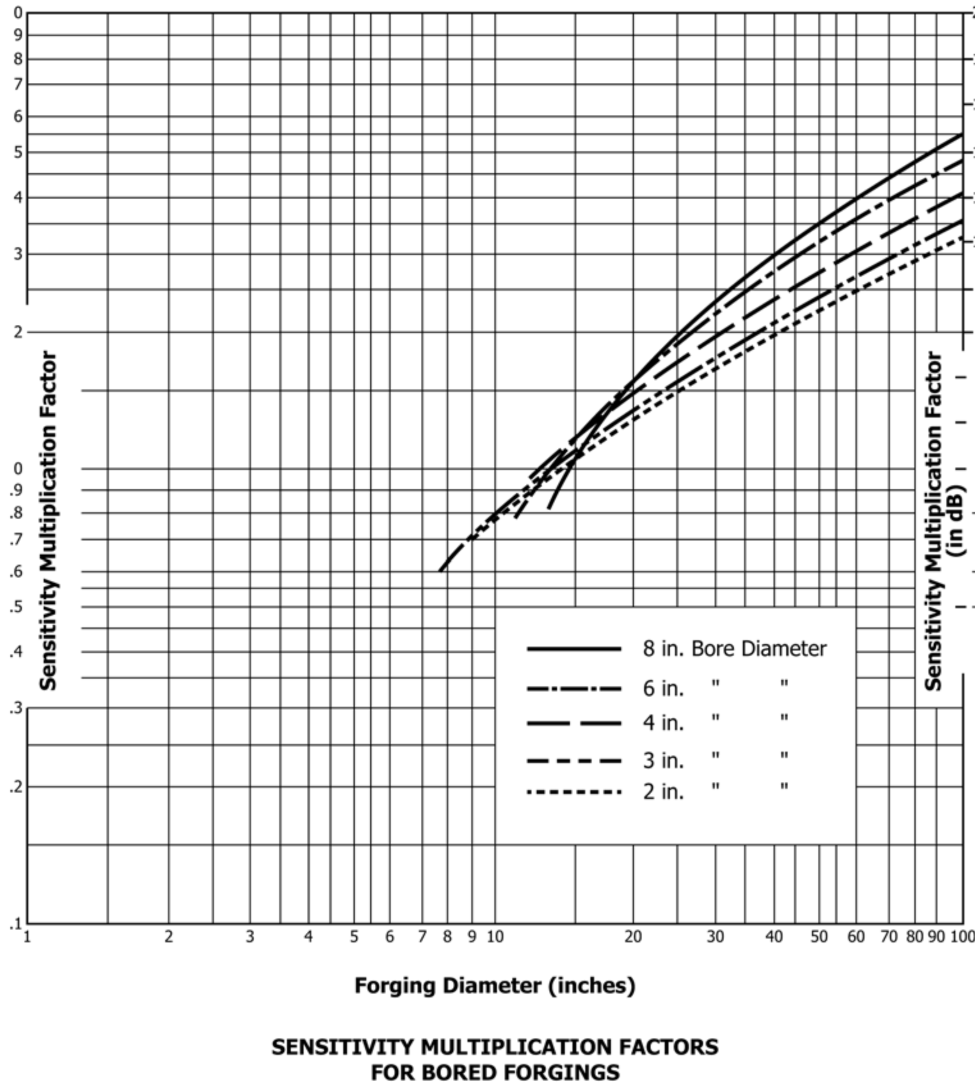
***A Summary of Changes section appears at the end of this standard**



NOTE 1—Sensitivity multiplication factor such that a 10 % indication at the forging bore surface will be equivalent to a ⅛ in. [3 mm] diameter flat bottom hole. Inspection frequency: 2.0 or 2.25 MHz. Material velocity: 2.30×10^5 in./s [5.85×10^5 cm/s].

FIG. 1 Bored Forgings

2.2 *ASTM Standards:*[2]

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

A470/A470M Specification for Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts

A768/A768M Specification for Vacuum-Treated 12 % Chromium Alloy Steel Forgings for Turbine Rotors and Shafts

A788/A788M Specification for Steel Forgings, General Requirements

A940/A940M Specification for Vacuum Treated Steel Forgings, Alloy, Differentially Heat Treated, for Turbine Rotors

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

E1065/E1065M Practice for Evaluating Characteristics of Ultrasonic Search Units

2.3 *Other Standards:*

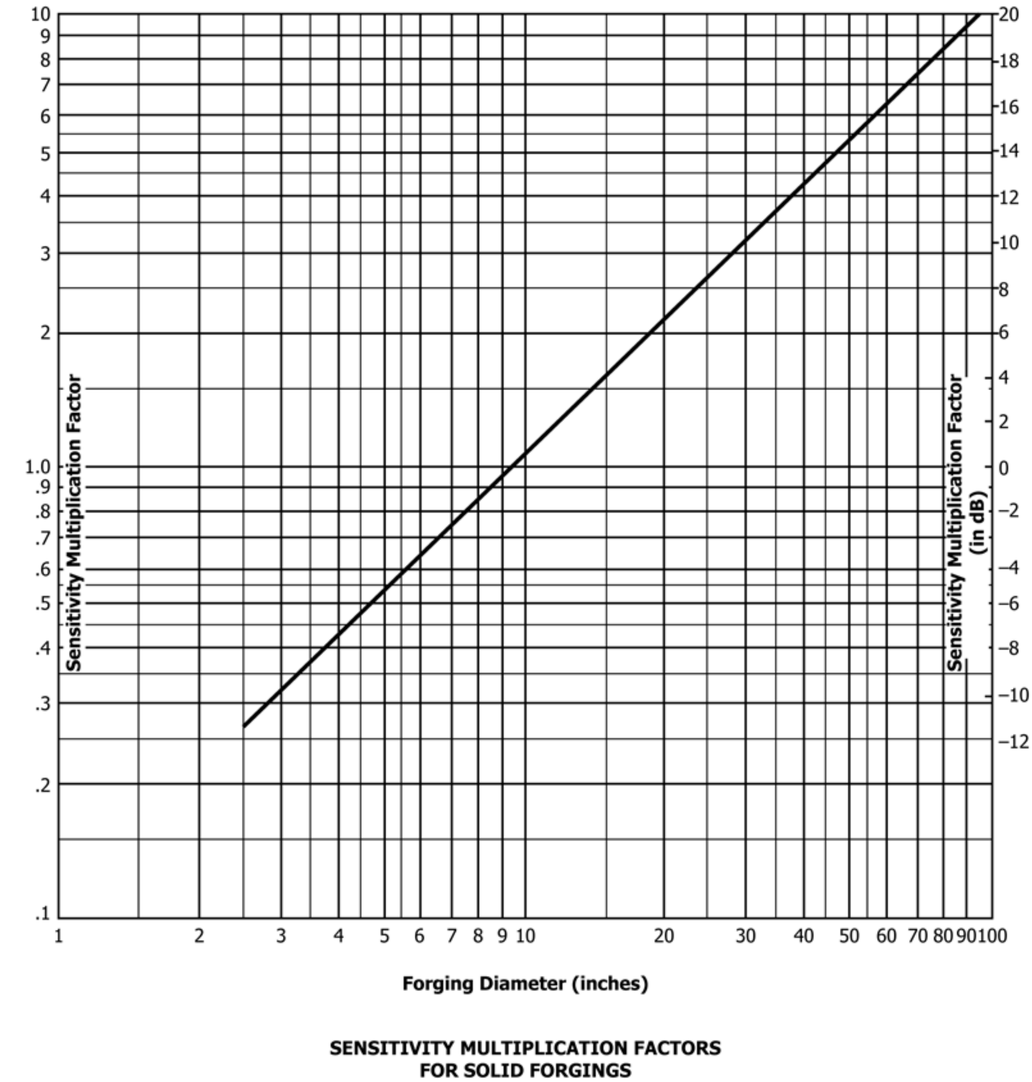
Recommended Practice No. SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing[3]

3. Significance and Use

3.1 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

[2] 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.

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



NOTE 1—Sensitivity multiplication factor such that a 10 % indication at the forging centerline surface will be equivalent to a ⅛ in. [3 mm] diameter flat bottom hole. Inspection frequency: 2.0 or 2.25 MHz. Material velocity: 2.30×10^5 in./s [5.85×10^5 cm/s].

FIG. 2 Solid Forgings

the number, amplitude, or location of discontinuities, or a combination thereof, which give rise to ultrasonic indications.

3.2 The acceptance criteria shall be clearly stated as order requirements.

4. General Requirements

4.1 As far as possible, the entire volume of the forging shall be subjected to ultrasonic inspection. Because of fillets at steps and other local configurations, access to inspect some portions of a forging may be limited.

4.2 The ultrasonic inspection shall be performed after final heat treatment of the forging. In those cases in which wheels, slots, or similar features are machined into the forging before heat treatment, the entire forging shall be inspected ultrasonically before such machining, and as completely as practicable after the final heat treatment.

4.3 For overall scanning, the ultrasonic beam shall be introduced radially. To conform with this requirement, external conical surfaces of the forging shall be replaced by stepped surfaces in order to maintain the ultrasonic beam perpendicular to the longitudinal axis. Such stepped surfaces shall be shown on the forging drawing.

4.4 Forgings may be tested either stationary or while rotated by means of a lathe or rollers. If not specified by the purchaser, either method may be used at the manufacturer's option. Scanning speed shall not exceed 6 in./s [15 cm/s].

4.5 To ensure complete coverage of the forging volume, the search unit shall be indexed no more than 75 % of the transducer width with each pass of the search unit. Mechanized inspection of the rotating forging wherein the search unit is mechanically controlled is an aid in meeting this requirement.

4.6 Frequencies of 1, 2.25, and 5 MHz may be used for accurately locating, determining orientation, and defining specific discontinuities detected during overall scanning as described in 4.4.

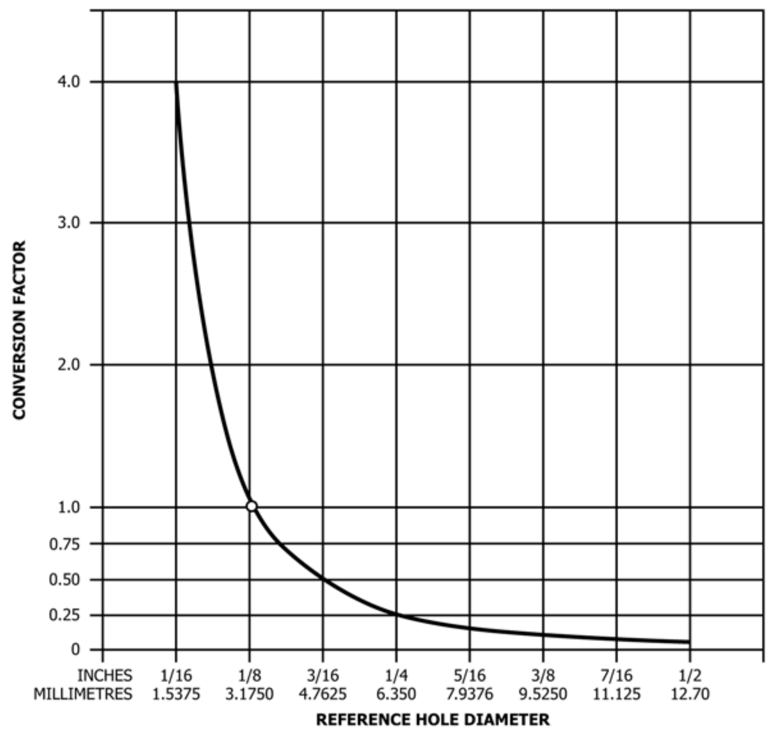


FIG. 3 Conversion Factors to Be Used in Conjunction with Fig. 1 and Fig. 2 if a Change in the Reference Reflector Diameter is Required

4.7 Axial scanning, if required, shall be performed at that frequency and transducer diameter which minimizes interfering ultrasonic reflections due to forging geometry and which gives optimum resolution. (Axial tests are normally used as a supplement to radial tests.)

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. Pulsed Ultrasonic Reflection Equipment and Accessories

6.1 *Electronic Apparatus*—A pulse-echo instrument permitting inspection frequencies of 1, 2.25, 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.

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 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.

6.1.3 If the rotor has a coupling or similar thin axial section with parallel sides, the accuracy of the linearity shall be checked by ultrasonically verifying the thickness of the coupling or axial section. If necessary, minor adjustments for differences in the ultrasonic velocities between the calibration bar and the forging shall then be made.

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

6.2.1 *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.

6.3 *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) (see Fig. 1 and Fig. 2).

6.4 *Search Units*—Longitudinal wave search units of known effective frequency should be used for radial scanning. A ¼ by 1 in. [6 by 24 mm], 2.0 or 2.25 MHz transducer, used with the 1-in. [24-mm] dimension parallel to the forging axis, will give a desirable combination of resolution and beam width on large sections 15 in. [380 mm] in diameter or larger if solid or 7.5 in. [190 mm] or greater wall thickness if bored. A 1-in. [24-mm] diameter, 2.0 or 2.25 MHz transducer may be used. If a transducer with dimension circumferentially oriented to the forging, larger than ¼ in. [6 mm] is used, additional inspection at lower frequency is recommended to provide a wide beam for off-axis inspection. A 0.5-in. [10-mm] diameter 2.0 or 2.25 MHz transducer is suitable for solid sections under 15 in. [380 mm] in diameter and bored sections under 7.5 in. [190 mm] in wall thickness. The multiplication factors given are valid for the frequency and material velocity indicated provided they are used in the far field. (The near field is a characteristic that is dependent on the transducer frequency and size.) For other frequencies and material velocities, applicable sensitivity multiplication factors shall be computed.

6.4.1 *Search Unit Calibration*—The transducers used in performing the tests described in this practice shall be calibrated in accordance with Practice E1065/E1065M.

7. Preparation of Forging for Ultrasonic Inspection

7.1 Machine turn the forging to provide cylindrical surfaces for the radial test.

7.2 The end faces of the shaft extensions and of the body of the forging shall be sufficiently perpendicular to the axis of the forging to permit axial test.

7.3 The surface roughness of exterior finishes shall not exceed 250 µin. [6.35 µm] where the definition for surface finish is as per Specification A788/A788M and the surface waviness shall not interfere with the ultrasonic test.

7.4 At the time of ultrasonic testing, the surfaces of the forging shall be free of tool tears, loose scale, machining or grinding particles, paint, or other foreign material.

8. Procedure

8.1 *Radial Scanning:*

8.1.1 Select the transducer to be used for the primary inspection according to the following criteria:

8.1.1.1 Use a 0.5-in. [10-mm] diameter, 2.0 or 2.25 MHz transducer to inspect solid cylindrical sections under 15 in. [380 mm] in diameter and bored sections having wall thicknesses of less than 7.5 in. [190 mm].

8.1.1.2 Use a ¼ by 1 in. [6 by 24 mm] (or 1-in. [24-mm] diameter), 2.0 or 2.25 MHz transducer to inspect solid sections 15 in. [380 mm] or greater in diameter and bored sections having wall thicknesses of 7.5 in. [190 mm] or greater.

8.1.2 The reference signal shall be the signal reflected from the diametrically opposed surface for solid (unbored) forgings and from the bore surface of bored forgings. The signal amplitude shall be set to 100 % full screen height while scanning in an indication-free area.

8.1.3 The required evaluation sensitivity shall be obtained by increasing the 100 % full screen height reference signal by the appropriate multiplication factor calculated as follows. Establish the inspection sensitivity in accordance with the curves in Fig. 1 (bored rotors) and Fig. 2 (solid rotors), which show the multiplication factors that shall be used to adjust a 100 % full screen height, bore, or back reflection to the required inspection sensitivity. These sensitivities are sufficient to detect a ⅛ in. [3 mm] diameter reflector near the centerline of the forging. The inspection sensitivity must be adjusted if the outside diameter changes by more than 2 in. [50 mm] when using the larger transducer on heavy sections or by 1 in. [25 mm] when using the smaller transducer on smaller sections. Fig. 3 provides a means to convert this sensitivity level to the sensitivity level required to similarly display smaller or larger reference holes. The derivation of the sensitivity multiplication factors is summarized in the appendix.

8.1.4 Adjust the sweep length control to position the bore or back reflection approximately three-fourths of the distance across the display.

8.1.5 Search each diameter of the forging and record indications 10 % or greater of the sweep-to-peak CRT segment at the prescribed high sensitivity. Mark the position of the search unit on the surface of the forging when indications are observed so that they may be investigated in accordance with 8.1.7 and 8.2.2.

8.1.6 When the forgings are tested while they are rotated, the maximum speed of rotation shall be calculated as follows:

$360/\pi d$ = maximum revolutions per min.
d = diameter of forging in inches.
$915/\pi d$ = maximum revolutions per min.
d = diameter of forging in centimetres.

The search unit may be held by a suitable fixture attached to the tool post of the lathe and traversed mechanically for scanning of the rotating forging or may be hand-held. If not specified by the purchaser, either method may be used at the manufacturer's option.

8.1.7 Measure the amplitude and extent of all indications and perform detailed investigation of specific indications with the forging stationary.

8.1.7.1 If the 0.5-in. [10-mm] diameter transducer can be satisfactorily calibrated for heavy sections, use this transducer to perform detailed investigations of indications located within 6 in. [150 mm] on the surface, regardless of the transducer used in the initial inspection. For indications lying beyond 6 in. [150 mm] from the test surface, perform the detailed investigation using the transducer with which the indication was detected during the primary scan.

8.1.7.2 Measure the extent of traveling and planar indications axially and circumferentially between the peak and ½-amplitude points.

8.1.8 For indications in heavy sections, if the 0.5-in. [10-mm] diameter transducer can be satisfactorily calibrated for the section, evaluate all indications located within the first 6 in. [150 mm] from the test surface using the 0.5 in. [10-mm] diameter transducer, regardless of the transducer used to locate the indication during the primary scan and regardless of the scan method employed during the primary scan (shaft rotating or hand scan).

8.2 *Supplementary Tests:*

8.2.1 *Special Radial Tests*—Test at additional frequencies may be used for accurately locating and determining the orientation of each recordable indication and for evaluating the minimum reflecting area of each large indication.

8.2.2 *Axial Tests*—When required, scan the flat surfaces normal to the forging axis. Establish the sensitivity level and recordable standards for the axial tests by agreement between purchaser and supplier (see 4.7).

9. Report

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

9.1.1 Each diameter shall be numbered on a sketch starting with rotor diameter No. 1 at the stenciled end. When an entire rotor is tested, a complete sketch showing the diameters shall be submitted with the test results. When a portion of the rotor is tested, a sketch of the portion of the rotor tested shall be submitted. When no recordable indications are found, a sketch is not required.

9.1.2 Recordable indications as described in 8.1.5 shall be located on the sketch (see 8.1.1) (*1*) radially with respect to the centerline or bore surface, (*2*) axially with respect to the stenciled end of the forging, and (*3*) circumferentially with the center point of the serial number which shall be used as 12 o'clock. The accuracy of the indication characterization shall be sufficient to permit the relocation and reproduction of the data.

9.1.3 Unless specified otherwise, the supplier shall report recordable indications as described in 8.1.5 as percentages of the 100 % full screen height at the prescribed gain level, along with the distances to the discontinuity and to the bore or centerline (solid forgings) and shall be identified as normal, traveling, continuous, or indication level, or a combination thereof. When flaw size estimates are required, these data shall be used for calculations as indicated in 8.1.5 and as limited by X1.4 of Appendix X1.

9.1.3.1 Normal indications are single indications that show a normal decrease in amplitude as the search unit is moved in any direction from the position of maximum amplitude and display none of the characteristics defined in 9.1.3.2 through 9.1.3.4. Normal indications shall be reported individually.

9.1.3.2 Traveling indications are 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. The variation in radial depth and planar area of traveling indications shall be determined and reported.

9.1.3.3 Planar indications shall be considered continuous over a plane if they have a major axis greater than 1 in. [25 mm]. Their minor axes shall be reported when measurable in accordance with 8.1.7.2. In recording these flaw characteristics, corrections must be made for beam divergence at the estimated flaw depth.

9.1.3.4 Indication levels are group indications 10 % (5⁄32 in. [4 mm]) or larger of 100 % full screen height at the prescribed high sensitivity showing continuously on the screen as the transducer is moved over the area tested.

9.1.4 When required, recordable indications shall be expressed as minimum reflecting areas as follows:

$$\textit{solid forgings}: A_F = A_R \times \left(\frac{a}{L}\right)^2 \times \frac{P}{10} \quad (1)$$

$$\textit{bored forgings}: A_F = A_R \times \left(\frac{a}{L}\right)^2 \times \frac{P}{10}\sqrt{\frac{b}{d}} \quad (2)$$

where:

A_F = minimum reflecting area of discontinuity,
A_R = reflecting area of reference (0.012 in.^{2} [8 mm^2]),
a = distance to discontinuity, in. (or mm),
L = distance to bore or centerline of solid forgings, in. (or mm), and
P = discontinuity reflection amplitude (percent of sweep-to-peak CRT segment at the prescribed high-sensitivity level).
b = bore diameter
d = forging cylinder diameter.

9.1.5 Observable loss of bore or back reflection at the scanning sensitivity.

9.1.6 Couplant.

9.1.7 Type of instrument, manual or automated scanning, inspection frequency, and type transducers employed for the inspection.

9.1.8 Inspector's name or identity and date of test.

10. Keywords

10.1 generator material; nondestructive tests; rotors, turbine, or generator; steel forgings; steel forgings—alloy; turbine materials; ultrasonic examination; ultrasonic examination method

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements apply when specified by the purchaser in the contract or order.

S1. Forging Rotation During Examination

S1.1 Forgings shall be rotated during testing by means of a lathe or rollers. Scanning speed shall not exceed 6 in./s [15 cm/s].

S2. Enhanced Inspection Coverage

S2.1 The search unit shall be indexed approximately 50 % of the transducer width with each pass of the search unit. The search unit shall be held by a suitable fixture attached to the tool post of the lathe and traversed mechanically for scanning of the rotating forging. See 8.1.6 for recommended forging rotation speeds.

S2.2 Hand-held transducer testing is only permitted in those areas where the transducer holder interferes with the inspection coverage.

S3. Axial UT of the Entire Diameter

S3.1 The shape of the forging during axial UT shall be such as to permit inspection of the entire outside diameter of the part that will be machined from it.

S4. Use of Dual Element Transducers

S4.1 Dual-element transducers shall be used to axially inspect those regions of a forging containing a bore to ensure coverage of areas in the near field of the single element transducers used for axial scanning.

S4.2 Dual-element transducers shall be used to inspect areas near the back-wall of solid regions of forgings where indications caused by noise exceed the reporting requirements shown in 8.1.5.

S5. Surface Finish

S5.1 The surface finish shall not exceed 125 µin. [3.17 µm] where the definition for surface finish is as per Specification A788/A788M.

APPENDIX

(Nonmandatory Information)

X1. DERIVATION OF SENSITIVITY MULTIPLICATION FACTORS

X1.1 Theoretical formulas relating properties, such as discontinuity area, distance, and echo amplitude, may be derived at various levels of complexity. Detailed descriptions of such methods of analysis may be found in standard texts on acoustics or ultrasonics, and will not be given here. The method used in deriving the curves of Fig. 1, Fig. 2, and Fig. 3 uses the spherical-wave approximation to describe the behavior of the sound field, with analytical techniques analogous to those of geometric optics. The resulting relations between theoretical echo amplitudes are as follows:

$$\frac{\text{echo from small disk reflector}}{\text{echo from large plane or solid cylinder}} = \frac{2dA}{a^2\lambda}$$

$$\frac{\text{echo from small disk reflector}}{\text{echo from cylindrical bore}} = \frac{(d-b)A}{a^2\lambda}\sqrt{\frac{d}{b}}$$

where:

a = distance to disk reflector (flat-bottom hole),
b = bore diameter,
d = forging cylinder diameter,
A = area of disk reflector, and
λ = wavelength of sound used for inspection.

X1.2 Using the procedure described in the main body of this standard, the echo from a forging back wall or bore is set at 100 % of (linear) screen height, and sensitivity is then adjusted by a multiplying factor M such that the theoretical echo amplitude from a disk reflector of given area A at the forging centerline or bore surface would be 10 % of screen height, that is, multiplying factor (M) times the echo from the small disk reflector (A) would equal 10 % of the echo from opposite surfaces of solid cylinders or from bore surfaces of bored cylinders. These multiplying factors would be:

$$\text{Solid cylinder: } M = \left(\frac{10}{100}\right)\left(\frac{a^2\lambda}{2dA}\right) = \frac{d\lambda}{80A}$$

$$\text{Bored cylinder: } M = \frac{(d-b)\lambda}{40A}\sqrt{\frac{b}{d}}$$

X1.3 The curves given in Fig. 1 and Fig. 2 have been calculated from these formulas, using a reference disk-reflector of 0.125-in. [3-mm] diameter, and values of sound velocity and frequency typical for steel forging inspection to define the wavelength. The validity of these theoretical curves has been checked experimentally. Fig. 3 shows an additional multiplication factor to be used if the reference reflector diameter is changed.

X1.4 Because of the approximations made in the derivation, these formulas and multiplication factors should not be used for any reflecting surface less than three near-field lengths from the transducer. The length N of the near-field may be calculated as follows:

$$N = \frac{D^2 - \lambda^2}{4\lambda}$$

where D is the effective transducer diameter. Other restrictions are as follows: (*1*) the reference hole diameter must be much smaller than the ultrasonic beam cross-section; (*2*) neither the reference hole diameter nor the apparent diameter of a discontinuity should be less than $\lambda/2$; (*3*) the bore diameter must be much larger than λ; and (*4*) attenuation in the material to be inspected should be negligibly small. Accuracy will also be impaired by test instrument nonlinearities, including built-in "reject" or "zero suppression." It is important that back reflection amplitudes be set from surfaces unobstructed by holes, fillets, or other changes in cross section within their area of intersection with the cross section of the ultrasonic beam.

X1.5 With sensitivity set in this manner, the theoretical minimum equivalent reflecting area of a discontinuity is given in terms of the area A_R of the reference hole and the percentage of screen height, P, of the discontinuity indication, as:

$$A_F = \frac{2a^2 A_R P}{5d^2} \text{ for a solid forging}$$

$$A_F = \frac{2a^2 A_R P}{5(d-b)^2} \text{ for a bored forging}$$

Thus, a 10 % indication at the centerline ($a = d/2$) or the bore surface [$a = (d - b)/2$] has an area equivalent to that of the reference hole. These equations may be combined by setting L = (d/2) or ($d - b$)/2, to obtain the relation given in 9.1.4.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A418/A418M–10) that may impact the use of this standard. (Approved May 1, 2015.)

(1) Added definition of surface finish by reference to Specification A788/A788M in 7.3 and S5.