Designation: ~~A418/A418M – 15 (Reapproved 2020)~~ A418/A418M – 24

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 practice 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~~2.30 in. ~~in./s~~ ⁄s × 10^5 in. ~~in./s~~⁄s [5.85 cm ~~[5.85 cm/s~~ ⁄s × 10^5 cm ~~cm/s].~~ ⁄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.

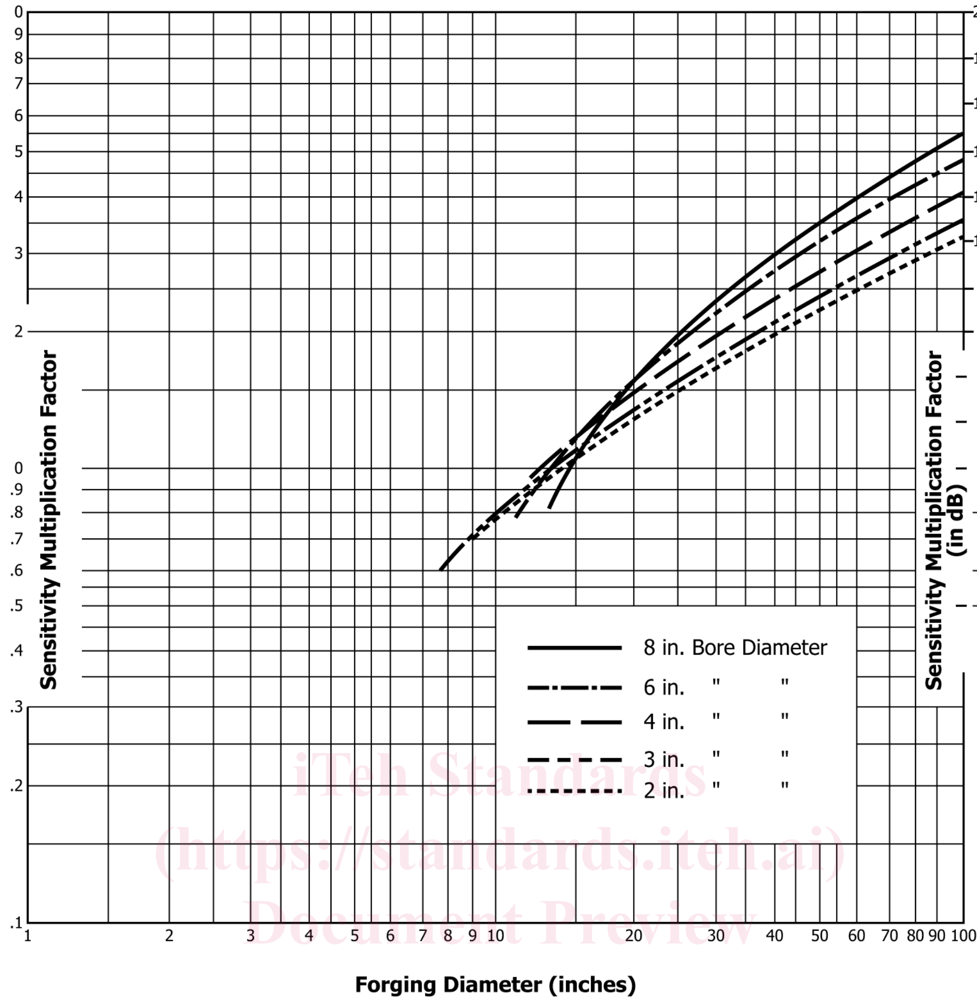
1.5 This practice for inspection applies to solid cylindrical forgings having outer diameters of not less than 2.5 in. ~~[64 mm]~~ [64 mm] nor greater than 100 in. [2540 mm]. It also applies to cylindrical forgings with concentric cylindrical bores having wall thicknesses of 2.5 [64 mm] in. or greater, 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] 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.

Current edition approved ~~March 1, 2020~~May 1, 2024. Published ~~March 2020~~May 2024. Originally approved in 1957. Last previous edition approved in ~~2015~~2020 as ~~A418/A418M~~A418/A418M – 15 (2020).~~–15.~~ DOI: ~~10.1520/A0418_A0418M-15R20.~~10.1520/A0418_A0418M-24.

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



SENSITIVITY MULTIPLICATION FACTORS
FOR BORED FORGINGS

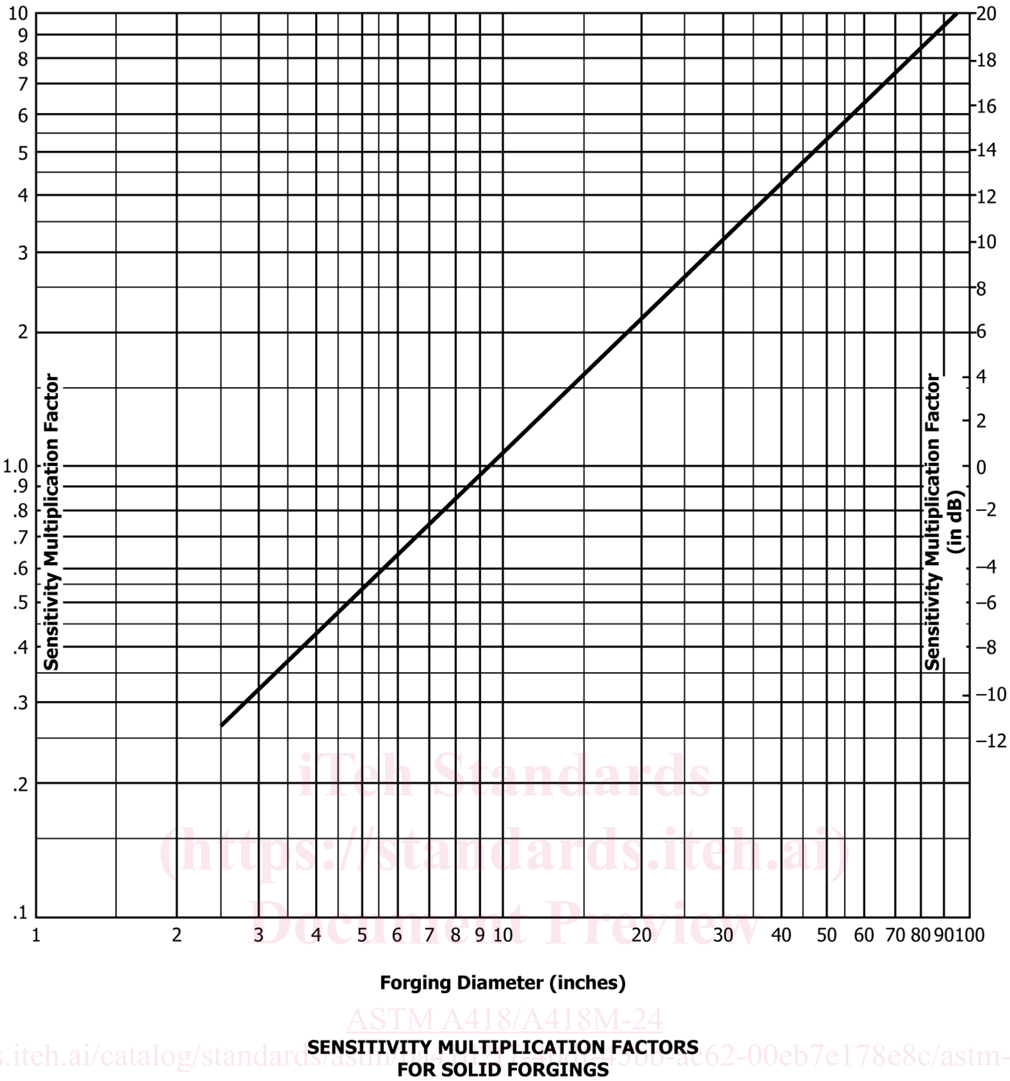
NOTE 1—Sensitivity multiplication factor such that a 10 % indication at the forging bore surface will be equivalent to a ⅛ in. [3 mm] diameter flat bottom hole. Inspection frequency: 2.0 MHz or 2.25 MHz. Material velocity: 2.30 in./s × 10^5 in./s [5.85 cm/s × 10^5 cm/s].

FIG. 1 Bored Forgings

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 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.

1.8 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *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.*



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 MHz or 2.25 MHz. Material velocity: 2.30 in./s × 10^5 in./s [5.85 cm/s × 10^5 cm/s].

FIG. 2 Solid Forgings

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.

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 Forgings for Turbine Rotors and Shafts (Withdrawn 2018)[3]
A788/A788M Specification for Steel Forgings, General Requirements
A940/A940M Specification for Vacuum Treated Steel Forgings, Alloy, Differentially Heat Treated, for Turbine Rotors (Withdrawn 2017)[3]

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

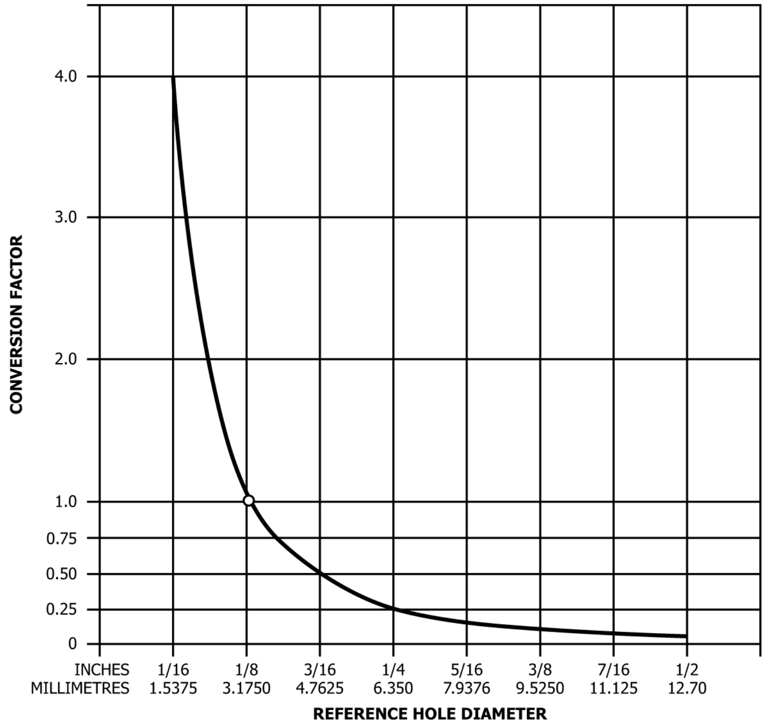


FIG. 3 Conversion Factors to Be Used in Conjunction with Fig. 1 and Fig. 2 if a Change in the Reference Reflector Diameter is Required

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
E1316 Terminology for Nondestructive Examinations

2.3 *Other Standard:*
Recommended Practice No. SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 For definitions of terms used in this standard that are not included in Specification A788/A788M, refer to Terminology E1316.

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 acceptance criteria shall be clearly stated as order requirements.

5. General Requirements

5.1 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.

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

5.3 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.

5.4 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].

5.5 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.

5.6 Frequencies of ~~1, 2.25, and 5 MHz~~ 1 MHz, 2.25 MHz, and 5 MHz may be used for accurately locating, determining orientation, and defining specific discontinuities detected during overall scanning as described in ~~4.4~~5.4.

5.7 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.)

6. Personnel Requirements

6.1 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.

7. Pulsed Ultrasonic Reflection Equipment and Accessories

7.1 *Electronic Apparatus*—A pulse-echo instrument permitting inspection frequencies of ~~1, 2.25, and 5 MHz~~ 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.

7.1.1 *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.

7.1.2 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.

7.1.3 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.

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

7.2.1 *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~~ 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.

7.3 *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).

7.4 *Search Units*—Longitudinal wave search units of known effective frequency should be used for radial scanning. A ¼ in. by 1 in. [6 mm by 24 mm], 2.0 MHz 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 MHz 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 MHz 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.

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

8. Preparation of Forging for Ultrasonic Inspection

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

8.2 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.

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

8.4 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.

9. Procedure

9.1 *Radial Scanning:*

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

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

9.1.1.2 Use a ¼ in. by 1 in. [6 mm by 24 mm] (or 1 in. ~~[24 mm]~~ [24 mm] diameter), 2.0 MHz 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.

9.1.2 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.

9.1.3 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]~~ [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.