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Standard Practice for Ultrasonic Examination of Turbine-Generator Steel Retaining Rings[1]

This standard is issued under the fixed designation A 531/A 531M; 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 covers the procedures to be followed when performing ultrasonic shear and longitudinal wave tests on turbine-generator retaining rings with an inside diameter to wall thickness ratio equal to or greater than 5:1 and with wall thicknesses from 1 to 4 in. (25 to 102 mm).

1.2 Although this practice describes methods of ultrasonically testing retaining rings by either the contact or immersion method, it shall not restrict the use of improved inspection methods as they are developed. It is recognized that techniques for examination and evaluation may be chosen in order to enhance or improve the results or to accommodate variations in procedures, equipment, or capabilities. Considering these characteristics, forgings may be inspected by a combination of both the contact and the immersion methods, as mutually agreed upon between the manufacturer and the purchaser.

1.3 This practice 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.

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks

2.2 *Other Document:*

Recommended Practice for Nondestructive Personnel Qualification and Certification SNT-TC-1A, Supplement C-Ultrasonic Testing[3]

3. Personnel Requirements

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

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

3.2.1 Ultrasonic terminology,

3.2.2 Instrument calibration,

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

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

3.2.5 Effect of test distance on test results,

3.2.6 Effect of nonlinearity on test results,

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

3.2.8 Effect of surface roughness on test results.

3.3 A qualification record (see Note 1) of personnel considered suitable by the manufacturer to perform examination in accordance with this practice shall be available upon request.

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

4. Ordering Information

4.1 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:

4.1.1 The method or combination of methods to be used for inspection.

4.1.2 The frequency to be used for conducting each inspection.

4.1.3 Report requirements including C-scan plot, if applicable.

[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 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 the American Society for Nondestructive Testing, 914 Chicago Ave., Evanston, IL 60202.

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5. General Requirements

5.1 As far as possible the entire volume of the retaining rings shall be subject to ultrasonic inspection. Circumferential and axial faces shall be machined flat and parallel to one another.

5.2 The ultrasonic inspection shall be performed after final processing and heat treatment for properties, unless otherwise specified in the order or contract.

5.3 Rings may be tested either stationary (contact) or while rotating (immersion). If not specified by the purchaser, a combination of methods may be used at the manufacturer's option. Scanning speed shall not exceed 6 in./s (152 mm/s), unless automatic recording (C-scan) equipment is employed.

5.4 To ensure complete coverage (during contact testing), the search unit shall be indexed approximately 75 % of the transducer width with each pass of the search unit. During immersion testing establish a transducer index adjustment which will ensure complete coverage with sufficient overlap.

5.5 During the testing, a combination of methods and frequencies of 1 MHz, 2¼ MHz, and 5 MHz may be used for accurately locating, determining orientation, and defining specific discontinuities detected during overall scanning.

5.6 For reporting purpose, location of indications shall be circumferentially defined by clock position. The test notch or a similar locator, such as a reference line bisecting the serial number, shall be used to define and identify the 12 o'clock position.

6. Apparatus

6.1 *Ultrasonic, Pulsed, Reflection Type of Instrument*, shall be used for the examination. The system shall have a minimum capability for examining at frequencies from 1 to 5 MHz.

6.1.1 The amplifier and the cathode ray tube shall provide linear response (within 5 %) for at least 75 % of the screen height (sweep line to top of screen).

6.1.2 The instrument shall contain a calibrated gain control or signal attenuator (in each case, accurate within ±5 %) that will allow indications beyond the linear range of the instrument to be measured.

6.1.3 When the immersion method of inspection is employed, suitable equipment must be available so that the retaining rings can be immersed in a liquid coupling agent or can be subject to inspection by the use of a column or stream of the couplant through an appropriate container attached to the part or transducer. Equipment must also include fixturing for smooth mechanical rotation of the part or the transducer during scanning.

6.2 *Search Units*:

6.2.1 *Contact Method*:

6.2.1.1 A 2.25 or 1.0-MHz, 45° angle beam shear wave search unit shall be employed for shear wave testing (2.25 MHz shall be used unless acoustic attenuation of the material is such that 1 MHz must be employed to obtain adequate penetration of the ring section). Adequate penetration is the ability to clearly resolve the calibration notch above resultant noise level.

6.2.1.2 A 5, 2.25, or 1-MHz, ¾ to 1⅛-in. (19.0 to 28.6-mm) diameter, longitudinal wave transducer shall be used for performing the longitudinal wave test.

6.2.1.3 Acrylic resin shoes ground to the curvature of the retaining ring may be used to maintain the optimum contact angle between the transducer and outside diameter of the ring.

6.2.1.4 When agreed upon between the purchaser and supplier, alternative test frequencies may be used to perform the required tests.

6.2.2 *Immersion Method*:

6.2.2.1 A 5, 2.25, or 1-MHz transducer, ¾ to 1 in. (19.0 to 25.4 mm) in diameter, suitable for water immersion, shall be used for performing the required test.

6.2.2.2 The manipulator (holder) for the search tube or transducer, or both, shall provide for angular manipulation of the transducer for optimum response from the internal discontinuities. The tolerance or play present in the manipulation and in the traversing unit should not be excessive so as to prevent ultrasonic examination at the required sensitivity level.

6.2.2.3 When agreed upon between the purchaser and supplier, alternative test frequencies may be used to perform the required tests.

6.2.2.4 *Accessory Equipment*—Coaxial cables and search tubes used in conjunction with the electronic apparatus capable of conducting the electrical pulses while immersed in a liquid, and collimators for shaping the sound beam may be used.

6.3 Recording instruments or alarm systems, or both, may be used, provided sufficient range and sensitivity are available to properly monitor the test.

7. Preparation of the Forging for Ultrasonic Examination

7.1 Surface roughness on the outside and inside diameter and radical face surfaces of the ring shall not exceed 125 µin. (3.18 µm) and waviness shall not exceed 0.001 in. (0.02 mm) measured in both the axial and circumferential directions. The radical faces of the ring shall be sufficiently perpendicular to the axis of the forging to permit axial tests.

7.2 All surfaces of the ring to be examined shall be free of extraneous material such as surface tears, loose scale, machining or grinding particles, paint, and other foreign matter.

8. Ultrasonic Couplants

8.1 For contact testing, a suitable couplant, such as clean SAE 20 motor oil, shall be used to couple the transducer to test surfaces.

8.2 For immersion testing, a liquid such as water, oil, glycerin, etc., capable of conducting ultrasonic vibrations from the transducer to the material being tested shall be used. Rust inhibitors, softeners, and wetting agents may be added to the couplant. The couplant liquid with all additives should not be detrimental to the surface condition of the test specimen or the container, and it should wet the surface of the material to provide an intimate contact. Couplant may be heated to a comfortable working temperature and must be free of air bubbles.

9. Method for Shear Wave Testing

9.1 *Calibration Reference*:

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9.1.1 Place a calibration V-shaped notch, with an included angle of 60 to 90° and ¼ in. (6.35 mm) long, in the outside diameter surface of the ring at a sufficient distance from the end of the ring to eliminate side wall interference. Determine the location of the notch by scanning the ring at a sensitivity high enough to show the material structure and with the shear wave beam directed circumferentially. Using this procedure, then locate the notch in an area representative of the ring material.

9.1.2 Place the notch axially in the ring to a depth of 1 % of the wall thickness or 0.020 in. (0.51 mm), whichever is greater. Make the depth measurement after removal of the upset material adjacent to the notch.

9.1.3 For the inspection of finish machined rings, an outside reference block of the same alloy, wall thickness, and curvature as the ring being tested may be used. The block must be at least 4 in. (102 mm) wide and long enough to permit three bounces from the reference notch.

9.1.4 For axial shear wave examination by the immersion method, place a circumferentially oriented notch into the outside diameter surface of the ring at a sufficient distance from the end of the ring so that it can be clearly resolved from the outside diameter corner reflection. Dimensions of notch shall be the same as described in 9.1.1.

9.2 *Contact Method for Equipment Calibration*:

9.2.1 Connect the 2.25-MHz or 1-MHz angle beam search unit to the test instrument and place it directly over the calibration notch with the crystal directed circumferentially. Move the search unit circumferentially, directing the sound beam toward the notch until an indication from the notch appears. Continue to move the search unit in the same direction until a maximized second bounce indication appears.

9.2.2 Adjust the sweep length so that the first and second bound indications from the notch are about 1½ in. (38 mm) apart. Mark and designate the first and second bounce positions on the sweep line.

9.2.3 Adjust the gain until the first bounce indication has a sweep-to-peak amplitude of 1.5 in. (38 mm). Mark the upper tip of this indication and the point midway between the tip and the sweep line. Check the notch in the reverse direction; if a marked difference in amplitude is found, make a new notch.

9.2.4 In a similar manner, locate and mark the position of the tip and point midway between the tip and sweep line of the second bounce notch indication. Draw a line connecting the two points designating the amplitudes of the first and second notch indications. Likewise, draw a line through the half-amplitude points. Refer to these lines as the amplitude and half-amplitude reference lines.

9.3 *Immersion Method for Equipment Calibration*:

9.3.1 *Circumferential*:

9.3.1.1 With the transducer located perpendicular to the outside diameter so as to obtain a 3 ± ¼-in. (76 ± 6.35-mm) water path, adjust the sweep delay and sweep length to position the water steel interface reflection at the left of the screen, and the first back reflection from the outside diameter of the ring slightly to the left of center of the screen, so that at least two angular passes through the ring will be visible on the screen. Position the transducer over the calibration reference and adjust the angle and horizontal position to maximize the indication from the reference notch. Check the notch in the reverse direction; if a marked difference in amplitude is noted, make a new notch.

9.3.1.2 Adjust the gain until the first bounce indication has a sweep-to-peak amplitude of 1.5 in. (38 mm). Mark the upper tip of this indication and the point midway between the tip and the sweep line.

9.3.1.3 In a similar manner, locate and mark the position of the tip and point midway between the tip and sweep line of the second bounce notch indication. Draw a line connecting the two points designating the amplitudes of the first and second notch indications. Likewise, draw a line through the half-amplitude points. Refer to these lines as the amplitude and half-amplitude reference lines.

9.3.2 *Axial*:

9.3.2.1 With the transducer located perpendicular to the outside diameter so as to obtain a 3 ± ¼-in. (76 ± 6.35-mm) water path as previously described in 9.3.1.1, position the transducer over the circumferential reference notch, and adjust the angle and horizontal position to maximize the indication from the reference notch while directing the ultrasonic beam toward the nearest end face of the ring.

9.3.2.2 Adjust the gain until the first bounce indication has a sweep-to-peak amplitude of 1.5 in. (38 mm). Mark the upper tip of this indication and the point midway between the tip and the sweep line.

9.3.2.3 In a similar manner, locate and mark the position of the tip and point midway between the tip and sweep line of the second bounce notch indication. Draw a line connecting the two points designating the amplitudes of the first and second notch indications. Likewise, draw a line through the half-amplitude points. Refer to these lines as the amplitude and half-amplitude reference lines.

9.4 *Scanning*:

9.4.1 *Contact Method*:

9.4.1.1 *Circumferential*—With the search unit held by hand or in a mechanical fixture, place it on the outside diameter surface of the ring with the sound beam directed circumferentially. Move the search unit in the circumferential direction while maintaining the proper contact angle as determined during calibration. Make successive parallel passes, each overlapping the previous pass at least 15 % of the transducer (not search unit) width, until the entire surface of the ring has been scanned. Rotate the search unit 180° and repeat the procedure.

9.4.1.2 *Axial*—The sensitivity established for the circumferential test shall also be used for the axial test. Place the search unit near one end of the ring and direct the sound axially toward this end. Move the search unit circumferentially over successive parallel passes, each overlapping the previous pass until the opposite end is reached. Reverse the direction of the search unit and repeat the procedure. In this manner, completely scan the entire outside surface of the ring.

9.4.2 *Immersion Method*:

9.4.2.1 *Circumferential*—With the transducer positioned as described in 9.3.1, rotate the part or the transducer in the circumferential direction (or traverse the transducer in the axial direction) while maintaining the proper angle as determined

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during calibration. Make successive parallel passes, each overlapping the previous pass by a minimum of 15 % of the transducer diameter, until the entire surface of the ring has been scanned. With the search unit repositioned to scan in the opposite circumferential direction, repeat this scanning procedure.

9.4.2.2 *Axial*—With the equipment calibrated in accordance with 9.3.2, rotate the ring or the transducer in the circumferential direction (or traverse the transducer in the axial direction) while maintaining the proper angle as determined during calibration. Make successive parallel passes until the entire surface of the ring has been scanned. With the search unit repositioned to scan in the opposite axial direction, repeat the scanning procedure.

9.5 *Report*:

9.5.1 The amplitudes of indications from discontinuities near (within approximately ¼ in. (6.35 mm)) the inside and outside diameter surfaces are influenced by trapping of the ultrasonic beam so that their amplitudes are greater than equivalent discontinuities that are below the surface (deeper than ¼ in.). Therefore, rate those discontinuities near the surface against the amplitude reference line and rate internal discontinuities against the half-amplitude reference line.

9.5.2 As the test proceeds, mark on the ring the locations of all indications exceeding the appropriate reference line. Recheck all indications found with the ring rotating, and record while the ring is stationary.

9.5.3 Record the number, amplitude, and location (axial, radial, and clock relative to 12 o'clock positions) of all indications reaching or exceeding their respective amplitude reference lines. Report indication amplitudes as percentages of their respective reference lines in increments of 10 %.

9.5.4 Where reportable indications are numerous, individually count and record the outstanding indications (see 9.5.3), and make an estimate of the number and amplitude of the remaining indications. A C-scan report may also be used to supply additional information.

10. Method for Longitudinal Wave Testing

10.1 *Reference Blocks (Radial Test)*:

10.1.1 In order to correct for the many variables involved in ultrasonic testing, it is necessary to use references to establish instrument settings, assist reproducibility of techniques, and evaluate discontinuities. The fabrication of reference blocks should be governed by the requirements described in Practice E 127.

10.1.2 The ultrasonic reference blocks should have ultrasonic characteristics, such as attenuation, noise level, and velocity similar to the metal being tested, or suitable correction should be made.

10.1.3 *Dimensions*—Calibration blocks prepared in accordance with the preceding paragraphs containing flat bottom holes of ⅛-in. (3.18-mm) diameter shall have metal travel within the following tolerances:

Wall Thickness (*T*) of Ring Being Tested, in. (mm)	Metal Travel Tolerance of Reference Test Block, in. (mm)
1 to 1½ (25 to 38)	*T* ± ¼ (±6.35)
1½ to 4 (38 to 101)	*T* ± ½ (±12.7)

10.2 *Calibration*:

10.2.1 *Contact Method (Radial Test)*:

10.2.1.1 Connect a longitudinal wave search unit (5 MHz for alloy steel rings and 2.25 MHz or 1 MHz for nonmagnetic rings) to the test equipment. Select an acoustically compatible calibration reference block with metal travel that is $T - \frac{3}{4}$ in. (19.0 mm) or $T - 1$ in. (25 mm) where T equals the wall thickness of the ring to be inspected.

10.2.1.2 Place the search unit on the entry surface of the calibration reference block and adjust the gain control of the instrument so as to obtain a 1.5-in. (38-mm) sweep-to-peak indication from the ⅛-in. (3.18-mm) flat bottom hole interface.

10.2.1.3 Place the search unit on the outside diameter of the ring to be inspected and adjust the sweep line so that at least two back reflections are displayed on the face of the cathode ray tube (CRT).

10.2.2 *Immersion Method (Radial Test)*:

10.2.2.1 Mount the transducer (5 MHz for alloy steel rings and 2.25 MHz or 1 MHz for nonmagnetic rings) in the holder or manipulator which has been coupled to the test equipment. Select an acoustically compatible reference block having ¾ in. (19.0 mm) metal travel (flat bottom hole in interface to test surface distance).

10.2.2.2 Position the transducer so as to obtain a 3 ± ¼-in. (76 ± 6.35-mm) water path, perpendicular to the front face of the calibration reference block.

10.2.2.3 With the transducer positioned over the entry surface of the reference standard, adjust the sweep delay and sweep length to position the water-steel interface reflection at the left of the screen. Adjust sensitivity or gain control to give a 1.5-in. (38-mm) sweep-to-peak indication from the ¾-in. (19.0-mm) deep reference hole.

10.2.2.4 Without changing the sensitivity setting, position the transducer normal to a circumferential surface of the retaining ring so there is a 3 ± ¼-in. (76 ± 6.35-mm) water path from the transducer to the surface of the ring. (Scanning can be performed from the inside diameter or outside diameter surface of the ring, depending on the supplier's equipment capabilities.) Adjust the sweep controls so that the first back reflection from the opposite surface is slightly to the left of center of the screen, so that at least two passes through the ring are visible on the screen.

10.2.3 *Axial Calibration*—When axial longitudinal wave examination is specified, perform it by the contact method. Adjust the sweep length to position the back reflection on the right hand side of the screen. Adjust the instrument controls so that the back reflection from the opposite face of the ring measures 1.5 in. (38 mm) sweep-to-peak. This standard amplitude shall represent a 100 % indication.

10.3 *Scanning by the Contact Method*:

10.3.1 *Radial Test*—With the search unit held by hand or in a mechanical fixture, place it on the outside diameter surface of the ring and move it in a circumferential direction while maintaining the proper contact angle as determined during calibration. Make successive parallel passes, each overlapping the previous pass until the entire surface of the ring has been scanned.

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10.3.1.1 Note any indications of magnitude greater than ⅜ in. (9.52 mm) in either the first or second pass.

10.3.1.2 Mark the location on the ring, and record all indications greater than ⅜ in. (9.52 mm). Also report any noticeable fluctuations or loss of back reflection associated with an indication.

10.3.2 *Axial Test*—Place the search unit on the shrink-fit end face of the retaining ring and move circumferentially. Make successive parallel passes, each overlapping the previous pass until the entire face of the ring has been scanned. Mark the location of indications exceeding 10 % of the first back reflection on the ring as encountered while the test is proceeding. Consider a back reflection loss of 50 % as an indication and report as such.

10.4 *Scanning by the Immersion Method*:

10.4.1 *Radial Test*—Scan the entire ring in overlapping passes by rotating the ring or the transducer (or traverse the transducer in the axial direction). The scan paths of the transducer shall be such that each pass overlaps the preceding pass.

10.4.1.1 Note any indications of magnitude greater than ⅜ in. (9.52 mm) sweep-to-peak in either the first or second pass.

10.4.1.2 Mark the location on the forging, and record all indications. Without changing sensitivity, report any loss of back reflection associated with an indication and any fluctuations or shift in back reflection.

10.5 *Report*:

10.5.1 *Radial Test*:

10.5.1.1 Recheck all indications found with the ring rotating, and record while the ring is stationary.

10.5.1.2 With the test notch or other locator designated as the 12 o'clock position, record the number, amplitudes, and location (axial, radial, and clock position) of all indications in excess of 25 % of the reference standard, in increments of 10 %, at estimated discontinuity depth. Additional reference standards, with ⅛-in. (3.18-mm) flat bottom holes, may be used to evaluate indication size at their depth from the testing surface.

10.5.1.3 Record as indications those areas showing a definite loss or shift of the multiple order pattern in radial testing and describe. Further explore them by expanding the sweep line and searching for discontinuities at higher frequencies or by use of other search units.

10.5.2 *Axial Test (Contact Method Only)*:

10.5.2.1 Recheck all indications found with the ring rotating, and record while the ring is stationary.

10.5.2.2 With the test notch designated as the 12 o'clock position, record the number, amplitudes, and location (axial, radial, and clock position) of all indications in increments of 10 % of the back reflection.

11. Report

11.1 Report the following information:

11.1.1 The results of the ultrasonic test shall be recorded and described in a written report, along with pertinent ring identification.

11.1.2 The following information shall be included: dimensions of the test notch, including width and depth; number, amplitudes, and relative locations of recordable indications (see 9.5 and 10.5). Identify those cases where a discontinuity is recorded from more than one direction.

11.1.3 Comments regarding abnormal travel or measured surface extent shall be made when discontinuities in these categories are detected.

12. Disposition

12.1 Rings containing no recordable indications are acceptable.

12.2 Rings of such coarse grain size or microstructure that the indication from the test notch cannot be distinguished above the noise level are subject to rejection.

12.3 All rings containing recordable ultrasonic indications shall be referred to the purchaser's engineering department for individual consideration.

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