Designation: E 588 – 95

Standard Practice for
Detection of Large Inclusions in Bearing Quality Steel by the Ultrasonic Method[1]

This standard is issued under the fixed designation E 588; 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 a procedure for the rating of rectangular steel sections by immersion ultrasonic techniques. Its purpose is to provide information on the content of large inclusions or clusters of small inclusions for determining the suitability of a steel lot for bearing applications. It should be recognized that this method was developed after several years of close cooperation between bearing manufacturers and bearing steel producers. References (**1-8**)[2] provide background information on developmental work. If its use for specification purposes is contemplated for other steel products, thought should be given to the possibility that a similar cooperative program between users and steel producers might be necessary. This practice in no manner defines or establishes limits of acceptability.

1.2 For this document, large inclusions are defined in ultrasonic terms as those having a reflecting area equivalent to or larger than a 1/64-inch diameter flat-bottom hole in a steel reference block of similar properties and thickness. In metallographic terms, large inclusions, defined in this way, are of approximately the same size as the smallest detectable sizes revealed by the macroscopic methods of Practice E 45. In some cases, inclusions smaller than those described previously can be detected either individually or in clusters, depending on their type, chemical composition, orientation to the ultrasonic beam and distance from the sound entry surface of the specimen.

1.3 *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:*

E 45 Practice for Determining the Inclusion Content of Steel[3]

E 214 Practice for Immersed Ultrasonic Examination by the Reflection Method Using Pulsed Longitudinal Waves[4]

E 428 Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection[4]

E 543 Practice for Evaluating Agencies that Perform Nondestructive Testing[4]

E 1316 Terminology for Nondestructive Examinations[4]

2.2 *ANSI/ASNT Standards:*

Recommended Practice SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing[5]

CP-189 Qualification and Certification of Nondestructive Testing Personnel[5]

2.3 *Military Standard:*

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[6]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, see Terminology E 1316.

4. Basis of Application

4.1 *Agreements Between Using Parties*—In order for this practice to be effectively used, the following items require agreement between the using parties.

4.1.1 *Evaluation of Nondestructive Testing Agencies*—An agreement is required as to whether the nondestructive testing agency, as defined in Practice E 543, must be formally evaluated and qualified to perform the examination. If such an evaluation is specified, a documented procedure such as Practice E 543 shall be used as the basis for evaluation.

4.1.2 *Personnel Qualification*—Nondestructive testing (NDT) personnel shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT CP-189, SNT-TC-1A, MIL-STD-410, or a similar document. The practice or standard used

[1] This practice is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.28 on Bearing Steels.

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[2] Boldface numbers in parentheses refer to the list of references at the end of this practice.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from the American Society for Nondestructive Testing, (ASNT), 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

and its applicable revision shall be specified in the contractual agreement between the using parties.

4.1.3 *Search Unit Performance Tests*—Annex A1 defines the minimum manufacturer's specifications for search units to be used with this practice. The extent of testing and verification of these parameters to be performed by the manufacturer shall be specified in the contractual agreement between the using parties.

5. Summary of Practice

5.1 The general technique used is immersion ultrasonic testing by the reflection method using pulsed longitudinal waves such as described in Practice E 214. Specific additional requirements for sample preparation, equipment operating parameters and calibration, and expression of results are delineated in this procedure. Special focused search units having operating characteristics as defined in Annex A1 are required.

6. Significance and Use

6.1 *Comparison with Other Inclusion Rating Methods*—Because the test is performed on a volumetric rather than a surface-examination basis, the ultrasonic method is inherently better able to detect infrequently occurring large inclusions or clusters of small inclusions than eddy current, magnetic particle, microscopical, or macroscopic examination procedures.

6.2 *Limitation of Inclusion Size and Type*—A limitation of the method is that it will not detect all inclusions. Inclusion chemistry, size, shape, location, and distribution may limit the ability of the method to provide indications distinct from those generated by the surrounding metallurgical structure. The recommended practice is only meaningfully applicable to examination of steel wherein the inclusion size and type are within the detection capabilities of the method. For steel wherein inclusion size, dispersion, and chemistry prevent optimum inclusion detection by ultrasonics, microscopical methods detailed in Practice E 45 may be applied.

7. Interference

7.1 *Reflections from Multiple Inclusions*—An ultrasonic indication can represent the reflection from a single inclusion; however, it typically represents the vector summation of reflections from clusters of small inclusions contained within a volume of a few cubic millimetres.

7.2 *Response as a Function of Inclusion Type*—The individual inclusion reflections can have different amplitudes because of different inclusion characteristics. In addition, the individual reflections may have different phase characteristics when arriving at the search unit if the travel distances are different.

8. Apparatus

8.1 *Equipment Required*—An equipment system with the following components is needed to conduct this test: ultrasonic test instrument, search unit, a means of recording signals of various amplitudes, a system reference block, instrument calibration block, and an immersion tank with suitable scanning accessories.

8.2 *Ultrasonic Instrument*—The ultrasonic instrument shall be capable of generating and receiving electrical pulses of 10-MHz frequency at levels compatible with the test requirements. It shall have both an A-scan presentation and an analog output. It shall be the ultrasonic instrument manufacturer's responsibility that instruments supplied for use with this test meet the minimum requirements delineated in this recommended practice.

8.2.1 *Receiver Characteristics*—The center frequency shall be 10 ± 0.5 MHz. The bandpass of the receiver shall be at least 1.3 MHz (3 dB points).

8.2.2 *Dynamic Range*—The dynamic range of the instrument shall permit detection of steel balls with a 16-to-1 diameter ratio at a given sensitivity. Balls shall be placed in water at the focal point of the search unit. Each size ball within this range shall give a significantly different amplitude of indication on both the visual oscilloscope presentation and the analog output.

8.2.3 *Stability*—The analog output voltage of a usable full-scale indication shall not vary more than 5 % after 1 h of instrument warm-up, and preferably by less than 2 % (4-h test with air temperature being held to ±1.2°C over a temperature range of 17.5 to 25.5°C).

8.2.4 *Sweep Length and Linearity*—Sweep length of oscilloscope presentation shall be capable of being adjusted to represent 1 mm = 1.27 mm of steel. A minimum of 80 mm of the sweep display shall be linear to within 5 % of full scale. Analog output voltage of an indication from a target shall not vary more than ±4 % over the gated portion of the sweep employed in calibration and testing.

8.2.5 *Repetition Rate*—The repetition rate of the pulser shall not be less than 500 pulses per second.

8.3 *Search Units*—Ultrasonic search units for this test shall be spherically focused immersion-type units. Uniform performance characteristics of search units are critical for obtaining reproducible test measurements. (See Annex A1, which delineates search unit performance characteristics to be met by search unit manufacturers.) Performance characteristics of search units requiring consideration are: the uniformity of focal distance in water, center frequency, frequency spectrum, lens radius, width of field, and beam symmetry.

8.3.1 *Focal Length*—A focused beam of radiated ultrasonic energy is recommended to provide lateral resolution of small defects and to improve testing sensitivity in the region near the focal point. The focal length of a search unit is defined in this discussion as the distance in water, on the search unit axis, between the search unit and the surface of a ½ -in. or 12-mm diameter ball target at which the highest reflection amplitude indication is obtained. Different focal length transducers may be used to obtain optimum response at selected distances below the test sample surface. (Variation of search unit-to-specimen surface water path would also affect the focal point within the test sample.)

8.3.2 *Search Unit Characteristics*—Search units generally employed have the following frequency and focal length as purchased:

Frequency	Focal Length in Water
10 ± 0.5 MHz	8.2 ± 0.3 in (208.3 ± 7.6 mm)

A search unit shall be discarded as no longer fit for use when its focal length has degenerated to 7.5 in. (190.5 mm).

8.3.3 *Beam Symmetry*—Each search unit should be rotated on its ultrasonic beam axis (not necessarily geometric axis) until a particular circumferential orientation is found which gives a maximum severity, or count, from the system reference block. This search unit orientation shall be identified and employed in subsequent tests. Search units that exhibit variations in indication amplitude in excess of 15 % during rotation shall not be considered satisfactory for the test. There are other methods, such as optimum response over a precision and uniform taut wire, that have been found to be usable.

8.3.4 *Performance*—The performance capabilities of all new search units shall be verified by an actual test on the system reference block. The data obtained for new search units should be compared with that obtained for other search units having the same specifications and tested under identical conditions.

8.4 *Immersion Tank and Accessories*—An immersion tank with associated scanning and indexing facilities shall be used.

8.4.1 *Search Unit Angulation*—The tank shall be provided with a manipulator capable of continuously angulating the search unit in two vertical mutually perpendicular planes permitting the required normalization.

8.4.2 *Scanning and Indexing*—The tank bridge and carriage assemblies shall provide *X-Y* motion to the search unit. The scanning shall be parallel or perpendicular (depending on the procedure) to the test specimen axis and the indexing shall be perpendicular to the scanning.

8.4.3 *Test Specimen Mounting*—The tank shall be provided with fixturing permitting the mounting of the entry surface of the test specimen parallel to the bridge travel so that the distance between search unit and specimen remains constant within ±1⁄64 in. (0.4 mm).

8.4.4 *Couplant*:

8.4.4.1 The inspection solution shall consist of tap or distilled water to which a wetting agent has been added to disperse air bubbles. The pH of the water shall be maintained within 7½ to 8½ . Rust preventives may also be added. All chemical additives shall be held within concentrations that do not adversely affect test performance. Water temperature must be held between 19.5 and 25.5°C. It is important that excessive thermal gradients do not exist between the search unit and the calibration standards. Billet inspection shall be made within 1.7°C of the temperature at which calibration was accomplished.

8.4.4.2 A means of circulating the immersion inspection solution shall be employed, when necessary, to dissipate thermal gradients.

8.5 *Readout Equipment*—Various types of instrumentation have been employed in conjunction with ultrasonic instruments for many years to determine the number of occurrences of various amplitude indications. These include level counters, pulse counters, integrators, strip chart recorders, B-scan recorders, C-scan recorders, memory oscilloscopes, and computer techniques. Analog output voltage from the ultrasonic instrument gate supplies information to these devices. With pulse counters, both repetition rate and scanning speed must be held within a 5 % tolerance and, preferably, 2 %.

8.6 *System Reference Block*—A system reference block of 4 by 4-in. (102 by 102-mm) cross section is required for initial adjustments and operational testing of the equipment. This sample should be selected to provide reflection signals at all counting levels. Depth distribution of inclusions in the selected reference block should make its response characteristics relatively insensitive to minor focal length variations between different search units. The reference block should give a minimum change in total counts of 10 % for each 10 % increase or decrease in amplitude setting. A maximum of 30 % change in count for each 10 % change in amplitude setting should not be exceeded. It should be suitably protected from corrosion to assure its longevity. Thermal conditioning and surface preparation should conform with the particular test method. This block may also serve as a secondary reference standard if flat-bottom holes are drilled in accordance with hole specifications defined in Practice E 428. Holes drilled at various depths beneath the entry surface permit distance amplitude correction when desired.

9. Test Specimens

9.1 *General*—Test specimens are obtained from wrought billets and may be either in the rolled or forged condition. Unless otherwise agreed upon, specimens shall be taken from the first, middle, and last portion of the heat as agreed upon between the supplier and the purchaser.

9.2 *Specimen Size and Shape*—Specimens shall have a minimum cross-sectional dimension after preparation of 3½ in. (88.9 mm). The area scanned shall be sufficient to permit testing of a minimum of 25 in.^{3}(410 cm^3) of the specimen. The tested volume equals the scanned area multiplied by the gated depth. This volume is necessarily smaller than the total specimen volume. If special consideration is given, thinner samples may be tested. Samples thicker than 4 in. (101.6 mm) after preparation also require special consideration.

9.3 *Entry Surface Finish*—The test surface through which the sound enters the specimen shall be machine finished. This finish in any direction over the surface shall be preferably 15 to 85 rms (or 0.34 µm to 1.94 µm aa). Final material removal may require a dressed grinding wheel to avoid spurious, near-surface indications.

9.4 *Heat Treatment*—Thermal conditioning of the specimens generally is required to minimize acoustic anomalies. Typical treatment of medium- and low-alloy steel samples consists of normalizing at 89°C (nominal) above the Ac_3 transformation temperature for 1 to 2 h at heat. An additional tempering of high-carbon steels to permit subsequent machining is permissible. Certain steels may require special thermal treatment such as a double temper to obtain suitable acoustic properties.

9.5 *Ultrasonic Penetrability*—The ultrasonic penetrability shall be determined to be suitable for the inspection. The penetrability is acceptable if the third back reflection of the specimen is 25 % of the highest level indication, over the center of the billet specimen, at standard test conditions and test sensitivity.

10. Procedure

10.1 *General*:

10.1.1 *Operating Frequency*—The operating frequency for most bearing steels is 10 MHz. Ten megahertz is recommended as the highest practical frequency available within existing manufacturing capabilities to produce search units with uniform performance characteristics. Higher frequencies give better resolution, while lower frequencies give better penetration.

10.1.2 *Normalizing Search Unit*—Normalizing the search unit beam to the entry surface is a precise adjustment and requires extreme care. Normalizing can be accomplished over billet specimens with parallel ground sides by adjusting for a maximum first far field back reflection in an area where no material discontinuities are present to distort the ultrasonic beam. An alternative method that has been found useful is to maximize the far field reflections from a hardened steel plate with parallel ground sides, such as a 58 to 64 HRC hardness test block, placed on top of the ground billet surface.

10.1.3 *Pulse Length*—If an instrument has a pulse length adjustment, it should be set as recommended by instrument manufacturers to give the most consistent center frequency output spectrum.

10.1.4 *Impedance Matching*—Impedance matching between the search unit and instrument is a necessity. It is important that the pulse length selected for the test be set before impedance matching. A method that may be employed is to determine the cable length that requires the lowest receiver sensitivity to obtain a given amplitude of back reflection indication, at the focal point or in the far field, from a steel block or plate. If the instrument has a tuning capacitor, to adjust the input circuit, adjust the capacitor to produce a maximum indication for each change in cable length. Cable length changes should be made in no more than 3-in. (75- mm) increments to avoid possible false resonance indications. If an instrument has two or more input jacks, the impedance match must be determined for the jack suitable for use.

10.1.5 *Water Distance*—The water distance between the search unit and entry surface shall not be less than 1 ± 1⁄16 in. (25.4 ± 1.6 mm) for every 4 in. (102 mm) of specimen thickness. In no case should the water distance be less than 1 ± 1⁄16 in.

10.1.6 *Monitoring Gates*—Either single or multiple gates may be employed. When specimens are suspected to have a nonuniform distribution of inclusions, or when locating specific volumes of high frequency of occurrence, special consideration can be given to inspecting the sample from more than one side. Similarly, if it is desired to detect inclusions immediately below the surface, the billet can be cut lengthwise into two equal sections, so that each billet half can be evaluated with the ultrasonic beam entering the surface representing the billet center. The most sensitive evaluation would occur if the search unit focal zone is near the original billet exterior surface.

10.1.7 *Scanning of Specimen*—Scanning of the specimen may be either perpendicular or parallel to the rolling direction with a scan index of 0.050 in. (1.27 mm). Scanning closer than ½ in. (12.7 mm) to the prepared surface edge should be avoided because of false echoes from the edge.

10.1.8 *Scanning Speed*—Permissible scanning speed is a function of counter response and instrument repetition rate. A generally accepted speed is 4 in. (101.6 mm)/s. It shall be limited to that which gives a recorded evaluation of a sample within 5 % of that obtained when the sample is scanned at less than 1 in. (25.4 mm)/s, or one third of normal operating speed, whichever is the slower.

10.1.9 *Sensitivity*—The test sensitivity shall not produce background material indications exceeding an amplitude of one half of the lowest counting level.

10.1.10 *Operational Performance*—Periodically check overall equipment performance by conducting a test on the system reference block specimen. The deviation permitted shall not exceed the variation in counts obtained by altering the electronic gain by ±10 %. For practical purposes, the ±10 % electronic gain shall be defined as equivalent to the difference in response from ball targets varying by 10 % in diameters.

10.2 *Description of Method*—This method is applicable to the determination of the relative cleanliness of bearing-quality steel. Equipment, calibration, and method of analyzing test results have been made as simple as possible within the limits of having a workable test. An immersed ultrasonic test is conducted with a 10-MHz focused search unit, three-level type counter to indicate test results, steel balls to establish counter levels, an instrument calibration block, and a system reference block specimen. The specimen is scanned in a direction perpendicular to the rolling direction, and counts are recorded only when the search unit passes transversely over either a single inclusion or a cluster of inclusions which give rise to a discrete ultrasonic indication exceeding a counting level.

10.2.1 *Special Equipment and Accessories*:

10.2.1.1 The test instrument shall include a gated analog output voltage circuit with a single adjustable gate. Changes in the instrument analog output voltage are used to actuate readout equipment.

10.2.1.2 A three-level pulse counter having separate adjustable voltage thresholds for each level shall be used to determine the number of occurrences of various amplitude indications. The input circuits to the counts shall employ sufficient filtering to eliminate counter operation from extraneous high-frequency signals. The equipment shall have sufficient hysteresis to prevent counting spurious variations (jitter). Hysteresis of counter circuits, at each amplitude level, shall not exceed 5 % of the analog voltage input corresponding to the highest usable signal level.

10.2.1.3 A digital voltmeter shall be used to monitor the analog output voltage of the instrument at each counting level.

10.2.2 *Calibration Standards*:

10.2.2.1 Counter calibration requires a set of three ball targets with size ratio of 12:7:4. Stainless steel ball sets with diameters of ¾ in., 7⁄16 in., and ¼ in., or 12 mm, 7 mm, and 4 mm, may be employed.

10.2.2.2 Test instrument calibration is performed with either: (*a*) a 10-mm hemispherically shaped hole instrument calibration block described in Annex A2, or (*b*) a 1⁄64 -in. (0.4-mm) flat-bottom hole standard. These reference targets shall be

1.7 in. (43.2 mm) below the entry surface of the standard. (A suitable 1⁄64 -in. standard with the prescribed metal path can be made by cutting down a standard ASTM steel block.)

10.2.2.3 When the 10-mm hemispherically shaped hole standard is employed, means of attenuating the signal in the ratio of reflections from two ball targets with a 16:1 diameter ratio shall be employed. Ball targets with diameters of 2 in. and 1⁄8 in., 1¾ in. and 7⁄64 in., or 32 mm and 2 mm, may be used.

10.2.2.4 A system reference block specified in 8.6 shall be employed to verify instrument calibration and to cross reference equipment performance between a number of instruments.

10.2.3 *Equipment Calibration Procedures*:

10.2.3.1 Prior to performing any calibration or setting of sensitivity, perform impedance matching and set tuning and pulse length in accordance with the methods delineated in 10.1.3 and 10.1.4.

10.2.3.2 Equipment calibration is a two-step procedure that requires counter level calibration followed by ultrasonic test instrument sensitivity calibration. Adjust the analog gate circuit to place the echo signals from calibration standards in the linear region of the gated display.

10.2.3.3 Adjust the three-level counter using a set of instrument-quality stainless steel balls having a diameter ratio of 12:7:4. Position the search unit above the largest ball at a distance for maximum signal amplitude corresponding to the focal distance specified in 8.3.2. Adjust the test instrument sensitivity to give a signal at or near the maximum usable linear range of the instrument that gives both a stable and relatively linear oscilloscope display and analog voltage output. At this setting, record the analog output voltage and adjust the level-three counter to count. This procedure determines the Level 3 (high) amplitude counting threshold. Without changing the test instrument sensitivity setting, position the search unit at its focal distance over the medium- and small-size balls. Adjust counter thresholds similar to the procedure for Level 3 and record analog voltages for the Level 2 (medium) and Level 1 (low) amplitude counting thresholds.

10.2.3.4 Adjust instrument sensitivity (gain) to set gated analog output voltage from the instrument calibration block (artificial discontinuity at focal point) equal to Level 3 counter threshold voltage, determined in accordance with 10.2.3.3.

10.2.3.5 When a 10-mm round-bottom hole standard is employed, set the instrument sensitivity control to provide an analog output voltage at the threshold voltage of the Level 3 counter (determined in accordance with 10.2.3.3). Then, increase the sensitivity by an amount equal to the difference in echo signal amplitudes from two ball targets with a 16:1 diameter ratio. Determine this signal difference by placing the search unit over the smaller ball target with water path equal to the focal distance. Then, place the search unit over the larger ball target at the same focal distance. Attenuation needed to reduce the signal amplitude to again give the same Level 3 analog output voltage is the increase in sensitivity needed to calibrate the test instrument for billet inspection. On instruments equipped with X0.1, X1.0, and X10.0 sensitivity range, switch the sensitivity difference by switching from X0.1 to X1.0 range. The internal range scaling adjustment of the instrument shall have been set to provide a 16:1 ball target echo difference instead of the nominal 10:1 signal ratio. (Refer to the instrument manual for additional details of this X0.1 potentiometer adjustment.) On instruments with decibel attenuation switching arrangements, switch "out" the decibel attenuator settings equivalent to the 16:1 ball target echo difference to increase the sensitivity of the specified amount.

10.2.3.6 When a 1⁄64 -in. (0.40-mm) flat-bottom hole standard is employed, adjust the sensitivity to give an analog output voltage for the calibration signal equal to the Level 3 voltage threshold.

10.2.4 *Cross Referencing Between Equipment Users*—If cross referencing of system reference blocks has been performed with other users of the method (as delineated in Annex A3), a fine adjustment of sensitivity (not to exceed ±10 % or 1 dB or a 10 % change in ball ratio) may be performed to discount variations in search unit response, counter hysteresis, and other instrumentation variables.

10.2.5 *General Instructions and Procedures*:

10.2.5.1 Adjust the water path distance so that the search unit face is located 1 ± 1⁄16 in. (25.4 ± 1.6 mm) from the test specimen entry surface. This adjustment may be performed with a rule, reference spacer, or by use of calibrated water path measurements on the test instrument display.

10.2.5.2 Adjust a single electronic gate to evaluate indications that occur in the zone 0.7 to 0.9 in. (17.8 to 22.9 mm) from the entry surface to 0.3 to 0.5 in. (7.6 to 12.7 mm) from the bottom of the specimen. For particular applications, the zone that is gated can be altered; however, this change must be given separate consideration. Specimens that are suspected of having a nonuniform distribution of inclusions can be inspected from perpendicular or opposite sides and the inspection results can be averaged.

10.2.5.3 Scan the specimen in a direction perpendicular to the rolling direction with a scan index of 0.050 in. (1.27 mm). Base volume of test on 20 scans per inch of sample length. The scanned area shall be bound by a perimeter that is not within 0.5 in. (12.7 mm) of the prepared surface edge. If the sides of the specimen are rough, a greater distance from the edge may be required to avoid spurious signals.

10.2.6 *System Reference Block Equipment Performance Test*—Periodically check overall performance of equipment by conducting a test on the system reference block. The deviation permitted shall not exceed the variation in counts obtained for a ±7.5 % sensitivity variation in analog voltage output from the Level 3 voltage threshold.

10.2.7 *Test Result Computation*:

10.2.7.1 Test result computation shall consist of separately counting the number of high-, medium-, and low-level indications; multiplying the number of indications in each level by a suitable weight factor; totaling the weighted result; and dividing by the volume tested. This provides a rating of the cleanliness, defined as weighted counts per cubic inch.

$$S = \frac{A(N_1) + B(N_m) + C(N_h)}{V} \quad (1)$$

where:

S = severity rating,

A, *B*, *C*	=	weighting factors,
N_l	=	number of low-level indications counted,
N_m	=	number of medium-level indications counted,
N_h	=	number of high-level indications counted, and
V	=	volume of material tested (gated depth × scanned area).

10.2.7.2 For convenience, weight factors of 1, 2, and 3 are generally applied to the counts for the low, medium, and high levels, respectively. These factors are used because they are inherent in the operation of a counting system wherein a single high-level indication is also counted in the other two levels. Under these conditions, the total weighted count is the total from the three counters. In special instances, other weighting factors may be necessary.

10.2.8 *Report*—The reported results should contain all the information about the test that is necessary in order to duplicate results at the same or some other location. As a minimum, this report should include sample identification, test results on system reference sample, manufacturer's name and type designation of instruments and search units, and date of test. It also may be desirable to keep certain additional information on record, such as length and type of search unit-to-instrument cable employed, serial numbers of all apparatus, air temperature, water temperature, sensitivity settings, history of additives to couplant, name of operator, etc.

11. Precision [7]

11.1 Two separate tests were employed by ten equipment users (ten different instrument installations) to compute precision of the method. A total of twelve search units were utilized in these tests.

		Calibration 10-mm Hemispherical Hole With Cross Referencing	Calibration 10-mm Hemispherical Hole Without Cross Referencing	Flat-Bottom Hole (1⁄64 in. (0.4 mm))
Test I	Number of tests	25	24	20
	Mean severity = $\bar{x}$	11.50	11.33	11.73
	Standard deviation = σ	0.44	0.76	1.25
	% error within 1σ	±3.8 %	±6.7 %	±10.6 %
Test II	Number of tests	25	24	20
	Mean severity = $\bar{x}$	6.87	6.75	6.9
	Standard deviation = σ	0.36	0.49	0.74
	% error within 1σ	±5.2 %	±7.3 %	10.6 %
Tests I & II Combined	Average error within 1 σ	±4.5 %	±7.0 %	±10.6 %

11.1.1 The most preferred method of calibration based on the tests shown above is to employ a 10-mm hemispherical hole standard in conjunction with cross referencing between different users of the method.

11.1.2 The 1⁄64 -in. (0.4-mm) flat-bottom hole method of calibration is the least preferred because of lack of precision obtainable. Difficulties arise with this type of standard both in reproducing setup and in manufacturing identical response blocks. Use of this standard should, therefore, be limited to specific purchaser/supplier agreement.

12. Keywords

12.1 bearing steel; cleanliness; nondestructive examination; steel; ultrasonic testing

[7] Supporting Data are available from ASTM Headquarters. Request RR: E04 – 1001.

ANNEXES

(Mandatory Information)

A1. MINIMUM REQUIREMENTS FOR THE MANUFACTURE OF SEARCH UNITS

A1.1 General Characteristics

A1.1.1 The general characteristics of the search units presently used and their tolerances are as follows:

Frequency, MHz	Focal Length in Water, in. (mm)
10 ± 0.5	8.2 ± 0.3 (208.3 ± 7.6)

A1.1.2 The focal length shall be measured while using an instrument of the type employed for testing billet sections. Proper impedance matching of the search unit to the instrument is a requirement. A ½ -in. or 10-mm diameter instrument-quality stainless steel ball target shall be used for this measurement.

A1.2 Spectrum Analysis

A1.2.1 A spectrum analysis of the radiated signal of the transducer shall be performed to determine operating frequency characteristics. The requirements of the spectrum analysis test are as follows:

A1.2.1.1 Pulse-generating equipment shall be used that produces unidirectional voltage pulses having a duration no greater than one-half period of the nominal test frequency, a maximum rise time of 10 ns, and a trace-to-peak amplitude adjustable to 150 ± 5 V when loaded by the search unit and cable.

A1.2.1.2 A ½ -in. or 10-mm diameter ball target in water shall be used. The ball target shall be placed in the search unit's far radiated field at 1.2 times the focal distance.

A1.2.1.3 The analyzed radiated signal shall be the front surface reflection from the ball target.

A1.2.1.4 A gate that does not modify signals should be used to avoid interference with the spectrum analysis by signal components from the gate.