Designation: E2192 − 13 (Reapproved 2022)

Standard Guide for Planar Flaw Height Sizing by Ultrasonics[1]

This standard is issued under the fixed designation E2192; 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 guide provides tutorial information and a description of the principles and ultrasonic examination techniques for measuring the height of planar flaws which are open to the surface. The practices and technology described in this standard guide are intended as a reference to be used when selecting a specific ultrasonic flaw sizing technique as well as establishing a means for instrument standardization.[2]

1.2 This standard guide does not provide or suggest accuracy or tolerances of the techniques described. Parameters such as search units, examination surface conditions, material composition, etc. can all have a bearing on the accuracy of results. It is recommended that users assess accuracy and tolerances applicable for each application.

1.3 This guide does not purport to provide instruction to measure flaw length.

1.4 This standard guide does not provide, suggest, or specify acceptance standards. After flaw-sizing evaluation has been made, the results should be applied to an appropriate code or standard that specifies acceptance criteria.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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

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

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E1316 Terminology for Nondestructive Examinations

E543 Specification for Agencies Performing Nondestructive Testing

2.2 *ASNT Standards*[4]

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

2.3 *AIA Standards*[5]

NAS-410 Nondestructive Testing Personnel Qualification and Certification

3. Terminology

3.1 *Definitions*—Related terminology is defined in Terminology E1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *corner reflection*—the reflected ultrasonic energy resulting from the interaction of ultrasound with the intersection of a flaw and the component surface at essentially 90 degrees.

3.2.2 *doublet*—two ultrasonic signals that appear on the screen simultaneously and move in unison as search unit is manipulated toward and away from the flaw. During tip-diffraction flaw sizing, the flaw tip signal and flaw base signal (corner reflector) will appear as a doublet.

3.2.3 *far-surface*—the surface of the examination piece opposite the surface on which the search unit is placed. (For example, when examining pipe from the outside surface the far-surface would be the inside pipe surface).

3.2.4 *focus*—the term as used in this document applies to dual crossed-beam search units that have been manufactured so that they have a maximum sensitivity at a predetermined depth or sound path in the component. Focusing effect may be

---

[1] This guide is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Method.

Current edition approved Dec. 1, 2022. Published December 2022. Originally approved in 2002. Last previous edition approved in 2018 as E2192 – 13(2018). DOI: 10.1520/E2192-13R22.

[2] This Standard Guide is adapted from material supplied to ASTM Subcommittee E07.06 by the Electric Power Research Institute (EPRI).

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

[5] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA22209-3928, http://www.aia-aerospace.org.

obtained with the use of dual-element search units having both refracted and roof angles applied to each element.

3.2.5 *near-surface*—the surface of the examination piece on which the search unit is placed. (For example, when examining pipe from the outside surface the near-surface would be the outside pipe surface).

3.2.6 *sizing*—measurement of the through-wall height or depth dimension of a discontinuity or flaw.

3.2.7 *30-70-70*—term that is applied to the technique (and sometimes the search unit) using an incident angle that produces a nominal 70° L wave in the examination piece. Provided that a parallel far-surface exists, the 30° shear wave, produced simultaneously at the near surface, reflects as a 30° shear wave and generates a nominal 70° L wave as a result of mode conversion off the far-surface. The 70° L wave reflects off a planar flaw and is received by the search unit as a 70° L wave.

4. Summary of Guide

4.1 This guide describes methods for the following flaw sizing techniques.

4.1.1 Far-surface creeping wave or mode conversion method,

4.1.2 Flaw-tip-diffraction method,

4.1.3 Dual element bi-modal method, and

4.1.4 Dual element, (focused) longitudinal wave or dual element, (focused) shear wave methods.

4.2 In this guide, ultrasonic sound paths are generally shown diagrammatically by single lines in one plane that represent the center of the ultrasonic energy.

4.3 Additional information on flaw sizing techniques may be found in the references listed in the Bibliography section.

5. Significance and Use

5.1 The practices referenced in this document are applicable to measuring the height of planar flaws open to the surface that originate on the far-surface or near-surface of the component. These practices are applicable to through-wall sizing of mechanical or thermal fatigue flaws, stress corrosion flaws, or any other surface-connected planar flaws.

5.2 The techniques outlined describe proven ultrasonic flaw sizing practices and their associated limitations, using refracted longitudinal wave and shear wave techniques as applied to ferritic or austenitic components. Other materials may be examined using this guide with appropriate standardization reference blocks. The practices described are applicable to both manual and automated examinations.

5.3 The techniques recommended in this standard guide use Time of Flight (TOF) or Delta Time of Flight (ΔTOF) methods to accurately measure the flaw size. This guide does not include the use of signal amplitude methods to determine flaw size.

5.4 Generally, with these sizing methods the volume of material (or component thickness) to be sized is divided into thirds; the inner ⅓, the middle ⅓ and the near ⅓. Using the far-surface Creeping Wave Method the user can qualitatively segregate the flaw into the approximate ⅓ zone.

5.5 The sizing methods are used in ⅓ zones to quantitatively size the crack, that is, Tip-diffraction for the far ⅓, Bi-Modal method for the middle ⅓, and the Focused Longitudinal Wave or Focused Shear Wave Methods for the near ⅓ . These ⅓ zones are generally applicable to most sizing applications, however, the various sizing methods have applications outside these ⅓ zones provided a proper reference block and technique is demonstrated.

6. Basis of Application

6.1 The following items are subject to contractual agreement between the parties using or referencing this standard.

6.2 *Personnel Qualification*

6.2.1 If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS-410, or a similar document and certified by the employer or certifying agency, as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.3 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Specification E543. The applicable edition of Specification E543 shall be specified in the contractual agreement.

6.4 *Procedures and Techniques*—The procedures and techniques to be utilized shall be as specified in the contractual agreement.

6.5 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results are not specified in this standard, they shall be specified in the contractual agreement.

6.6 *Reexamination of Repaired/Reworked Items*—Reexamination of repaired/reworked items is not addressed in this standard and if required shall be specified in the contractual agreement.

7. Ultrasonic Flaw Sizing Methods

7.1 *30-70-70 Mode Conversion or Far-surface Creeping Wave Method*—The far-surface Creeping Wave or 30-70-70 Mode Conversion method (as illustrated in Fig. 1) provides qualitative additional depth sizing information. This method has considerable potential for use when approximating flaw size, or, determining that the flaw is far-surface connected.

7.1.1 *Excitation of Creeping Waves*—The excitation of refracted longitudinal waves is always accompanied by refracted shear waves. In the vicinity of the excitation, the separation between these two wave modes is not significantly distinct. At the surface, a longitudinal wave cannot exist independently of a shear wave because neither mode can comply with the boundary conditions for the homogeneous wave equation at the free surface alone; consequently, the so-called headwave is formed. The headwave is always generated if a wave mode with higher velocity (the longitudinal wave) is coupled to a wave mode with lower velocity (the direct shear wave) at an interface. The longitudinal wave continuously energizes the

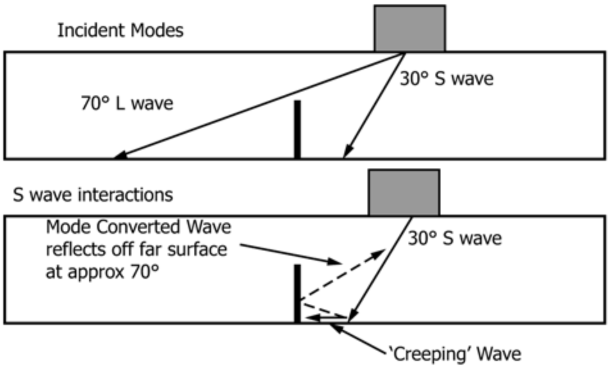

FIG. 1 Wave Generation for the Far-surface Creeping Wave/30-70-70 Mode-Conversion Search Unit

shear wave. It can be concluded that the longitudinal wave, which in fact "creeps" along the surface, is completely attenuated a short distance from the location of the excitation. (See Fig. 2 for generation of the near-side creeping wave). With the propagation of the near-surface creeping wave and its continuous conversion process at each point it reaches, the energy converted to shear is directed into the material as shown in Fig. 3. Thus, the wave front of the headwave includes the head of the creeping wave, direct and indirect shear waves.

7.1.2 *Far-Surface Creeping Wave Generation*—When the headwave arrives at the far-surface of the component, the same wave modes will be generated which were responsible for generating the shear wave energy, due to the physical law of reciprocity. Thus, the indirect shear wave and part of the direct shear wave will convert into a far-surface creeping wave and a 70-degree longitudinal wave. The far-surface creeping wave will be extremely sensitive to small surface-breaking reflectors and the longitudinal wave will be engulfed in a bulk longitudinal beam created by beam spread. Additionally, these reflection mechanisms are responsible for a beam offset so that there is a maximum far-surface creeping wave sensitivity at about 5 to 6 mm (0.20 to 0.24 in.) from the ideal conversion point on the far surface. The sensitivity range of the far-surface creeping wave extends from approximately 2 to 13 mm (0.080 to 0.52 in.) in front of the index point. The far-surface creeping wave, as reflected from the base of a far-surface notch or flaw, will convert its energy into a headwave since the same principles apply as established earlier for the near-surface creeping wave. The shear wave will continue to convert at multiple V-paths if the material has low attenuation and noise levels.

7.1.3 *Typical Echoes of the Far-Surface Creeping Wave/30-70-70 Mode Conversion Technique*—When the search unit approaches a far-surface connected reflector, three different signals will occur in sequence: (*1*) 70-degree longitudinal wave direct reflection; (*2*) 30-70-70 mode-converted signal; and (*3*) A far-surface creeping wave signal, as a result of mode conversion of the indirect shear wave.

7.1.3.1 *Direct Longitudinal Wave Signal*—If the flaw extends to within approximately 10 to 16 mm (0.375 to 0.625 in.) of the scanning surface (near surface), the direct longitudinal wave will reflect from the upper extremity of the flaw face, which is very similar to the high-angle longitudinal wave sizing method discussed later.

7.1.3.2 *Mode Converted Signal*—If the flaw exceeds a height of 10 to 20 % of the wall thickness, an indication from the mode converted signal will occur at a typical wall thickness-related position. This mode converted signal results from the headwave or direct shear wave, which mode converts the 70-degree longitudinal wave that impinges on the reflector at its highest part; it is reflected as a 70-degree longitudinal wave back to the search unit as depicted by position 1 in Fig. 4. The presence of the mode-converted echo is a strong indication of a flaw with a height greater than 10 to 20 % of the wall thickness. In the case of smooth or at least open flaws, amplitude versus height function curves can give a coarse estimate of flaw height.

7.1.3.3 *Far-Surface Creeping Wave Signal*—If a far-surface connected reflector is within the range of sensitivity (as described above), the far-surface creeping wave will be reflected and mode converted into the headwave or shear wave directed to the search unit (Fig. 5). Since the far-surface creeping wave is not a surface wave, it will not interact with weld root convexity and will not produce an indication from the root as shown by position 1 in Fig. 6. However, if the search unit is moved too far toward the weld centerline, the direct shear wave beam could result in a root signal, but there is at least 5 mm (0.2 in.) difference in positioning as shown in Fig. 6. The far-surface creeping wave signal is a clear, sharp signal with a larger amplitude than the mode converted signal. It does not have as smooth an echo-dynamic behavior as does

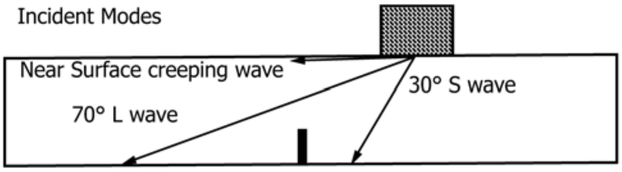

FIG. 2 Near-Surface Creeping Wave Occurs for a Short Distance in Association with the Incident Longitudinal Wave