Designation: E3101 – 18

Standard Practice for Microwave Examination of Polyethylene Butt Fusion Joints[1]

This standard is issued under the fixed designation E3101; 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 microwave (MW) examination of butt fusion joints made entirely of polyethylene for the purpose of joining polyethylene piping or vessel parts.

NOTE 1—The notes in this practice are for information only and shall not be considered part of this practice.

NOTE 2—This practice references HDPE and MDPE for pipe applications as defined by Specification D3350.

1.2 MW examination detects differences between the dielectric constant(s) of the materials being examined. These differences may be due to material construction (expected) or flaws such as voids, cracks, or foreign material intrusion (unexpected).

1.3 The butt fusion joining process can be subject to a variety of flaws including, but not limited to, lack of fusion, particulate contamination, inclusions, and voids.

1.4 This practice is intended for use on polyethylene butt fusion joints of pipe diameters of 4 in. to 65 in. (100 mm – 1650 mm) and wall thickness of 0.5 in. to 4 in. (12 mm – 100 mm). Greater and lesser thicknesses and smaller diameters may be tested using this standard practice if the technique can be demonstrated to provide adequate detection on mockups of the same wall thickness and geometry.

1.5 This standard practice does not address microwave examination of electrofusion joints, socket joints, or saddles.

1.6 This standard details inspection requirement only. Accept/reject criteria must be established contractually and is typically done using multiple samples with mechanical test (that is, tensile test) validation.

1.7 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, 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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

F2620 Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings

F2634 Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints using Tensile-Impact Method

2.2 *ASNT Documents:*[3]

Recommended Practice SNT-TC-1A for Nondestructive Testing Personnel Qualification and Certification

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

2.3 *Military Standard:*[4]

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification

2.4 *AIA Document:*[5]

NAS 410 Certification and Qualification of Nondestructive Testing Personnel

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.10 on Specialized NDT Methods.

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

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

[5] Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, http://www.aia-aerospace.org.

2.5 *Welding Authority Documents:*[6]

AWS G1.10M:2016 Guide for the Evaluation of Thermoplastic Welds

DVS Direction 2202-1 Imperfections in Thermoplastic Welded Joints; Features, Descriptions, Evaluation

2.6 *ISO Standard:*[7]

ISO-9712 Non-destructive Testing – Qualification and Certification of NDT Personnel

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 Related terms are defined in Terminology E1316.

3.1.2 *cell classification, n—for polyethylene pipe resin*, this is a six digit code and letter describing the primary properties that are considered important in the manufacture of PE piping, in the heat fusion joining of this material, and in defining the long-term performance capabilities and color/UV stability. The classification categories are defined in Specification D3350.

3.1.3 *cold fusion, n*—a joint or a region within a joint in which there is little commingling of the polymer chains due to reasons other than contamination.

3.1.4 *dimension ratio (DR), n*—this is the average outside pipe diameter divided by the minimum wall thickness.

3.1.4.1 *Discussion*—The wall thickness increases when the DR decreases.

3.1.4.2 *Discussion*—Standard Dimension Ratio (SDR) is an ANSI term to describe specific DRs in the series, that is, DR9, DR11, DR17, and others.

3.1.5 *E plane, n—in the case of a linearly polarized probe*, this is the plane that contains the electric field and is at a right angle to the H plane.

3.1.6 *H plane, n—in the case of a linearly polarized probe*, this is the plane that contains the magnetic field, and it is at a right angle to the E plane.

3.1.7 *high density polyethylene (HDPE), n*—a tough, flexible, thermoplastic resin made by polymerizing ethylene, having a density range of >0.940 g/cm^3 – 0.965 g/cm^3 per Specification D3350.

3.1.8 *index, n*—the movement of the probe in the circumferential direction at the completion of a scan line, typically in small increments, to position the probe to the start of the next scan.

3.1.9 *material designations, n*—a shortened code to identify the pipe material's short-term and long-term properties.

3.1.9.1 *Discussion*—For polyethylene, the "PE-XXXX" format represents the density (1st digit), slow crack growth resistance (2nd digit), and Hydrostatic Design Stress (HDS, last two digits) where Specification D3350 is the reference.

3.1.10 *medium density polyethylene (MDPE), n*—a tough, flexible, thermoplastic resin made by polymerizing ethylene, having a density range of >0.926 g/cm^3 – 0.940 g/cm^3 per Specification D3350.

3.1.11 *MW transducer, n*—an electronic device that generates an electromagnetic field in the microwave frequency range (1 – 100 GHz) and is equipped with at least one microwave detector that converts the microwave energy into voltage.

3.1.12 *polyethylene butt fusion joint, n*—a joint made by holding the prepared squared ends of two pipes or pipe and fitting against a heated plate per the conditions of a qualified fusion procedure, which allows for the ends to be brought together after forming the proper melt, and then allowing the joint to cool while maintaining the appropriate applied force. It is recommended that fusion procedures comply with Practice F2620.

3.1.13 *probe, n*—a MW transducer with a waveguide or other MW antenna enclosed in a fabricated container used specifically for MW inspection.

3.1.14 *scan, n*—the movement of the probe in a straight line, usually along the long axis of the part being examined, where data is collected.

3.1.15 *standoff, n*—the radial distance from the outside surface of the pipe to be examined to the end of the MW probe that is adjustable to provide proper examination of the joint.

4. Summary of Practice

4.1 This practice provides a general description of the procedures to carry out microwave examination of polyethylene butt fusion joints in piping systems.

4.2 This practice consists of bathing the butt fusion joint in a field of electromagnetic radiation at a specific frequency (or range of frequencies) in the microwave range using a MW Probe. This probe is passed over the butt fusion joint in a controlled technique using a specified scan and index pattern until the entire part or the region of interest has been completely covered. The reflected microwave energy is measured by the transducer along the scan lines and the resulting transducer voltage is recorded along with its position as measured by scan and index coordinates. Upon completion, the voltage and position matrix is displayed by assigning either a false color range or a gray scale range to the voltages.

4.3 The image that is created is interpreted by a user qualified per 6.2 and compared to scans generated from the reference components with the intent to non-destructively assess the overall joint quality.

4.4 Other analysis of the resulting measured voltages may be performed to gain additional information and assessment of the overall joint quality.

4.5 This practice provides a method for routine inspection of butt fusion joints prior to placing them in service as well as for continuing in-service inspections of the joints.

4.6 Examination results from the inspection using this practice may be used in combination with acceptance criteria based on workmanship or fitness for purpose.

[6] Available from IHS, 15 Inverness Way East, Englewood, CO 80112, http://www.global.ihs.com.

[7] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

5. Significance and Use

5.1 Polyethylene piping has been used instead of steel alloys in the petrochemical, power, water, gas distribution, and mining industries due to its resistance to corrosion, erosion, and reliability. Recently, polyethylene pipe has also been used for nuclear safety related cooling water applications.

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 Qualifications:*

6.2.1 Personnel performing examinations to this standard 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, NAS 410, or a similar document. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties. (Note that MW Inspection training requirements are specifically described in SNT-TC-1A.)

6.2.2 Personnel shall be certified by the employer or certifying agency, as applicable.

NOTE 3—MIL-STD-410 is canceled and has been replaced with NAS 410; however, it may be used with agreement between contracting parties.

6.3 *Qualification of Nondestructive Agencies:*

6.3.1 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 Technique*—The procedures and techniques to be used shall be as specified in the contractual agreement. It shall include at least the following information:

6.4.1 Type, dimensions, location, method of manufacture, and number of artificial flaws to be placed in the reference components.

6.4.2 Method(s) for measuring dimensions of artificial flaws in the reference components and tolerance limits if different than specified in Section 10.

6.5 *Scope of Examination*—The scope of the examination as defined in the report shall include these defined items:

6.5.1 Size and type of butt fusion joint to be examined.

6.5.2 Number or percentage of joints to be examined.

6.5.3 The stage(s) in the manufacturing process at which the joints will be examined.

6.5.4 The surface condition of the inspected area.

6.6 *Reporting Criteria*—Reporting criteria for the examination results shall be in accordance with Section 15 unless otherwise specified. It shall include at least the following information:

6.6.1 Requirements for permanent records of the response from each joint, if applicable.

6.6.2 Contents of examination report.

6.7 *Repaired/Reworked Items*—Re-examination of repaired/reworked items is not addressed in this standard and if required or permitted, shall be specified in the contractual agreement.

7. Surface Preparation

7.1 All inspection surfaces shall be clean and free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of examination results. The methods used for cleaning and preparing the surfaces for microwave examination shall not be detrimental to the base material or the surface finish. Excessive surface roughness or scratches can produce signals that interfere with the examination.

7.2 **Warning—**Do not use mechanical devices (such as flapper wheels, grinders, sanders, etc.) to clean PE welds or any part to be inspected. This action renders the part unacceptable for inspection.

7.3 Surfaces should be smooth and free of any deep grooves, gouges, dents, or other surface geometry that may adversely impact the inspection. Surface flaws of sufficient size and/or depth that they appear in the scan image shall be noted in the inspection report as “surface flaw.” The parties using or referencing this standard shall determine if the flaws are of sufficient depth to render the part unacceptable.

8. Apparatus

8.1 A MW transducer with a single frequency, or a frequency range if a swept frequency device is used, shall be used for this examination. The frequency or frequency range selected shall be shown to be capable of detecting the reference flaws of the types described in Section 10 to the extent required in the standardization and procedure qualification described in Sections 11 and 12.

8.2 The transducer shall be mounted in a probe assembly and shall be capable of detecting the reference flaws of the types described in Section 10 to the extent required in the standardization and procedure qualification described in Sections 11 and 12.

8.3 The stand-off and orientation (that is, E or H Field) of the probe shall be capable of being adjusted to produce a satisfactory signal-to-noise ratio (S/N) for the detection of the required flaws as compared to background “noise” response from irregularities such as surface roughness and agglomerates of carbon black particles used for UV protection in the polyethylene or other processing flaws.

8.4 The final configuration of the probe and equipment shall be selected to produce a desirable S/N for the inspection. For example, the minimum value for the S/N for the smallest flaw in the reference pipe described in 10.4 should be at least 1.5. A higher minimum value is desirable and may be specified by the contracting agency.

8.5 The equipment is set up such that the scan direction is axial to the pipe and the index is in the circumferential direction. Select a scan speed and index that provides a reasonable total scan time without sacrificing S/N quality. Typically, a 0.1 in. (2.5 mm) index is chosen and a maximum index is considered to be 0.25 in. (6.4 mm).

8.6 Encoder positional information is calibrated and verified in both the circumferential and axial directions from a reference start position and shall be accurate to within 1 % of the total scan length or 0.4 in. (10 mm), whichever is less.