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Standard Practice for Guided Wave Testing of Above Ground Steel Piping with Magnetostrictive Transduction[1]

This standard is issued under the fixed designation E2929; 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 provides a guide for the use of waves generated using magnetostrictive transduction for guided wave testing (GWT) welded tubulars. Magnetostrictive materials transduce or convert time varying magnetic fields into mechanical energy. As a magnetostrictive material is magnetized, it strains. Conversely, if an external force produces a strain in a magnetostrictive material, the material's magnetic state will change. This bi-directional coupling between the magnetic and mechanical states of a magnetostrictive material provides a transduction capability that can be used for both actuation and sensing devices.

1.2 GWT utilizes ultrasonic guided waves in the 10 to approximately 250 kHz range, sent in the axial direction of the pipe, to non-destructively test pipes for discontinuities or other features by detecting changes in the cross-section or stiffness of the pipe, or both.

1.3 GWT is a screening tool. The method does not provide a direct measurement of wall thickness or the exact dimensions of discontinuities. However, an estimate of the severity of the discontinuity can be obtained.

1.4 This practice is intended for use with tubular carbon steel products having nominal pipe size (NPS) 2 to 48 corresponding to 60.3 to 1219.2 mm (2.375 to 48 in.) outer diameter, and wall thickness between 3.81 and 25.4 mm (0.15 and 1 in.).

1.5 This practice only applies to GWT of basic pipe configuration. This includes pipes that are straight, constructed of a single pipe size and schedules, fully accessible at the test location, jointed by girth welds, supported by simple contact supports and free of internal, or external coatings, or both; the pipe may be insulated or painted.

1.6 This practice provides a general practice for performing the examination. The interpretation of the guided wave data obtained is complex and training is required to properly perform data interpretation.

1.7 This practice does not establish an acceptance criterion. Specific acceptance criteria shall be specified in the contractual agreement by the cognizant engineer.

1.8 *Units*—The values stated in SI 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.

1.9 *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.*

1.10 *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]

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

IEEE/SI-10 American National Standard for Metric Practice

2.2 *Other Standards:*[3]

SNT-TC-1A Personnel Qualification and Certification in Non-Destructive Testing

3. Terminology

3.1 Definitions of terms specific to this standard are provided in this section. Some common terms such as *defect* may be referenced to Terminology E1316.

[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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *circumferential extent*—the length of a discontinuity in the circumferential direction, usually given as a percentage of the pipe circumference.

3.2.2 *circumferential orientation*—the circumferential position of a localized indication on the pipe, usually given as the clock position or degrees from the top circumferential position of the pipe.

3.2.3 *coherent noise*—indications caused by real discontinuities causing a background noise, which exponentially decays with distance (see Terminology E1316).

3.2.4 *cross-sectional area change (CSC)*—the change in the circumferential cross-section of pipe from its nominal total cross-section, usually given in percentage.

3.2.5 *dead zone*—this is an area that can be up to 1 m (3 ft) long on either side of the transducer ring that is not inspected during the testing. The area of the dead zone is a function of the excitation frequency and the number of cycles transmitted. The area is inversely related to frequency and directly related to the number of cycles.

3.2.6 *estimated cross-sectional loss (ECL)*—this is sometimes used instead of Cross-Sectional Area Change, where the feature is related to a defect.

3.2.7 *flexural wave*—wave propagation mode that produces bending motion in the pipe.

3.2.8 *guided wave (GW)*—stress waves travelling in a structure bounded in the geometry and configuration of the structure.

3.2.9 *guided wave testing (GWT)*—non-destructive test method that utilizes guided waves.

3.2.10 *incoherent noise*—random signals caused by electrical and ambient radio frequency signal pollution, giving rise to a constant average noise floor. The terms "Ambient Noise" and "Random Noise" are also used.

3.2.11 *pipe feature*—pipe components including but not limited to weld, support, flange, bend, and flaw (defect) cause reflections of a guided wave due to a change in geometry.

3.2.12 *reflection amplitude*—the amplitude of the reflection signal typically reported as CSC or reflection coefficient.

3.2.13 *reflection coefficient*—a parameter that represents the amplitude of reflected signal from a pipe feature with respect to the incident wave amplitude, usually expressed in percentage and called "% reflection." Used in lieu of CSC to characterize the severity of indications.

3.2.14 *shear wave couplant*—couplant designed specifically to effectively couple directly generated shear waves (waves not generated through refraction of longitudinal waves).

3.2.15 *signal to noise ratio (SNR)*—ratio of the amplitude of any signal of interest to the amplitude of the average background noise which includes both coherent and non-coherent types of noise.

3.2.16 *test location*—location where the transduction device is placed on the pipe for inspection.

3.2.17 *time controlled gain (TCG)*—gain applied to the signal as a function of time or distance from the initial pulse used to compensate wave attenuation in the pipeline. The TCG normalizes the amplitude over the entire time scale displayed. For example, using TCG, a 5 % reflector near the probe has the same amplitude as a 5 % reflector at the end of the time display. The TCG plot can be used in lieu of DAC curve plot.

3.2.18 *torsional wave*—wave propagation mode that produces twisting motion in the pipe.

3.2.19 *transduction device*—a device used to produce and detect guided waves. It is commonly called "guided wave probe."

3.2.20 *wave mode*—a particular form of propagating wave motion generated into a pipe, such as flexural, torsional or longitudinal.

4. Summary of Practice

4.1 GWT evaluates the condition of metal pipes to primarily establish the severity classification of defects by applying GW over a typical test frequency range from 10 to approximately 250 kHz which travels along the pipe. Reflections are generated by the change in cross-sectional area or local stiffness of the pipe, or both.

4.2 The transduction device attached around the pipe generates guided waves that travel in the pipe wall. The direction of wave propagation is controlled or can be in both directions simultaneously. These guided waves can evaluate long lengths of pipe and are especially useful when access to the pipe is limited.

4.3 This examination locates areas of thickness reduction(s) and provides a severity classification as to the extent of that damage. The results are used to assess the condition of the pipe, to determine where damaged areas are located along the length of the pipe, and their circumferential position on the pipe (when segmented transmitters or receivers, or both, are used). The information can be used to program and prioritize additional inspection work and repairs.

4.4 Reflections produced by pipe features (such as circumferential welds, elbows, welded supports, vents, drainage, insulation lugs, and other welded attachments) and that are not associated with areas containing possible defects are considered as relevant signals and can be used for setting GW system defect detection sensitivity levels and time calibration.

4.5 Other sources of reflection may include changes in surface impedance of the pipe (such as pipe supports and clamps). These reflections are normally not relevant, but should be analyzed and classified in an interpretation process. In the advanced applications which are not covered by this practice, these changes may also include various types of external/internal coatings, entrance of the pipe to ground, or concrete wall.

4.6 Inspection of the pipe section immediately connecting to branch connections, bends or flanges are considered advance applications which are not covered by this practice.

4.7 False indications are produced by phenomena such as reverberations, incomplete control of wave propagation direction, distortion at elbows, and others. These signals should be analyzed and classified as false echoes in the interpretation process.

5. Significance and Use

5.1 The purpose of this practice is to outline a procedure for using GWT to locate areas in metal pipes in which wall loss has occurred due to corrosion or erosion.

5.2 GWT does not provide a direct measurement of wall thickness, but is sensitive to a combination of the CSC (or reflection *coefficient*) and circumferential extent and axial extent of any metal loss. Based on this information, a classification of the severity can be assigned.

5.3 The GWT method provides a screening tool to quickly identify any discontinuity along the pipe. Where a possible defect is found, a follow-up inspection of suspected areas with ultrasonic testing or other NDT methods is normally required to obtain detailed thickness information, nature, and extent of damage.

5.4 GWT also provides some information on the axial length of a discontinuity, provided that the axial length is longer than roughly a quarter of the wavelength.

5.5 The identification and severity assessment of any possible defects is qualitative only. An interpretation process to differentiate between relevant and non-relevant signals is necessary.

5.6 This practice only covers the application specified in the scope. The GWT method has the capability and can be used for applications where the pipe is insulated, buried, in road crossings, and where access is limited.

5.7 GWT shall be performed by qualified and certified personnel, as specified in the contract or purchase order. Qualifications shall include training specific to the use of the equipment employed, interpretation of the test results, and guided wave technology.

5.8 A documented program which includes training, examination, and experience for the GWT personnel certification shall be maintained by the supplying party.

6. Basis of Application

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

6.2 *Personnel Qualifications*—Unless otherwise specified in the contractual agreement, personnel performing examinations to this practice shall be qualified in accordance with one of the following:

6.2.1 Personnel performing examinations to this practice shall be qualified in accordance with SNT-TC-1A and certified by the employer or certifying agency, as applicable. Other equivalent qualification documents may be used when specified in the contract or purchase order. The applicable revision shall be the latest unless otherwise specified in the contractual agreement between parties.

6.2.2 Personnel qualification accredited by the GWT equipment manufacturers.

6.3 This practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.4 *Qualifications of Non-destructive Testing Agencies*—Unless otherwise specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Specification E543, and the applicable edition of Specification E543 shall be specified in the contractual agreement.

6.5 *Procedure and Techniques*—The procedures and techniques to be utilized shall be specified in the contractual agreement. It should include the scope of the inspection, that is, the overall NDT examination intended to identify and estimate the size of any indications detected by the examination, or simply locate and provide a relative severity classification.

6.6 *Surface Preparation*—The pre-examination site preparation criteria shall be in accordance with 8.3 unless otherwise specified.

6.7 *Required Interval of Examination*—The required interval or the system time in service of the examination shall be specified in the contractual agreement.

6.8 *Extent of the Examination*—The extent of the examination shall be in accordance with 6.5 above unless otherwise specified. The extent should include but is not limited to:

6.8.1 The sizes and length(s) of pipes to be inspected.

6.8.2 Limitations of the method in the areas of application.

6.8.3 Drawings of pipe circuits, pipe nomenclature and identification of examination locations.

6.8.4 Pipe access method(s).

6.8.5 Safety requirements.

6.9 *Reporting Criteria*—The test results of the examination shall be documented in accordance with the contractual agreement. This may include requirements for permanent records of the collected data and test reports. The report documentation should include:

6.9.1 Equipment inspector and test results reviewed by (if applicable).

6.9.2 Date and time of the examination performed.

6.9.3 Equipment used.

6.9.4 Test procedure/specification used.

6.9.5 Acceptance criteria.

6.9.6 Inspection location.

6.9.7 Identification of areas inspected.

6.9.8 Identification of the inspection range.

6.9.9 Any other information deemed necessary to reproduce or duplicate test results.

6.10 *Reexamination of Repairs/Rework Items*—Examination of repaired/reworked items is not addressed in this practice and, if required, shall be specified in the contractual agreement.

7. Apparatus

7.1 The GWT apparatus shall include the following:

7.1.1 *Transduction Device Transmitter*—A transduction system using the magnetostrictive effect for the generation of guided wave modes with axial propagation on cylindrical pipes.