



Designation: **E2929–13** ~~E2929 – 18~~

Standard Practice for Guided Wave Testing of Above Ground Steel Piping with Magnetostrictive Transduction¹

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 ~~technology~~ 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.~~ 48 in.) outer diameter, and wall thickness between 3.81 and 25.4 mm (0.15 and ~~1 in.~~ 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. ~~No other units of measurement are included in this~~ 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~~ safety, health, and ~~health~~ 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

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.

[E1065 Practice for Evaluating Characteristics of Ultrasonic Search Units](#)

[E1316 Terminology for Nondestructive Examinations](#)

[E1324 Guide for Measuring Some Electronic Characteristics of Ultrasonic Testing Instruments](#)

[E2775 Practice for Guided Wave Testing of Above Ground Steel Pipework Using Piezoelectric Effect Transduction](#)

[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](#).

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 *reflector orientation*—the circumferential position of the feature on the pipe. This is reported as the clock position or degrees with regards to the orientation of the transduction device.

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.

³ Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlington Ln., Columbus, OH 43228-0518, <http://www.asnt.org>

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.

7.1.2 *Transduction Device Receiver*—A system for the detection of the signal reflected by the geometric features on the pipe, which can be the same as the transmitter or an analogous transduction system.

7.1.3 *Instrumentation*—The GWT instrumentation shall be capable of generating, receiving and amplifying electrical pulses within the frequency range used by GWT. Additionally, it shall be capable of communicating with a computer so that collected data can be processed and recorded.

7.1.4 *Processing System*—This is a software interface for processing and analyzing the signal, capable of distinguishing at least one guided wave mode for the specific detection system.

8. Examination Procedure

8.1 It is important to ensure that the proposed inspection falls within the capabilities of the technology and equipment and that the using party or parties understand the capabilities and limitations as it applies to their inspection.

8.2 *Pre-examination Preparation:*

8.2.1 All test equipment shall have current and valid calibration certificates.

8.2.2 Follow the equipment manufacturer's recommendations with regard to equipment pre-test verification and check list. As a minimum this check list should include but is not limited to:

8.2.2.1 Electronics fully operational.

8.2.2.2 Verification that interconnection cables are in good condition and functioning correctly.

8.2.2.3 Correct transduction device size for the intended pipes.

8.2.2.4 The transduction device is functioning correctly.

8.2.2.5 Any computer used with the system is functioning correctly and has sufficient storage capacity for the intended work scope.

8.2.2.6 Supplementary equipment, such as an ultrasonic flaw detector or specialized pit gauges are available and functioning correctly.

8.2.2.7 All necessary accessories such as tape-measure and markers are available.

8.2.3 Ensure all site safety requirements and procedures are reviewed and understood prior to starting any field work.

8.3 *Examination Site Preparation:*

8.3.1 *Pipe Surface Condition*—To obtain the best coupling condition, the surface shall be clean and free of any loose paint, dirt, oxidation, or any foreign substance that may interfere in energy transmission. Wire brushing or sanding, or both, are usually sufficient to prepare the surface if it is safe and permitted to do so.

8.3.2 *Insulation*—If the pipe is insulated, carefully remove an amount of insulation for mounting the magnetostrictive transduction device to the pipe (a minimum of 0.3 m (1 ft)). Prior to removing the insulating material ensure it is safe and permissible to do so.

8.3.3 GWT is most effective for testing long lengths of pipe. However, short radius elbows distort GWT signals, making interpretation of signals obtained at distances beyond the elbow difficult. Where possible, it is good practice to exclude from evaluation sections of pipe immediately after elbows. In any case, no signals after two elbows should be analyzed. It is sometimes better to take additional data at different locations than interpreting a signal beyond multiple features or those with complicated geometries. Consider taking a second reading at a second test location (as recommended by the manufacturer) for confirmation of features and false echo identification.

8.3.4 *Visual Inspection*—Visually inspect the pipe where possible for potential damage areas or corrosion, such as the support areas, if possible defect indications are found in the GWT result.

8.3.5 *Surface Temperature*—Verify that the surface temperature of the pipe to be tested is within the manufacturer's specifications for the equipment.

8.3.6 *Thickness Check*—Before mounting the transduction device, verify that there is no degradation in the pipe wall thickness at the test location. As a minimum requirement, thickness measurements at no less than four equally spaced positions around the pipe should be made using an appropriate thickness measuring instrument and procedure. Some agencies may also require thickness measurement of the entire dead zone. It is important to note that attaching the transduction device at locations with very severe corrosion may cause further damage to the pipe if a mechanical force system is used for coupling.

8.4 *Transduction Device*—The transduction device should be attached to the pipe using proper coupling methods.

8.5 *Couplant*—Good coupling is obtained by simply applying sufficient mechanical force on the transduction device or by the use of epoxy bonding or shear wave couplant on the transduction device in lieu of mechanical force devices.

8.6 *Choosing Test Location*—After completing the examination site preparation outlined in 8.3, attach the transduction device to the pipe. The test location should be chosen so as to minimize false echoes. Avoid placing the transduction device near a feature as the corresponding signal may appear within the dead zone. In the dead zone, no echoes are received, as a practice, a minimum of 0.13 m (0.4 ft) should be used to the first area of inspection. Features such as welds which are used for the DAC curves or TCG correction fitting, should be outside the dead zone to ensure valid amplitude. Additionally, transduction devices should not be positioned equidistant between two features to avoid masking of the mirror echoes, if any.

8.7 *Attaching the Transduction Device*—When attaching the transduction device, it is important to ensure that the FeCo flat strip is in good contact with the pipe and that the transduction device is mounted parallel to the circumference of the pipe. Further, it is important to apply the appropriate air pressure, clamp torque settings (if dry coupling is used), or bonding or shear wave couplant as specified in the manufacturer's operating manual for proper installation of the transduction device.

8.8 *Directionality and Orientation*—The reported directionality and orientation of the features depend on the way the transduction device is installed. It is good practice to keep the direction between different test locations the same, and in the direction of product flow if known. To ensure the correct orientation is reported, a segmented transduction device should be attached in accordance with the GWT manufacturer's recommendations.

8.9 *Reproducibility*—The examination pipe should be marked with a paint marker indicating the transduction device position, direction, and date of examination. This can assist, should it be necessary, to reproduce the examination in the future. This information should also be included in the examination documentation.

8.10 *Test Location Information*—The following amount of information about the test location is needed in the processing software to ensure the exact location can be identified. This information to be recorded shall include the following:

8.10.1 *Site Name*—The name of the site, which may include the plant name, plant unit number, approximate mile marker or any relevant reference if available.

8.10.2 *Pipe*—The pipe identification if available. If not, the pipe diameter should be recorded.

8.10.3 *Datum*—The reference feature from which the test location is measured. Typical reference features used are welds and flanges.

8.10.4 *Distance*—The distance between the datum and the center of the transduction device shall be recorded. It is also important to include both positive and negative signs in front of the distance value for positive and negative direction of the ring respectively.

8.11 *Coupling Check*—It is important that all transduction devices are well coupled to the pipe. Prior to collecting any test data, perform a coupling test in accordance with the manufacturer’s guidelines.

8.12 *Examination Precautions*—There are several precautions that need to be addressed when analyzing the collected data. These include:

8.12.1 *Dead Zone*—The length 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. In order to get a 100 % coverage of the pipe there are two options:

8.12.1.1 Inspection of the dead zone with an alternative NDT method such as ultrasonic testing.

8.12.1.2 Collect additional data from another test location that provides an overlap of the previous test location. Some agencies require a 20 % overlap on all data collected where possible.

8.12.2 *Expected Examination Range*—There are several physical test conditions on or around the pipe which affect the maximum examination range that can be achieved (see [Appendix X1](#) for more detail). There are also equipment parameters such as frequency and gain settings, which can be varied so as to optimize the test parameters for specific test conditions on or around the pipe. The maximum inspection range is defined in [8.18](#).

8.12.3 *False Echo (False Signals)*—Signals other than from a real feature. Care should be taken to minimize the potential for false signals to interfere with the interpretation of the data. The most common sources of false echoes are:

8.12.3.1 *Reverberations*—Multiple reflections either between two large features along the pipe, or between the two ends of a long feature. Echoes caused by reverberations typically have small amplitudes.

8.12.3.2 *Mirrors*—Occurs due to insufficient control of the propagation direction of the guided wave. The mirror echo appears at the same distance from transduction device, but the opposite direction, as the real reflection.

8.12.3.3 *Modal Noise*—Occurs when the transduction device is unable to control all the wave modes propagating in the pipe. Even though the magnetostrictive transduction device generates mostly torsional waves, reflectors in the pipe can generate various guided wave modes; therefore, some modal noise exists in the received waveform.

8.13 *Collection Protocol*—The collection protocol varies certain collection parameters to optimize the data quality based on the pipe diameter and the expected mechanism(s) on and around the pipe. Most manufacturers include a procedure for determining the optimum collection parameters automatically for a specific test condition. These collection parameters include:

8.13.1 *Frequency*—GWT is typically performed at frequencies between approximately 10 and 250 kHz. When performing a test, data should be collected with enough different frequencies so as to be able to categorize each indication.

8.13.2 *Bandwidth*—Changing the signal bandwidth can assist in resolving the attributes of a signal. A narrow bandwidth enhances the frequency dependency of a signal while a wider frequency bandwidth can improve the axial resolution of signals such as closely spaced reflections.

8.13.3 *Wave Mode*—The GWT uses an axi-symmetric wave mode excitation which generates a torsional wave mode.

8.14 *Data Collection*—After installing the transduction device and performing the coupling check, the next step of the examination procedure is data collection. It is important that the data recorded are sufficient and comprehensive to evaluate and interpret any signals which may be present on the pipes. Choose the most appropriate collection protocol (see [8.13](#)) and collection range to perform the initial data collection as per the equipment manufacturer’s guidelines. Immediately after the data collection, it is important to review the collected data to ensure proper operation of the equipment during the test and the quality meets the required standard. The data review should include an evaluation of the SNR and the transducer balance. Poor SNR is usually caused by poor coupling of the magnetostrictive transduction device, poor magnetic conditioning of the magnetostrictive strip material, or high incoherent noise. Should there be any significant problems observed in the data, the data should be discarded and the problem addressed.

8.15 *Distance Amplitude Correction (DAC) or Time Corrected Gain (TCG)*—As the excitation signal travels away from the transduction device, its signal amplitude decreases. There are several reasons for the energy loss, including material damping, reflections at features, energy leakage, and surface conditions. The DAC or TCG provides the ability to determine the signal amplitude at a point away from the transduction device. This allows for determining the relative amplitude of an echo, expressed in either CSC, ECL, or reflection coefficient, at a given distance. When using the magnetostrictive transduction guided wave technology, DAC or TCG gain compensation can be used. When the DAC curve is used, a curve representing the attenuation as a function of distance for a given reflection amplitude is displayed on the waveform screen. When TCG is used, the gain of the unit is corrected so that a given amplitude reflector has the same amplitude across the entire length of the exam, removing the effect of attenuation on the displayed amplitude. If the DAC curves are set too low or the TCG is applied incorrectly, the size of possible defects may be overestimated or underestimated, and vice versa. Therefore, it is vital that the DAC levels or the TCG, or both, are set correctly before interpreting the data as they provide reference CSC or reflection coefficient levels to all other signals for comparison. There are four DAC curves or TCG settings that can be used in evaluating GWT reflections. Most systems provide