



# Standard Practice for Guided Wave Testing of Above Ground Steel Piping with Magnetostrictive Transduction<sup>1</sup>

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 ( $\epsilon$ ) 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.) 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. No other units of measurement are included in this 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 and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards*:<sup>2</sup>

[E543 Specification for Agencies Performing Nondestructive Testing](#)

[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*:<sup>3</sup>

[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:*

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

<sup>1</sup> 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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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.

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

3.2.16 *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.

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

3.2.18 *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.

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

3.2.20 *transduction device*—a device used to produce and detect guided waves. It is commonly called “guided wave probe.”

3.2.21 *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.

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 inspectors the means of manually adjusting these curves. (Fig. 1 shows data with the DAC and TCG applied and Fig. 2 illustrates a signal with a DAC curve showing coherent and incoherent noise).

8.15.1 *Flange DAC or TCG Setting*—This is a DAC curve or TCG setting that represents the expected amplitude of a reflection from a large feature which reflects approximately a 100 % (that is, 0 dB) of the amplitude of the excitation signal and no energy can therefore pass through.

8.15.2 *Weld DAC or TCG Setting*—Pipe girth welds typically present 10 to 35 % CSC. The amount of energy reflected at the weld is the reason why the maximum number of pipe joints that can be inspected is limited.

8.15.3 *Call DAC or threshold after application of TCG*—This is the typical threshold level that is used to determine the severity of a defect if found.

8.16 *Ambient Noise*—Ambient noise causes an increase in the overall incoherent noise level. Special precautions should be taken when ambient noise is higher than normal. Most equipment manufacturers offer special protocols to test in high ambient noise areas.

8.17 *Detection Threshold (DT)*—The DT of an examination is equivalent to the sensitivity, and it is typically set to 6 dB above the background noise but it can also be manually set by the inspectors.

8.18 *Inspection Range*—The section of pipe between the transduction device and the end of test in one direction where the sensitivity is greater than the Call level (see 8.15.3). Depending on the coverage requirements, this inspection range is often used to determine the subsequent test locations. As the attenuation varies with frequency, the inspection range is normally specified for a particular frequency. The inspection range is also limited by the presence of a flange, or any feature that is not within the scope of the standard.

8.19 *Distance Standardization*—The acoustic properties of different grades of steel varies slightly, causing an offset in the reported distance of the features. The software typically uses the acoustic properties of carbon steel. In most cases, the distance offset is very small, and therefore, it is not necessary to perform distance standardization. However, where the pipe material is not carbon steel, it is good practice to standardize distance in the software against a physical measurement prior to analyzing the data. Some systems have the ability to calibrate the velocity of the material based on known locations of weld or flanges.

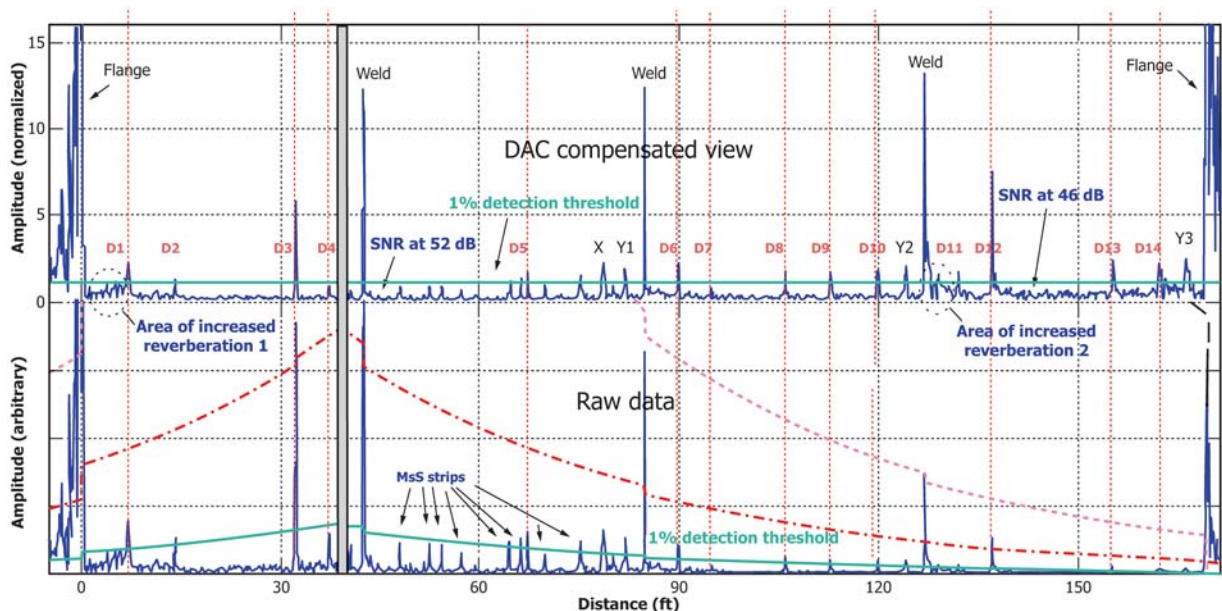


FIG. 1 Comparison of TCG data plot (Top) and its DAC curve plot (Bottom) using magnetostrictive transduction (Both results are displayed in the linear amplitude scale)

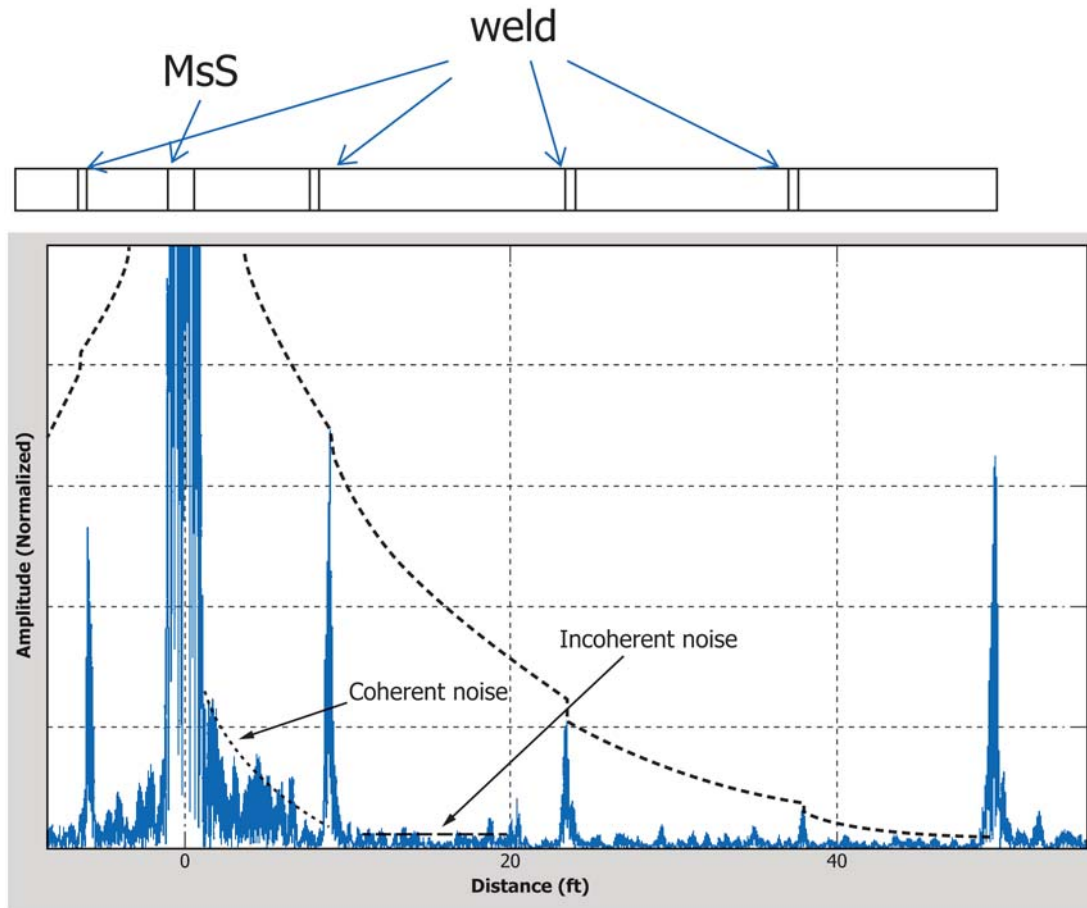


FIG. 2 MsS data plot showing a DAC curve and signals from welds and coherent and incoherent noise

8.20 Data Review—The initial review of the data is to separate data into relevant, non-relevant signals and indications. Data review is a process that each specific GWT system manufacturer provides detailed training in how to use their data review or data analysis software.

8.20.1 Signal Interpretation—Interpretation of GWT signals is the difficult part of this method. A number of tools are available to help analyzing and distinguishing signals between various features, and these tools include:

8.20.1.1 Shape of Reflected Signal—The shape provides information on the axial length of a feature. An irregular reflection is typically associated with a feature that extends along the pipe such as a corrosion patch, whereas a short uniform reflection would indicate a short reflector such as a weld.

8.20.1.2 Amplitude—The signal amplitude is indicated by the relative signal amplitude of the axi-symmetric wave, in terms of CSC or reflection coefficient. The shape of the signal also affects the amplitude to some extent because of the interference of reflections and scattering within the discontinuity boundaries. For a defect, the amplitude correlates to the percentage of cross-section loss of the defect at that particular position.

8.20.1.3 Behavior at Different Frequencies—Additional information can be obtained by observing the signal response of certain features at different frequencies. The amplitude and the

shape of the signal for an axially short feature, such as welds, remain unchanged as the frequency is changed. However, if the axial length is long, such as a corrosion patch, multiple signals are generated within the feature, causing interference that changes with frequencies; therefore, both amplitude and shape typically change with frequencies for axially long features. Additionally, the amplitude of features causing a change in stiffness, such as contact supports, is also generally frequency dependent.

8.20.1.4 Phase—As the signal amplitude can be caused by either an increase or a decrease in CSC, the phase information provides a way to determine the difference between them. For example, a weld which is an increase in CSC would have a different phase to that of a defect, which is a decrease in CSC. When evaluating the change in phase with respect to other reflectors, the intent is not to determine the actual phase of each reflection signal but instead determine which of the reflectors can be grouped into similar responses. The phase information is only accurate when the SNR is good, therefore, this tool is not normally used alone.

8.20.1.5 Attenuation Changes—When there is a change on the expected attenuation pattern, it indicates there is a change in the pipe condition. Be it caused by general corrosion or internal deposit, further investigation is usually required to determine the source.



8.20.1.6 *DAC and TCG Fittings*—The DAC curves and TCG are set typically using at least two reference reflectors, as shown in Fig. 2, commonly welds or features with a known approximately CSC or reflection coefficient value. For this reason, it is imperative to be able to identify the signals corresponding to the reference reflectors either by the signal characteristics or visually. Note that attenuation in GWT is heavily frequency dependent; therefore, DAC curves are usually set at all collected frequencies in the data. An illustration of the DAC fitting can be found in Appendix X2.

8.20.2 *Relevant Signals*—Relevant signals are generated by physical fittings of the pipe, which include, but are not limited to, features such as welds, flanges, valves, elbows, T-pieces, supports, and diameter changes. These features are identified both by the signal characteristics and visually, when possible, as to their positions on the pipe. It is important to correlate the guided wave indications with the visual observations of the pipe. These indications should be noted in the software of the GWT test equipment. See Annex A1 for guidelines in determining reflector characteristics.

8.20.3 *Non-Relevant Indications*—Non-relevant signals are those associated with noise, false echoes and other non-useable information. The following may be used to help identify the non-relevant indications:

8.20.3.1 *Mirrors*—If the system displays a large feature in one direction and a small feature at the equal distance in the opposite direction from the test location, there is a high possibility that the smaller indication is a mirror echo. The most effective way to deal with mirror echoes is to move the transduction device approximately 0.6 m (2 ft) and repeat the test. This causes the mirror echoes to move or disappear as the test position changes.

8.20.3.2 *Reverberations*—This usually occurs when the transduction device is between two larger reflectors. The reverberation echo typically appears as a small indication past the first feature. Most of the GWT systems have software that helps analyze the presence of reverberations. If reverberation is confirmed, move the transduction device to a location outside of the two reverberating features and perform additional examinations to obtain inspection results.

8.20.4 *Indications*—All other indications should be considered unclassified and further analysis should be performed on each one to determine their source and orientation.

8.20.5 *Classification of Data*—For the magnetostrictive transduction system the classification is determined based on the reflection coefficient, and their relationships with the call DAC level. If the call level is set too low, inspectors are likely

to overcall; while if the call level is set too high, inspectors are likely to under-call. It is important that the call level set reflects the detection requirements which should be agreed between parties beforehand.

8.20.6 *Severity Classification Use and Significance*—Assigning a severity classification should be used for reference, classification of indications and setting priorities for follow-up inspection. The categories are usually assigned based on criteria described in 8.20.1.1, as shown in Table 1. It is, therefore, important that the call DAC level percentage or similar detection sensitivity requirement is specified in the contractual agreement which reflects the requirements of the industry. The GWT does not provide information regarding the remaining wall thickness or nature of the damage. This information can only be obtained as a result of follow-up inspection with other NDE methods on the areas where relevant indications associated with defects have been identified. GWT is a method for detection and classification of damage, and their result shall be treated as qualitative only.

## 9. Report

9.1 The test report shall document the results of the inspection. It must have all information to be able to reproduce the test at a future date if desired. Most, if not all, of the items detailed in 8.10 should be included. Additionally, all observations obtained from visual inspection, thickness measurements with UT, and other pertinent information that is deemed as having an effect on the quality, or characteristics, or both, of the data or results should be recorded and included in the final report. All relevant and non-relevant indications identified during the examination should be included with a classification provided those reflections deemed to be associated with defects. All results from follow-up inspection with other NDE methods shall be included in the report if available.

## 10. Keywords

10.1 guided wave testing; guided waves; magnetostrictive transduction; NDT of pipes; pipeline inspection

**TABLE 1 Severity Classification of Indications Observed with the Guided Waves Generated Using Magnetostrictive Transduction**

Assuming the noise floor is approximately 2 % CSC		
Minor indication is 2-4 % CSC	Medium indication is 5-10 % CSC	Major indication > 10 % CSC
Assuming the noise floor is greater than 2 % CSC		
Minor indication cannot be identified	Medium indication is 5-10 % CSC	Major indication > 10 % CSC



ANNEX

(Mandatory Information)

A1. REFLECTOR CHARACTERISTICS

A1.1 See [Table A1.1](#).

TABLE A1.1 Reflector Characteristics

Feature	Visual	Amplitude	Shape	Frequency	Symmetry	Phase	Orientation
Flange	Likely visible	Typically the highest	Irregular	Inconsistent	Symmetric	N/A	Fully circumferential
Weld	May be visible if not insulated	Medium	Clean, uniform, single echo	Consistent across wide range	Symmetric	Same as all welds	Fully circumferential
Elbow	Likely visible	Medium	1st Weld: Clean, uniform 2nd Weld: Mostly uniform	1st Weld: Consistent 2nd Weld: Inconsistent	1st Weld: Symmetric 2nd Weld: Non-symmetric	N/A	1st Weld: Fully circumferential 2nd Weld: Depending on elbow direction
Valve/Drain	Likely visible	Medium	Small size: Uniform Large size: Irregular	Small size: Consistent Large size: Inconsistent	Non-symmetric	N/A	Either top or bottom of the pipe
T-piece	Likely visible	Medium	Irregular	Inconsistent	Non-symmetric	N/A	Partial circumferential
Reducer	May be visible if not insulated	Medium	Irregular	Inconsistent	Symmetric	N/A	Fully circumferential
Short contact	Support likely visible	Low	Clean, uniform, single echo	Inconsistent	Non-symmetric	N/A	Bottom
Long contact	Support likely visible	Low	Irregular	Inconsistent	Non-symmetric	N/A	Bottom
Short Clamp support	Likely visible	Medium	Clean, uniform, single echo	Inconsistent	Symmetric	N/A	Fully circumferential
Axial support (welded)	Likely visible	Medium	Irregular	Inconsistent	Non-symmetric	N/A	Bottom
Saddle support	Likely visible	Medium	Irregular	Inconsistent	Non-symmetric	N/A	Bottom

APPENDIXES

(Nonmandatory Information)

X1. ATTENUATION

X1.1 Attenuation is the signal loss as it propagates along a structure. The loss can be caused by a combination of factors—dissipation, mode conversion, scattering due to surface roughness, absorption into other mediums and others. The rate of signal decay is the factor which determines the maximum test range for any given set up.

X1.2 *Attenuation Rate*—Attenuation rate is typically speci-

fied in loss per rate of distance traveled. This would be expressed as dB/m. Occasionally, if different frequencies have significantly different attenuation rates, it may be expressed as either dB/kHz or dB/kHz-m.

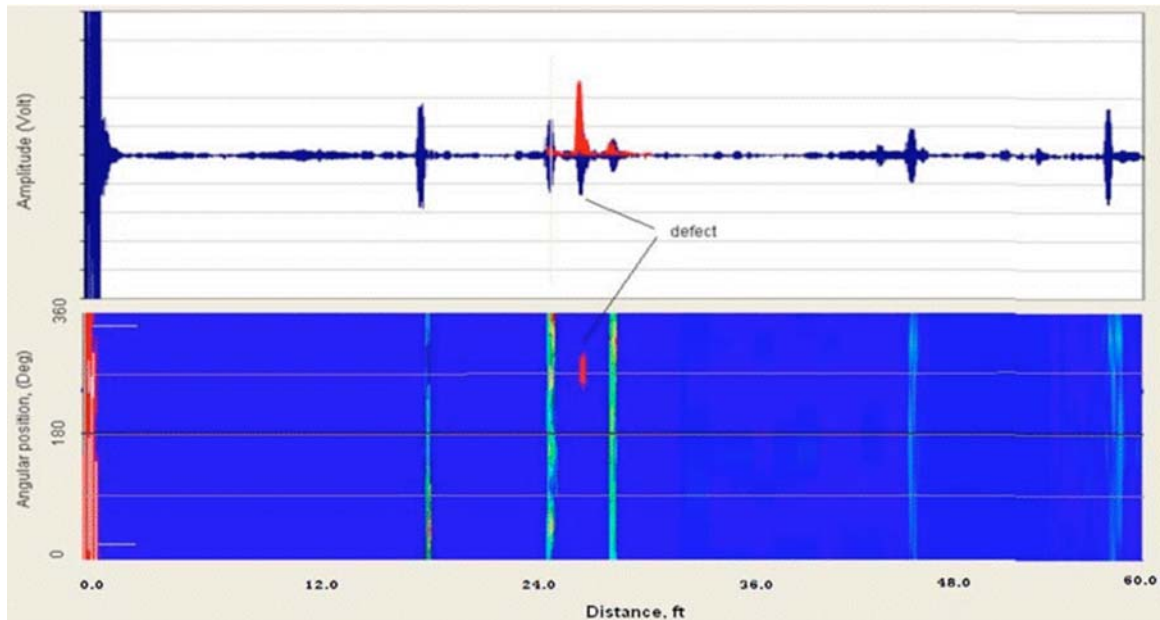
X1.3 Typical attenuation rates and average test range in each direction for different test pipe configurations are found in [Table X1.1](#)

**TABLE X1.1 Typical Attenuation Rates and Average Test Range in Each Direction for Different Test Pipe Configurations**

Test Condition	Typical Attenuation, dB/m (dB/ft)	Typical Range of Test, m (ft)
Clean, Straight Pipe	-0.15 to -0.5 (-0.046 to -0.17)	50 to 200 (164 to 656)
Clean, Wool Insulated	-0.17 to -0.75 (-0.052 to -0.23)	40 to 175 (131 to 574 ft)
Insignificant/Minor Corrosion	-0.5 to -1.5 (-0.152 to -0.457)	20 to 50 (65.6 to 164)
Significant Corrosion	-1 to -2 (-0.305 to -0.61)	15 to 30 (49.2 to 98.4)
Kevlar Wrapped	-0.15 to -1 (-0.046 to -0.305)	30 to 200 (98.4 to 656)
Spun Epoxy Coating	-0.75 to -1 (-0.23 to -0.305)	30 to 50 (98.4 to 164)
Well Packed Earth	-1 to -2 (-0.305 to -0.61)	15 to 30 (49.2 to 98.4)
Thin (<2.5mm), Hard Bitumen Tape	-1.25 to -6 (-0.381 to -1.83)	5 to 25 (16.4 to 82)
Thick (>2.5mm), Soft Bitumen Tape	-4 to -16 (-1.22 to -4.88)	2 to 8 (6.56 to 26.24)
Well Bonded Concrete Wall	-16 to -32 (-4.88 to 9.76)	1 to 2 (3.28 to 6.56)
Grout Lined Pipe	-1 to -3 (-0.305 to 0.91)	10 to 30 (32.8 to 98.4)
Loosely Bonded Concrete Wall	-4 to -16 (-1.22 to -4.88)	2 to 8 (6.56 to 26.24)

**X2. TYPICAL DISPLAY OF THE LINEAR AMPLITUDE VERSUS DISTANCE GWT DISPLAY USING MAGNETOSTRICTIVE TRANSDUCTION WITH SEGMENTED RECEIVERS**

X2.1 See Fig. X2.1



**FIG. X2.1 Typical Display of the Linear Amplitude Versus Distance and B-scan Image for the Magnetostrictive Transduction GWT when Using Segmented Receivers**

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