



Designation: E2775 – 16 (Reapproved 2023)

# Standard Practice for Guided Wave Testing of Above Ground Steel Pipework Using Piezoelectric Effect Transduction<sup>1</sup>

This standard is issued under the fixed designation E2775; 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 procedure for the use of guided wave testing (GWT), also previously known as long range ultrasonic testing (LRUT) or guided wave ultrasonic testing (GWUT).

1.2 GWT utilizes ultrasonic guided waves, sent in the axial direction of the pipe, to non-destructively test pipes for defects 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 defects/defected area; an estimate of the defect severity however can be provided.

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

1.5 This practice covers GWT using piezoelectric transduction technology.

1.6 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.

1.7 This practice provides a general procedure for performing the examination and identifying various aspects of particular importance to ensure valid results, but actual interpretation of the data is excluded.

1.8 This practice does not establish an acceptance criterion. Specific acceptance criteria shall be specified in the contractual agreement by the responsible system user or engineering entity.

<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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1.9 *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.

1.10 *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.*

1.11 *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:*<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](#)

2.2 [Equipment Manufacturer's User's Manual](#)

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

3.1.2 *coherent noise*—indications caused by real discontinuities causing a background noise, which exponentially decays with distance.

3.1.3 *Cross-Sectional Area Change (CSC)*—the CSC is calculated assuming that a reflection is purely caused by a

<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.

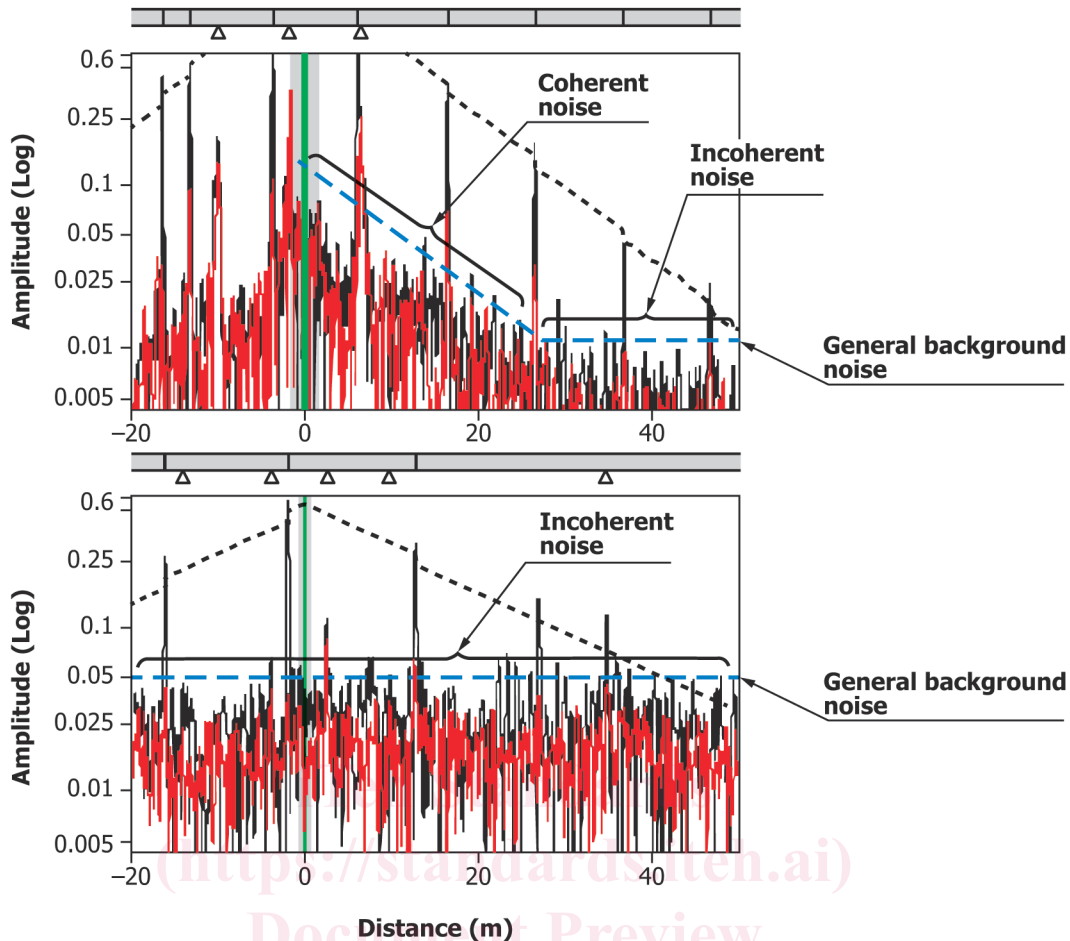


FIG. 1 Typical GWT Results Collected in Normal Environment (Top) and in High Ambient Noise Environment (Bottom). (Both results are displayed in the logarithmic amplitude scale.)

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<https://standards.iteh.ai/catalog/standards/astm/bb23c97d-93a6-4518-b9c6-279a0f5c08a7/astm-e2775-162023>

change in cross-section. It is given as a percentage of the total cross-section. However it is commonly used to report the relative amplitude of any signal regardless of its source.

3.1.4 *Distance Amplitude Correction (DAC) curve*—a reference curve plotted using reference reflections (for example, weld reflections) at different distances from the test position. This curve corrects for attenuation and amplitude drops when estimating the cross-section change from a reflection at a certain distance.

3.1.5 *Estimated Cross-Sectional Loss (ECL)*—this is sometimes used instead of cross-sectional area change, where the feature is related to a flaw.

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

3.1.7 *Guided Wave (GW)*—stress waves whose characteristics are constrained by the system material, geometry and configuration in which the waves are propagating.

3.1.8 *Guided Wave Testing (GWT)*—non-destructive test method that utilizes guided waves.

3.1.9 *longitudinal wave*—wave propagation mode that produces compressional motion in the pipe.

3.1.10 *incoherent noise*—random indications caused by electrical and ambient signal pollution, giving rise to a constant average noise floor. The terms “ambient noise” and “random noise” are also used.

3.1.11 *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.

3.1.12 *reflection amplitude*—the amplitude of the reflection signal typically reported as CSC.

3.1.13 *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 transducer ring.

3.1.14 *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 as defined in Fig. 1.

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

3.1.16 *transducer ring*—a ring array of transducers that is attached around the circumference of the pipe to generate GW. It is also commonly known as the ring.

3.1.17 *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 at a typical test frequency of up to 150 kHz, which travels along the pipe. Reflections are generated by the change in cross-sectional area or stiffness of the pipe, or both.

4.2 A transducer ring attached around the pipe screens the pipe in both directions simultaneously. It can evaluate long lengths of pipe, and is 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 and their circumferential position on the pipe. The information can be used to program and prioritize additional inspection work and repairs.

4.4 Reflections produced by pipe features that are not associated with areas containing possible defects are considered as relevant signals. These features can be used for setting GW system DAC levels and identifying the relative position and distance of discontinuities and areas containing possible defects. Examples of these features are: circumferential welds, elbows, welded supports, vents, drainage, insulation lugs, and other welded attachments.

4.5 Other sources of reflection may include changes in surface impedance of the pipe. These reflections are normally not relevant, but should be analyzed and classified in an interpretation process. Examples of these changes are the presence of pipe supports and clamps. In the advanced applications, which are not covered by this standard, these changes may also include various types of external/internal coatings or 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 standard.

4.7 False echoes are produced by phenomena such as reverberations, incomplete control of 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 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, 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 of the excitation signal.

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 that 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 standard.

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 standard 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 manufacturers.

6.3 The 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, 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 *Re-examination of Repairs/Rework Items*—Examination of repaired/reworked items is not addressed in this standard and if required shall be specified in the contractual agreement.

## 7. Apparatus

7.1 The GWT apparatus shall include the following:

7.1.1 *Transducer Ring Transmitter*—A transduction system using piezoelectric effect for the generation of guided wave modes with axial propagation on cylindrical pipes.

7.1.2 *Transducer Ring 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 Proper charging of batteries.
- 8.2.2.3 Verification that interconnection cables are in good condition and functioning correctly.
- 8.2.2.4 Correct transducer ring size for the intended pipes.
- 8.2.2.5 Sufficient transducer modules (including spares) are available to test the largest diameter pipe in the work scope.
- 8.2.2.6 The transducer ring, modules, and transducers are functioning correctly.

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

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

8.2.2.9 All necessary accessories, such as tape-measure markers, are available.

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

8.2.4 The test equipment shall be calibrated in accordance to the equipment manufacturer's procedure at regular intervals.

### 8.3 *Examination Site Preparation:*

8.3.1 *Pipe Surface Condition*—To obtain best coupling condition, any loose material such as mud, flaking paint and loose corrosion must be removed from the surface of the pipe where the transducer ring is attached. However, well-bonded paint layers of up to 1 mm (0.04 in.) can stay in place. 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 approximately 1 m (3 ft) band of insulation for attaching the transducer ring. 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, tight radius elbows distort GWT signals, making interpretation of signal beyond them 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 to interpret a signal beyond multiple features or those with complicated geometries. Consider taking a second reading 1 m (3 ft) apart 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. Testing at elevated temperatures does not in general affect the performance of the GWT, however caution must be exercised to avoid injuries to personnel. When testing low temperature pipes, ensure that no ice forms between the sensor face and the surface of the pipe.

8.3.6 *Thickness Check*—Before mounting the transducer ring, 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 also require thickness measurement of the entire dead zone and near field. It is important to note that attaching the transducer ring at locations with very severe corrosion may cause further damage to the pipe.

8.4 *Transducer Ring*—The type of ring, the transducer orientation and their spacing can vary depending on the type of collection protocol. Refer to 8.13 when selecting the transducer ring assembly for the type of examination to be performed.

8.5 *Couplant*—Couplant is generally not required for this method. GWT utilizes relatively low frequency compared to those used in conventional UT, typically in the regions of tens of kilohertz (kHz) as opposed to megahertz (MHz). At these frequencies, good coupling is obtained by simply applying sufficient mechanical force on the transducer ring.

8.6 *Choosing Test Location*—After completing the examination site preparation outlined in 8.3, attach the transducer ring to the pipe. The test location should be chosen so as to minimize false echoes. Avoid placing the ring near a feature as the corresponding signal may appear within the near field or the dead zone. In the dead zone, no echoes are received, and in the near field, the amplitude of the echoes is typically lower than normal. As a practice, a minimum of 1.5 m (5 ft) should be used to the first area of inspection. Features such as welds, which are used for the DAC curves fitting, should be outside the near field to ensure valid amplitude. Additionally, transducer rings should not be positioned equidistant between two features to avoid masking of the mirror echoes if any.

8.7 *Attaching the Transducer Ring*—When attaching the transducer ring it is important to ensure that all transducers are in good contact with the pipe and that the ring is mounted parallel to the circumference of the pipe. Apply the appropriate air pressure or clamp torque settings as specified in the manufacturer’s operating manual for proper installation of the transducer ring. Any pressure gauge or torque meter used shall be checked regularly for correct functionality.

8.8 *Directionality and Orientation*—The reported directionality and orientation of the features depend on the way the transducer ring is installed. It is good practice to keep the direction between different test positions the same, and in the direction of product flow if known. To ensure the correct

orientation is reported, the transducer ring should be attached with the correct ring attachment configurations.

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

8.10 *Test Location Information*—As the data collections of most GWT equipments are fully recorded electronically, a minimum amount of information about the test location is needed in the processing software to ensure the exact location can be identified. This information 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 transducer ring 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 transducers are well coupled to the pipe. Prior to collecting any test data, perform a coupling test in accordance with the manufacturer’s guidelines. As a minimum, this shall include a way of simulating “signals” on the pipe and verifying that all transducers detect it with a similar magnitude and sensitivity.

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*—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. In order to get a 100 % coverage of the pipe there are two options:

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

8.12.1.2 Locate the next shot so that there is overlap of the previous transducer ring position. Some agencies require a 20 % overlap on all shots where possible.

8.12.2 *Near Field*—This is an area that could extend to as far as 3 m (10 ft) on either side of the transducer ring. In this area, the amplitudes are artificially lower than normal, and mirrors (see 8.20.4.1) can appear, making analysis of reflections in this area difficult. While this area is inspectable, extreme care must be taken when reviewing signals in this area. The length of this area depends on the length of excitation signal. It is possible to reduce the extent of the near field effect by employing special collection protocols.

8.12.3 *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](#).

8.12.4 *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:

8.12.4.1 *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.

8.12.4.2 *Mirrors*—Occurs normally in the near field due to insufficient control of the propagation direction of the guided wave. The mirror echo appears at the same distance from transducer ring, but the opposite direction, as the real reflection.

8.12.4.3 *Modal Noise*—Occurs when the transducer ring is unable to control all the wave modes propagating in the pipe.

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 10 kHz and 150 kHz. When performing a test, data should be collected with enough different frequencies so as to be able to categorize each indication. Ideally, frequency can be changed quasi-continuously to observe frequency dependence. If this is not available in the instrument, multiple different frequencies including the optimum frequency should be collected. It is worth noting that the exact frequencies used vary depending on the pipe geometry.

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 can either be a torsional or longitudinal wave mode. Both wave modes provide valid inspection results. However in practice, torsional mode is commonly used as it is sensitive to most flaw types. Nevertheless it is sometimes advantageous to use longitudinal mode over torsional mode if certain special flaw types, such as corrosion at the axially welded supports, are known to be present on the pipe.

8.14 *Data Collection*—After installing the transducer ring and performing the coupling check, the next step of the examination procedure is data collection. It is important that the data recorded is 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 that 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 high incoherent noise, low transducer coupling, or low transducer output. Should there be any significant problems observed in the data, it should be discarded and the problem addressed.

8.15 *Distance Amplitude Correction (DAC)*—As the excitation signal travels away from the transducer ring, 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 provides the ability to determine the signal amplitude at a point away from the transducer ring. This allows for determining the relative amplitude of an echo, expressed in either CSC or ECL, at a given distance. If the DAC curves are set too low, the size of possible defects may be overestimated, and vice versa. Therefore it is vital that the DAC levels are set correctly before interpreting the data as they provide reference CSC levels to all other signals for comparison. There are four DAC curves that can be used in evaluating GWT reflections. Most systems provide inspectors the means of manually adjusting these curves.

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

8.15.2 *Weld DAC*—Pipe girth welds typically present 20 % to 25 % 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*—This is the typical threshold level that is used to determine the severity of a defect if found. Most systems set the call DAC level to roughly 6 % CSC by default, but also allow this level to be modified in accordance with the detection sensitivity requirement of the industry.

8.16 *Ambient Noise*—Ambient noise causes an increase in the overall incoherent noise level. In [Fig. 1](#), the effect of an increased ambient noise is demonstrated, as both the detection sensitivity and the maximum inspection range are reduced as a result. 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 transducer ring 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