BS 9690-2:2011

BSI Standards Publication

Non-destructive testing – Guided wave testing

Part 2: Basic requirements for guided wave testing of pipes, pipelines and structural tubulars

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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to ii, pages 1 to 16, an inside back cover and a back cover.

Foreword

Publishing information

This part of BS 9690 is published by BSI and came into effect on 31 October 2011. It was prepared by Technical Committee WEE/46, *Non-destructive testing*. A list of organizations represented on this committee can be obtained on request to its secretary.

Relationship with other publications

This document is part of a series which is intended to cover different applications of guided wave testing.

Currently, BS 9690, *Non-destructive testing – Guided wave testing*, comprises the following parts.

Part 1: *General guidance and principles*.

Part 2: *Basic requirements for guided wave testing of pipes, pipelines and structural tubulars*.

However, it is anticipated that further parts of the standard will be introduced to cover the interpretation of measurements; the testing of advanced cases of pipes, pipelines and structural tubulars; and the application of guided wave testing to other structures and components.

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Where optional recommendations are included, they are expressed in sentences in which the principal auxiliary verb is "should". The word "may" is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word "can" is used to express possibility, e.g. a consequence of an action or an event.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This part of BS 9690 specifies the basic requirements for screening pipes and similar tubular objects using the guided wave testing (GWT) method, including set-up, data collection and basic interpretation of the data. It is intended to be read in conjunction with BS 9690-1.

NOTE 1 Some background to the GWT method is given in Annex A.

This part is applicable to the testing of ferritic carbon and low-alloy steel pipes (tubes used for the transport of fluids) and structural tubulars (tubes used for load-bearing constructions) in the diameter range 1 inch (25 mm) to 60 inches (1.52 m), with maximum wall thickness of 2.2 inches (55 mm).

NOTE 2 The term "pipes" is used throughout this document to mean pipes, pipelines and structural tubulars within this scope of materials and dimensions.

This part of BS 9690 is applicable to the use of the GWT method using the pulse-echo technique with the transducer mounted on the outside of pipes for which the testing is straightforward. Advanced cases, in which the factors listed in Clause **4**, items a) to i), are encountered so that the testing is not straightforward, fall outside the limitations of the scope as given above. For such cases, additional provisions are necessary.

For some of the advanced cases that are currently not covered by BS 9690 it might be possible to inspect using specific instructions provided by the GWT equipment manufacturers. These instructions are likely to differ between manufacturers according to the details of the equipment. Such instructions are referred to here as "supplementary instructions". The intention is that some of these advanced cases will eventually be covered by other parts of BS 9690 as commonly accepted approaches emerge.

For those advanced cases that are not covered by other parts, it is necessary for supplementary procedures to be added to those specified in this part of BS 9690. It is necessary for any such supplementary procedures to be documented and agreed between the inspector and the clients [see **5.2**, item a)].

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 9690-1:2011, *Non-destructive testing – Guided wave testing – Part 1: General guidance and principles*

BS EN 473, *Qualification and certification of NDT personnel – General principles*

BS EN 1330-2, *Non-destructive testing – Terminology – Part 2: Terms common to the non-destructive testing methods*

BS EN 1330-4, *Non-destructive testing – Terminology – Part 4: Terms used in ultrasonic testing*

BS EN 14127, *Non-destructive testing – Ultrasonic thickness measurement*

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions in BS 9690-1, BS EN 1330-2 and BS EN 1330-4 apply.

4 Factors influencing the performance of guided wave testing of pipes

The following factors can adversely affect the propagation of guided waves in pipes and/or the ability to interpret the resulting responses from features and imperfections (they are listed in approximate order of severity).

a) Generally roughened surfaces, inside or outside.

b) Short sections of pipe between major features, such as flanges or bends. The pipe needs to be sufficiently long that it can be tested, in consideration of axial resolution and dead zone.

c) Bends, in particular sharp radius elbow fittings.

d) Welded supports.

e) Branches and other attachments.

f) The presence of a viscous liquid in the pipe.

g) The presence of external or internal coatings, particularly if they lead to rapid loss of sound energy and hence to high attenuation rates.

h) The pipe being buried in the ground.

i) A break in the continuous metal path for sound propagation, typically a flanged joint.

NOTE 1 Non-metallic paint and epoxy layers up to 1mm (0.04 in) thick do not normally affect the propagation of guided waves.

These factors affect the rate of loss of the ultrasonic energy, increasing the rate of attenuation, or the degree of scattering, resulting in coherent background signals (similar to grain noise in conventional ultrasonic testing). Their overall effect is to shorten the diagnostic range which may be achieved for a certain sensitivity level for detection of discontinuities.

The following limits shall therefore be applied for this part of BS 9690

NOTE 2 Testing beyond these limits might be permissible according to the requirements of other parts of BS 9690. If not, supplementary procedures may be used, if available.

1) The factors in items a), f), g) and h) cause losses from the transmitted pulse, which is observed as high attenuation and/or raised background levels of scatter. If severe, this can lead to signals which cannot readily be interpreted without special procedures. In tests where the attenuation rate exceeds 1 dB/m the requirements of this part of BS 9690 shall be deemed not to have been met. See **10.1** for a method of determining the attenuation rate.

2) Short sections of pipe [item b)]: The long wavelengths and tone burst excitation used for GWT produce pulse lengths which can be 0.5 m long or more. This limits the axial resolution possible. GWT is therefore not optimized for testing short lengths of pipe. See item i) regarding flanges. This factor also limits the proximity permitted between the transducer position and features (see **9.1.3**) such that it might not be possible to test the whole length of the pipe section, even if more than one transducer position is used.

3) Bends [item c)]: Testing shall not be carried out beyond an elbow fitting. To

test the region beyond a fitting, the transducer has to be moved to a test position on the other side of the bend. This restriction does not apply to "pulled" bends where a straight length of pipe is formed into a curve.

4) Welded supports [item d)]: Testing shall not be carried out beyond a welded support if the amplitude of response from it is less than 6 dB lower than the weld DAC curve.

NOTE 3 Welded supports can generate reflections that are both large in amplitude and axial extent. The reflections are composed of direct reflections from the change in section at the front and back of the support with combinations of signals from internally within the support that are continuously radiated causing a large tail on the direct reflections. The internal signals from the support or structures rigidly attached to the support arrive at a distance beyond the support and can have amplitudes an order of magnitude larger than the supports direct reflections.

5) Branches and tees [item e)]: Testing can be carried out beyond a branch where the diameter of the branch is not greater than half the diameter of the pipe being tested. In such cases the interaction of the guided wave with the branch is such that the onward travelling pulse is not significantly distorted.

6) Flanged joints and other breaks [item i)]: Such breaks do not allow the passage of sound across them, so that testing beyond these is not possible.

5 Information and requirements to be agreed and documented

5.1 Information to be supplied by the client

5.1.1 The following information to be supplied by the client shall be fully documented. For compliance with the standard both the definitive requirements specified throughout the standard and the following documented items shall be satisfied.

a) Pipe nominal diameter and wall thickness.

b) Standard to which the pipe is manufactured.

c) Actual pipe outer diameter if manufacturing standard is not known, or of non-standard size.

d) Material (ferritic steel, austenitic stainless steel, etc.).

e) Pipe type (spiral welded, seam welded or seamless).

f) Geometry (straight lengths, bends, Ts, welded or flanged construction).

g) Type and location of any supports (simple contact, welded, doubler plate, etc.).

h) Whether pipe is above or below ground, or has an external sleeve or casing.

i) Clearance between ground and adjacent pipework, or other obstructions.

j) Coatings, if present (internal/external, type and thickness).

k) Insulation, if present (type and ease of removal for transducer locations).

l) Operating temperature and pressure at time of test.

m) Pipe contents.

n) Trace heating, if present (electrical/steam piping, number of traces, stand-off distance from pipe).

o) Any special requirements for preparation of the surface, including restrictions on methods or transducers which may be used.

p) Any special requirements for training (see Clause **7**), operating procedures and personal protective equipment required for access to the inspection site.

NOTE Additional useful information may include:

- *approximate distance between welds or flanges;*
- *general photographs of pipework in question;*
- *details of any known/suspected damage and mechanisms;*
- *results of any previous GWT inspections, or other NDT;*
- *the direction of flow of the pipe contents, if applicable.*

5.1.2 The organization responsible for performing the test shall provide the following information.

a) The minimum clearance requirement for fitting and removing the transducer at each test location.

b) Length of pipe surface to be prepared for attachment of the transducer (see **9.1.1**).

5.2 Items to be agreed

The following items to be agreed between the contracting parties are specified in the clauses referred to and shall be fully documented. For compliance with the standard both the definitive requirements specified throughout the standard and the following documented items shall be satisfied.

a) Supplementary documented instructions, if required [see Scope; Clause **6**, item q); Clause **7**; **10.1**, item f); and **10.3**].

b) The permitted methods of surface preparation [see **9.1.1**, item b)].

c) The threshold for the reporting of indications [the "call level": see **10.2.2**, item e)].

d) How test results are to be reported [see Clause **11**, item j)].

6 Test procedure

GWT shall be carried out in accordance with a written test procedure, which as a minimum, includes the following.

a) Description of the pipe to be tested.

b) Reference documents.

c) Qualification and certification of test personnel.

d) State of the pipe to be tested.

e) Region(s) to be tested.

f) Preparation of the surface(s) on which the testing is to take place.

g) Description of the GWT equipment.

h) Description of any ancillary equipment required to test and to calibrate the GWT equipment and to perform associated tests, such as wall thickness measurement.

i) Acceptable environmental conditions for performing the test.

j) Calibration and settings.

k) Description and sequence of test operations.

l) Determination of the diagnostic range.

m) Recording and evaluation levels.

n) Characterization of discontinuities.

o) Acceptance criteria.

p) Reporting requirements.

q) Supplementary procedures, if required [see **5.2**, item a)]

7 Personnel qualification

Personnel performing GWT shall be qualified to the appropriate level on the topic of GWT according to a certification scheme which meets the requirements of BS EN 473 or equivalent as agreed.

Inspectors shall only inspect pipes within the scope of their certification.

Inspections shall normally be conducted by an operator qualified at least to GWT Level 2. Level 1 inspectors may perform certain tasks, as defined by the relevant certification scheme, under the supervision of a Level 2 technician.

Prove-up testing, for example ultrasonic testing (UT) and visual testing (VT), shall be carried out by an inspector with appropriate training and qualification in the corresponding field of non-destructive testing.

If the testing involves GWT operations which lie outside the scope of this part of the standard, and supplementary procedures have been agreed [see **5.2**, item a)], then the advanced testing shall be carried out by an inspector with appropriate specific training and qualification for that task.

8 Equipment calibration

All equipment requiring calibration shall have a current calibration certificate from the GWT equipment manufacturer or other recognized body (see **9.1.2**).

9 Testing

9.1 Set up

9.1.1 Preparation of the test position

If the pipe to be tested is operating above ambient temperature, the surface temperature of the pipe shall be measured to ensure it does not exceed the maximum temperature specified in the GWT equipment manufacturer’s specifications or in the test procedure.

The pipe surface shall be prepared to permit satisfactory coupling of the transducer to the pipe. As a minimum the following steps shall be taken.

a) The pipe surface at the planned transducer location(s) shall be checked to ensure it is free from external corrosion and other loose material, such as dirt, poorly-adhering paint, corrosion products and residues following coating removal.

   NOTE Ideally, a surface condition is required which is similar to that for conventional UT.

b) If it is safe and permitted to do so, loose material shall be removed from the surface at the transducer location(s). The permitted methods of surface preparation shall be as agreed with the client [see **5.2**, item b)].

c) For each test location, the organization responsible for performing the test shall specify whether any protective coating needs to be removed and its extent [see item d)].

d) Well-adhered non-metallic paint or epoxy layers up to approximately 1 mm thick shall only be removed if the signal-to-noise ration (SNR) requirements in **9.2.4** cannot be met.

e) The pipe wall thickness shall be measured in accordance with BS EN 14127. A wall thickness measurement and scanning for internal corrosion shall be carried out within the area of the test position. A minimum of four readings of the pipe wall thickness shall be recorded at roughly equally spaced positions around the pipe circumference. If the pipe is horizontal at the test position, these positions shall include the top and the bottom of the pipe. If there are local variations in thickness of more than 10% of the mean measured value at the test position, another test position shall be used.

If there is external metal loss at the test position, the depth shall be measured and reported, as well as its axial and circumferential extent and angular position. Even if the metal loss prevents good preparation of the surface at the test position, a test can be performed if it is safe to do so. However, the quality of the results could be adversely affected if there is metal loss within the dead zone. In this case, or when it is not safe to perform a test because of metal loss, an alternative test position shall be used.

9.1.2 Pre-testing checks on the test equipment

Checks shall be carried out in accordance with the GWT equipment manufacturer's specifications to ensure that the transducer and the GWT instrument are working properly prior to the commencement of testing. Such checks may include, but are not limited to, measurement of capacitance value per channel, electrical continuity and resistance, plus visual examination of the transducer and leads.

Where the GWT instrument performs self-checks, the results of these checks shall be stored with the sampled data. Any equipment faults shall be rectified before continuing the test.

9.1.3 Installation of the test transducer

The transducer shall be mounted at the prepared test position in accordance with the GWT equipment manufacturer's instructions and the written test procedure. Care shall be taken to ensure that uniform coupling is obtained between all parts of the transducer and the pipe surface.

Where possible the prepared area shall be not less than 1.0 m from the nearest major pipe feature (i.e. a circumferential weld, branch or flange) and shall not be located mid-distance between two adjacent features.

NOTE The following general instructions are regarded as good practice.

- *The transducer should be mounted such that the forward direction of the test coincides with the flow direction of the product in the pipe, unless otherwise specified by the client.*
- *When conducting subsequent tests on the same pipe, the axial direction and angular orientation of the transducer should be kept consistent.*
- *The location of the test position should, when possible, be determined using a global positioning system (GPS) unit that allows tracking of the test positions after a series of tests.*

The length of the dead zone and any other restrictions on testing near the transducer shall be determined and stated in the test report. It is not possible to report results in this zone.

Any restrictions on the access to install the transducer which have an impact on the adequacy of installation, ultrasonic coupling or angular orientation of the transducer shall be recorded and included in the test report.

9.1.4 Identification of the test location

At each test site, the location(s) of the transducer shall be determined in relation to a known datum, which might be a visible pipe feature or other physical feature, from GPS data or from measurements along the pipe.

NOTE 1 The referencing of transducer location to a physical feature is particularly important for future correlation of indications with follow-up activity.

The datum and transducer locations shall be recorded on a drawing. All visible features, such as girth welds, supports, branches, coating start location, casing locations and start of soil, shall be included on the drawing. The direction of North relative to the pipe orientation and other specific information required by the facility operator shall be included on the drawing.

NOTE 2 Photographic records of the test location are recommended, where permitted.

9.2 Data gathering

9.2.1 Operating conditions

The pipework under test can be in service and on-stream, so long as the requirements of the agreed test procedure are met. The measured pipe surface temperature shall be within the range stated in the operating procedure for the equipment which is being used.

9.2.2 Determination of test conditions

The test parameters shall be determined with reference to the GWT equipment manufacturer's instructions for the pipe geometry to be tested, and recorded. The parameters recorded shall be sufficient to allow the test to be repeated independently.

9.2.3 Data collection

If the instrument used allows an automated data collection sequence which includes a coupling check, any deviations from an acceptable condition shall be recorded. If a manual coupling check is required, the results shall be recorded.

It is normally expected that the pipe is tested in each direction from the transducer position. In each direction the distance over which the data are collected shall be sufficient to record information over the desired test length.

All test data shall be checked for quality (see **9.2.4**) while the transducer is still in position. If the data quality is not adequate, the test shall be repeated. The data shall be saved electronically before the transducer is removed from the pipe.

9.2.4 Data quality review

The quality of the collected data is extremely important: the better the quality of the data, the lower the noise, and thus the longer the permissible test range (see **10.3**). The quality is determined mainly by the transducer coupling and the SNR.

The transducer coupling shall be assessed in accordance with the GWT equipment manufacturer's procedure and threshold. If the coupling is found not to meet the threshold, then the surface preparation shall be improved, the transducer re-applied and the data re-sampled.

9.2.5 Next test position

Where testing is required from more than one test location along a pipe, the spacing of these locations shall be such that full coverage of the pipe length to be examined is obtained within the diagnostic ranges of each test.

NOTE 1 It is recommended that there is a degree of overlap in the diagnostic ranges from adjacent test positions.

NOTE 2 For confirmation of complete coverage, it is advisable to be able to identify a common pipe feature from adjacent test positions.

The next test position shall conform to **9.1.3** and **9.1.4**. The length of pipe tested and any areas which cannot be tested within the scope of the test shall be recorded in the test report.

9.2.6 Storage and back-up of data

Each test (or series of tests if there is an automated data collection protocol) at each test position shall be given a unique identifier. This identifier shall be included in the file name for saving and storing the test data.

NOTE Data saved during the test should be backed up on to a removable medium.

10 Initial interpretation of results

10.1 Amplitude calibration and setting up DAC/TCG curves

GWT requires response amplitudes to be compared with reference levels derived from distance amplitude correction (DAC) curves or via time-corrected gain (TCG) amplitude levels. These curves represent levels of constant sensitivity with range and allow responses to be compared with those from known features. Setting the DAC or TCG curves correctly is a reference calibration process. It is important for the correct reporting of pipe features and discontinuities. It is also necessary in order to identify when supplementary procedures [see Scope and **5.2**, item a)] are needed to deal with cases of strong attenuation.

a) If the equipment permits absolute calibration of amplitude, then that shall be used. Otherwise calibration shall be carried out using reflections from features of the pipe which have known, predictable reflectivity. This procedure is conceptually identical to the use of drilled holes in calibration blocks for conventional UT (see, for example, BS EN 583-2). As the surface of a cut end of a pipe represents the entire cross section of the pipe wall, this is considered to be the ideal 100% reflector so this level is used as the comparator for other signal levels, and is defined as the zero decibels (0 dB) level. Regardless of the amplitude calibration method used, the amplitudes of other signals shall be reported relative to this reference level.

   NOTE 1 Many pipe lengths are manufactured with a pre-cut bevel on the ends for welding. If it is decided to assess the true reflectivity of a pipe end for calibration purposes, any such bevels should be removed. The plane of the cut end should be not greater than 3° from the perpendicular to the pipe axis.

   NOTE 2 Pipe ends terminating in a flange fitting will not exhibit the same reflectivity as a cut end; the response will also be considerably more complex as there will be secondary reflections and mode conversions arising from the flange fitting geometry. It is not recommended that flanges are used for amplitude calibration purposes.

b) In practice it is often not possible to use reflectors with accurately known reflectivity. In such cases, reflectors whose amplitude of reflection is approximately known shall be used. The most commonly used reference reflectors are the circumferential girth welds on the pipe.

c) For pipes in the commonly encountered thickness range of 7 mm to 13 mm and welded in accordance with commonly used standards for fabrication of pressure containing pipework, the increase in thickness at the reinforcement of the girth welds gives a reflection amplitude of approximately 20% of the notional signal obtained from a cut end of the pipe (equivalent to -14 dB relative to the pipe end reference signal). If the GWT is being performed solely for screening, and if accurate calibration is not possible, this response amplitude may be used as an approximate means of setting the reference (0 dB) level

d) If a girth weld is to be used as a reference reflector in pipes outside this thickness range, or if it is intended that the response amplitude will be used to estimate a value of the cross-sectional change (or estimated cross section loss), then the approximate level of 14 dB shall not be used. Instead, an accurate calibration shall be performed. In such cases calibration of the reference 0 dB level can be achieved from knowledge or measurements of the dimensions of the weld by using the appropriate amplitude correction factor. Such calibration shall be performed according to the GWT equipment manufacturer's procedures. The correction factor to achieve 0 dB shall be recorded.

e) If two welds can be identified as reference reflectors, they can be used to determine the decay rate of the guided wave signal. Otherwise the decay rate shall be estimated by other means. The decay rate of the guided wave signal shall be calculated following the GWT equipment manufacturer's procedure. This usually makes use of reference reflections from two welds.

f) Critically, the decay rate of the DAC (or rate of change of time-corrected gain) is an important measure, which shall be used to determine whether the test lies within the scope of this part of BS 9690. A large decay rate is one of the complicating phenomena that require supplementary instructions [see Scope and **5.2**, item a)].

g) The two principal parameters of DAC (or TCG) curves are their vertical position relative to the data and their gradient with range. The preceding steps allow these to be determined, so that the position of other curves (see **10.2**) relative to the 0 dB reference level can be established at all points along the test range.

10.2 Determination of test sensitivity and reporting level

10.2.1 The limit of sensitivity of the test (i.e. the capability of the test to detect discontinuities) is determined by the SNR. Small amplitude responses from discontinuities will appear just above the background noise. Signals which do not have sufficient amplitude to appear above the background "noise" level (see note) will not be detected on an A-Scan display. To avoid the erroneous reporting of noise signals as discontinuities, a call level for reporting shall be set. This call level is the level at which responses are required to be evaluated, and is represented by a DAC or TCG curve. This level is always set at a higher amplitude than the noise floor.

NOTE The "noise" floor on a guided wave test consists of random noise and non-random scatter from components, which together produce a background signal level along the whole length of the test trace.

10.2.2 To ensure a consistent approach for the setting of sensitivity and reporting levels, the following steps shall be taken.

a) The amplitude of the noise level in the test range (see Note 1) shall be determined and recorded by means of the generation of a noise line. This line shall be determined using an appropriate procedure for assessment of the noise level with range, as supplied by the GWT equipment manufacturer or from a standard method. This operation shall be performed on the data set for each combination of test conditions (wave mode, frequency, excitation pulse shape/length/amplitude) at each test position (see Note 2).

NOTE 1 If the noise level is deemed to be excessive at long range, so that the signals at the far end of the test range from the test location are deemed to be uninterpretable, the noise level may be determined over a shorter proportion of the test range. If this is done, the range over which the noise level is determined should be recorded. No interpretation of the signals beyond this range is permitted.

NOTE 2 For data subjected to TCG, the noise curve should be established after application of the time-dependent gain correction.

b) Once the noise line has been established, additional operations on the data set to which it relates, such as filtering or other signal processing operations, shall not be undertaken.

c) For adequate discrimination between the background and valid signals from discontinuities and features, a SNR of at least 2:1 (= 6 dB) shall be applied. A curve representing the maximum usable sensitivity shall therefore be plotted on the test data which, at all points, is 6 dB above the noise line. This is the maximum usable sensitivity line. The purpose of this line is to set a limit so that no indications below this amplitude level are reported.

d) A call level (DAC or TCG) shall be set (see BS 9690-1:2011, **3.3**), which:

   1) is at a higher amplitude level than the maximum usable sensitivity line within the diagnostic range [see **10.3**];

   2) has the same slope as the 0 dB DAC curve, or has a fixed value if using TCG.

e) The amplitude, in dB, of the call level (DAC or TCG) relative to the 0 dB reference level shall be recorded and included in the test report. The call level (DAC or TCG) to be used shall be agreed between the contracting parties [see **5.2**, item c)].

10.2.3 The following DAC/TCG and other curves shall be overlaid on the A-Scan response from each test and shall be present on any data presented in the test report (see Clause **11**).

a) The 0 dB DAC curve (or TCG level).

b) The amplitude calibration DAC curve (or TCG level), whether this is derived from welds or by another method.

c) The call level (DAC or TCG).

d) The maximum usable sensitivity line.

e) The noise line.

10.2.4 For the DAC curves and TCG levels, the difference in amplitude, in dB, from the 0 dB reference level shall be stated.

EXAMPLE: Method of determining sensitivity and reporting levels

Figure 1 shows an example set of guided wave test data. This includes a number of responses from pipe girth welds and a general level of background noise.

Here, the reference level has been set with reference to the girth weld responses. The reference 0 dB level curve appears in the top right-hand corner of the plot. The noise line is shown by the dashed black line. The line of maximum usable sensitivity is shown by the heavy line. This is at twice the amplitude of the noise line at all points along the test data.

NOTE For this example, the noise and maximum usable sensitivity lines are linear, but it might be more appropriate to fit a more complex curve to the noise in some cases.

In this example the point at which the call level line no longer exceeds that of the maximum usable sensitivity line occurs at the point labelled "limit of diagnostic range". Therefore, this is the limit of the diagnostic range. Detection of discontinuities required to be reported at the call level cannot be guaranteed beyond this point and interpretation beyond this range is not permitted.

10.3 Determination of valid test range: the "diagnostic range"

For clear discrimination between discrete responses and the general background "noise" floor, a 2:1 ratio (i.e. 6 dB) shall be applied between the signal and the background. Hence, the maximum usable sensitivity curve [see **10.2.2**, item c)] represents the minimum amplitude of responses which can be reported. The slope of this curve and that of the call level (DAC or TCG) [see **10.2.2**, item d)] will be different. Therefore, at some point these two curves will intersect (see Figure 1). The limit of the diagnostic range is the nearest location from the test position (excluding the dead zone) at which the amplitude of the call level (DAC or TCG) lies below the maximum usable sensitivity line.

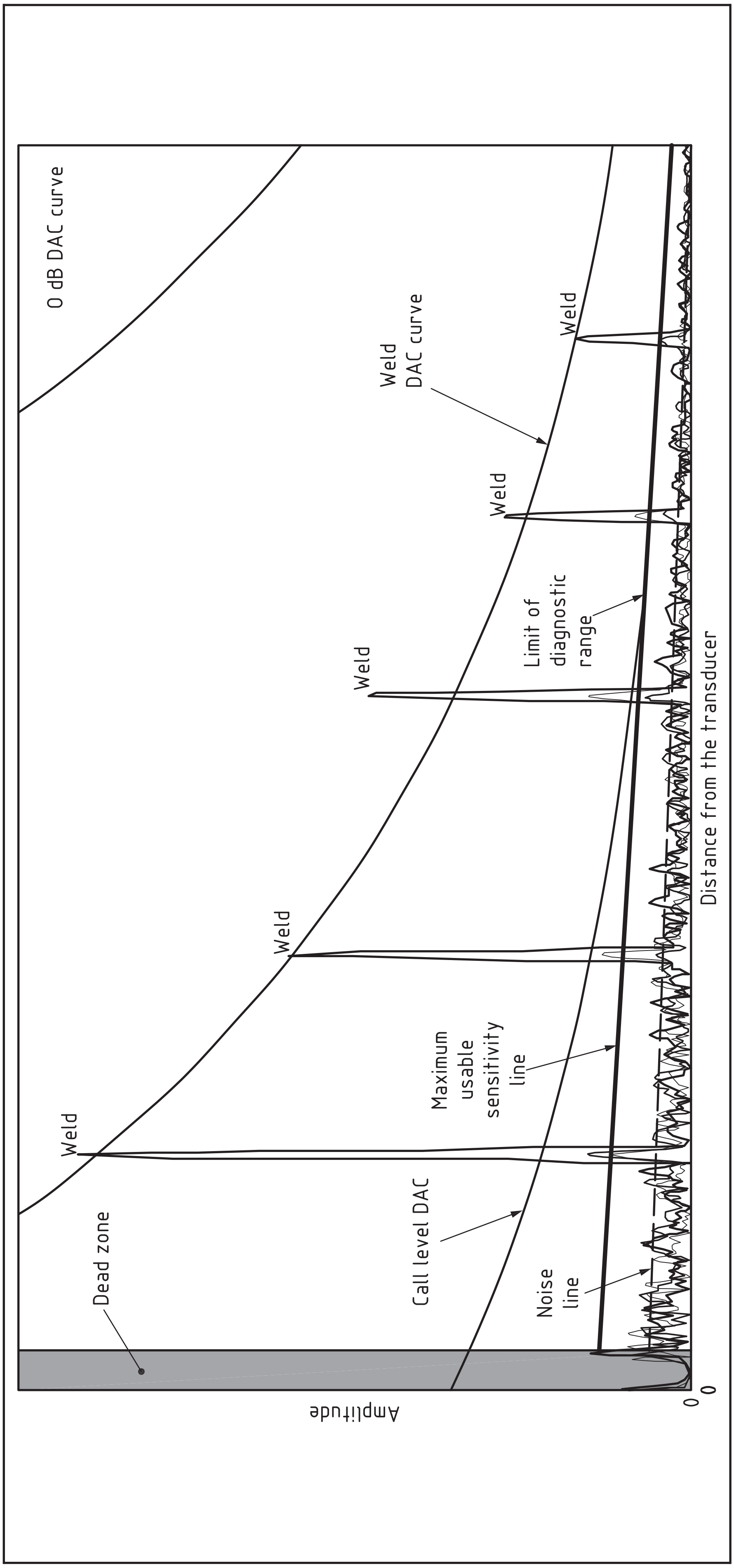
This criterion shall be applied independently for both test directions from the test position, as the ultrasound attenuation and noise levels can differ from one direction to the other. The diagnostic range in each test direction at each test position shall be recorded.

The end of the diagnostic range is also imposed by any reflector beyond which the testing cannot be performed.

*NOTE For the requirements specified by this part of BS 9690, such reflectors are identified in Clause **4**.*

Tests beyond these reflectors may still be permissible, provided that supplementary instructions [see **5.2**, item a)] appropriate to the specific reflectors are satisfied.

Figure 1 **Example guided wave data (linear amplitude scale A-scan) showing the relationship between the DAC curves, noise line and maximum usable sensitivity line**



10.4 Initial identification of discontinuities

Responses appearing above the call level shall be identified so that they can be subjected to the interpretation procedure (see Note 1). This may involve gathering additional data in accordance with **10.5**. The identification may be based on the degree of axisymmetry and amplitude with respect to the DAC or TCG curves. Responses lower in amplitude than the call level may be evaluated if the signal amplitude is greater than the line of maximum usable sensitivity.

NOTE 1 Standardized interpretation procedures are being developed and will eventually be provided by BS 9690-3 (in preparation).

As a minimum, the amplitude of each discrete response shall be recorded, relative to 0 dB, as shall its distance from the datum point for that test (see **9.1.4**).

The locations of pipe features shall be confirmed visually where possible. Wherever practical, distances to accessible pipe features shall be confirmed using a physical measurement, such as a tape measure or range finder. The results of such measurements shall be recorded in the test report.

NOTE 2 Guided wave systems rely on calculated values for the wave velocity. This can vary slightly depending on the condition of the pipe being tested. If the actual distance to a visible feature can be measured, the calculated distance can be calibrated. The difference between actual and calculated distance is not normally expected to exceed 2%. Larger differences could lead to features being misplaced and potentially misinterpreted.

10.5 Collection of additional data

If the initial evaluation of the test data indicates that additional data are required, these shall be collected in accordance with **9.2**.

NOTE Additional data might be required due to:

- *excessive levels of coherent noise masking responses from discontinuities at the required sensitivity level;*
- *incomplete coverage of the length of pipe required to be tested;*
- *a need for more detailed information about discontinuities, for example from focused tests.*

10.6 Data interpretation

All data gathered at the test position shall be reviewed and evaluated in order to produce a test result. The first step in this process is to determine whether a response arises from a pipe feature (e.g. a weld, support, branch etc) or from an area of degradation. The second step is to establish the extent of any such degradation. As discussed in **A.2**, the remaining wall thickness is not given directly from the results.

The format of the presentation of results shall be as agreed by contracting parties [see **5.2**, item d)]. However, the following is the minimum information which is recommended to be provided about responses exceeding the call level.

a) The distance from the specified datum.

b) The amplitude relative to the 0 dB reference level.

c) The decision as to whether the response is from a geometrical feature of the pipe or from a metal loss discontinuity.

d) An A-scan plot of the diagnostic range in which responses are reported, with the reported indications clearly marked.

Where the cross section change at a discontinuity is required to be determined, the percentage cross section change represented by the call level shall be stated in the report.

11 Test report contents

The test report shall contain at least the following information.

a) Identification of the client, and/or order number or job identification number.

b) Complete identification of the test object.

c) Place of testing.

d) Surface condition of the test object.

e) Identification of the test equipment used.

f) Reference to contractual documents, standards, etc.

g) Reference to the test procedure.

h) Name, qualification and signature of the inspector or any other personnel responsible for the test.

i) Date of test.

j) Results of the test and evaluation [see **5.2**, item d), and **10.6**].

NOTE Any plots of test data should include the DAC (or TCG) and other calibration curves as stated in ***10.2****.*

k) Any deviation from the procedure.

l) The identification of the test object, including the outer diameter and wall thickness.

m) Location of test position(s) and description of reference datum points.

n) The agreed call level in dB relative to the reference level.

o) Length of pipe tested within the valid diagnostic range and any areas which could not be tested within the scope of the test.

p) Wave mode(s) and test frequencies used.

q) For equipment that is controlled by software:

    1) name of software and release version used; and

    2) filename(s) of data associated with the test.

Annex A (informative) Background to the GWT method

A.1 Principle of operation

The guided wave pipe testing method utilizes guided stress waves (sonic or ultrasonic guided waves) sent along the length of the pipe to test pipes non-destructively for the detection of pipe features and imperfections by detecting changes in the geometry and/or acoustic impedance of the pipe. Details of the principles and means of implementation of the method are given in BS 9690-1.

A.2 Practical context of guided wave testing of pipes

GWT offers the ability to test large volumes of material from a limited number of test locations in order to gain information about the condition of long lengths of pipe rapidly. The results show that either the pipe is in good condition or that there are areas that need to be examined more closely to determine their fitness for continued service. Important factors are:

a) that long distances can be tested from each test point (compared with conventional UT);

b) portions of the object which are inaccessible for testing can be examined from adjacent accessible locations; and

c) full coverage of the pipe wall volume is achieved over the diagnostic range.

However, the ability to test large volumes of material from a single point imposes some limitations on the capability of the method. To obtain long range propagation much lower ultrasonic frequencies are required than are used in conventional UT. The wavelengths used are, therefore, much larger than for conventional UT so that resolution is reduced. Further, the sensitivity to imperfections relies on the detection of loss of cross-sectional area on a transverse section through the pipe, so that a measurement of remaining wall thickness is not directly obtained.

Thus, the general application of GWT is as a screening method: first the GWT measurements are used to screen a large volume of material rapidly, then a follow-up test of areas where indications are reported is performed using other local, methods.

Acceptance or rejection of indications may be determined by comparing the response amplitude to a threshold DAC or TGC curve that has been set up to achieve equal sensitivity at all locations along the test length. The response may also be interpreted to give an approximate value of the cross-sectional area change (CSC) loss, normally expressed as a percentage of the full pipe wall cross section, or an estimate of depth based on the degree of localization and response amplitude. However, neither of these interpretations gives a measurement of the remaining wall thickness at the location of the reported discontinuity. Furthermore, this part of BS 9690 does not provide the basis to calculate the estimated CSC from the reflection amplitude, nor set threshold values for acceptance or rejection; these need to be agreed by the contracting parties [see **5.2**, item c)]. To preserve a link with sensitivity calibration, it is necessary to state the cross section change represented by the call level specified.

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN 583-1, *Non-destructive testing – Ultrasonic examination – Part 1: General principles*

BS EN 583-2, *Non-destructive testing – Ultrasonic examination – Part 2: Sensitivity and range setting*

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