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PCN ISI_GEN APPENDIX B1 GUIDELINES ISI ISSUE 2 DATED 22nd JULY 2015

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Guidelines for Detection and Monitoring of Corrosion and Determination of Material Thickness using Manual Ultrasonic Testing

ASSOCIATED DOCUMENTS:

Appendix Z1 to PCN/GEN (examination syllabus compendium) - for General Theory of UT only

Appendix A1-ISI to PCN ISI_GEN - Certification of Personnel for In-Service Inspection – Manual Ultrasonic Testing - Via the Modular Route

CONTENTS

INTRODUCTION

1.1 Piping systems and vessels can suffer from various forms of service induced degradation such as corrosion or erosion. These items may contain hydrocarbons, hazardous liquids and gases that may be under high pressure and/or at elevated temperature. These items may remain in service for many years therefore the detection of corrosion and determination of the remaining material thickness using ultrasonic techniques forms an important tool in maintaining their integrity.

1.2 For ease of use term corrosion has been utilised throughout this document to represent material thickness loss regardless of the actual degradation mechanism.

1.3 Corrosion detection and determination of remaining wall thickness are often considered as the same test but they should be considered as two separate examinations. Corrosion detection requires testing at a higher sensitivity (gain) level to allow for the detection of early stage corrosion pitting. While in many cases early stage corrosion may not be cause for concern it permits the items to be identified for future, or more frequent monitoring.

1.4 Thickness readings may be taken at predetermined locations or at the thinner areas located during corrosion detection scans.

1.5 Corrosion rates may vary from a fraction of, to several, millimetre per year. A reliable inspection technique is needed to ensure corrosion rates can be accurately determined. This is of particular importance as inspection periods may be separated by many years.

1.6 Often the aim of the thickness measurements is to determine corrosion rates rather than minimum thickness. In such cases small systematic errors (e.g. coating thickness included) in thickness measurement are acceptable provided all repeat inspections are carried out using the same test technique.

SCOPE

1.7 These guidelines define the methods and techniques that can be utilised for carrying out manual ultrasonic testing for the detection and monitoring of corrosion and the determination of material thickness within in-service vessels and piping. The examination should determine the nature and extent of all indications and ascertain the minimum material thickness within the tested areas.

1.8 These guidelines are applicable to carbon, duplex, and stainless materials though other materials may be tested using these methods and techniques provided suitable calibration blocks are available

OVERVIEW

1.9 The guidelines cover three ultrasonic pulse echo Test Methods, three Test Modes, and three Test Levels; these may be utilised in various combinations.

1.10 Described below is a brief description of each more detailed descriptions are included within the documents main body, with additional information contained within the annexes when applicable.

TEST METHODS

Technique	Description
Spot	Individual fixed point thickness reading.

Line	Corrosion detection and minimum thickness along a scanned line of predefined length.
Area	Corrosion detection and minimum thickness within a test area of predefined size.

1.10.1 The spot test method is used for material thickness determination only, it is unlikely to detect corrosion due to the small area examined.

TEST LEVELS

Level	Description
1	Single line scans
2	Twin line scans and some small areas scans
3	Area scans

1.10.2 Note: Some companies may designate their highest Test Level as 1 and lowest as 3.

1.10.3 The test techniques and Test Level requirements are specified by the client and must be provided prior to commencement of testing.

1.11 TEST MODES **(as per EN 14127)**

Mode	Description
1	Measure the transit time from an initial excitation pulse to a first returning echo, minus a zero correction to account for the thickness of the transducer wear surface and the couplant layer (single echo mode)
2	Measure the transit time from the end of a delay line to the first back-wall echo (single echo delay line mode)
3	Measure the transit time between back-wall echoes (multiple echoes).

1.11.1 Unless otherwise requested Test Mode 1 is utilised as it is considerably quicker to apply than Test Mode 3. For Test Mode 1, the thickness reading reported will therefore include the ultrasonic (not actual) coatings thickness. Test Mode 3 is used only when accurate remaining material thickness is required.

REFERENCES

1.12 The latest edition, including amendments, of the following documents have been referenced in the preparation of these guidelines:

1.12.1 EN ISO 16810 Ultrasonic examination - General Principles.
1.12.2 EN ISO 16811 Ultrasonic examination - Sensitivity and Range Setting.
1.12.3 EN-12668-1 Characterisation & verification of ultrasonic equipment - Instruments.
1.12.4 EN-12668-2 Characterisation & verification of ultrasonic equipment- probes.
1.12.5 EN 12668-3 Characterisation & verification of ultrasonic equipment - combined equipment.
1.12.6 EN 1330-4 Terminology - Terms used in ultrasonic testing.
1.12.7 EN 14127 Ultrasonic thickness measurement.
1.12.8 EN ISO 2400 Ultrasonic examination - Specification for calibration block No 1.
1.12.9 EN ISO 7963 Calibration block No 2 for ultrasonic examination of welds.
1.12.10 EN ISO 9712 Qualification and Certification of NDT personnel.
1.12.11 EN ISO 17025 General requirements for the competence of testing and calibration laboratories

1.13 Clients may also specify standards that have not been adopted by the European Union (i.e. EN) for ultrasonic thickness measurement, e.g. ISO 16809 or ASTM E797.

ABBREVIATIONS AND DEFINITIONS

1.14 The following abbreviations have been used within this document:

1.14.1	FSH	Full screen height.
1.14.2	BWE	Back wall echo, 1BWE =1st back wall echo, 2BWE = 2nd back wall echo, etc.
1.14.3	A-Scan	A form of display in which the signal amplitude is displayed in one axis (typically the vertical) and the time or distance is displayed in the other.
1.14.4	HAZ	Heat affected zone
1.14.5	TOFD	Time of Flight Diffraction.
1.14.6	SDH	Side drilled hole
1.14.7	POD	Probability of Detection

HEALTH AND SAFETY

1.15 All work should be carried out using good safe working practices, in accordance with all statutory and local requirements. Safety procedures and documentation together with Product Data Sheets, Risk Assessments and Control of Substances Hazardous to Health Assessments applicable to the work being carried out, should be available for review at the work site.

1.16 Removal of surface coatings, corrosion blisters and thick scale is the responsibility of the client. It must not be carried out by test technicians unless it is included within the project contract and applicable training has been provided. Appropriate coating removal procedures and risk assessments will be required. Corrosion blisters and thick scale should normally be removed when the item is de-pressured and out of service.

PERSONNEL

1.17 Personnel carrying out thickness testing should have received appropriate training and be certificated under the EN ISO 9712 certification scheme in "In-Service Inspection in the Oil and Gas Sector - Corrosion Monitoring and Thickness Measurements using Manual Ultrasonic Techniques".

1.18 All test personnel should have successfully passed an annual vision acuity and colour perception examination in accordance with the requirements given in PCN document PSL44.

EQUIPMENT MEASURING INSTRUMENTS

1.19 Only ultrasonic flaw detectors having an A-scan display and the capability of operating in both compression and shear waves mode shall be utilised. Digital thickness meters are not permitted.

1.20 All flaw detectors require a current certificate of conformity, or calibration to EN 12668-1. Whenever practicable, calibration should be carried out by an EN ISO 17025 accredited calibration laboratory. Calibration periods should not exceed 12 months.

PROBES

1.21 The selection of the applicable probe will be determined by a number of factors including; material thickness, test surface condition, radius of test item and accuracy of results required.

1.22 Shown below are examples of typical probes and their application. Frequency and element diameters are approximate, other probes may be considered more applicable to specific applications. For thicknesses below approximately 6 mm delay line or specialised probes may be utilised.

1.23 Based on the use of standard probes a minimum nominal thickness of 6 mm and pipe diameters of above 2" nominal bore is recommended. For materials below nominally 6 mm the probe to be utilised should be assessed to determine its thickness measurement capability, delay line or specialised near surface resolution probes may be required.

Angle	Elements	~MHz	~Ø mm	Thickness mm	Minimum OD mm
0°	twin	5	5	≥ 6 to 50	25
0°	twin	10	10	≥ 6 to 20	60
0°	single delay line	5 - 10	5	≤ 10	25
0°	single	2 - 5	20	≥ 50	200
45°, 60° & 70°	Twin	5	10	≥ 6 10	100
45°, 60° & 70°	single	5	10	≥ 10	100

1.24 Single element 0° probes often have a ceramic type face that makes then unsuitable for use on surfaces that are not smooth. Single probes with wear rings or protective coverings, or twin element probes may be more suitable. The probe face may become worn therefore regular verification of the calibration range is required.

1.25 Care should be taken to ensure the probe is held perpendicular to the surface tangent. Twin element probes when used on small bore piping are to be positioned so the acoustic barrier is orientated both perpendicular and then parallel to the axis of curvature. The minimum reading obtained should be recorded.

1.26 Twin element probes can suffer from inherent errors due to the tilting of the elements design which creates a focusing effect. Working outside their recommended test range should therefore be avoided when high accuracy is paramount. There are available specific probes for testing thin materials. (See also Annex H).

1.27 Thickness testing on convex or concave surfaces can result in a reduction in the contact surface between the probe and test surface. This can result in a reduced ultrasonic coupling efficiency which may cause a loss of signal quality. To minimise these effects and to increase test repeatability, the probes element diameter should not exceed 25% of the test surface radius.

1.28 Most probes are rated for use between around –20° C to +50° C. At temperatures below minus 20° C specially designed probes may be required. Testing at temperature above 50° C up to approximately 500° C is possible however specifically designed high temperature probes and couplants are required.

1.29 Angle probes may be utilised to assist in the determination of flaw type morphology. It should be noted that the refracted beam angle is affected by increasing temperature, therefore the accuracy of flaw positioning and depth determination can be compromised.

QUALITY CONTROL CHECKS

1.30 Prior to use and at predefined intervals thereafter the equipment and probes should be checked to ensure their continued suitability for their intended use. Details of the checks and frequency required are contained within EN 12668-3. The results of the checks should be recorded and made available for review if required.

TEST METHODS

1.31 Following are details of the types of measuring methods that may be utilised to carry out a corrosion detection and/or thickness assessment. The intention is to obtain the minimum thickness reading at the specified test location. Average thickness determination is not required.

1.32 <u>Spot tests</u>

Spot tests are not a recommended test method for the detection of corrosion due to the very small area being sampled. The test comprises of a series of individual thickness reading carried out at pre-defined locations, e.g. the cardinal points or 3, 6, 9 and 12 o-clock positions, or at random locations. In some cases the locations at which the reading is to be taken may be permanently marked on the test surface.

1.32.1 A limitation of this method is that at the actual test location there may be a test restriction (e.g. paint blister). Therefore another location must be selected, and this is generally chosen by the test technician at a convenient close-by location. This variation in test location can result in significant differences in the thickness measurement recorded which can be of particular concern if a wall loss trend is being monitored.

1.33 Spot - grid test

1.33.1 With the same limitations as spot testing, it is mainly utilised on larger items like vessels and columns. The area to be tested is marked out with grid lines, typically 50 mm spacing for piping and 100 mm spacing for vessels, though other spacing may be specified. The probe is positioned at the intersection points and the thickness obtained recorded for each location.

1.33.2 Grid tests can be useful when general corrosion loss trending over an extended time period is required, however accuracy depends on the probe being positioned at exactly the same location each time, even small location errors can cause significant variations to the results obtained.

1.33.3 This technique can useful on elevated temperature surfaces when the probe contact time must be minimised to prevent overheating.

1.34 Line scans

1.34.1 Line scans are considered as the minimum or "standard" test technique by many companies. It is used to both detect corrosion and highlight the areas of minimum thickness.

1.34.2 A scan length is specified, typically for piping this is a 360° circumferential scan and the thinnest reading obtained recorded. The inspected area is increased by orders of magnitude over that of a spot check. To increase the probability of detecting corrosion and the minimum thickness multiple parallel line scan may be requested.

1.34.3 Line scans are recommended as the minimum requirements for piping with increased coverage from Test Level 1 to Test Level 3 as risk increases.

1.35 Area scans

Area scans have the highest probability of detecting corrosion and mainly used on systems with high risk or high consequences of failure, and also those areas considered to be susceptible to, or known to, contain corrosion.

1.35.1 The area is 100% scanned with each scan line overlapping the previous one by a minimum of 20% of the element size. The designated area can be quite large particularly if being used for corrosion detection. Sub-dividing the area into grids, typically 500 mm square, and testing and reporting each zone separately is recommended.

1.35.2 High speed, high gain scanning of around 250 mm per second is recommended for the detection scan. Experience has shown flaws are more likely to be detected as a change in overall screen pattern rather than as a small individual change. However evaluation and sizing will require a reduction in the scanning speed. This technique is valid when there is a sound, smooth surface where there is little prospect of loss of couplant due to the surface conditions.

1.35.3 Area scans are the minimum requirements for Test Level 3 testing and is the recommended technique for high risk areas in vessels and piping.

TEST LEVELS

1.36 The Test Level selected is generally based on the probability of corrosion and the consequences of a leak. A combination of two or more levels may be utilised, for example Test Level 1 may be requested for the vertical section of a piping system and Test Level 2 for the horizontal sections which are more prone to corrosion.

1.37 Test level 1

1.37.1 This is recommended as the minimum test requirement for low risk systems and most vertical piping sections.

1.37.2 Typically this would include non-hydrocarbon piping systems and may also include some low pressure hydrocarbon piping determined to have a low probability of internal corrosion. Includes piping systems determined to have a low probability and low consequences of failure that are unlikely to cause adverse effects to personnel, equipment or the environment and have a minimal financial impact.

1.37.3 Testing typically comprises of a single line scan adjacent to welds and other additional selected test locations e.g. the outer radius of bends. Line scans may also be carried out at specified spacing along straight pipe runs (e.g. every 3 metres on horizontal lines).

1.38 Test level 2

1.38.1 This is recommended as the minimum test requirement for all medium risk systems.

1.38.2 Typically this would include medium pressure hydrocarbon piping and all other low and medium pressure systems that are considered to have a risk of internal corrosion. Includes all systems with a consequence of failure that has the potential to cause risk to personnel, equipment or the environment and have a small but significant financial impact.

1.38.3 Typically testing will comprise of twin line scans one centred nominally 25 mm from the weld toes and the other adjacent to welds at the selected test locations. Multiple line, or area scans, are utilised at the outer radius of bends. Line scans may also be carried out at specified spacing along straight pipe runs (e.g. every 2 metres on horizontal lines).

1.39 Test level 3

1.39.1 This is recommended as the minimum test requirement for all high risk systems.

1.39.2 Typically this includes all high pressure hydrocarbon carrying piping, steam lines and medium and low pressure systems considered to have a high probability of internal corrosion. Additionally, any system with a consequence of failure that has the potential to cause significant risk to personnel, equipment or the environment, or have a high financial impact

1.39.3 Typically testing will comprise of a minimum of 100 mm wide area scans adjacent to welds and at the selected test locations. Full surface area scans on all bends and surfaces impinged by direct fluid flow, typically at "Tee" joints. Line scans may also be carried out at specified spacing along straight pipe runs (e.g. every 1 metre on horizontal lines). Often Test Level 2 is specified as the minimum requirement with an increase to Test Level 3 if internal corrosion is detected.

TEST MODES

1.40 Mode 1 - Single echo

1.40.1 May be applied using single or twin element probes this mode is suitable for scanning areas to identify local thinning. This is considered as the standard test technique and it can also be used to determine the remaining ligament between the test surface and the top of a flaw even when the corrosion type affects the back wall morphology so that no repeat echoes are detected.

1.40.2 Calibration is generally carried out on uncoated materials and therefore incorporates zero position correction to take account for the thickness of the probe shoe and couplant layer. Thickness reading taken on uncoated surfaces will be determined at the position of the first reflected signal.

1.40.3 Thickness reading taken on coated surfaces will be also determined at the position of the first reflected signal but will include the ultrasonic thickness of the coating. The ultrasonic thickness of the coating however is not the true coating thickness as the velocity of sound will be based on the material under test and not the coating. (see fig 5)

1.40.4 When readings include the coating thickness a note to this effect should be included on the test report.

1.40.5 While considered as the standard test mode for thickness reading it should not be considered as the technique for corrosion detection. Multiple peaks are required so that the collapse of the signals amplitudes or a change in the echo pattern spacing can be observed.

1.41 Mode 2 - Single echo delay line

1.41.1 Applied using single element probes with a delay line. The accuracy obtainable is comparable to Test Mode 1, but it can give significantly improved near surface resolution and therefore it is more commonly used on materials below 6 mm thickness.

1.41.2 Calibration is generally carried out on uncoated materials and therefore incorporates zero position correction to take account for the thickness of the thick probe shoe (delay line) and couplant layer. Thickness reading taken on uncoated surfaces will be determined at the position of the first reflected signal.

1.41.3 Thickness reading taken on coated surfaces will be determined at the position of the first reflected signal and will therefore include the ultrasonic thickness of the coating. The ultrasonic thickness of the coating however is not the true coating thickness as the velocity of sound will be based on the material under test and not the coating. (see fig 5)

1.41.4 When readings include coating thickness a note to this effect should be included on the test report.

1.42 Mode 3 - Multiple echo

This is a measure of the transit time between repeat back wall echoes (from 1st to 2nd BWE, 2nd to 3rd BWE, etc). With this method, measurements are made from two consecutive back wall echo signals. It is recommended peak to peak measurements are utilised and not flank to flank. However if flank readings are taken, it is important to adjust the amplitude of the repeated signals to a height corresponding to the calibration signal amplitude.

1.42.1 This method is best carried out with single element probes, although twin probes may be used provided that the test range is within the focal distance of the probe.

1.42.2 It is typically used to take thickness measurements from materials that have a coated surface. The thickness reading between two repeat echoes will not include the additional delay caused by the coating, and the thickness can therefore be taken directly from a digital readout provided the threshold recording gates are suitably positioned.

1.42.3 In general, this technique should not be utilised when using analogue ultrasonic equipment. The first and subsequent BWE will all move on the time base corresponding to the changes in coating thickness making the constant monitoring of the reading between the signals difficult.

1.43 Mode 3 - Multiple echo averaging.

1.43.1 This mode is applicable to analogue equipment as digital equipment can utilise the technique described in Mode 3 - Multiple echo. Single element probes are recommended as twin element probes can suffer from inherent errors due to the tilting of the elements which create a focusing effect.

1.43.2 To obtain the greatest accuracy it is recommended calibration and measurements are made from signal peaks rather than from rising flanks.

1.43.3 This Mode is generally utilised to measure thin materials with good far surface conditions. The distance is measured between the first echo and one of the multiples, this distance is then divided by the number of peaks utilised, e.g. if the distance between the 1st & 6th back-wall echoes is 32 mm then the actual thickness is 32 ÷ 5 = 6.4 mm. Note: This Mode is mainly used with analogue UT sets as most digital UT sets have the capability to set twin "gates" which can accurately determine the material thickness between any two consecutive gated peaks.

1.43.4 Coating thickness, probe stand-off and couplant layer thicknesses can all be ignored when averaging between echoes. The first back-wall signal therefore will represent the test surface.

1.43.5 When determining pitting depth multiple repeat echoes may not be visible, therefore Test Mode 1 or Test Mode 2 will be more suitable.

1.43.6 This multiple peak technique is also suitable as a fast screening method for detecting the presence of internal pitting or corrosion, the rapid collapse of the signals or a change in the echo pattern spacing indicating a suspect area.

TEST LOCATIONS AND EXTENT CONSIDERATIONS

1.44 The location and Test Level requirements should be defined within a work-scope. Corrosion risks and consequences of failure are taken into consideration when determining the extent of testing required.

1.45 During testing if significant material loss is detected it may be necessary to increase the extent of scanning. It is recommended that test technicians report their finding as soon as practicable as test results indicating significant differences to those expected may require a variation to the work scope.

THICKNESS TESTING ACCURACY CONSIDERATIONS AND LIMITATIONS

1.46 The use of ultrasonic testing as a thickness measuring tool on new clean materials can achieve high accuracies, for in-service items however this is not always the case.

1.47 Factors affecting accuracy include but are not limited to the following:

1.47.1 the condition of the test surface
1.47.2 the condition of the reflecting surface
1.47.3 the flaws reflecting face morphology

1.47.4 temperature and temperature transitions
1.47.5 velocity and velocity transitions

1.48 Poor condition of both the test and reflecting surfaces can cause sound dispersion and loss of efficiency.

1.49 The reflecting face morphology will be a significant factor in determining which ultrasonic Test Mode can be applied. Fine pits only provide a small reflecting surface area which can restrict the examination to Test Mode 1 only. More general wall loss generally provides larger reflecting areas that may allow either Test Mode 2 or 3.

1.50 The accuracy of the thickness reading obtained is dependent on a number of factors including all of the above plus; accuracy of calibration, probe type and size suitability and resolution capability of the ultrasonic equipment. Assuming good top and bottom surface conditions the following accuracies should generally be achievable: however for many in-service inspections the surface conditions generally do not permit this degree of accuracy.

Surface condition	Good	Poor
Thickness Range	**Accuracy**	**Accuracy**
0 - 10 mm	± 0.1 mm	± 0.5 mm
0 - 25 mm	± 0.2 mm	± 1.0 mm
0 - 50 mm	± 0.5 mm	± 2.0 mm
0 - 100 mm	± 1.0 mm	± 2.0 mm

1.51 Digital equipment may permit thickness readouts to two or three decimal points e.g. 6.347 mm, this should always be rounded down and recorded to only one decimal point.

1.52 The reading obtained may be partially compromised on rough and corroded surfaces that have been recoated. The coating will have a tendency to smooth the surface as it fills the hollows in the undulating surface. These variable coating thicknesses will affect the accuracy of reading obtainable, often increasing the apparent thickness.

1.53 Note that in general the thickness reading taken using Test Mode 1 or 2 may include the coating. This is not a significant problem when corrosion rates are being determined as all previous and subsequent tests will also include the same error. When actual remaining material thickness is required Test Mode 3 must be utilised

1.54 The following sketch and table shows how variations in coating thickness can affect the ultrasonic reading obtained. There are a number of other factors including material velocity and temperature that can also affect the results. Note; the following is an example only and does not reflect actual measurements.

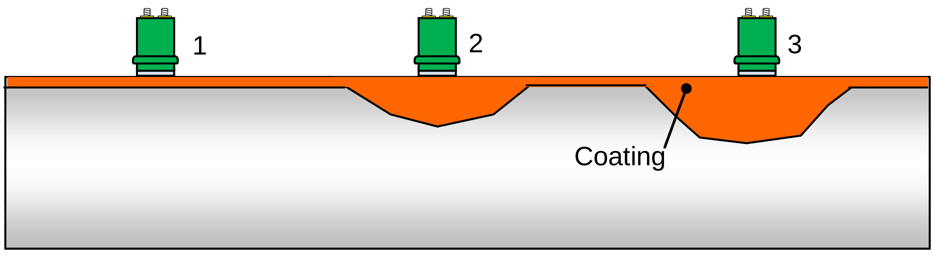


Fig 5: Sketch showing location of thickness reading through a coated surface.

Location	Ultrasonic reading	Actual thickness
1	10 mm	9 mm
2	11 mm	8 mm
3	12 mm	7 mm

1.55 It is sometimes possible that thickness reading can be obtained when a small diameter probe is positioned on a smooth weld cap. The reading obtained may be compromised on irregular "as welded" caps particularly if coated. The coating will have a tendency to smooth the surface as it fills the hollows in the undulating surface. These variable coating thicknesses will affect the accuracy of reading obtainable, often increasing the apparent thickness and when added to a cap height which is also an unknown, it becomes apparent why this is not a recommended technique.

CALIBRATION AND REFERENCE BLOCKS

1.56 All calibration and reference blocks including step type wedges, should be uniquely identified and have a measurement certificate that shows the actual measured dimension of all pertinent sections. Blocks should be dimension verified at periods not exceeding five years.

1.57 For other than carbon steel, the blocks material type should be clearly and permanently identified using hard stamping or engraving. It is also recommended that the material velocity is permanently engraved on the block.

1.58 Calibration blocks conforming to the requirements of EN ISO 2400 or EN ISO 7963 as applicable shall be utilised for the calibration of screen range for angle probes. Additionally, reference blocks containing 3 mm diameter side drilled holes (SDH) shall be available for setting sensitivity levels for angle probes. The minimum recommended thickness of this block is 50 mm with a minimum of three SDH positioned at a minimum of ¼, ½, and ¾ thicknesses.

1.59 Known thickness reference blocks, (e.g. step-wedges) may be used for the calibration of screen range for 0° probes. Block thicknesses should be suitable to cover the thickness range of the item to be measured

COUPLANT

1.60 The coupling medium to be used should be chosen to suit the test surface conditions. The same couplant should be used for calibration as is to be used for the inspection.

1.61 Testing at temperatures ≤ 5°C the couplant chosen should retain its acoustic characteristics and have a freezing point below the test temperature. Testing at temperatures ≥ 50°C will require the use of high temperature probes and a suitable high temperature couplant.

1.62 Halogen free couplants should be utilised where contamination could be detrimental to the integrity of the component. (e.g. most types of stainless steels).

IDENTIFICATION AND DATUM

1.63 The items to be examined need to be uniquely identified and detailed within the inspection request. Identification should at least include the items unique number together with any other information to unambiguously determine its identity and location, (e.g. P & ID reference, drawing and/or isometric reference, etc.). Any variations to the requested test area need to be clearly detailed within the inspection report.

1.64 The location of the test datum should be based on the following listing. When more than one could be applicable the one highest up the list should be utilised.

Piping	Vessels, etc
Top dead centre	North
Outside radius for bends	Top dead centre
Opposite the Tee for branches	East
North	

SURFACE CONDITION

1.65 The surface of the component under test should be clean, dry and free from oil, grease, paint, rust, scale etc. and be of sufficiently uniform contour and smoothness to allow suitable acoustic coupling.

1.66 Coated surfaces

1.66.1 Surface coatings if fully bonded do not generally require removal provided they do not adversely affect the transmission of ultrasound.

1.66.2 For coated surfaces it is unlikely that the coating will be of a constant thickness, generally reading are taken using Test Mode 1 and therefore will include the coating thickness, a note stating that it includes the coating thickness should be included on the test report. Test Mode 3 the multiple echo technique may be used when accurate material thickness is required however this technique can only be applied when the test and reflecting surfaces are good.

1.66.3 Removal of surface coatings, blistering and scabs is the responsibility of the client. It must not be carried out by test technicians unless it is included within the project contract and specific training has been provided. Appropriate coating removal procedures and risk assessments will be required.

1.67 Uncoated surfaces

1.67.1 Testing through uncoated surface generally only requires the removal of any surface contaminants and corrosion product. Light corrosion product may be removed by surface scraping and wire brushing.

1.68 Thermal Sprayed Aluminium

1.68.1 Thermal Sprayed Aluminium (TSA) is applied to surfaces that have been prepared by grit blasting; they are then sprayed with a melted aluminium compound. Generally the TSA is sealed with a coloured topcoat.

1.68.2 Sealed TSA is a complex, multi-layer coating, and there are many variables that can affect testing through it. Generally the sealer has been shown to produce little or no effects to the gain required to test the item and in fact it may be beneficial in reducing the gain required to produce a back wall echo.

1.68.3 Testing through unsealed TSA however generally requires the use of additional gain. Whilst this increase is relatively small for twin crystal and delay line probes, typically up to 6 dB, single crystal probes may require an additional 30+ dB to achieve a signal with the same height back wall echo. The main effect of this is to increase the width of apparent dead zone below the top surface, whilst this is not considered a problem when looking for internal corrosion on thicker materials, single crystal probes should not be used on thinner materials that are coated with unsealed TSA.

TEMPERATURE COMPENSATION

1.69 The velocity of ultrasound within a material is dependent on the elastic properties of that material and these properties vary in relationship to temperature. Where the temperature of an item varies through its thickness, the ultrasonic velocity within the material will also vary accordingly. Readings at elevated temperatures will therefore always be inferior to those taken at ambient temperature.

1.70 During thickness testing the reading obtained should be recorded, if compensation corrections are required they should be applied at a later date.

1.71 Details of the procedure to carry out temperature compensation corrections are detailed within Annex G.

SCREEN RANGE CALIBRATION

1.72 O° screen range should be calibrated on blocks of known thickness manufactured from the same material type as that to be tested. The calibration block material must be noted on the inspection report.

1.73 If the test block material differs from the material being examined compensation must be made for the difference in ultrasonic velocity. When compensation corrections are applied a note to this effect and details of the velocities used should be included within the test report. Details of velocity compensation corrections are contained within Annex G.

1.74 Angle beam screen range calibration may be carried out using either the EN: No 1 or No 2 block.

1.75 It should be noted that shear wave probe designated angles (45°, 60° and 70°) are applicable only to carbon steels. The use of these probes on materials with sound velocities different than that of carbon steels (3240 m/s) will produce beam angles that may differ significantly from its designated angle.

TEST PROCEDURE – GENERAL

1.76 Thickness testing and corrosion detection are often considered as the same test but they are not.

1.77 Thickness testing just determines the thickness of the material at the location the probe is positioned. Therefore significant corrosion and thinning may be missed that only a few millimetres away from the test point.

1.78 Corrosion detection involves the testing of a specified area utilising a 0° probe to determine if corrosion is present. This followed by an assessment of the general condition to determine if there is general or more localised indications in the area of interest, and also when a loss of the BWE is encountered. When this has been established, specific indications should then be evaluated. This is achieved by evaluating the response from the indication itself, and that of the back wall, this may also require assessing the indication with an angle probe.

1.79 The evaluations of detected indications play a critical integral part in determining future actions, these can include a more detailed programme of monitoring, an engineering critical assessment (also called fitness for service), item replacement or if considered necessary immediate shut down of a plant or system. Given the potential consequences of incorrect interpretation of results, the technician should refrain from passing judgement until the full evaluation is completed. It is recommended that results from previous inspections be reviewed to assist in evaluation and interpretation of results.

1.80 Vigilance is necessary in areas of variable geometry, or when obstructions are present as there may be some areas that may not be possible to examine, these areas should be reported as a test limitation.

1.81 Included within Annex A is a memory refresher covering guidelines on typical corrosion mechanisms and typical ultrasonic indication responses.

TEST PROCEDURE - SPOT OR GRID READINGS

1.82 <u>Test Method</u>

1.82.1 Spot or Grid tests.

1.82.2 This test method is used for thickness testing only, it must not be utilised for the detection or monitoring of corrosion, (though it may occasionally detect some) and should only be used when specifically requested.

1.83 <u>Test mode</u>

1.83.1 Reading may be taken using Test Modes 1, 2, or 3 with Test Mode 3 being recommended as it eliminates the coating thickness, however on internally corroded parts this may not be possible.

1.83.2 Gates may be used to record the minimum thickness, either the distance to the 1BWE, which will include any coating thickness, or the distance between the 1BWE and 2BWE may be recorded as this will eliminate coating thickness. The test report should state which method is utilised.

1.83.3 Gate threshold height should be set to between 20 - 40% FSH

1.84 <u>Test Level</u>

1.84.1 Not applicable, test levels are not applicable to spot or grid readings.

1.85 <u>Screen Range</u>

1.85.1 Prior to calibration the test equipment should be set to measure peak reading as this minimises thickness reading errors due to variations in signal height.

1.85.2 Screen range calibration may be set on any suitable reference block of known thickness and it shall be such that it incorporates the 2BWE.

1.86 <u>Sensitivity setting</u>

1.86.1 Sensitivity may be set on the material under test so that the applicable BWE (1^{st} or 2^{nd}) exceeds the gate recording threshold.

1.87 <u>Transfer correction</u>

1.87.1 Not applicable.

1.88 <u>Technique</u>

1.88.1 The test comprises of a series of individual thickness reading carried out at pre-defined locations, e.g. the cardinal points or 3, 6, 9 and 12 o-clock positions, or if specified random locations. In some cases the locations at which the reading is to be taken may be permanently marked on the test surface.

1.88.2 Details of the techniques are detailed within Annex F Technique UT-TCS-T1.

TEST PROCEDURE - LINE AND AREA SCANS

1.89 <u>Test Method</u>

1.89.1 Line or area scans, used initially for the detection or monitoring of corrosion followed by the determination of the thinnest thickness reading within the tested area.

1.89.2 Angle beams are also used to assist in determining the nature of internal reflectors detected with 0º probes.

1.90 <u>Test mode</u>

1.90.1 Corrosion detection requires continuous monitoring of the display utilising pattern recognition techniques. Digital thickness readouts should be disregarded during detection and monitoring examinations.

1.90.2 When pitting and corrosion is detected repeat signals may not be produced, in such cases Test Mode 1 (or 2) should be utilised.

1.91 <u>Test Level</u>

1.91.1 Test Levels 1, 2 or 3 or any combination of these may be utilised.

1.92 Screen Range

1.92.1 Prior to calibration the test equipment should be set to measure flank reading.

1.92.2 0° calibration for screen range may be set on any suitable block. Screen range shall be such that it incorporates a minimum of 4BWE.

1.92.3 Angle beam screen range shall be such that it exceeds the full skip beam path distance.

1.93 Sensitivity setting

1.93.1 For material up to nominally 25 mm thickness, a reference block (step wedge) of similar thickness to the item to be tested shall be used. The gain shall be adjusted so that the 2nd BWE is at FSH. The gain setting should be noted.

1.93.2 Once calibrated on the step wedge or the calibration block the technician must take into account the transfer correction required to adjust for both surface condition (including coatings) and material difference(s). The gain must be adjusted to give the same second back wall echo at full screen height as was achieved on the calibration/reference block. The difference between the two is added to the test sensitivity.

1.93.3 If additional gain is found to be excessive (>12db) it may be due to coating or surface condition, then an assessment must be made of the component's suitability for inspection using ultrasonic techniques.

1.93.4 Another reason for such a difference however may be due to a severely corroded internal surface, however in this case there will also be a reduction in material thickness which would indicate its presence.

1.93.5 Corrosion detection and monitoring shall be carried out at reference sensitivity plus transfer correction. This may be reduced when determining minimum material thickness.

1.93.6 Angle probes sensitivity shall be set from a 3.0mm diameter side drilled hole located at approximately twice the thickness of the material under test. The amplitude from the hole shall be set at 80% FSH and then a minimum of 12 dB shall be added.

1.93.7 Angle probes are utilised to assist in evaluation of suspect and known flawed areas. Transfer correction is therefore not applicable however, it is recommended that sufficient gain is added to provide a 5% back wall noise (grass) level when internal pitting is to be detected.

1.94 Technique -0°

1.94.1 Initial examination is for the detection or monitoring of corrosion. This requires continuous monitoring of the display utilising pattern recognition methodology. Experience has shown flaws are more likely to be detected as a change in overall screen pattern rather than as a small individual change. Test personnel must look for changes in signal amplitude and pattern changes and must not rely on the minimum wall thickness displayed on the UT equipment following scanning of an area.

1.94.2 High speed scanning of around 250 mm per second is recommended for the initial detection scan. However evaluation and sizing will require a reduction in the scanning speed.

1.94.3 Measuring to the flank of the echo from the deepest pit (i.e. closest to scanning surface) eliminates possible errors that can occur from higher amplitude signals emanating from shallower pits following closely behind on the time base.

1.94.4 To reduce the errors associated with signal flanks crossing the recording gate threshold at different positions due to variations in amplitude, the calibration signal height and all readings should be taken with the reflected signal height adjusted to 80% FSH. The recording threshold (typically 20 to 40%FSH) should be set during calibration and remain at this level for all subsequent testing.

1.94.5 If indications are detected angle probes are to be utilised to assist in evaluation.

1.94.6 If the reading recorded includes a coating thickness a note to this effect should be included within the test report.

1.94.7 Details of the techniques are detailed within Annex F Technique UT-TCS-T2 or UT-TCS-T3.

1.95 <u>Technique - angle probes</u>

1.95.1 Whenever practicable 45° angle probes shall be utilised, though other angles may be used if required.

1.95.2 Gain shall be set on a smooth flaw free area of the item under test, so the back wall grass level is set to 5 – 10% FSH. Gain may be adjusted as required to maintain this level.

1.95.3 Note angle beams are used to assisting in determining the nature of internal reflectors detected with 0º probes. Small inclusions will, in general, also permit sound to skip of the back surface below the indication. Hydrogen induced cracking (HIC) may give responses from their characteristic "stepped" interconnections and pitting responses from the lower corner sound trap

1.95.4 Details of the techniques are detailed within Annex F Technique UT-TCS-T4.

TEST PROCEDURE - ROOT CORROSION DETECTION

1.96 <u>Guidelines</u>

1.96.1 Prior to carrying out root corrosion detection it is highly recommended that section 26 and Annexes D and J are read so that the limitations of this test are fully understood.

1.96.2 When applying the testing parameters contained within this section (25.2 through 25.8) of this procedure the following applies:

1.96.3 Great care should be taken to ensure a full scale drawing is made and the testing parameters are understood. The defect mechanism is such that the profile of the weld root corrosion is infinitely variable and high amplitude signals such as those expected from lack of weld root fusion and lack of root penetration may not occur – very low amplitude signals are common

1.96.4 Use all possible angles to inspect the area – not just a 70 or 60 degree probe – use both if access to the root area or adjacent Heat Affected Zone (HAZ) is possible

1.96.5 The high scanning sensitivity stated in paragraph 25.6 is often necessary to detect the weld root corrosion due to its low reflection face morphology.

1.96.6 When inspecting components with material thicknesses exceeding nominally 20.0mm the sensitivity levels may lead to high *Signal Grass Levels* (in excess of 10%). Under these circumstances the gain may be reduced until the Grass Level is acceptable – i.e. less than 5%.

1.96.7 Taking all of these limitations into consideration the POD of all of the weld root corrosion in low and therefore it is recommended that a statement to this effect is included in each test report.

1.97 <u>Test Method</u>

1.97.1 0° Line scans both in the parent materials and on the weld cap, plus 45°, 60° and 70° angle beam scans.

1.98 <u>Test mode</u>

1.98.1 Thickness reading may be taken using Test Modes 1 or 2 as it is unlikely that Test Mode 3 would be suitable, particularly when the probe is positioned on the weld cap.

1.99 <u>Test Level</u>

1.99.1 0° Test Level 1 plus 45°, 60° and 70° angle beam scans.

1.100 <u>Screen Range</u>

1.100.1 0° screen range shall be such that it exceeds twice the material thickness

1.100.2 Angle beam screen range shall be such that it exceeds the full skip beam path distance.

1.101 <u>Sensitivity setting</u>

1.101.1 0° sensitivity may be set on the material under test so that the 1BWEFSH. When the probe is positioned on the weld cap it may be necessary to increase the gain to obtain a reflected signal.

1.101.2 Angle beam reference sensitivity shall be set at 80% FSH from a 3 mm Ø SDH located at the material depth. Scanning sensitivity shall be reference gain plus 12dB.

1.102 <u>Transfer correction</u>

1.102.1 Not applicable.

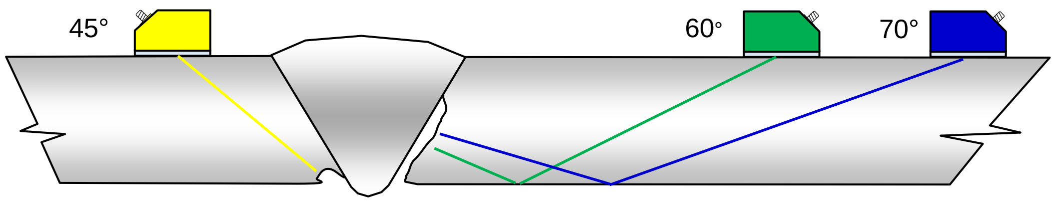
1.103 <u>Technique</u>

1.103.1 The parent materials adjacent to the weld shall be examined with a 0° probe looking for any signs of material loss.

1.103.2 A 0° probe shall now be positioned on the weld cap and is as much as is practicable the full length and width should be 100% tested and suspect areas recorded. The thickness reading obtained should exceed that of the parent material as it will include the weld cap and root.

1.103.3 Angle probes shall now be utilised to examine an area which shall encompass the weld, HAZ and a minimum of 10 mm of the adjacent parent materials.

1.103.4 45° angles are good at detecting corrosion in the parent material area adjacent to weld but hidden under the weld cap. 60° and 70° angle probes for detection in the root area and up the fusion faces.



Sketch showing angle probe scan areas

1.103.5 Details of the techniques are detailed within Annex F Technique UT-TCS-T5.

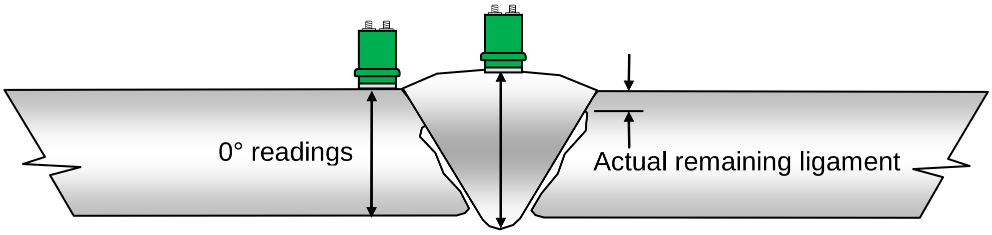
ROOT CORROSION DETECTION & TEST LIMITATIONS

1.104 The detection of weld root corrosion with manual UT is not recommended (see Annex J) however, it is realised that this technique is frequently requested by clients mainly due to the additional costs involved for utilising more reliable techniques.

1.105 Test access can be limited, particularly for angle probes, due to unfavourable geometry or restricted access often caused by fitting (flanges, valves etc.). All test restrictions must be included within the test reported.

1.106 Root corrosion is a generic name for preferential material corrosion that occurs within the weld root, HAZ or adjacent parent material. The ultrasonic test method therefore must encompass all the potential corrosion areas, however, even utilising both 0° and angle probes the probability of detection remains low.

1.107 To increase the POD thickness reading are taken on the weld cap if possible. Thickness reading taken from the weld cap can indicate the presence of corrosion in the weld material, however a significant limitation is its inability to detect significant wall loss in the heat affected zones. The sketch below shows how the reading obtained would indicate no signs of corrosion when in fact the item is close to failure.



Sketch showing limitation of taking 0° thickness reading from the weld cap

NON-COMPLIANCE

If the ultrasonic technician is unable to comply with the requirements of the work request for whatever reason, it should be recorded in detail on the test report.

REPORTING

1.108 A report of the inspection should be produced, the report should include:-

a) Identification of company carrying out the test
b) Designation of the document. (e.g. Ultrasonic Inspection Report)

c) Unique report reference, to be included on all pages.
d) Page number and total number of pages. (e.g. page 4 of 12)
e) Date or dates on which tests were carried out.
f) Identification of the Client, and work location.
g) Identification of the items tested.
h) Description of the work ordered with reference to any formal request reference.
i) Identification of the items tested, drawing numbers etc.
j) Material type and specified: diameter, nominal thickness, etc.
k) Test items physical condition, e.g. heat treatment, test temperature and surface conditions.
l) Specific details of areas/zones covered during the survey including reference to datum points.
m) Test procedure and test technique reference, including revision status.
n) Test equipment details, including probe types, angle, size and frequency.
o) Temperature and/or material velocity correction factor applied (if applicable).
p) Details of test restriction or deviations from procedure, including locations.
q) Details of results obtained, including applicable comments, e.g. readings include coating thickness.
r) Name, signature and qualification status of test personnel and date of issue of report

1.109 Additional information in the form of sketches, line drawings, photographs etc. may also be included if considered applicable. A sample report is included within Annex I.

ANNEX A – Typical Corrosion Types and Ultrasonic Response Guidelines

Individuals carrying out ultrasonic testing for corrosion detection and thickness monitoring should attend training courses covering corrosion types and mechanisms, and the ultrasonic techniques detailed within this document. This Annex, which is intended as a memory refresher, provides details of the expected ultrasonic responses from a number of different types of corrosion.

Corrosion & Erosion

Corrosion is the result of a reaction between the piping and/or vessel material and a product contained within it. General corrosion tends to form uniformly across the surface of the material showing a gradual reduction in thickness. As corrosion increases the thickness of remaining wall thickness will vary and can become more multi-faceted.

Erosion is the result of the product travelling at speed through the container. The product erodes the material where it meets an obstruction either due to geometry of the component or a defect.

A reduction in the material thickness and a possible reduction in the amplitude of the back wall echo are indicative of both corrosion and erosion.

The reflected back wall signal amplitude from corroded and eroded material is also likely to be less consistent.
Erosion is generally the easier to detect as it causes a more consistent reduction in thickness. It is often localised and can be associated to specific causes.

Early stage indication responses

0°: Will have a back wall signal close to the nominal material thickness but may be accompanied by a loss in amplitude of the first and second back wall echoes and also a reduction of the third and fourth back wall echoes. (Figure 1)

45°: Unlikely to be detected though back wall response may be slightly above general noise level. (Figure 5)

Intermediate stage indication responses

0°: Will still have a back wall signal but the nominal material thickness will be reduced, the first back wall echo will be of a lower amplitude and will be accompanied by significant reduction of the second and probable loss of the third and fourth back wall echoes. (Figure 2)

45°: Reflections from the half-skip distance will be above general noise level with increased amplitude signals evident from any raised profile from the corroded area. (Figure 6)

Advanced stage indication responses

0°: Signals appear at the corrosion depths, there will be considerable amplitude reduction in the first echo and there may be a loss of repeat echoes. (Figure 3).

45°: Reflections from the half-skip distance will be increased in amplitude accompanied by varying beam path distances. (Figure 7)

Pitting – general guidelines

Pitting is corrosion which occurs over small deep areas, generally caused by a localised breakdown of coating or a localised chemical reaction between the fabric of the fluid container and the fluid itself.

CO_2 corrosion is noted for being particularly small in area, deep with steep sides and sharp edges, care should be taken to confirm connection with back wall and not confuse with inclusions.

Pitting may be present over a large area, but each pit may be small in area and is difficult to both detect and assess.

Multiple indications at varying depths often with variable and rapid amplitude changes including total signal loss are indicative of pitting.

Pitting can generally also be confirmed with a 45° angle probe.

Early stage indication responses

0°: Early stages pitting, or a pinhole type, will often have a back wall signal at the nominal material thickness. Depending on the type of pitting the signals from the back wall may be distorted by the signal creeping up the back wall echo. On occasions the only indication of such defects will be a change to the back wall echo pattern

45°: Reflections from the half-skip distance may be slightly above general noise level but, depending on the type of pitting may not be evident. (Figure 5)

Intermediate stage indication responses

0°: Intermediate stage, or a shouldow wide type, may still have a back wall signal at the nominal material thickness but it will cause reduction in amplitude of the first and second and a loss of the third and fourth back wall echoes. (Figure 2)

45°: Reflections from the half-skip distance will be evident. They will be straight up and down in nature and give varying amplitude heights. (Figure 6)

Advanced stage indication responses

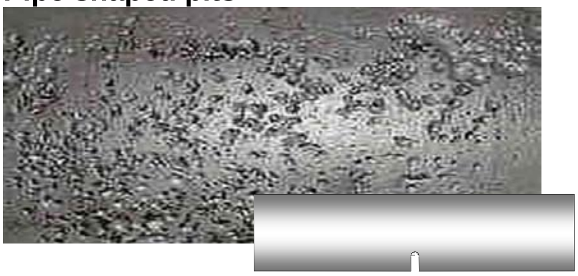
0°: Signals will be reflected from the pitting as opposed to the back wall. There will be considerable amplitude and depth variations, with some areas giving no reflections due to the unfavourable geometry of the pits. An indication of the severity of the pitting will be the reduction or loss of the back wall echo pattern. (Figure 3)

45°: Reflections, often multiple, from the half-skip distance will be evident. The beam path distances may be shorter in places. (Figure 7)

Loss of Back Wall Echo Pattern:

The near or total loss of, a back wall signal, may be caused by a number of significant factors. These areas must be included and their location identified within the inspection reported. The highlighting of these areas will allow for additional and more suitable testing to be carried out determining the actual cause.
The depth of pitting will be measured by the minimum noted beam path; the area of the pit should be measured by plotting the extremes using a zero degree probe.

ANNEX B – Illustrations of Various Forms of Pitting

Lake type pits 	Lake type pitting, where the bottom is reasonably flat, good signals can be obtained provided that the UT probe is placed over the pit. If a spot check grid system is used there is obviously a chance that the probe will **not** be placed over the pit. Line or area scans are more likely to detect this type of flaw.
Cone shape pits 	Cone shaped cause the UT signal amplitude to drop. The bottom of the pit will be small in area and may not give a recognisable signal. Because of this any results may underestimate the wall loss present. Often a total loss of all reflectors - similar to loss of couplant. Evaluation of remaining wall thickness may be difficult.
Pipe shaped pits 	Pipe shaped pitting may be the result of Sulphur Reducing Bacterial attack (SRB). Both difficult to detect and size. Only the most sophisticated of UT scanning techniques is capable of detecting these pits particularly if isolated. Loss of amplitude in the multiple reflected echoes is often the first indication.

<u>Inherent inclusions</u>

0°: An inclusion will generally give a significant signal, the amplitude will depend on its cross sectional area relative to the cross sectional area of the probe. Inclusions are generally small in area and are planar in cross section. A reduction, but not loss, of back wall response is likely.

45°: Unlikely to give any indication response.

<u>Laminations</u>

0°: Laminations will cause a complete loss of the back wall echo and a new signal to be introduced at a shorter range that will have repeat echoes associated with it. The reflected signal will be of generally uniform amplitude. Laminations tend to occur within the mid wall area. It will not be possible to detect corrosion or pitting underneath a lamination.

45°: This scan will not detect laminations.

<u>Multiple indications</u>

If combinations of the above occur together great care must be taken to discriminate them, particularly pits with respect to inclusions. Each indication has to be scrutinised independently to look for shifts in time base range.

ANNEX C – examples of screen displays

Examples of screen displays	
Zero degree probes	

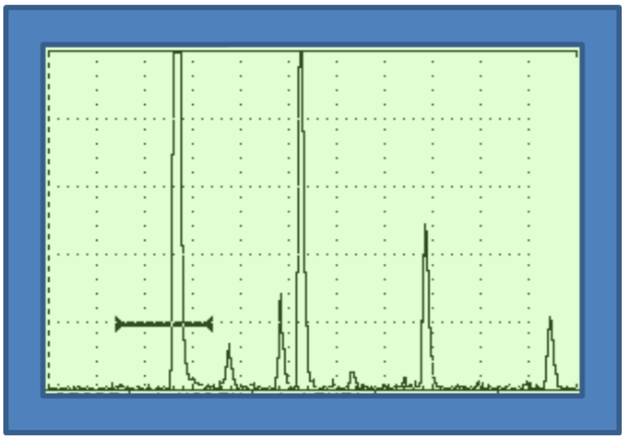
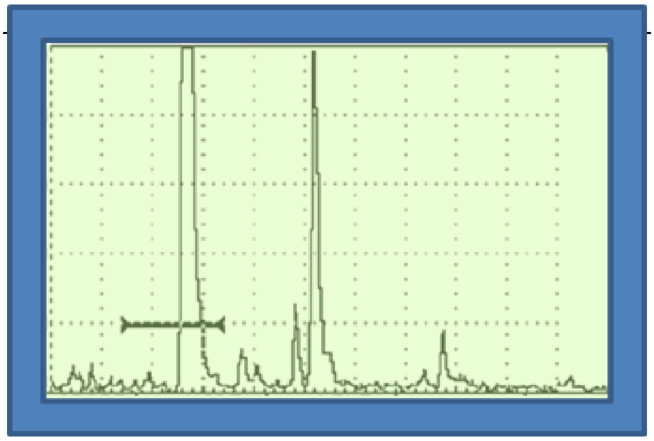

	

Figure 1	Figure 2
Early stage corrosion. **Signal similar to that obtained from a machined finish reference block.** **No sigificant reduction in material thickness**	**Intermediate stage corrosion.** **Loss or significant reduction in third or fourth back wall echoes.** **A small reduction in material thickness**

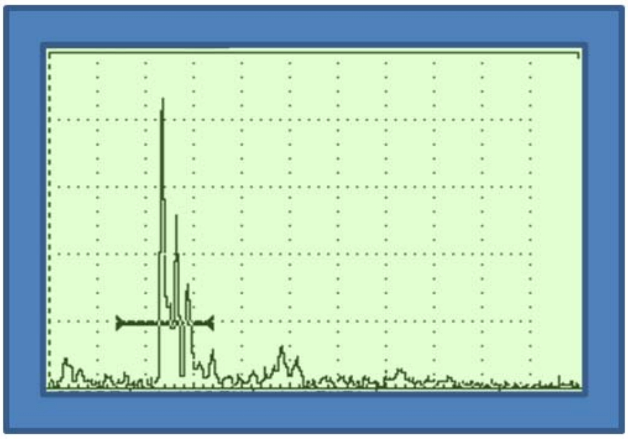



Figure 3	
Advanced stage corrosion **Low amplitude or no second or subsequent back wall echoes.** **A more significant reduction in material thickness**	

Examples of screen displays	
Angle probes	

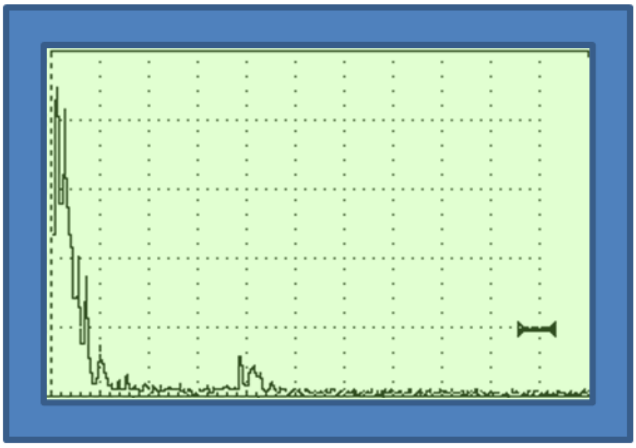
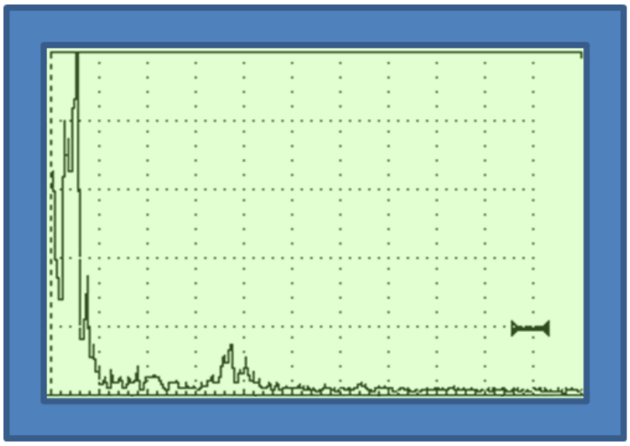

	

Figure 04	Figure 05
Reference sensitivity, back wall grass level at 5 – 10% full screen height.	**Standard ripple from the half skip distance evident. Relatively smooth back surface**

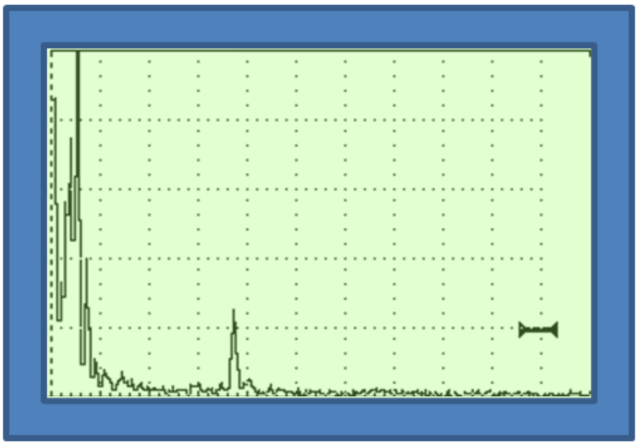
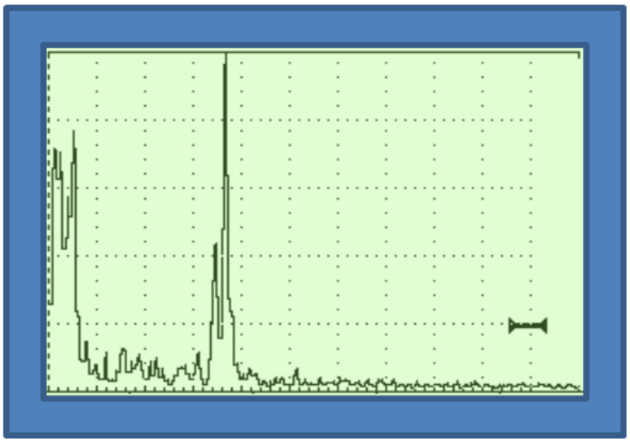

	

Figure 06	Figure 07
Low amplitude signal from the back wall at half skip distance. Evidence of rougher inside surface and possibly early stage corrosion.	**Significant increase in amplitude from the back wall at half skip distance. Evidence of intermediate or advanced stage corrosion.**

Similar responses can be expected from the full skip signal when looking for near surface flaw depth under scabs, or at pipe corroded pipe supports.
Note that full skip testing can only be carried out if the internal surface is in good condition.

ANNEX D – Typical Weld Root Corrosion Mechanism Guidelines

Corrosion overview

The mechanism involves the selective corrosion of a part of the weld zone, due to a difference in the galvanic potential of adjacent zones, correctly identified as Preferential Weld Root Corrosion (PWRC). This may be the result of selective leaching (dissolution), constituent chemical composition, precipitation of elements during the welding process or differences in the effectiveness of corrosion inhabitation of the base metal and weld in a chemically inhibited system. If the weld material is more susceptible to corrosion than the base material, wash out of the weld causes groove corrosion.

A similar corrosion mechanism can also affect the material in the heat affected zones. Corrosion in this case can be restricted to a narrow groove, or grooves, in the weld fusion face.

Erosion overview

With single sided welds as used in pipe butt welds it is difficult to control the profile of the root bead. Therefore it is not uncommon for there to be a protrusion that can disturb the fluid flow. Eddies can form leading to preferential flow at particular points close to the weld. The mechanical damage by the impacting fluid imposes disruptive shear stresses or pressure variations on the material surface and the protective surface film. Erosion-corrosion may be enhanced by particles (solids or gas bubbles). Other factors such as turbulence, cavitation, impingement or galvanic effects can add to the severity of attack.

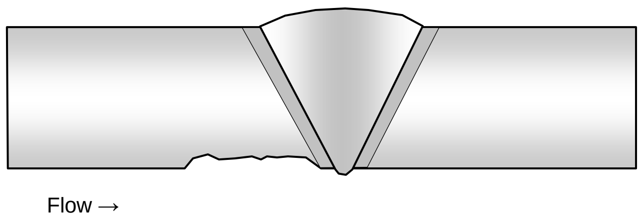
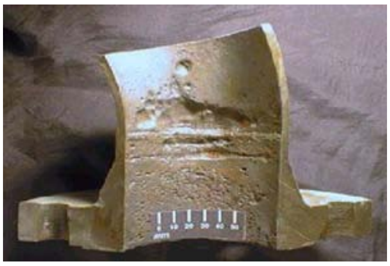
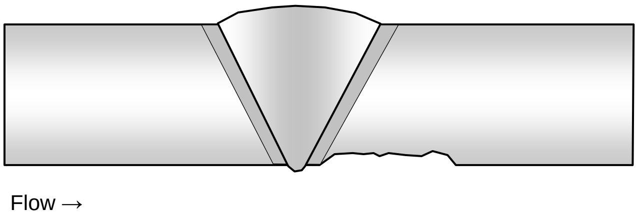
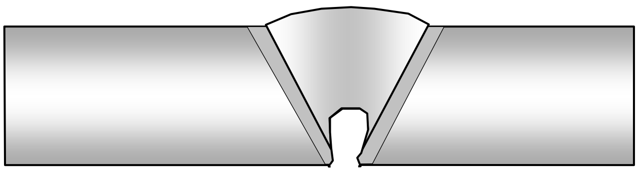
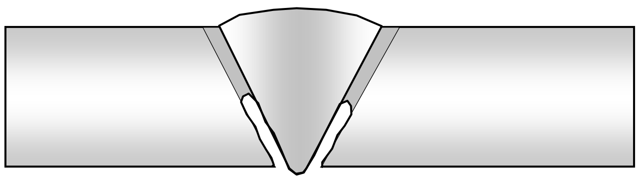
At certain flow velocities the resulting turbulence or cavitation can result in erosion of material downstream of the discontinuity. The flow-induced mechanical removal of the protective surface film results in a subsequent corrosion rate increase.

Erosion and corrosion whilst being different mechanisms often work together.

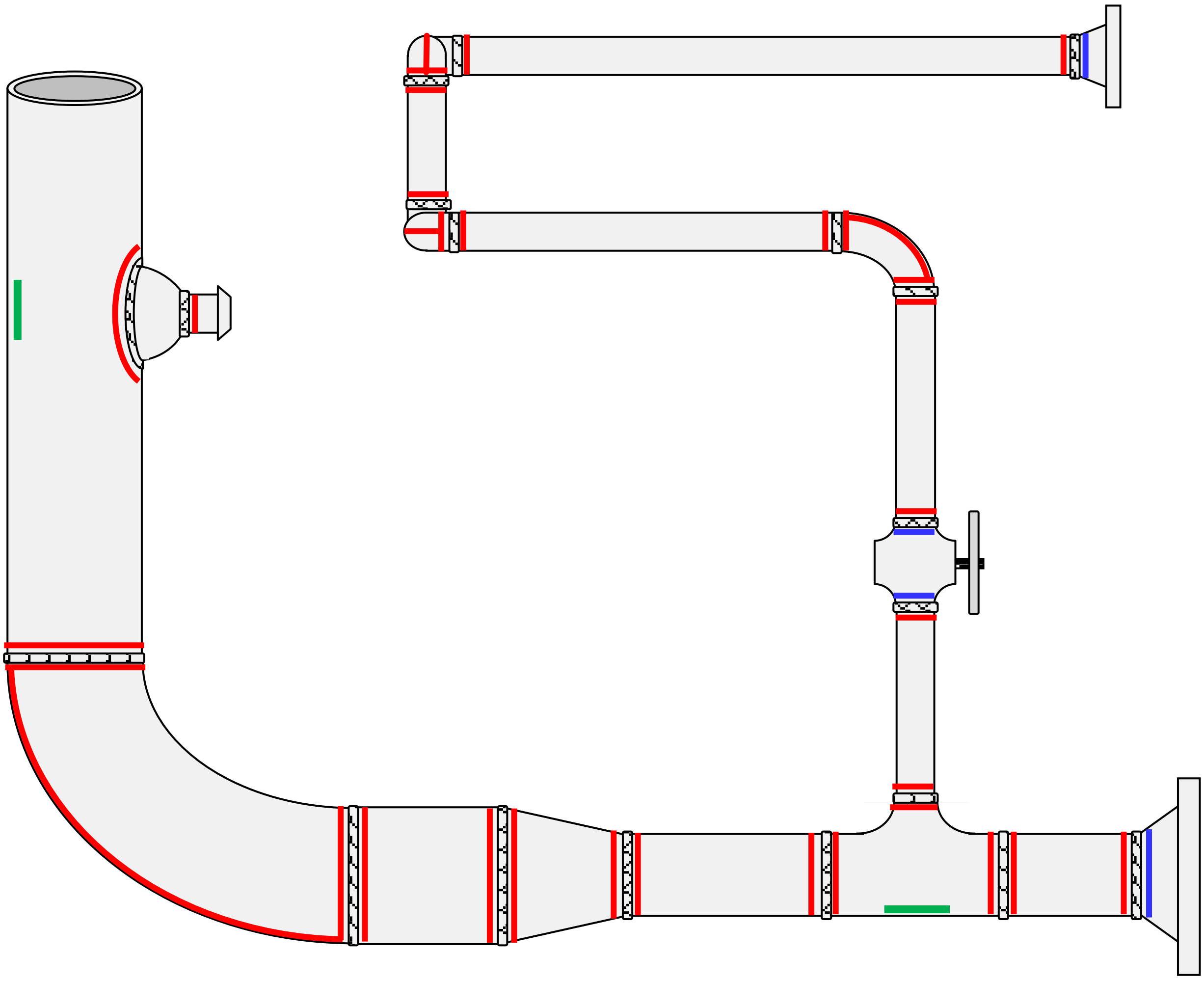
From an ultrasonic testing perspective, we do not know what type of erosion or corrosion could be present therefore the examination should look for all types.

Location of degradation

Depending on the principal mechanism which is responsible for the degradation, the predominant material loss can be from different areas of the weld, as shown in the sketches and photos below.

Description	Example
	
Up-stream erosion	
	
Downstream erosion	
	
Groove corrosion	
	
HAZ/fusion line corrosion	

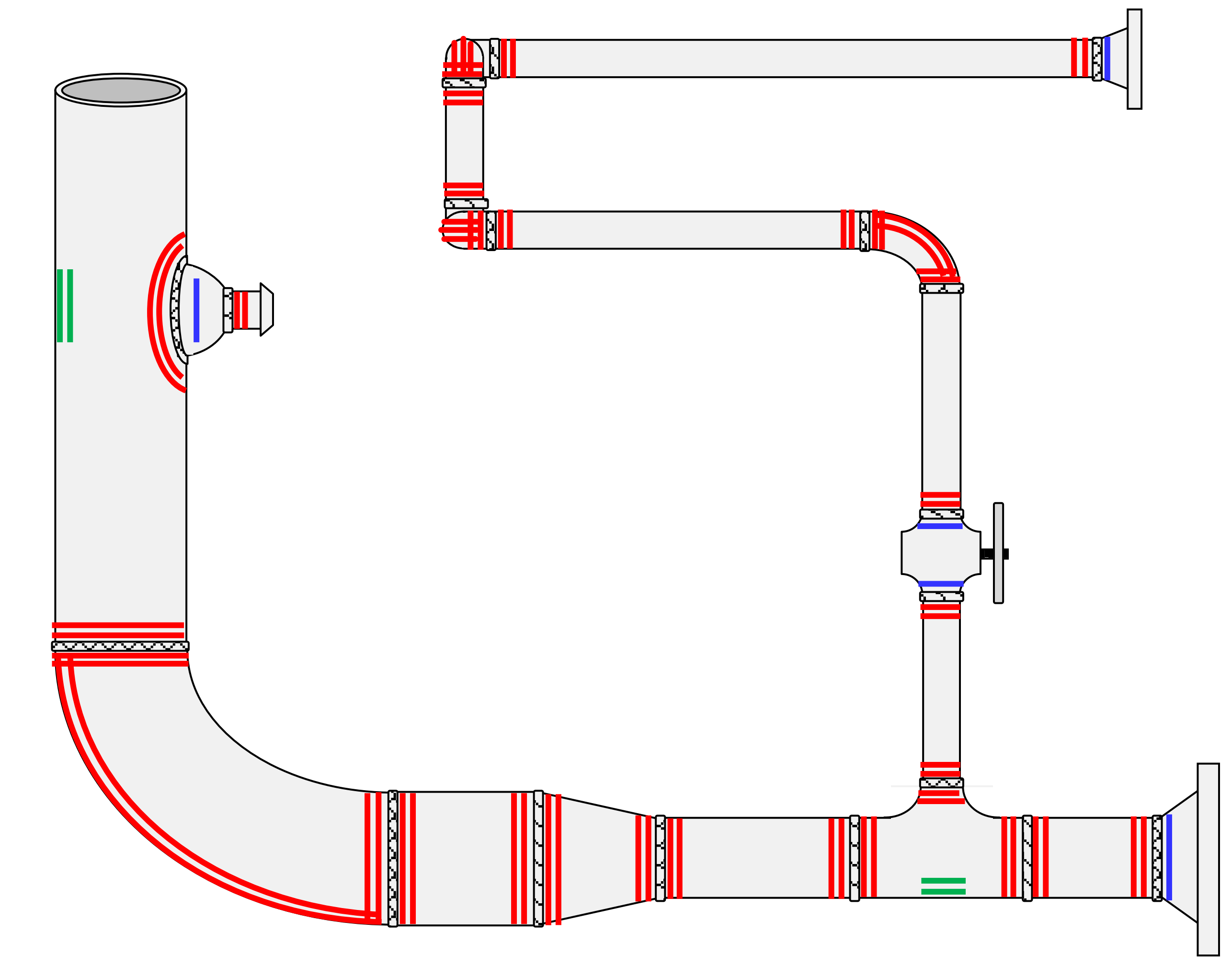
ANNEX E – Test Level Guidelines

Recommended test areas for piping - Test Level 1
Red = Required test areas Blue = Test area if part geometry permits Green = Test of this area depends on fluid flow.


Location	Description
Pipe to pipe	Single line scans around circumference adjacent to welds.
Pipe to Fitting	Single line scans around pipe circumference adjacent to welds. Single line scans around fitting circumference adjacent to welds if practicable.
Tee and branches	Single lines around circumference adjacent to all welds. Small area scan opposite Tee leg. (requirement depends on fluid flow)
Bends	Single lines scan around the bend circumference adjacent to welds. Single lines around along the outer radius.

Recommended test areas for piping - Test Level 2

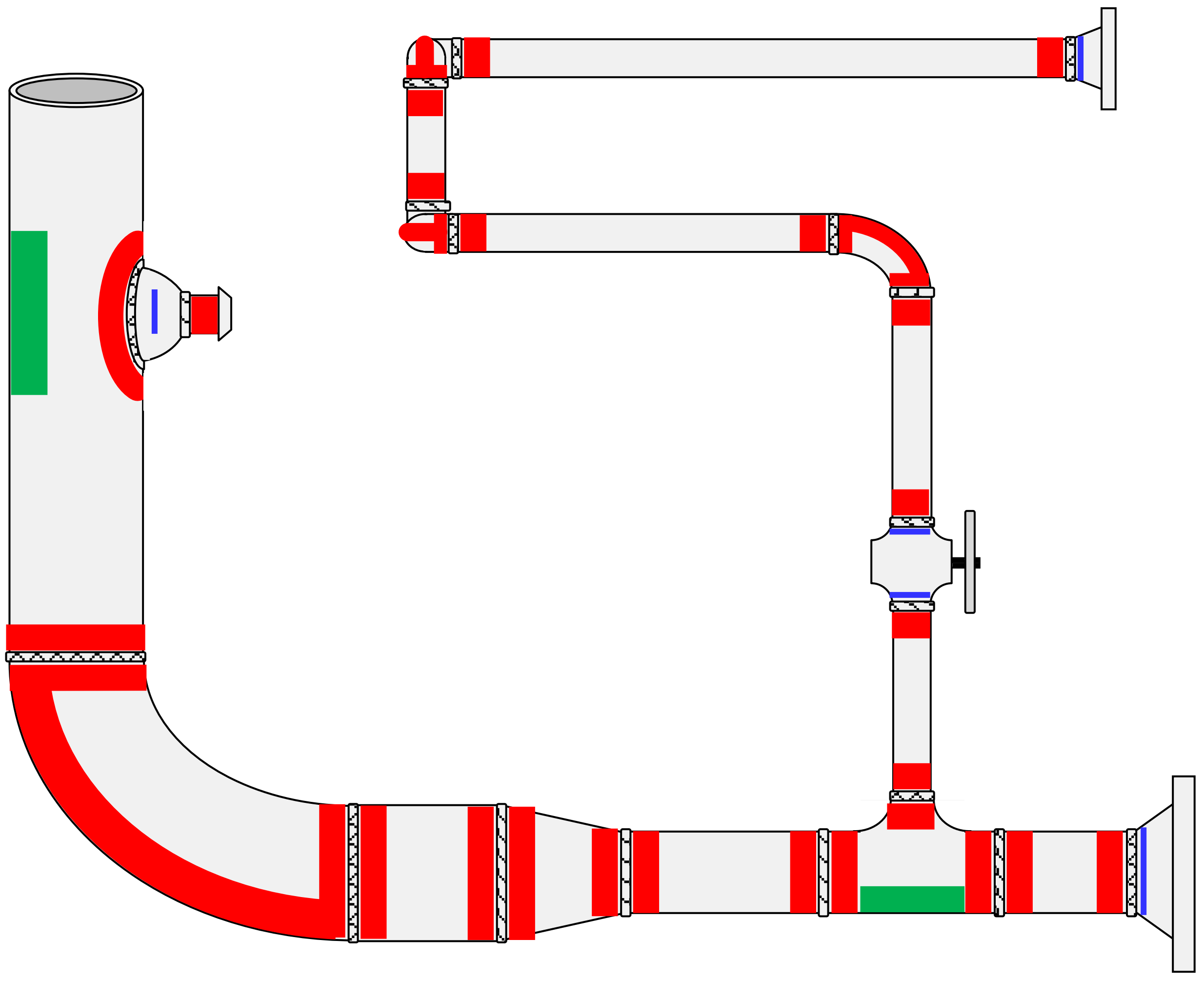
Red = Required test areas
Blue = Test areas if geometry permits
Green = Test of this area depends on fluid flow.



Location	Description
Pipe to pipe	Twin line scans around circumference adjacent to welds.
Pipe to Fitting	Twin line scans around pipe circumference adjacent to welds. Twin line scans around fitting circumference adjacent to welds if practicable.
Tee and branches	Twin lines around circumference adjacent to all welds. Small area scan opposite Tee leg. (requirement depends on fluid flow)
Bends	Twin lines scan around the bend circumference adjacent to welds. Triple lines around along the outer radius.

Recommended test areas for piping - Test Level 2

Red = Required test areas
Blue = Test areas if geometry permits
Green = Test of this area depends on fluid flow



Location	Description
Pipe to pipe	Area scans 100 mm wide around pipe circumference adjacent to welds.
Pipe to Fitting	Area scans 100 mm wide pipe circumference adjacent to welds. Single line scans around fitting circumference adjacent to welds if practicable.
Tee and branches	Single lines around circumference adjacent to all welds. Small area scan opposite Tee leg. (requirement depends on fluid flow)
Bends	Area scans 100 mm wide around the bend circumference adjacent to welds. Area scan covering 25% of pipe circumference length on centred on outer radius.

Annex F – Test Technique Guidelines

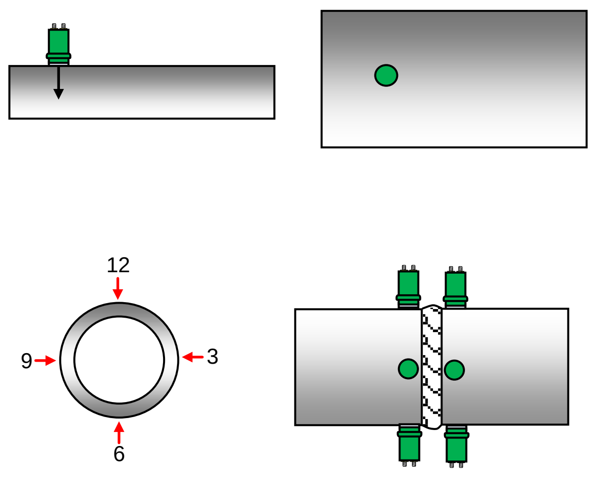
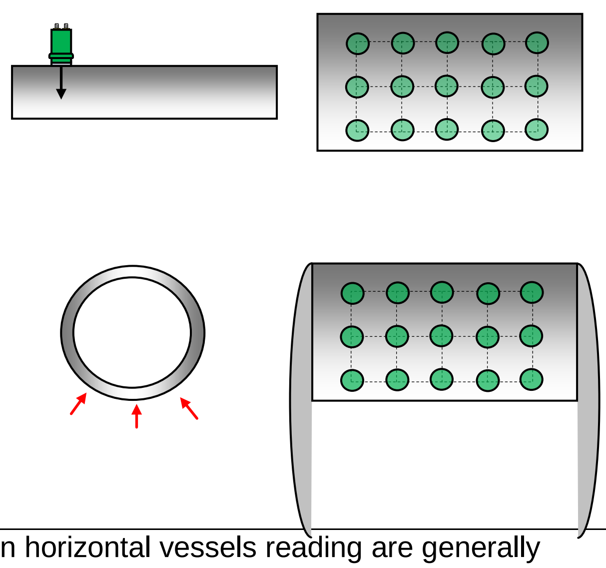
Test Type	Spot & Spot grid checks	Ref.	UT-TCS-T1
Application	Thickness measurement	Rev.	0
Test standards	EN 14127		
Materials types	All metals with known or determinable velocities.	Range	≥ 6 mm

Equipment	"A" scope flaw detector	0° Ref level ≤ 25 mm	2nd BWE to FSH
Probe type	See below	0° Ref level > 25 mm	1st BWE + 12 dB
Test mode	1 , 2 or 3	0° Transfer correction	Not applicable
Calibration block	No. 1 or No. 2	θ° beam ref level	Not applicable
Reference block	Step wedge	θ°Transfer correction	Not applicable
Test temperature	-20° C to 50° C	θ° Scan level	Not applicable

Recommended 0° probe type

Nominal thickness	Frequency	Probe diameter	Type	Item diameter
< 6 mm	5 – 10 MHz	5 mm	Single - delay line	< 100mm
6 - 10 mm	5 – 10 MHz	5 mm	Twin element	< 100mm
10 - 40 mm	4 – 5 MHz	5 mm	Twin element	< 100mm
10 - 40 mm	4 – 5 MHz	10 mm	Twin element	> 100mm
40 - 100 mm	2 – 4 MHz	10 - 20 mm	Single element	> 100mm
100 - 200 mm	2 MHz	20 - 25 mm	Single element	> 100mm

Other probes may be selected if determined to be more appropriate

Test type - Spot checks	Test locations - piping example
Section view / Plan view	Section view / Plan view
	
Unless otherwise specified reading should be taken at cardinal points or 3, 6, 9 and 12 o-clock positions.	On horizontal vessels reading are generally between 4 and 8 o-clock positions.

Notes

1 Thickness below ~6 mm may be tested provided the probes near surface resolution capability is verified.
2 Test Mode 1 to be utilised unless specifically requested otherwise.
3 Test Mode 1 and 2 to include: "Thickness readings includes coating" on the test report.

4 If the probe cannot be positioned were specified it should be reported.
5 Reading shall only be taken from the weld cap when specifically requested
6 Testing above 50° is permitted providing the appropriate probe and couplant are utilised.
7 Low thickness reading may be indicative of corrosion, alternative test techniques are recommended.

Approved by		

Test Type	Line Scans	Ref.	UT-TCS-T2
Application	Corrosion detection, monitoring & thickness measurement	Rev.	0
Test standards	EN 14127		
Materials types	All metals with known or determinable velocities.	Range	≥ 6 mm

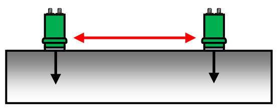
Equipment	“A” scope flaw detector	0° Ref level ≤ 25 mm	2nd BWE to FSH
Probe type	See below	0° Ref level > 25 mm	1st BWE + 12 dB
Test mode	1 , 2 or 3	0° Transfer correction	As applicable
Calibration block	EN: No. 1 or No. 2	θ° beam ref level	See technique UT-TCS-T4
Reference block	Step wedge	θ°Transfer correction	See technique UT-TCS-T4
Test temperature	-20° C to 50° C	θ° Scan level	See technique UT-TCS-T4

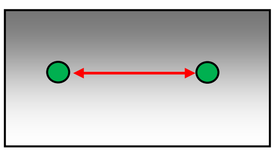
Recommended 0° probe type

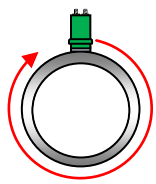
Nominal thickness	Frequency	Probe diameter	Type	Item diameter
< 6 mm	5 – 10 MHz	5 mm	Single - delay line	< 100mm
6 - 10 mm	5 – 10 MHz	5 mm	Twin element	< 100mm
10 - 40 mm	4 – 5 MHz	5 mm	Twin element	< 100mm
10 - 40 mm	4 – 5 MHz	10 mm	Twin element	> 100mm
40 - 100 mm	2 – 4 MHz	10 - 20 mm	Single element	> 100mm
100 - 200 mm	2 MHz	20 - 25 mm	Single element	> 100mm

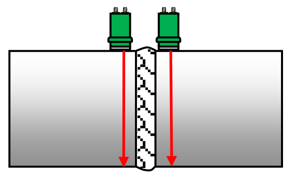
Other probes may be selected if determined to be more appropriate

Test type – Line scan		Test locations - piping example	
Section view	Plan view	Section view	Plan view









Notes

1	Thickness below ~6 mm may be tested provided the probes near surface resolution capability is verified.
2	Test Mode 1 to be utilised unless specifically requested otherwise.
3	Test Mode 1 and 2 to include: "Thickness readings includes coating" on the test report.
4	If the probe cannot be positioned were specified it should be reported.
5	Angle probes shall be utilised to assist in determining flaw type.
6	If significant wall loss is detected, these zones should be supplemented with area scans.
7	Testing above 50° is permitted providing the appropriate probe and couplant are utilised.

Approved by		

Test Type	Area Scans	Ref.	UT-TCS-T3
Application	Corrosion detection, monitoring & thickness measurement	Rev.	0
Test standards	EN 14127		
Materials types	All metals with known or determinable velocities.	Range	≥ 6 mm

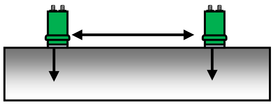
Equipment	"A" scope flaw detector	0° Ref level ≤ 25 mm	2nd BWE to FSH
Probe type	See below	0° Ref level > 25 mm	1st BWE + 12 dB
Test mode	1 , 2 or 3	0° Transfer correction	As applicable
Calibration block	EN: No. 1 or No. 2	θ° beam ref level	See technique UT-TCS-T4
Reference block	Step wedge	θ°Transfer correction	See technique UT-TCS-T4
Test temperature	-20° C to 50° C	θ° Scan level	See technique UT-TCS-T4

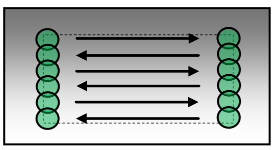
Recommended 0° probe type

Nominal thickness	Frequency	Probe diameter	Type	Item diameter
< 6 mm	5 – 10 MHz	5 mm	Single - delay line	< 100mm
6 - 10 mm	5 – 10 MHz	5 mm	Twin element	< 100mm
10 - 40 mm	4 – 5 MHz	5 mm	Twin element	< 100mm
10 - 40 mm	4 – 5 MHz	10 mm	Twin element	> 100mm
40 - 100 mm	2 – 4 MHz	10 - 20 mm	Single element	> 100mm
100 - 200 mm	2 MHz	20 - 25 mm	Single element	> 100mm

Other probes may be selected if determined to be more appropriate

Test type – Area scans

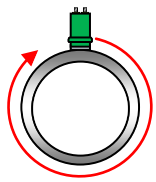


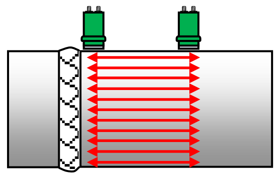


Test locations - example

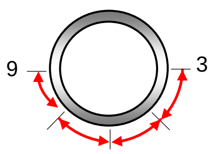
Section view / Plan view

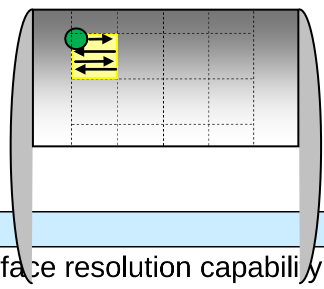
Piping





Vessels





Notes

1 Thickness below ~6 mm may be tested provided the probes near surface resolution capability is verified.
2 Test Mode 1 to be utilised unless specifically requested otherwise.
3 Test Mode 1 and 2 to include: "Thickness readings includes coating" on the test report.
4 If the probe cannot be positioned were specified it should be reported.
5 Angle probes shall be utilised to assist in determining flaw type.
6 If significant wall loss is detected, these zones should be supplemented with area scans.
7 Testing above 50° is permitted providing the appropriate probe and couplant are utilised.

Approved by		

Test Type	Angle beam	Ref.	UT-TCS-T4
Application	Assessment of suspect area detected with 0° probe.	Rev.	0
Test standards	EN 583-1, EN 583-5		
Materials types	Carbon steels.	Range	≥ 6 mm

Equipment	"A" scope flaw detector	0° Ref level ≤ 25 mm	N/a
Probe type	See below	0° Ref level > 25 mm	N/a
Test angle	45°	0° Transfer correction	N/a
Calibration block	EN: No. 1 or No. 2	θ° beam ref level	80%FSH off 3 mm Ø sdh
Reference block	DAC block with 3 mm Ø sdh	θ°Transfer correction	N/a
Test temperature	-20° C to 50° C	θ° Scan level	+ 12 dB

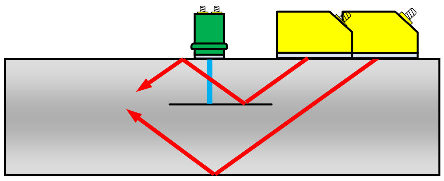
Recommended probe type

Nominal thickness	Frequency	Diameter	Type
< 40 mm	4 – 5 MHz	10 mm	Single
> 40 to < 70	4 – 5 MHz	10 – 15 mm	Single
> 70 to < 100	2 – 3 MHz	20 – 25 mm	Single

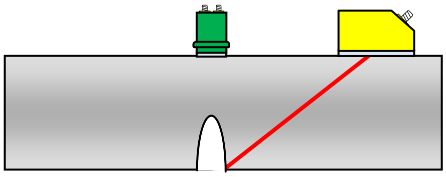
Other probes may be selected if determined to be more appropriate

Typical examples

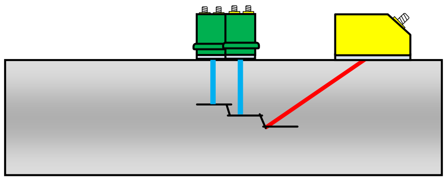
Lamination and inclusions
Reflector with 0º at constant depth.
No response from flaw with angle probe as sound skips away.
No corner reflector from angle probe.
Angle probe should pick up back surface rumble below indication.



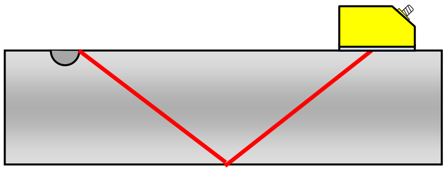
Pits
Reflectors with 0º vary in depth.
Angle probe may pick up low amplitude reflectors of side of pits.
Angle probe often picks up corner reflectors at back-wall.



Hydrogen Induced cracking
Reflectors with 0º at multiple depths.
Angle probes may pick up corner reflectors from the "stepped" interconnecting elements that are characteristic with this form of cracking as it reaches its later stages.



External wall connected flaw – (for use under scabs or restriction)
Corner reflector probable, amplitude dependent on flaw type and size
Flaw top reflection with 45° possible, but may be low amplitude and not indicate true depth.



1	Typically a 45° probe should be utilised, other angles may also be used if considered appropriate.
2	Reference hole should be at material thickness depth for internal flaws.
3	
4	
5	

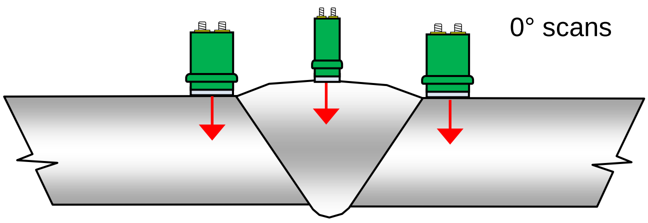
Approved by		

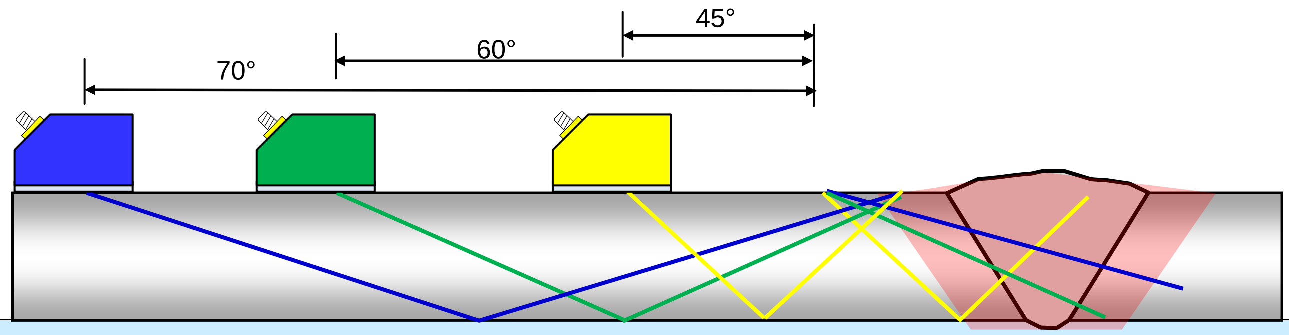
Test Type	Weld root corrosion	Ref.	UT-TCS-T5
Application	Detection	Rev.	0
Test standards	EN 583-1, EN 583-5		
Materials types	Carbon steels.	Range	≥ 6 mm

Equipment	“A” scope flaw detector	0° Ref level ≤ 25 mm	2nd BWE to FSH
Probe type	See below	0° Ref level > 25 mm	1st BWE + 12 dB
Test angle	0°, 45°, 60° and 70°	0° Transfer correction	As applicable
Calibration block	EN: No. 1 or No. 2	θ° beam ref level	80%FSH off 3 mm Ø sdh
Reference block	Step wedge & DAC block	θ°Transfer correction	N/a
Test temperature	-20° C to 50° C	θ° Scan level	+ 12 dB

Probes	Frequency	Nominal size	Type
0°	2 - 5 MHz	10 mm Ø	Single or twin
0°	5 - 10 MHz	5 mm Ø	Twin or delay line
45°	2 - 5 MHz	10 mm Ø	Single
60°	2 - 5 MHz	10 mm Ø	Single
70°	2 - 5 MHz	10 mm Ø	Single

0° Parent materials and weld cap if practicable
45° ½ to 1 skip
60° 0 - ½ - 1 skip,
70° 0 - ½ - 1 skip





1	The shaded area represent the area under inspection
2	0° and all angle probes are to be utilised during this inspection.
3	A small diameter probe may be required to allow for placement on the weld cap.
4	
5	
6	
7	

Note: This technique is not recommended for weld root corrosion as it has both a low probability of detection and low remaining ligament sizing capability. It should therefore only be utilised when requested by the client.

Approved by		

ANNEX G – Temperature & Sound Velocity Compensation Procedure Guidelines

Temperature Compensation Procedure

Wherever practicable the calibration of the equipment should take place with the block at the same temperature as the item under test, however it may not be desirable or practical to maintain the calibration block at this temperature.

Unless using specifically designed high temperature probes the contact time of the probe on a hot surface must be kept to an absolute minimum and therefore only the Spot Test Method would be suitable placing the probe on the test surface and then activating the screen freeze facility can be useful as it allows the technician to assess the signal response on the display screen after removing the probe from the surface.

The probe should be cooled to the calibration temperature between each contact with the hot surface. Calibration must be checked regularly and if any change or drift is noted, the frequency of checking the calibration must be increased.

When the calibration block cannot be raised in temperature then the following "rule of thumb" may be used to compensate for the variation.

The apparent thickness reading obtained from steel having elevated temperatures is approximately over estimated by a factor of about 1% per 55° C temperature difference between the test block and the item under test.

Therefore, if the equipment was calibrated at 20° C, and if a reading was taken with a temperature of 200° C which equals 180° difference, this equates to approximately 3 x 55° C. The reported reading should therefore be reduced by 3%.

The 1% per 55° C correction value is applicable to many types of steels, however correction values would be required to be determined empirically for other materials.

Sound Velocity Compensation Procedure

Basic Principle

Thickness when measured by the pulse echo ultrasonic testing method is a product of the velocity of sound in the material and one half the sounds transit time through the material. This may be expressed as:

$$Tm = \frac{Vt}{2}$$

Where:
- Tm = material thickness
- V = material velocity
- t = transit time

The velocity of the material is a function of the physical properties of the material and is generally assumed to be a constant for a given class of material at a given temperature.

Velocity Differences

It is preferred that the calibration block/sample be made from material with the same physical properties as the material under test and ideally a sample of the test material. For carbon steels standard calibration blocks e.g. EN standards No 1 and No 2 blocks and proprietary manufactured step wedges are readily available. However, this may not be the case for other materials.

There are two ways in which the material sound velocity can be established by:

i) Physical measurement
ii) Estimation

The method used to establish the ultrasonic velocity should be stated on the test report.

Physical Measurement method

Where a sample of the material or part of the test area is accessible for physical measurement, then the velocity may be established as follows:

Using a calibrated micrometer or vernier physically measure the thickness of the sample.

Calibrate the ultrasonic equipment on a test block of known material velocity.

Measure the sample of material ultrasonically at the same position as the physical reading.

Calculate the velocity from:

$$Vm = \frac{Tp \times Vcb}{Tu}$$

Where
Vm = material velocity
Tp = physically measured thickness
Vcb = velocity of calibration block
Tu = ultrasonically measured thickness

Estimation method

If the material type is known the sound velocity may be looked in tables that are published by a number of organisations.

Once established the velocity of the material can be used to determine a correction factor (k) using the formula:

$$K = \frac{Vm}{Vcb}$$

The ultrasonic thickness values can then be adjusted by multiplying the results by the correction factor (k).

The physical measurement method provides an accurate value for sound velocity therefore resulting in accurate test results. The estimation method is exactly that, and the results are therefore prone to error.

Correction for velocity between test block and sample material is not made then serious error may result. Two examples are given below

Example 1

Equipment calibrated using a calibration block with a material velocity of 5.96 mm/s. A type 302 austenitic stainless steel is tested and gives a thickness of 12 mm. Its velocity is 5.66 mm/s. What is the actual thickness?

Transposing the formula given above the ultrasonic measured thickness would be:

$$Tu = \frac{Tp \times Vcb}{Vm} = \frac{12 \times 5.96}{5.66} = 12.63 \text{ mm}$$ equivalent to a 5.2% over-sizing error.

Example 2

Equipment calibrated using a calibration block with a material velocity of 5.96 mm/s. A cast iron item is tested and gives a thickness of 12 mm. Its velocity is 4.80 mm/s. What is the actual thickness?

$$Tu = \frac{Tp \times Vcb}{Vm} = \frac{12 \times 5.96}{4.80} = 14.9 \text{ mm}$$ equivalent to a 24% over-sizing error.

Note: When correction factors are applied it is important that both the measured and corrected thicknesses are recorded, together with an example of a calculation showing the velocity values utilised.

ANNEX H – Limitations of using twin element zero degree transducers

The standard ultrasonic transducer generally issued to test technicians for carrying out thickness measurements is a 4-5 MHz, twin element, 10 mm diameter.

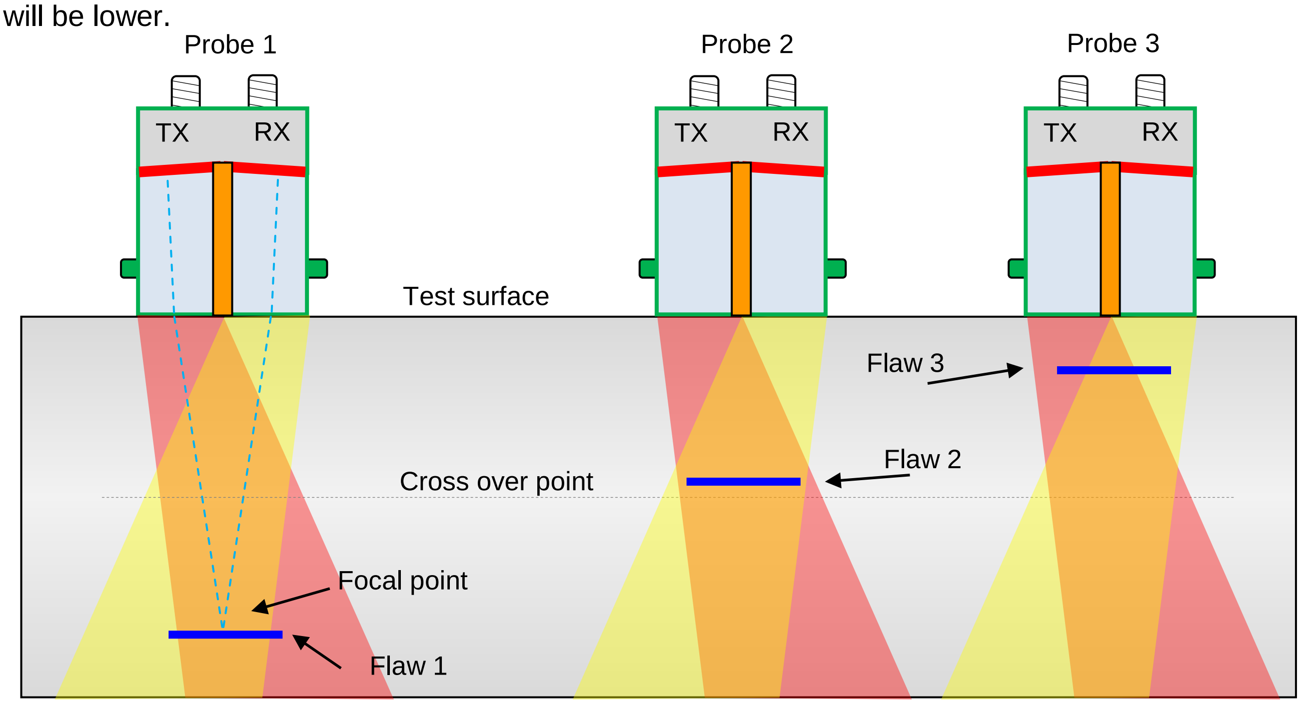
These twin element probes consist of two elements housed in the same case, separated by an acoustic barrier. One element transmits (Tx) longitudinal waves and the other element acts as a receiver (Rx). The elements are tilted towards each other to create a V-shaped sound path in the test material. For standard probes this tilt angle is typically around 3.5° which produces a focal point at a depth of approximately 25 mm. This "Pseudo-Focus" enhances resolution within the focal zone.

The following sketch shows three probes positioned on a test surface.

Probe 1 indicates the transducer located on the test surface with the transmitter beam (red) and the receiver zone (yellow) and their overlapping zone (orange). Only when a flaw is present within the overlapping zone will a flaw be detectable. Outside this region, either the transmitter does not interrogate the spot or the receiver does not catch the echo It can be clearly seen that in the zone above the cross over point the scanned area is reducing in size as it gets closer to the top surface. This reduces the probability of flaws being detected within this area as the centre of the probe must be directly over the flaw.

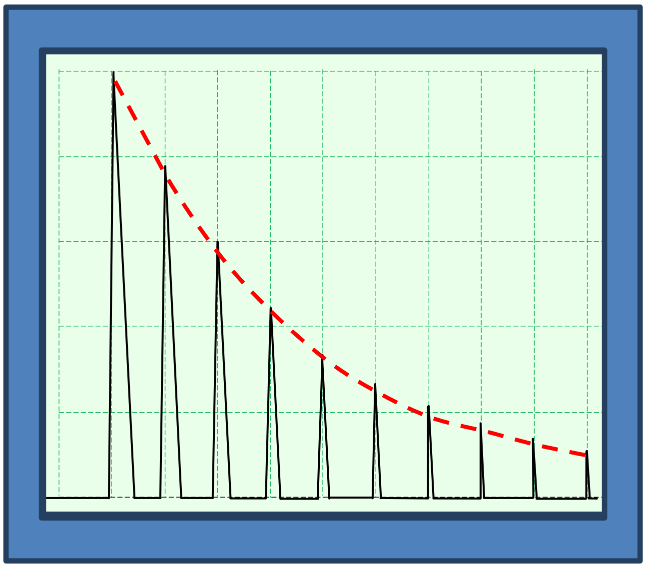
Probe 2 indicates a flaw located close to the cross over point, the whole of the transmitted sound is being reflected back to the receiver element producing a high amplitude response.

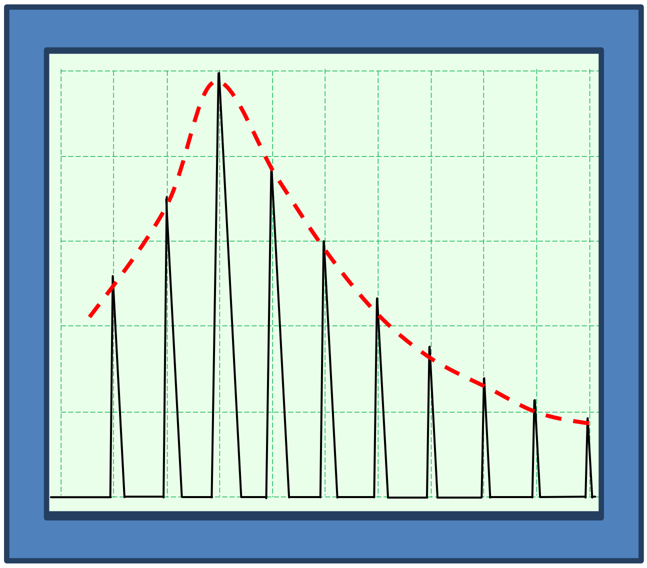
Probe 3 indicates the same size flaw located close to the top surface, only a small section of the transmitting beam is hitting the flaw within the orange zone and only a small amount of sound is reflected to the receiver element. Because less sound is being received the signal amplitude response will be lower.



This is highlighted within the two A Scan screen images.
Screen A is calibrated from 0 to 100 mm using a 10 mm thick reference block. The repeat echoes fall in amplitude as expected.

Screen B is calibrated from 0mm to 30 mm using a 3 mm thick reference block. In this case the first back-wall echo is lower than the second which in turn is lower than the third. After this the amplitude drops as expected.





Screen A - Typical response
Range: 0 - 100 mm- (1 mm steps)

A similar amplitude fall off would be created from flaws 1 & 2 above.

Screen B - Typical response
Range: 0 - 30 mm - (3 mm steps)

Note the loss of amplitude near the top surface below approximately 10 mm.
This is typical for a 10 mm Ø, 5 MHz, twin probe.

Conclusion:

When testing thin materials or looking for pitting that may be close to the test surface, probes with good near surface resolution are required to increase the probability of detection.

Note: Too little gain and the use of suppression (also called reject) will also reduce the likelihood of detecting near surface flaws.

ANNEX I – Example of a typical test report

Test Company Ltd	**Ultrasonic Test Report**	Report No.	*NBTS-123456*		
A Road, UK	**Thickness & Corrosion Survey**	Issue date	*31-12-14*	Page	*1 of 3*

Client	*A.N. Oil Company Ltd*	Contract reference	*Abcdef-123456*		
Asset/Location	*Northampton Bravo*	Test dates - From	*25-12-14*	to	*31-12-14*
Description	*Oil separator piping*	WB or request ref	*NB-WB-123456*		
Location/System	*Separator & upper deck level*				
Line No(s)	*OSP-123-2 & & OSP-1234-1*	Test procedure	*UT-TCS-P1234*	Rev	*4*
Drawing/ISO No.	*6"-OSP-123-2-2-1*	Test Technique	*UT-TCS-T3*	Rev	*2*
P & ID	*NB-CB-123-234*	Test Technique	*UT-TCS-T4*	Rev	2
Material	*Carbon Steel*	Test Technique	*UT-TCS-T6*	Rev	2

Scope and Limitation of Examination

Corrosion and thickness survey on above detailed line. Piping on upper deck untested as insulation not removed.

Test Parameters			Angle	Type	Frequency	Size	Ref level
Equipment	*Sonatest D10*		*0°*	*CD*	*4 MHz*	*10 mm Ø*	*2BWEFSH*
Serial No	*Xyz123456*		*0°*	*CD*	*5*	*5 mm Ø*	*2BWEFSH*
Cal date	*21-5-15 & [illegible]*		[illegible]	*MAP*	*4 MHz*	*10 mm Ø*	*DAC + 6dB*
Cal block ref	*CB 1234*		*60°*	*MAP*	[illegible]	[illegible]	*DAC + 6dB*
Surface temp	*~ 10 °C*		*70°*	*MAP*	*4 MHz*	*10 mm Ø*	*DAC + 6dB*

Results

Item	Test Point	Loc	Test Level	Surface	Test mode	Nom thickness	Test Result	Comments
1	*TP1*	*F*	*1*	*G*	*1*	*7.2*	*8.8*	
2	*TP2*	*P*	*1*	*F*	*1*	*7.2*	*6.8*	
3	*TP2*	*P*	*1*	*F*	*1*	*7.2*	*8.2*	*Inclusion noted 4 mm deep at 35 mm*
4	*TP3*	*B*	*1*	*F*	*1*	*8.4*	*9.2*	
5	*TP4*	*P*	*1*	*F*	*1*	*7.2*	*6.7*	
6	*TP4*	*P*	*2*	*G*	*1*	*7.2*	*6.8*	
7	*TP5*	*B*	*2*	*F*	*1*	*7.2*	*7.9*	
8	*TP6*	*P*	*1*	*G*	*1*	*7.2*	*5.3*	*See note*
9	*TP6*	*P*	*1*	*F*	*1*	*7.2*	*6.8*	

10	*TP7*	*B*	*2*	*F*	*1*	*7.2*	*6.9*	
11	*TP8*	*P*	*2*	*F*	*1*	*7.2*	*6.7*	
12	*TP8*	*P*	*2*	*F*	*1*	*7.2*	*8.1*	
13	*TP9*	*B*	*2*	*P*	*1*	*7.2*	*6.6*	
14	*TP10*	*P*	*2*	*VP*	*1*	*7.2*	*6.7*	*No reading from 200 – 650 mm*
15	*TP10*	*P*	*2*	*P*	*1*	*7.2*	*8.0*	
16	*TP11*	*B*	*1*	*F*	*1*	*7.2*	*7.0*	
17	*TP12*	*P*	*1*	*P*	*1*	*7.2*	*10.1*	
18	*TP13*	*O*	*1*	*P*	*1*	*7.2*	*-*	*No reading possible*
19	*TP14*	*P*	*1*	*VP*	*1*	*7.2*	*7.1*	
20	*TP15*	*P*	*2*	*P*	*1*	*7.2*	*7.0*	
54					*1*	*7.2*	*6.8*	
55					*1*	*9.4*	*10.6*	
56								

Comments

Item 8: Test area extended, Internal corrosion noted at 6 o clock position full length of pipe.
Items 15: Significant external corrosion and severe coating breakdown on Tee.

Test location key	F = Flange	P = Pipe	B = Bend	T = Tee	R = reducer	O = Other

Surface condition definitions - As related to ability to carry out ultrasonic testing.

G = Good: As or close to original condition ≥ 90% coverage achievable	P = Poor Deterioration resulting in approximately 50% to 75% test coverage achievable
F = Fair: Minor deterioration – approximately 75% - 90% test coverage achievable	VP = Very poor: Significant deterioration resulting in > 50% test coverage achievable.

Test personnel	*A. Tester*	*D. Tester*		
Qualifications	*PCN level 2*	*PCN level 1*		

Prepared by	A. Tester	Reviewed by	*A.N. Other*	Approved for issue	D Boss
Signature P.P. Tester(s)		Signature		Signature	
Date	*31-12-14*	Date	*01-01-15*	Date	03-01-15

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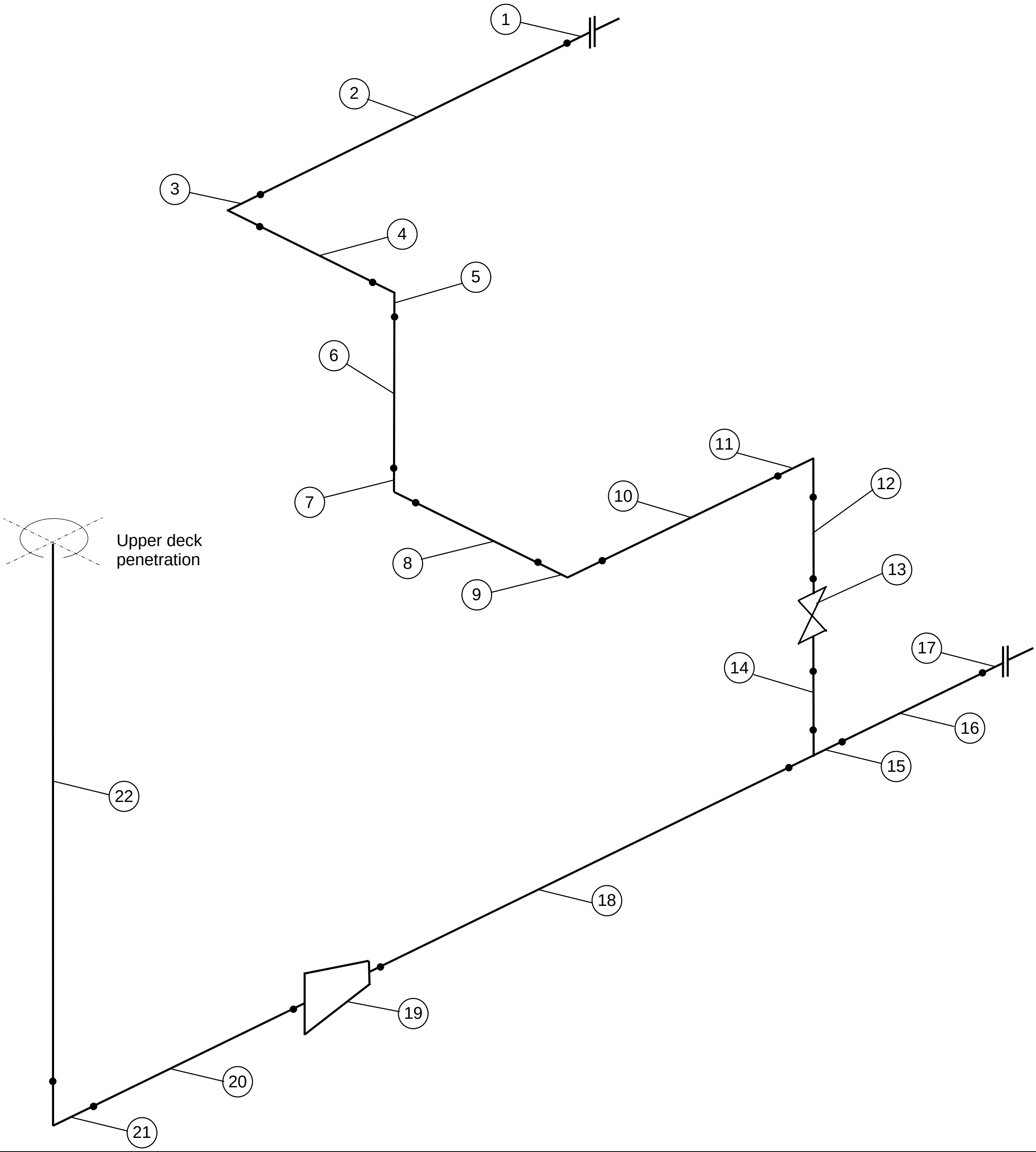
Comments



Guidelines note: This isometric details the same piping set-up as those shown in the Annex F, Test Level Guideline sketches.

ANNEX J – Selection of Test Method for the Detection of Root Erosion Guidelines

Test Method

Described briefly below, in order of preference, are a number of techniques that have the capability of detecting, and accurately sizing in some cases, weld root corrosion. The capabilities, advantages and limitations are based on the method and technique being utilised correctly.

Time of Flight Diffraction

TOFD is an advanced ultrasonic technique, requiring access to both sides of the weld cap. It involves the placement of a transmitter probes one either side of the weld and a receiver probe on the opposite side. These probes are held in some form of jig or scanner which may be either motorised or manually driven. This is linked to an ultrasonic/computer instrument for data capture and display. The technique is based on measurement of signal arrival times, which may then be converted to distance to determine remaining ligament values. TOFD requires specifically trained personnel and sophisticated software for data processing and interpretation. It is generally accepted as being capable of high detection reliability and high accuracy in measurement of remaining ligament.
The main limitations of this technique are it requires smooth surface conditions to permit good quality data collection, and it is not generally suitable for thin wall (< 6 mm) or small diameter pipe work (< 3" OD) without specialist equipment.

Radiography

There are a number of techniques that can be utilised depending of wall thickness and pipe diameters. In general the use of computed or digital methods are preferred to film, electronic formats permit the use of software with capabilities to measure remaining ligaments.

The double-wall double image radiography (DWDI) technique is typically utilised on smaller diameter pipes (< 4" OD). The source is positioned at a known distance remote from the pipe and the film or detector as close as practicable.

Detection reliability is generally good and the measurement of remaining ligament can also good. A limitation is the measurements can only be made at the tangent positions and if the thinnest area is not at this position, incorrect lowest measurements can be obtained.
This technique does not require direct access to the components surface and is unaffected by coatings, poor surface condition or the presence of insulation.

For larger sized piping the coverage of this technique is limited to circumferential positions very close to the tangent position. For this reason, this technique is often used in conjunction with double wall single image (DWSI) or DWDI techniques to locate the circumferential position of the most severe weld corrosion

For larger diameter pipes the tangential technique may not be possible therefore the DWSI is used, in which the source is positioned as close as practicable to one pipe wall with the film or detector on the opposite side. The presence of corrosion can be detected by changes in film density, or image grey level. Some qualitative information on the extent of material loss is available based on the amount of the changes in film density or image grey level. The presence of liquid product in the pipe can limit the capability of this technique.

Angle beam phased array ultrasonic testing

The phased array ultrasonic technique (PAUT) involves the use of special multi-element probe linked to a portable computerised instrument. The firing of groups of elements with pre-defined time delays (phases) permits multiple angles to be produced from the same probe.

This technique has not to date been widely used for weld corrosion inspection, and shares many of the limitations of manual angle beam testing. PAUT does however provide some advantages over MUT due to the presentation of results from multiple probe angles in various different colour presentations. Also if encoded scanning is undertaken, some instruments allow permanent storage of the collected data, allowing data manipulation and display of the results obtained.

Angle beam manual ultrasonic testing

This is an ultrasonic technique, based on use of a single manually deployed angled shear-wave pulse-echo probe linked to a portable flaw detector.

Historically, there have been a lot of negative experiences of MUT being utilised for weld corrosion inspection in terms of low detection reliability and poor sizing capability. However, recent in-service experience of this technique using technicians trained in working to application specific procedures has been more positive. The combination of multiple angled beam inspection from both sides of the weld, and small 0° button probes for inspection through the weld cap does increase the probability of detection. These application specific techniques however do not improve the very poor sizing accuracy, therefore additional testing using a technique having a higher sizing accuracy is recommended.

Limitations with respect to detection capability remain, since this can be strongly influenced by flaw morphology and material condition. There have been a number of instances in which MUT has either failed to detect the presence of weld corrosion, or has given false calls therefore manual UT should remain as the least preferred choice.

Ranking of techniques

Technique	Detection reliability	Sizing accuracy	Sensitive to surface condition
TOFD	High	High	Yes
Tangential radiography	High	Medium to high	No
Double wall radiography	High	Qualitative only	No
Angled beam PAUT	Can be Low	Low	Yes
Angle beam MUT	Can be Low	Low	Yes