GUIDANCE NOTES
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CHINA CLASSIFICATION SOCIETY

GUIDELINES FOR APPLICATION OF AUTOMATED ULTRASONIC TESTING (AUT) TECHNIQUES

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CONTENTS

Chapter 1 General

Section 1 General

1.1.1 Purpose

1.1.1.1 In order to ensure the welding quality of pipelines or tubular structural members of ships and offshore installations, the Guidelines are developed to provide reference to the construction units when they select the AUT techniques for the testing of pipeline girth butt welds.

1.1.2 Application

1.1.2.1 The Guidelines apply to the testing and acceptance of girth butt welds of steel pipelines of 6 mm to 50 mm in wall thickness, using the automated ultrasonic testing system with multi-channels, acoustic focus and zonal discrimination.

1.1.2.2 The Guidelines apply to the testing of girth butt welds of steel pipelines of 150 mm or more in diameter. It may be applied to other thicknesses and diameters, provided that the requirements for zonal discrimination are met, i.e. there is neither any un-tested part nor any signal interfering with each other.

1.1.2.3 The Guidelines apply to the testing of steel pipelines. For stainless steel material, verification by relevant tests needs to be carried out and relevant testing procedures are to be submitted to CCS for approval.

1.1.2.4 The welding bevels of pipeline girth welds in the structures of ships and offshore engineering installations, to which the Guidelines apply, are to comply with the requirements of welding procedures. In general machined bevel and automatic welding techniques are to be used. Where other methods are used, they are to be submitted to CCS for approval.

1.1.3 Testing personnel

1.1.3.1 Only when the testing personnel hold a qualification certificate for ultrasonic NDT issued by CCS and comply with the requirements of 1.1.3.2 of this Section, can they be engaged in automated ultrasonic testing. Personnel certified to Level II and above carry out testing and issue reports, while personnel certified to Level I only provide assistance to the testing. For their responsibilities, refer to responsibilities of Level I and II personnel given in CCS Rules for Qualification and Certification of Non-destructive Testing Personnel.

1.1.3.2 Personnel engaged in automated ultrasonic testing are to be subject to training with regard to equipment performance, calibration and evaluation, and pass theoretical and practical examinations. For the interpretation and evaluation of testing results, personnel are to be subject to special training with regard to data interpretation and relevant examinations. Only those having passed the examinations can be engaged in data interpretation and evaluation.

1.1.3.3 Personnel with color blindness are not to be engaged in automated ultrasonic testing.

1.1.4 Review personnel

1.1.4.1 Review personnel are to hold a Level III qualification certificate of ultrasonic NDT personnel issued by CCS and to be subject to training with regard to automated ultrasonic testing and data interpretation as specified in 1.1.3.2, and pass relevant examinations. For their responsibilities, refer to responsibilities of Level III personnel given in CCS Rules for Qualification and Certification of Non-destructive Testing Personnel.

Section 2 Terminology and Definitions

1.2.1 For the purpose of the Guidelines:

1.2.1.1 AUT means Automated Ultrasonic Testing.

1.2.1.2 Calibration block means a specimen made of materials having properties which are the same as or similar to the tested materials or cut directly from the pipeline, in accordance with weld thickness and bevel type, in order to adjust the primary reference sensitivity and verify performance of the system.

1.2.1.3 Time of Flight Diffraction (TOFD) means a method relying on diffraction of low-amplitude longitudinal waves from “corners” and “ends” of internal structures (primarily imperfection) in a workpiece being tested for the testing, sizing and positioning of reflectors.

1.2.1.4 Lateral wave means a signal of longitudinal wave transmitting by the shortest path under the material surface, which is a special type of wave form of the TOFD technique.

1.2.1.5 Back wall echo means a signal of longitudinal wave of the TOFD technique which is reflected from the bottom surface of material.

1.2.1.6 Imperfection means a discontinuity of material detected by means of NDT.

1.2.1.7 Defect means an imperfection meeting the standards for rejection as agreed in the contract between both parties.

1.2.1.8 Gate means a given threshold value corresponding to the monitor range which is used to monitor the position or amplitude of signals within a specified distance or time.

1.2.1.9 Dual-gates mean amplitude gate and time gate, which are used respectively to monitor the amplitude value and position of signal within the gate range.

1.2.1.10 CRC bevel means a double side V-notch composite bevel used by the weld machine of CRC-Evans Company for the welding of girth welds of pipelines.

1.2.1.11 Zonal discrimination means a technique whereby the weld is divided into several vertical zones in accordance with wall thickness of weld and bevel type, each zone being assessed by a focus beam of a given angle from a pair of independent crystals (or search units).

1.2.1.12 Strip chart means a scanning chart displaying testing results of different zones. In general different color blocks are set to represent the range of amplitude value within the amplitude gate. The maximum amplitude value of signal is represented by the envelope curve. The height of color blocks corresponds to the position of signals within the time gate.

1.2.1.13 Fusion zone means a zone adjacent to the fusion line of bevel.

1.2.1.14 Time of flight means the time for the ultrasonic wave to transmit by a given path.

Chapter 2 Ultrasonic Equipment

Section 1 General Provisions

2.1.1   General requirements

2.1.1.1   The ultrasonic system to be used should be accepted through qualification, i.e. under the supervision of the surveyor, the testing system is capable of detecting all the defects in the calibration block and demonstrating the satisfactory condition of the system and procedure.

2.1.1.2   The ultrasonic system may use pulse-echo techniques, TOFD techniques etc. It is to have a fully automatic recording system to indicate the location of defects and integrity of acoustic coupling. The system is to be configured such that the section perpendicular to the weld is divided into zones of a height generally not exceeding 3 mm. Zones of a height exceeding 3 mm may be used for heavy wall thickness, if agreed.

2.1.1.3   The ultrasonic system may be used for testing of weld repairs as detailed below:

(1)   Manual UT may be used to support the AUT on weld repairs unless the groove shape is controlled to be within given tolerances and the repair weld inspection procedure is made.

(2)   AUT system may be used if weld repair grooves are made with automatic equipment that consistently prepares the same groove geometry and the repair weld inspection procedure is made.

2.1.1.4   If specifically required, the ultrasonic system is to incorporate facilities for detection of transverse defects.

Section 2 Testing Equipment

2.2.1   Ultrasonic system

2.2.1.1   The automated ultrasonic equipment is to include ultrasonic electronic system, motor-driven scanner system, water coupling system, software system, etc. The ultrasonic system is to provide an adequate number of detection channels to ensure the complete scanning of the zones in weld through thickness.

2.2.1.2   The instrument linearity is to be determined once every 6 months in accordance with the procedures of recognized standards. The tolerance of vertical linearity is to be within 5% of FSH, and the tolerance of horizontal linearity is to be within 1% of FSH. The position, width and height of gates are to be adjusted continuously.

2.2.2   Recording system

2.2.2.1   An encoder is to be used for recording the circumferential scanning position of search units and a correction factor will be incorporated to ensure the circumferential distance recorded on the chart corresponds to the search unit position on the pipe outer surface to an accuracy of typically ±10 mm over the circumference of the weld.

2.2.2.2 There is to be recordable signal outputs for at least each 2 mm of weld length.

2.2.2.3 Strip-chart display is to be used for weld scanning records. B-scan or other form of “mapping” displays may be used for volumetric defect detection and characterizations and Time of Flight Diffraction (TOFD) channels may be added to improve characterization and sizing. TOFD techniques may augment pulse-echo techniques but cannot replace pulse-echo techniques. Satisfactory acoustic coupling is to be recorded on the weld scanning chart.

2.2.2.4 Where TOFD techniques are employed the recording system is to be at least capable of a 256-level grayscale display and be capable of recording full R-F wave forms for the TOFD search unit pairs.

2.2.3 Search units

2.2.3.1 For most applications the use of contact focused search units is required to avoid interfering signals originating from off-axis geometric reflectors and to avoid excessive overlap with adjacent zones.

2.2.3.2 Each search unit is to be marked with a method to identify the manufacturer’s name, search unit type, frequency, crystal size, incidence point, incident beam angle or refracted beam angle, and is to comply with the technical requirements for testing.

2.2.3.3 The search unit array design is to be specific to the wall thickness and bevel type where the testing is to be performed.

2.2.3.4 All search units are to be contoured to match the curvature of the pipe surface, and to be ground as necessary.

2.2.4 Couplant

2.2.4.1 Liquid is to be used as the couplant. It is to have good sound transmission quality and liquidity, pose no harm to the material, human body and environment, and be easy to clean or with no residue remaining after it has evaporated.

2.2.4.2 The typical couplant is water. Where ambient temperatures are below 0℃ (32℉) a methyl alcohol washer fluid or a similar medium may be used.

2.2.4.3 The same type of couplant is to be used during instrument adjustment and testing.

Chapter 3 Calibration Block

Section 1 General Provisions

3.1.1 Specification

3.1.1.1 Materials used for the calibration block of automated ultrasonic testing are to comply with the following requirements:

(1) the grain size of block materials is to be uniform and free from any internal impurities. There is not to be any signal of defect affecting the use during the ultrasonic testing;

(2) the attenuation coefficient of ultrasonic waves in the block materials is to be the same as or similar to that in the tested workpiece. Where the amplitude of the first back wall echo is adjusted to 90% of FSH, the difference between the summation of the amplitudes of the first three back wall echoes for the plate block material and that of tested material of the same thickness is to be within ±25%;

(3) materials with acoustic velocity which is the same as or similar to that of the tested workpiece are to be used for the block. The difference between the two is not to be greater than ±1%;

(4) materials used for the manufacture of block are to have the same geometric features (i.e. wall thickness and curvature) as the tested workpiece. A specimen from the same manufacturer and same batch is recommended, taking into account the rolling direction of materials, or it is cut from the tested workpiece on site. Materials used for the manufacture of block are to have smooth surface and free from any rust, corrosion, abrasion, flake, scratch, fine crack, irregularity, etc.;

(5) when testing is carried out by means of ultrasonic longitudinal wave straight beam techniques, the echo amplitude of defect is not to be greater than 1/4 of that of Φ2 mm flat-bottom holes.

Section 2 Design of Calibration Block

3.2.1 Design basis

3.2.1.1 The type, angle and depth of targets on the calibration block are to be designed in accordance with the wall thickness, weld bevel type and size of the tested workpiece, as shown in Figure 3.2.1.1.

The design of block is to be symmetrical on both sides, beginning from the root and upwards along the bevel. The targets are arranged as follows: root targets, land for cross penetration targets, hot pass targets, fill targets, cap slots, volumetric channel targets, and centerline through holes or slots. Additional targets (transverse slots and TOFD verification slots) may be machined as required by the testing standards. The targets are set as shown in Appendix A.

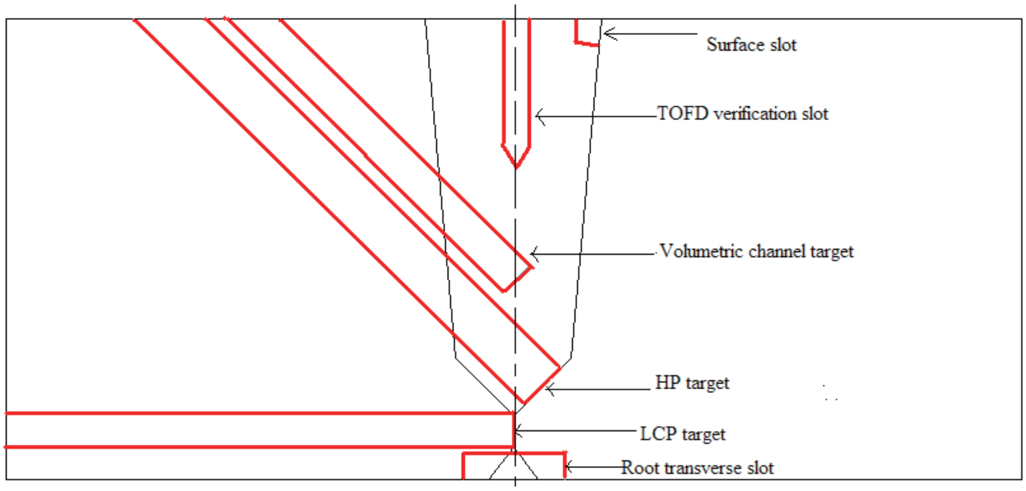


Figure 3.2.1.1 Illustration of weld bevel and targets

3.2.2 Design of targets

3.2.2.1 Hot pass targets and fill targets are typically flat-bottom holes (FBH) of 2 mm to 3 mm in diameter.

3.2.2.2 Square slots 1 mm in depth and 2 mm in width are to be machined typically 10 mm to 20 mm in length on the design fusion line to indicate locations where undercut or surface breaking non-fusion would occur on the pipe outer surface.

3.2.2.3 Root targets are to be at the angle of root bevel. Where the vertical height of root is not greater than 2 mm, square slots or sharp-angled slots of not greater than 1 mm in vertical height are to be used. Root slots are to be typically 10 mm to 20 mm in length and their depth and angular configuration are to be identical to the root bevel used in the weld process being tested. Where the vertical height of root is greater than 2 mm, the number of root targets needs to be increased, i.e. adding a flat-bottom hole of 2 mm to 3 mm in diameter.

3.2.2.4 A through hole of 2 mm in diameter, or a through slot of 5 mm in length and 1 mm in width is to be drilled at the centerline between the upstream and downstream of the calibration block to verify the gate length is sufficient to cover the weld and ensure the detectability of centerline defects.

3.2.2.5 Additional targets, if required, may be machined on the calibration block in accordance with the following requirements:

(1) transverse slots: square slots of 6 mm in length, 2 mm in width and 2.5 mm in depth are to be machined on the outer surface and square slots of 4 mm in length, 2 mm in width and 1.5 mm in depth are to be machined on the inner surface;

(2) TOFD verification slots: a sharp-angled (60°) square slot of 10 mm in length, 1 mm in width and 60% *T* (*T* is the wall thickness) in depth is machined on the outer surface. The result calculated from 60% *T* is rounded down to the nearest integer [*N*]. A sharp-angled (60°) square slot of 10 mm in length, 1 mm in width and generally 3.5 mm in depth is machined on the inner surface. Such depth has a fixed value irrespective of the wall thickness;

(3) volume targets: the volumetric channel is used for testing of volumetric defects such as porosity, slag inclusion, etc. The targets are flat-bottom holes of 1.5 mm in diameter, with an angle of 45° and arranged on the centerline. The principle for determining the number is to divide the wall thickness by coefficient 8 and the result is rounded to the nearest integer. Irrespective of the bevel type, where more than 2 flat-bottom holes of 1.5 mm in diameter and with an angle of 45° are machined, one principle is to be followed, i.e. the wall thickness is to be evenly divided at the intersection point of centerline of flat-bottom holes and weld centerline and the value of spacing is to be rounded down to the nearest integer.

3.2.2.6 The lateral spacing of all the targets is to be sufficient to allow for independent signals of adjacent targets. All the targets on the block correspond to different beams and all the beams correspond to targets. The interfering signals originating from adjacent targets to the primary target is limited to a certain extent in the vertical direction.

3.2.2.7 The allowable tolerances of targets on the block are to comply with the following requirements:

(1) the planeness tolerance of FBH bottom surface is not to be greater than 0.03 mm and the surface roughness is not to be greater than R_a3.2 µm. The allowable tolerance of FBH diameter is ±0.05 mm. The tolerance of FBH angle is ±0.5°;

(2) the longitudinal slot is to be paralleled to the axis of the block and the parallel tolerance is ±0.05 mm while the transverse slot is to be vertical to the axis of the block and the vertical tolerance is ± 0.05 mm. The planeness tolerance of slot side and rectangular bottom is ±0.03 mm and the surface roughness is not to be greater than R_a3.2 µm. The tolerance of slot size is ±0.05 mm; the tolerance of angle between the rectangular bottom and side and the test surface is ±0.1°; the tolerance of angle of sharp-angled slot is ±0.1°;

(3) the vertical tolerance between the through hole and slot and the test surface is ±0.05 mm and the size tolerance is ±0.03 mm. The surface roughness is not to be greater than R_a1.6 µm. The planeness of the side of through slot is ±0.03 mm.

3.2.2.8 For the set-up of the block, supporting frame and guide-band, refer to Appendix B.

Chapter 4 System Calibration

Section 1 System Setting

4.1.1 Definitions of weld parameters

4.1.1.1 The definitions of weld parameters mainly include bevel type, height and number of zones. During the system setting, the weld is to be divided into zones. The weld zones are generally as shown in Figure 4.1.1.1.

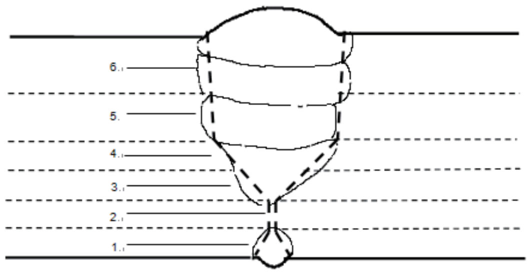


Figure 4.1.1.1 Schematic representation of weld zones

1 — Root 2 — Land for Cross Penetration

3 — Hot Pass (lower) 4 — Hot Pass (upper)

5 — 1st Fill 6 — 2nd Fill

4.1.2 Weld zone

4.1.2.1 Each zone is 2 mm to 3 mm in height being assessed by a corresponding focused channel, in order to avoid interfering signals originating from off-axis geometric reflectors and to avoid excessive overlap with adjacent zones.

4.1.2.2 The size (hole diameter and slot height) and number of holes (flat-bottom holes and through holes) and slots (square slots, sharp-angled slots and through slots) of the targets on the calibration block are determined by the height and number of zones.

4.1.3 Setting of detection channels and beams

4.1.3.1 The design of detection channels is to comply with the following requirements:

(1) in accordance with the division of zones, each zone is to be tested by an independent detection channel. For channels of the fusion zone, dedicated focused beam is to be used for testing;

(2) dedicated volumetric channels are to be set for testing of internal volumetric defects of welds;

(3) dedicated coupling monitor channels are to be set to ensure the reliability of coupling, for which pitch and catch techniques or other methods may be used;

(4) it is recommended to add TOFD channels to improve the testing of the internal defects of welds such as volumetric defects, crack of centerline, etc., and improve the characterization, sizing and positioning of defects;

(5) the entire weld is tested for both sides and single surface. The channels on both sides of the weld are to be set in a manner that allows for consistency and symmetry about the weld centerline.

4.1.3.2 The design of testing beams is to comply with the following requirements:

(1) root channel: the root is generally tested by means of single traverse. The incidence direction of the beam is to be vertical to the root bevel and the beam is to be focused at the bevel position;

(2) land for cross penetration channel: the LCP bevel angle is 90° and it is generally tested by means of single traverse. For testing angle, it is recommended to use shear wave of 65° to 75°. The beam is to be focused at the bevel position;

(3) hot pass channel: the hot pass is generally tested by means of double traverse. The beam is to be vertical to the bevel and focused at the bevel position;

(4) fill channel: the fill is generally tested by means of double traverse. The beam is to be vertical to the bevel and focused at the bevel position. Where the bevel angle is less than 20°, it is to be tested by means of tandem scanning techniques so as to increase the testing rate for non-fusion discontinuities. Where the tandem scanning techniques are not suitable for the channel of the uppermost fill, it is to be tested by means of single traverse of 70°;

(5) volumetric channel of fusion zone: double traverse of 45° is to be used for testing and focused beam is not to be used;

(6) root volumetric channel: single traverse of 45° to 70° may be used for testing and focused beam is not to be used;

(7) coupling monitor channel: pitch and catch techniques or other methods may be used;

(8) TOFD channel: the intersection point of beams of the channel is to be at the 2/3 of wall thickness of the workpiece. Where the thickness is not greater than 20 mm, TOFD search units of 5 MHz to 10 MHz are to be used for testing; where the thickness is greater than 20 mm, TOFD search units of 5 MHz are to be used for testing.

4.1.4 Search unit positioning and primary reference sensitivity

4.1.4.1 The search unit positioning is to comply with the following requirements:

(1) the scanner on the track is fitted with search units based on the corresponding position of targets on both sides of the simulated weld centerline of the calibration block and the accuracy of set-up of the track is to be controlled within ±0.5 mm;

(2) move the scanner and adjust the distance from the holding device of search units to the weld so that a peak signal from the target corresponding to the search unit position is achieved, i.e. the position of the search unit.

4.1.4.2 The determination of primary reference sensitivity is to comply with the following requirements:

A peak signal from the target on the block corresponding to each channel is to be adjusted to 80% of full-screen height (FSH), i.e. the primary reference sensitivity of the target corresponding to the channel. The lateral wave of TOFD channel on the sound part of the block is to be adjusted to 40% to 80% of full-screen height (FSH), i.e. the primary reference sensitivity of TOFD search unit.

4.1.5 Setting of gate and scanning parameters

4.1.5.1 Using the reflectors in the fusion zone, each gate is set to start at least 3 mm before the weld preparation and ends at least 1 mm past the weld centerline, taking into account the effect of changes to factors such as heat affected zones, wall thickness, welding methods, etc.

4.1.5.2 For the gate setting of volumetric channels related to the fill region (including cap and hot pass), the reflectors in the fusion zone may be used to adjust the sensitivity of volumetric channels and each gate is set to start at least 1 mm before the weld preparation and long enough to encompass the weld bevel on the opposite side of the weld centerline. Scanning sensitivity of the fill region is to be appropriately 8 dB to 14 dB over the primary reference sensitivity of fusion zone, but not to be so great as to impact the correct evaluation. For tested workpiece of thickness greater than 12 mm, beam characteristics may require the use of more than one channel for porosity detection in the fill regions. Porosity provides a weak and characteristically different reflected signal compared to perpendicular reflection from non-fusion discontinuities. Dedicated channels using B-scan presentations are recommended for detecting and characterizing porosity and other volumetric defects. Scanning sensitivity is to be typically 8 dB to 14 dB over the primary reference sensitivity, but not to be so great as to cause interfering electrical or geometric noise that could be misinterpreted.

4.1.5.3 The gate position is determined by using the reflectors in the root region on the block. Each gate is set to start at least 3 mm before the weld preparation and long enough to ensure coverage of the weld root area. The gate setting for the other side of the region is the same as above. Scanning sensitivity is typically 8 dB to 14 dB over that required to achieve an 80% of FSH signal from a root slot typically 1 mm in height, but not to be so great as to impact the correct evaluation.

4.1.5.4 TOFD display range is set on the sound part of the block to start before the lateral wave and end after the back wall echo. The length of display range is at least to be equal to the wall thickness of the tested workpiece. If required by testing, the length of display range may encompass back wall shear wave, starting before the lateral wave by generally 0.5 μs to 1 μs and ending after the back wall echo by generally 0.5 μs to 1 μs. If required by testing, the mode conversion signal may be included.

4.1.5.5 The evaluation threshold for each detection channel is to be typically 20% of full screen height or greater for fusion zones. All signals above this amplitude are to be evaluated in accordance with the owner's acceptance criteria. Volumetric detection channels may use a threshold for evaluation or patterns in mapping type channels and transit time may be used to characterize volumetric defect.

4.1.5.6 Channel output signals are to be arranged on the recording display of weld scanning chart in a manner that allows each reflector to be presented symmetrically on either side of the simulated weld centerline or to be arranged on "mapping" displays (B-scan, TOFD). The recording of actual scanning length is to cover the entire weld length and also encompass both ends of the weld. The coverage is not to be less than 20 mm.

4.1.5.7 The circumferential scanning velocity of tubular structural members may be obtained from the following formula:

$$V_c \leqslant W_c \cdot PRF/3 \quad \text{……………………………………(4-1)}$$

where: V_c —— circumferential scanning velocity, in mm/s;

W_c —— the narrowest beam width at the appropriate operating distance(s) of the all search units in accordance with half-amplitude method, in mm;

PRF —— the effective pulse repetition frequency per search unit, in Hz.

Section 2 Dynamic Calibration

4.2.1 Calibration of sensitivity

4.2.1.1 With the system optimized the calibration block is to be subject to a general scanning at the same speed at which the testing will be performed, in addition to complying with the following requirements:

(1) the peak signal from each reflector is to reach 70%-99% of FSH;

(2) the lateral wave amplitude of TOFD is to be 40%-80% of FSH.

4.2.2 Calibration of records

4.2.2.1 Where the amplitude of reflectors on the block during scanning reaches 80% of full screen height, the amplitude of adjacent reflectors on both sides is at least 6 dB and not more than 14 dB lower than that of the primary reflector. Failure to reach this value is to require repositioning of the search unit or a complete search unit replacement for re-calibration.

4.2.3 Calibration of coupling monitor channels

4.2.3.1 A general scanning of block is to produce a record showing no lack of coupling for the coupling monitor channels, or else re-calibration is to be performed.

4.2.4 Calibration of encoder position

4.2.4.1 The tolerance of encoder position for recording distance of reflectors relative to each other to the actual circumferential position is to be within ±2 mm and the tolerance of encoder position for recording actual circumferential distance of reflectors relative to starting point is within ±10 mm. Detailed calibration steps are given in Appendix C.

Chapter 5 Field Testing

Section 1 Requirements for Field Testing

5.1.1 General requirements for field testing

5.1.1.1 During field testing, the configuration and procedure of the ultrasonic system used for testing are to be in compliance with the system and procedure used for qualification.

5.1.2 Weld surface condition

5.1.2.1 In order to avoid surface conditions which may interfere with the movement of search units and the coupling fluid, the scanning area on each side of the weld needs to be ground. The size of the area to be ground is determined in accordance with the testing equipment, bevel type and pipe wall thickness and it is typically not less than 150 mm in width on each side of the weld.

5.1.2.2 The longitudinal seam welds are to be ground flush and smooth for a specified distance, normally in the range of 150 mm from the factory bevel face. The pipe coating is to be cut back from the original factory bevel face for a specified distance, normally around 300 mm to 400 mm for concrete coating and 150 mm for corrosion coating.

5.1.2.3 The actual cut back dimension requirements are to be advised and confirmed by the body conducting the testing.

5.1.3 Weld identification and reference line

5.1.3.1 Each weld is to be identified by a unique number. The starting point for each scan is to be clearly marked on the pipe and the scan direction is to be clearly marked using an arrow. This mark is not to interfere with scanning. The specific methods of numbering and identification may be agreed between the testing personnel and the owner. The scan direction is to be kept uniform as far as practicable during the testing process.

5.1.3.2 Prior to welding a reference line is to be scribed on pipe outer surface on one side of the weld, for the accurate positioning of set-up of track. A distance of not less than 40 mm ± 0.5 mm is to be ensured from the reference line to the centerline of the weld preparation.

5.1.4 Scanner track

5.1.4.1 The track length is to be determined according to the diameter of pipes to be tested. The track size is to meet the requirements of the scanner.

5.1.4.2 The set-up of track is to ensure the circumferential direction of track is paralleled to the pipe surface, and the tolerance of positioning is not to exceed ±0.5 mm. For pipes with large diameter, at least 6 points are to be measured to ensure the consistency of the distance from the measured points to the weld centerline. Micro-adjustment is to be ensured for the track during the set-up. After the adjustment of position, the track is to be locked tight. Re-examination needs to be performed after the set-up of track.

Section 2 System Re-examination

5.2.1 Sensitivity re-examination

5.2.1.1 The calibration block is to be used to re-examine scanning sensitivity of the system at the start of each shift and at the conclusion of each shift or at intervals defined by the contracting agency. For each standard target, the corresponding channel during sensitivity re-examination is to indicate values of amplitude of 70% to 99% of FSH, and the amplitude of adjacent reflectors on both sides is at least 6 dB and not more than 14 dB lower than that of the primary reflector. The amplitude of lateral wave for TOFD channel is to be 40% to 80% of FSH. Signal of verification outside of this range requires the re-calibration of system.

5.2.1.2 The calibration block is to be used to re-examine scanning sensitivity after scanning of each weld for the first 20 welds and thereafter for other welds at intervals not exceeding 2 h or ten welds. The verification method is the same as that in 5.2.1.1. For the testing of submarine pipelines, system re-examination is to be carried out at the conclusion of each shift. Signal of verification outside of this range requires the re-calibration of system. Re-interpretation is to be carried out for results indicating defects and if it is impossible, re-testing is to be carried out.

5.2.1.3 The sensitivity verification is to be carried out for the system in any of the following cases. Where the requirements for system setting cannot be met, parameters are to be adjusted for re-calibration of system:

(1) where the calibration specimen and the original specimen are not the same one;

(2) where there is any change to the plate thickness of the tested workpiece;

(3) where there is any replacement of components of the testing system;

(4) where the testing is carried out before and after weld repairs, which might affect the bevel profile.

5.2.2 Circumferential position accuracy verification

5.2.2.1 The positional accuracy of the chart distance markers is to be verified prior to commencement of the project and verified monthly.

5.2.2.2 The scanner is to travel from the zero position with the scanning frame and the pipe zero position coincident. At the 1⁄4, 1⁄2 and 3⁄4 positions, the index marks on the scanning frame and pipe are to be aligned. The tolerance of chart circumferential position to the actual position is to be less than 10 mm, or else the encoder is to be re-calibrated.

5.2.2.3 Each verification result is to be recorded.

5.2.3 Temperature differential verification

5.2.3.1 Where temperature differences between calibration specimen and tested workpiece cause shifts in refracted angle which result in the beam being focused outside the corresponding zone, a means of verifying the temperature of the calibration block and tested workpiece needs to be employed such that the temperature change is not to exceed ±10℃.

5.2.3.2 AUT system is to be provided with a temperature measuring system.

5.2.4 Coupling

5.2.4.1 The coupling channel is to be set to avoid the impact of reinforcement of weld root in so far as practicable. The beam angle of the coupling channel is to be so arranged that the back wall echo is outside the root region of the weld.

5.2.4.2 For an area with lack of coupling as indicated by the absence of a coupling monitor signal over a circumferential distance exceeding the minimum allowable defect length, the entire weld needs to be re-tested.

5.2.4.3 During water coupling scanning, an eddy current formed by the accumulation of water flow on the end of wedge is to be avoided, which will interfere with the testing signal of adjacent zones.

Chapter 6 Acceptance Criteria

Section 1 Defect Display and Evaluation

This Section specifies the general requirements for defect display, and it also specifies the general requirements for evaluation of defect display and evaluation method.

6.1.1 General requirements for defect display

6.1.1.1 Strip-chart display is to be used for testing results and B-scan or other form of displays may be added so that the operator can make a quick judgment on whether the weld tested is acceptable.

6.1.2 General requirements for evaluation of defect display

6.1.2.1 Prior to the evaluation of imperfection display, it is to be confirmed that there is no condition of lack of coupling for the coupling channel.

6.1.2.2 Prior to the evaluation of imperfection, the geometric reflected signal from the weld is to be identified, so as to avoid any misinterpretation.

6.1.2.3 B-scan and TOFD display may be used to monitor bad shaping of the root, Hi-Lo, etc.

6.1.2.4 As a monitor signal, TOFD is not to be used as the basis for the final evaluation and the pulse-echo signal is to be used instead.

6.1.2.5 Evaluation of a weld imperfection and issuance of the weld testing record are to be completed prior to commencement of the subsequent testing.

6.1.3 Evaluation method

6.1.3.1 The display of imperfection is to be evaluated by integrating strip chart, B-scan, TOFD etc., generally in accordance with the following methods:

(1) with regard to the display of imperfection on the strip chart, or on all of the strip chart, B-scan and TOFD channel, relevant displays of 40% of FSH or higher on the strip chart are to be evaluated;

(2) with regard to the display of imperfection on B-scan and TOFD channel but no display on the strip chart or the displayed amplitude of less than 40% of FSH, ultrasonic or radiographic testing may be added for re-examination and measurement is to be carried out in accordance with relevant domestic standards.

6.1.3.2 The circumferential position of defects may be estimated quickly by means of circumferential position scale on the strip chart.

6.1.3.3 The defect depth is to be evaluated by the zone where it is located and the defect height is to be estimated by the affected number of zones on the strip chart.

6.1.3.4 The position of defect in the weld is determined by the time of flight of defect signal on the strip chart.

Section 2 Acceptance Criteria

This Section specifies the general principles of acceptance criteria to be used after AUT is performed.

6.2.1 Acceptance criteria

6.2.1.1 The acceptance criteria are developed by the testing party and the owner in accordance with specific requirements or implemented by referring to relevant criteria at home and abroad. They are to be submitted to CCS for approval.

6.2.1.2 Indications from weld imperfections are to be evaluated according to the imperfection acceptance criteria provided.

6.2.1.3 Indications from weld imperfections exceeding the requirements of criteria are to be reported to the owner in writing.

Chapter 7 Reporting and Filing

Section 1 Testing Records and Reports

This Section specifies the contents of testing records and printed files, as well as storage format of data files. It also specifies the content and format of the testing reports and the time for issuance of testing reports.

7.1.1 Testing records

7.1.1.1 A complete set of testing records is at least to include calibration charts, calibration datasheets, scanning charts, testing reports, etc, and to provide hard copy records of all calibration scans and each weld tested, records of testing data in electronic form, and records of assessment of the weld quality.

7.1.1.2 The data files are to be stored immediately following the testing of each weld. The stored data is to be in the same format as that used at the time of testing, which is used for data interpretation.

7.1.1.3 The testing record is to consist of a complete strip-chart type hardcopy showing the reference point, the direction of scanning, date and time of testing, and the name of the operator. The testing zone identified in each channel is also to be recorded. The hardcopy is to contain sufficient resolution and contrast so that the results of defect evaluations can be easily traced.

7.1.2 Testing reports

7.1.2.1 The testing reports produced as a permanent record are at least to include name of project, number of welds, bevel type, material property, specification, acceptance criteria, testing personnel (level), review personnel (level), date of testing, evaluation conclusion and stamp of testing unit.

7.1.2.2 The testing results are to be recorded on a standard ultrasonic report form.

7.1.2.3 All testing reports are to be completed immediately after testing of the weld. The reports are to be made available on a daily basis or on demand for information.

Section 2 Filing of Reports

This Section specifies the selection of storage media and format of scanning records and it also further specifies the storage period of scanning records and testing reports and any change to their management.

7.2.1 Specific requirement

7.2.1.1 The scanning records (images) are to be stored in compact disc, magnetic disk, etc.

7.2.1.2 The archives are to be recorded in the format complying with the requirements of the contract between the employer and the testing firm (or between Party A and Party B).

7.2.1.3 The maintenance and storage period of the scanning records and reports are to be in accordance with relevant requirements of CCS.

Appendix A Targets on Calibration Block

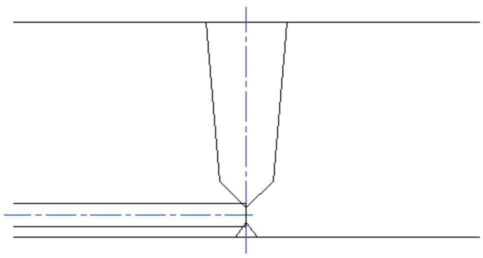


Figure A1 Φ2-Φ3 mm FBH machined at cross penetration land

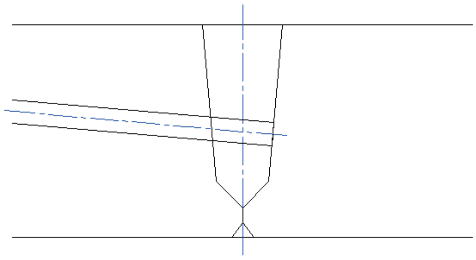


Figure A2 Φ2-Φ3 mm FBH machined at fill

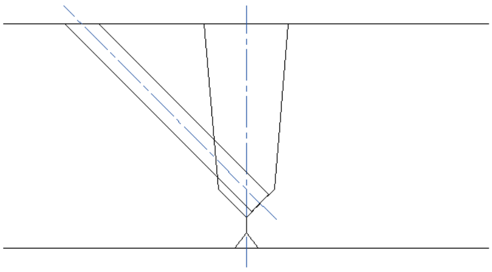


Figure A3 Φ2-Φ3 mm FBH machined at hot pass

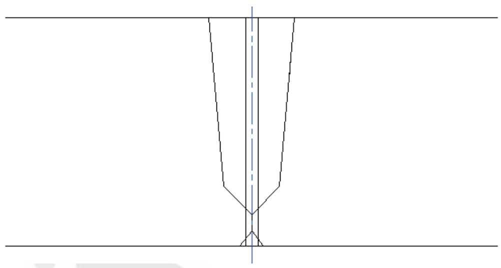


Figure A4 Through hole (Φ2 mm) or slot (5 mm×1 mm) along weld centerline

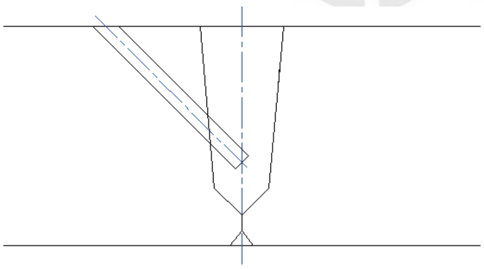


Figure A5 Φ1.5 mm FBH machined to weld centerline

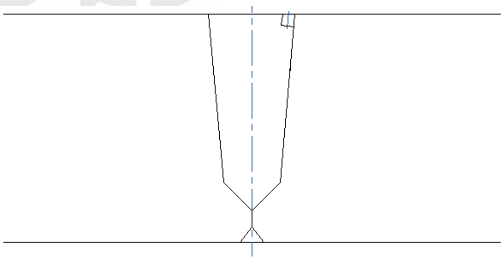


Figure A6 Square slot (1 mm×1 mm×10 mm) to indicate undercut or surface breaking non-fusion

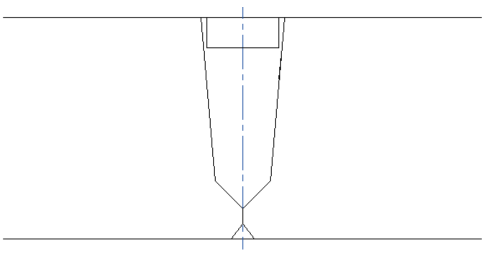


Figure A7 Transverse slot (6 mm×2 mm×2.5 mm) on outer surface

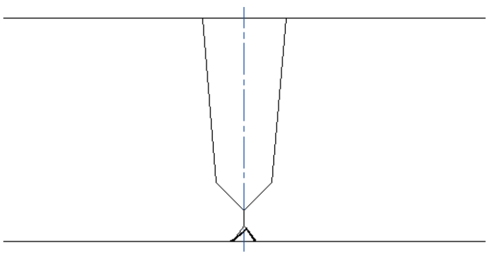


Figure A8 Φ2-Φ3 mm FBH machined at root

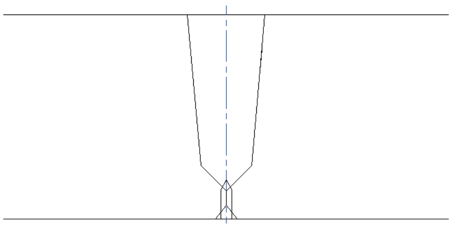


Figure A9 TOFD inner surface slot (10 mm×1 mm× 60%T)

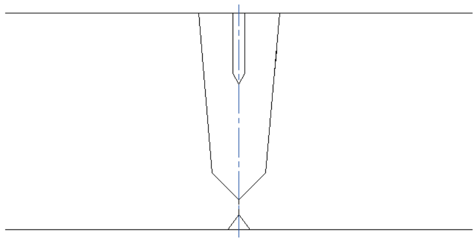


Figure A10 TOFD outer surface slot (10 mm×1 mm×3.5 mm)

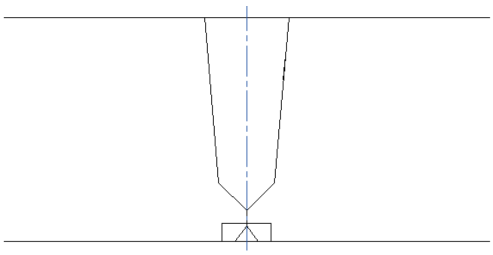


Figure A11 Inner surface transverse slot (4 mm×2 mm×1.5 mm)

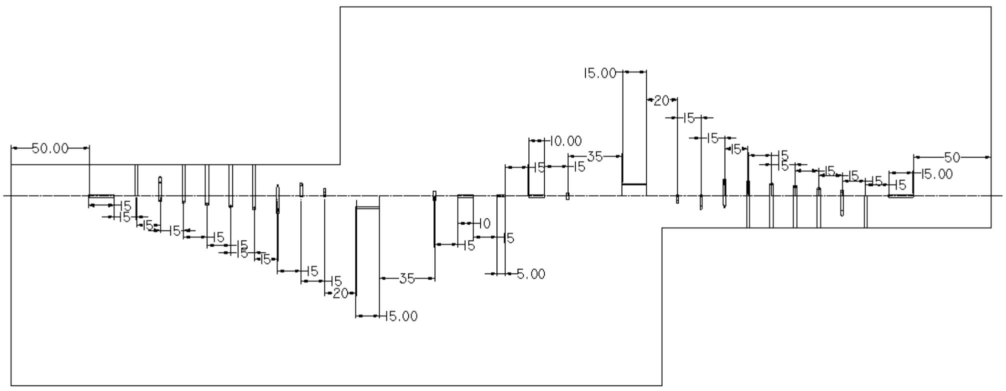


Figure A12 Illustrations of target layout on calibration block pipe section

Appendix B Set-up of Block, Supporting Frame and Guide-band

B.1.1   Requirements for set-up of block

B.1.1.1   A margin of 150 mm in length is required from both ends of the block supporting frame. The total width of the supporting frame is to be greater than 500 mm. The length of the supporting frame in use (or arc length) is not to be less than 1,000 mm.

B.1.1.2   A welding guide-band is fitted on one side of the supporting frame. The distance from the inner edge of the band to the simulated centerline of block is to comply with the requirements of the purchaser.

B.1.1.3   Holes are to be machined on the block supporting frame when the welding guide-band is being fixed, so that after the track is abraded, it may be micro-adjusted from one side of the weld simulated centerline in order to compensate the error caused by abrasion.

B.1.1.4   The band may be fixed by screw which is higher than the nut by 3 mm. The packing block between the band and the supporting frame is to be 18±0.1 mm in height.

B.1.1.5   All the lines for defects are to be led to the supporting frame. The simulated centerline is to be clearly visible on the block.

B.1.2   Requirements for set-up of guide-band

For the set-up of guide-band, the back-up is to be consistent in height with tolerance of ±0.1 mm, to ensure the guide-band is paralleled to the block surface. The edge of the guide-band is also to be paralleled to the weld centerline reference line, and the distance is to be accurately positioned (±0.5 mm) in accordance with the requirements of the owner. See Figure 3.2.2.8.

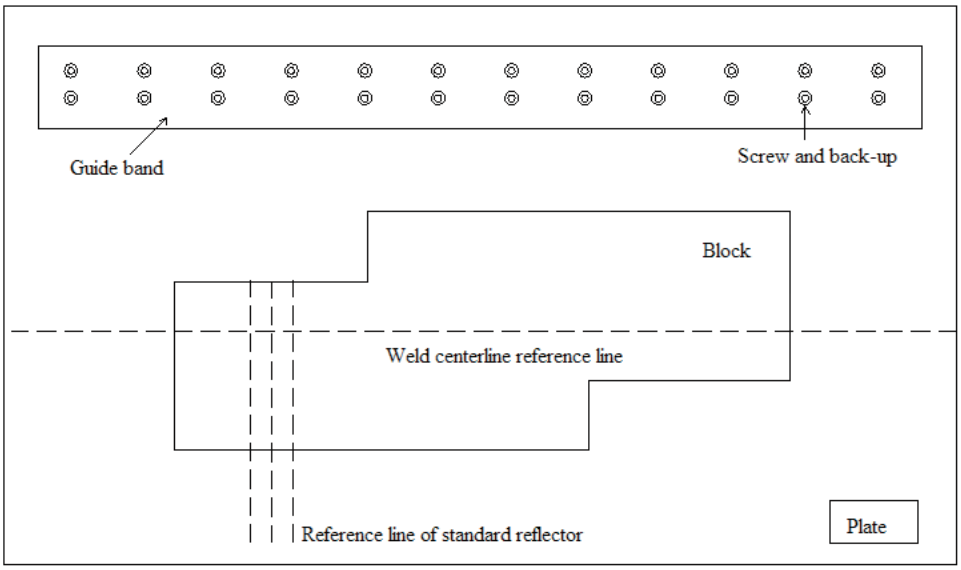


Figure 3.2.2.8 Illustration after set-up of block

Appendix C Encoder Calibration Steps

C.1.1.1 A reference point is to be selected and marked on the scanner, which may be located on one side of the supporting frame of search unit or on top surface of the scanner.

C.1.1.2 A line relative to the reference point is to be scribed on the pipe, which is used to accurately measure the displacement of scanner.

C.1.1.3 The distance of the search unit moving around the pipe is to be measured. In order to obtain average resolution, it is better to carry out calibration within the whole circumferential range (the testing is performed with one circumferential scan). As a result the circumference of the outside circle needs to be measured. Where it is impossible to measure the circumference, it may be obtained by the following formula: Circumference = $\pi \times$ diameter.

C.1.1.4 The value of reference resolution needs to be inputted in the two columns of motor and encoder, which will be used to calculate the accurate encoder resolution set as N/mm.

C.1.1.5 Use the operating handle to align the reference point exactly to the line on the pipe. Set the current position of scanner to 0 and use the handle to move the scanner around the pipe along the testing direction in one circle so that it returns to the starting point. The scanner is to be stopped accurately at the position where the line is scribed on the pipe.

C.1.1.6 The resolution is obtained from the following formula based on the displacement and pipe circumference:

$$\text{Resolution}=\frac{\text{Total counting}}{\text{Actual distance}}$$

Because the total counting is the number function of counting of each unit, the complete formula is as follows:

$$\text{Resolution}=\frac{\text{The total displacement from start to end} \times \text{N/mm}}{\text{Actual distance}}$$

The value is the resolution configured by machine.

Appendix D Design and Case of Bevel Testing Procedures

With regard to a specific tested workpiece, appropriate search units need to be selected and testing parameter are to be designed in a reasonable manner, so as to ensure the effectiveness of testing.

D.1 General design principle of bevel testing parameters

D.1.1 The entire weld is divided into several zones of 2 mm to 3 mm in height.

D.1.2 An independent beam focus is to be available at bevel position in each zone.

D.1.3 The search unit is to be as close to the weld as possible provided that its movement is not affected by the weld cap.

D.1.4 It is to be ensured that the incidence direction of the beam is vertical to the bevel in so far as practicable.

D.1.5 Pulse-echo or tandem techniques may be used.

Take CRC bevel type for example. Based on the bevel type of the weld, it is divided into fill, hot pass, land for cross penetration and root as specified in Chapter 4. Based on the different zone positions, beams of different angles are set for coverage and the setting of beam parameters for each zone is analyzed.

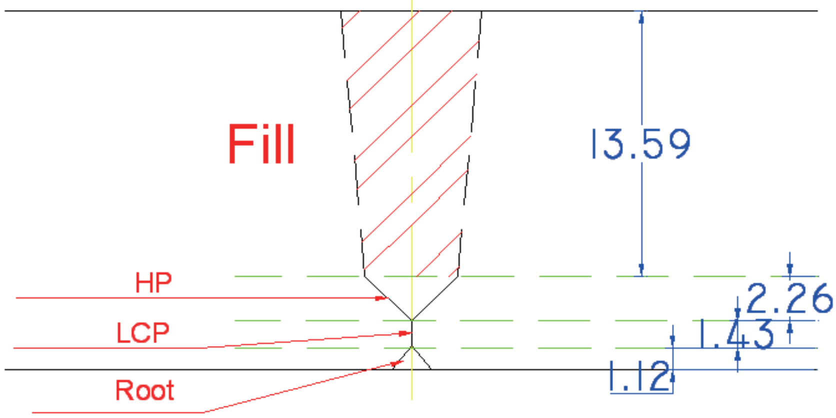


Figure D.1 CRC bevel type

Fill: it is generally tested by means of tandem techniques as the included angle between the bevel direction and the vertical direction is generally not large. The beam incidence angle θ is generally taken as 45°, which may be appropriately adjusted according to parameters such as search unit, plate thickness, etc. The receiving beam angle is $\theta+2a$ (where a is bevel angle). In order to avoid the effect of temperature change on the large angle beam, the angle of transmission and receiving beams is in general not to be greater than 70°. Where the angle of receiving beam is greater than 70°, the angle of transmission beam also needs to be adjusted. Due to the restriction caused by the position of the first zone near the upper surface, it is difficult to use the tandem techniques for testing and as a result the pulse-echo techniques are in general used.

Hot Pass: it is generally tested by means of pulse-echo techniques. The included angle between the bevel direction and the vertical direction is generally 45°, and as a result a double traverse with appropriately selected incidence angle may be such that the beam is totally vertical to the bevel direction, so as to achieve the best testing effect.

Land for Cross Penetration: it is generally tested by means of pulse-echo techniques and a single traverse with incidence angle of 70°. As the LCP bevel direction is vertical, it is impossible for the incident beam to be totally vertical to the bevel direction. As a result, it is tested by large angle beams of 70°.

Root: it is generally tested by means of pulse-echo techniques. The included angle between the bevel direction and the vertical direction is generally over 30°, and as a result a beam with appropriately selected incidence angle may be such that the beam is totally vertical to the bevel direction, so as to achieve the best testing effect.

D.2 Design case of CRC bevel testing parameters

D.2.1 Description of specimen

A pipe butt weld of 18.4 mm in wall thickness, the bevel direction of fill, hot pass and root is 5°, 45°, and 37.5° respectively.

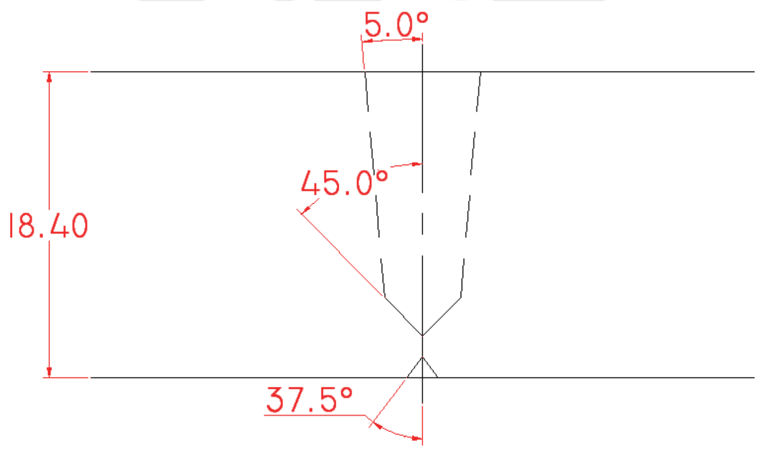


Figure D.2 Illustration of weld bevel

D.2.2 Testing plan

Take CRC bevel weld for example. Fill is divided into 5 zones while hot pass, land for cross penetration and root forms a zone respectively. The following testing plan is developed.

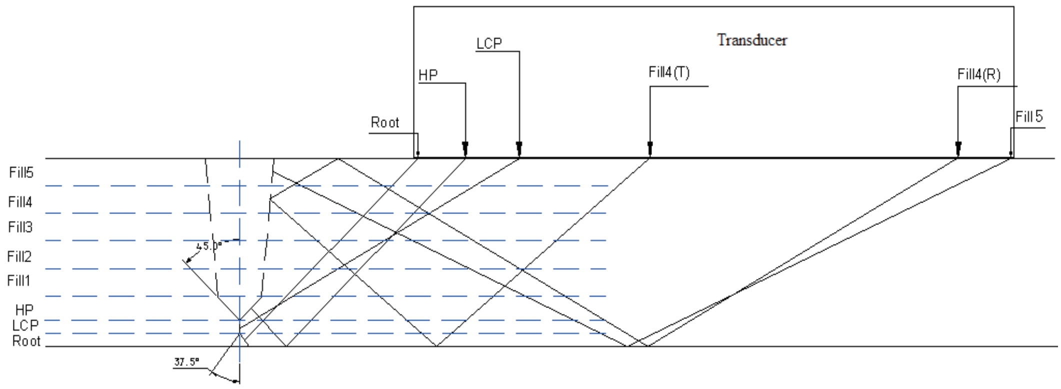


Figure D.3 Testing plan

Fill 5: As it is located closest to the surface, it is tested by means of pulse-echo techniques and double traverse of 65°.

Fill 4: it is tested by means of tandem techniques, using double traverse with incidence angle of 45° and receiving angle of 55°.

Fill 1, 2 and 3: reference may be made to fill 4 and it is not shown in the figure above.

HP: it is tested by means of pulse-echo techniques and double traverse of 45°.

LCP: it is tested by means of pulse-echo techniques and single traverse of 70°.

Root: it is tested by means of pulse-echo techniques and single traverse of 52.5°.

The coverage of weld bevel area by the beams may be realized through the above settings. In addition, corresponding volumetric channel and TOFD setting may be supplemented.

Appendix E Determining Acoustic Velocity in Pipe Steels

E.1 General

E.1.1 This Appendix specifies the method used to determine acoustic velocity of shear waves in line pipe steels.

E.1.2 The method specified by this Appendix to determine acoustic velocity of shear waves is conventional. Methods and equipment other than this method may also be used to determine acoustic velocity of shear waves in line pipe steels.

E.1.3 During the manufacturing process of pipes, the manufacturing techniques and selected materials may cause variations of acoustic velocity. As the accurate control of the position of beam focus is required for AUT, the acoustic velocity of shear waves needs to be determined.

E.1.4 Some line pipes exhibit varying degrees of anisotropy, and it is thus required to determine the acoustic velocity in different directions.

E.2 Equipment

E.2.1 For determining acoustic velocity, the following equipment needs to be prepared:

E.2.1.1 Micrometer or vernier caliper.

E.2.1.2 Shear wave search unit (5 MHz, Φ6 - 10 mm).

E.2.1.3 Coupling fluid for shear waves (honey or other non-Newtonian viscous fluids).

E.2.1.4 Ultrasonic apparatus with receiver with a -6 dB bandwidth typically from 1 MHz to 10 MHz and a display capable of displaying received RF signals and capable of at least 10 nanosecond resolution.

E.3 Specimen preparation

E.3.1 A specimen is cut from a section of pipe to be tested and the corresponding results are specific for a particular pipe type.

E.3.2 Steel used in line pipe is anisotropic, and therefore measurements made are to specify the direction of sound beam propagation. A minimum of three readings are to be made for each plane in which testing will be done and the average value is taken.

E.3.3 Steel used in line pipe is anisotropic, and therefore a minimum of two parallel surfaces are machined for the plane to be evaluated; one pair of surfaces is made in the radial direction (perpendicular to the outer surface) and the other pair made 20° from the perpendicular to the outer surface. Additional pairs of parallel surfaces may be machined at other angles in the plane to be evaluated if more data points are desired.

E.3.4 Specimen dimension is to be a minimum of 50 mm × 50 mm (2×2 in.), which may also be appropriately increased as necessary.

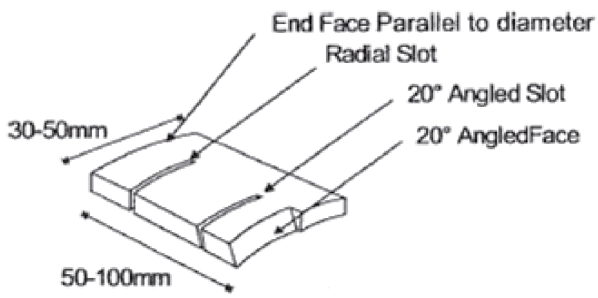
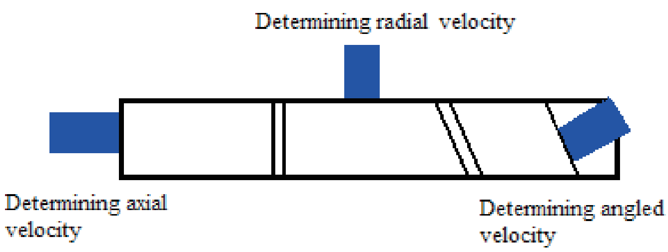


Figure E.3.1 Specimen dimension

E.4 Test procedure

E.4.1 Using the micrometer or vernier caliper measure the thickness of the steel specimen between the machined parallel faces three times to obtain the average value.

E.4.2 Place the shear wave search unit on the machined surfaces and the outer surface, using the couplant for coupling, and obtain a clearly defined reflection. There may be two peaks due to birefringence resulting from the anisotropic nature of the material. Read and record the interval of time between the faster of the two first signals. An example of the birefringent signal is shown in Figure E.4.1.



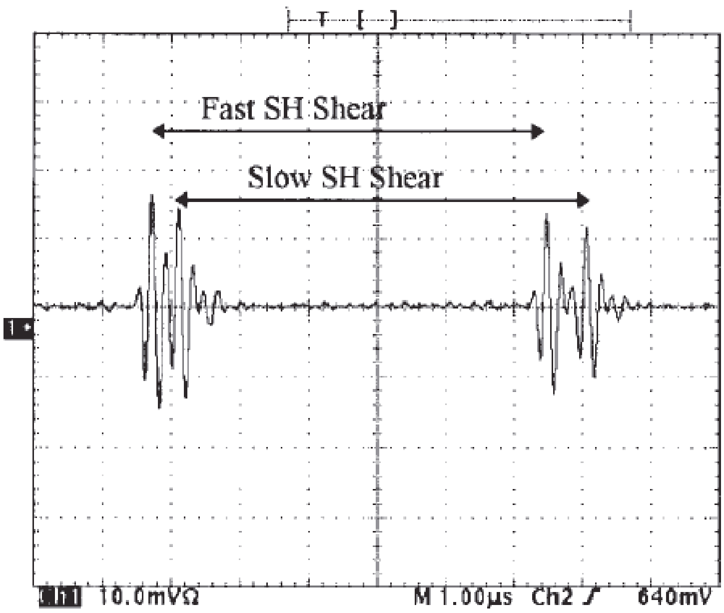


Figure E.4.1 Example of birefringent signal

E.4.3 Determine the acoustic velocities of the three directions assessed using the equation:

$$V = 2d/t$$

where: V = velocity;
d = sample thickness (physically measured);
t = time interval (measured by pulse-echo).

E.5 Tolerances

In order that the error in velocity determination be not greater than ±20 m/s (780 in./s), thickness measurements of the samples are to be accurate to ±0.1 mm (0.004 in.) and time measurements to be accurate to ±25 ms.

E.6 By plotting values for the velocities determined on a two-dimensional polar graph for a single plane, velocities at angles other than those made directly can be estimated.

E.7 When determining acoustic velocity, the temperature at which these readings have been made is also to be recorded.