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INSPECTION PROCEDURE FOR THE ENIQ PILOT STUDY

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1. INTRODUCTION

This document contains the inspection procedure for the ENIQ pilot study. The analysis and a complete list of the essential parameters, and evidence supporting the chosen parameters in the inspection procedure can be found in the technical justification (see reference document 13.1). The technical justification and the inspection procedure should be considered together.

This procedure is only produced for the purpose of the ENIQ pilot study. This means that some of the requirements in this procedure differ from a real ISI procedure. For example, the number of probes used in this procedure for detection is higher than the number normally used in ISI inspections.

The procedure contains a complete list of the essential variables, a thorough evaluations of each of these is given in the Technical Justification.

2. SCOPE OF THE INSPECTION PROCEDURE

The components to be inspected are austenitic pipe to pipe and pipe to elbow welds. The parent materials are wrought 304/316 austenitic steel and the welds are GTAW/SMAW. The inner surfaces of the assemblies are counterbored adjacent to the welds and the weld roots are undressed. The weld crowns are ground (not of second set of ISI assemblies). Access is limited to the outside surfaces.

Details of the geometry of the qualification specimens and the two sets of ISI assemblies are summarised below:

Qualification test pieces

- Diameter Range: 320 - 406 mm
- Thickness Range: 13.5 - 28 mm
- Weld Method: manual GTAW and SMAW
- Weld Material: E308 and E316

1st set of ISI assemblies

- Diameter Range: 320 - 406 mm
- Thickness Range: 25 - 28 mm
- Weld Method: manual GTAW and SMAW
- Weld Material: E308 and E316
- Weld crown: ground
- Weld root: as welded

The qualification test pieces are very similar to this 1st set of ISI test pieces.

2nd set of ISI assemblies

- Diameter Range: 320 - 710 mm
- Thickness Range: 16 - 30 mm
- Base Material unknown, possibly E304
- Weld Method: unknown, possibly MMA
- Weld Material: unknown
- Weld crown: as welded (possibility to grind unlikely)
- Weld root: as welded

The qualification test pieces doe not replicate in detail the size, geometry and macrostructure found in the 2nd set of ISI assemblies.

A full volumetric mechanised ultrasonic inspection of the weld and adjacent counterbore region of the parent materials is required to detect a range of flaws parallel to the welding. The defects that have been postulated as inspection objectives for the pilot study are as follows:

- IGSCC in the parent material adjacent to the welds. These defects originate at the inner surface of the pipes and are parallel to the weld with a maximum skew of ±10°. Mean angle of tilt is 0° but because of the irregular and branched nature of IGSCC, can vary by ±10°.
- Thermal fatigue cracks in the weld metal. These may originate at the weld surfaces or at pre-existing manufacturing defects within the body of the weld. Such defects are parallel to the weld with a maximum skew of ±10°. Angles of tilt can vary between 0° and the fusion face angles up to 30°.

The required performance of the inspection in the qualification is set out in the ENIQ document “Description of the input data for the ENIQ pilot study” (see reference document 13.3 section 7).

3. SURFACE CONDITIONS

The following requirements apply to the qualification specimens and the ISI components. Before the welds and counterbore regions are ultrasonically examined, the outside surface of the welds and adjacent[1] parent material shall be prepared to the following requirements:

- The weld cap shall be removed so that the surface of the weld is flush with the adjacent parent material. The profile of the surface of the weld and adjacent parent material shall not deviate from a perfect cylinder by more than ± 1.5 mm in an area of 50 mm x 50 mm.

- The RMS surface roughness of the weld and adjacent parent material shall not exceed 6.3 µm Ra.

Comment: [1] *with "welds and adjacent parent material" is understood an area from the weld centre line to the position of the counterbore + 6T, where T is the wall thickness. This will allow working with a 70 degree probe in full skip distance in the counterbore area.*

4. CO-ORDINATE SYSTEM

After removing the weld cap and preparing the weld and parent material surfaces, the weld shall be located by etching. The position of the weld fusion lines and the weld centre line shall either be marked by engraving tools or centre punch marks. The weld centre line shall be used as a reference during the scanning of the components, but the reporting of the inspection shall be done in accordance with the marked references. See figure below:

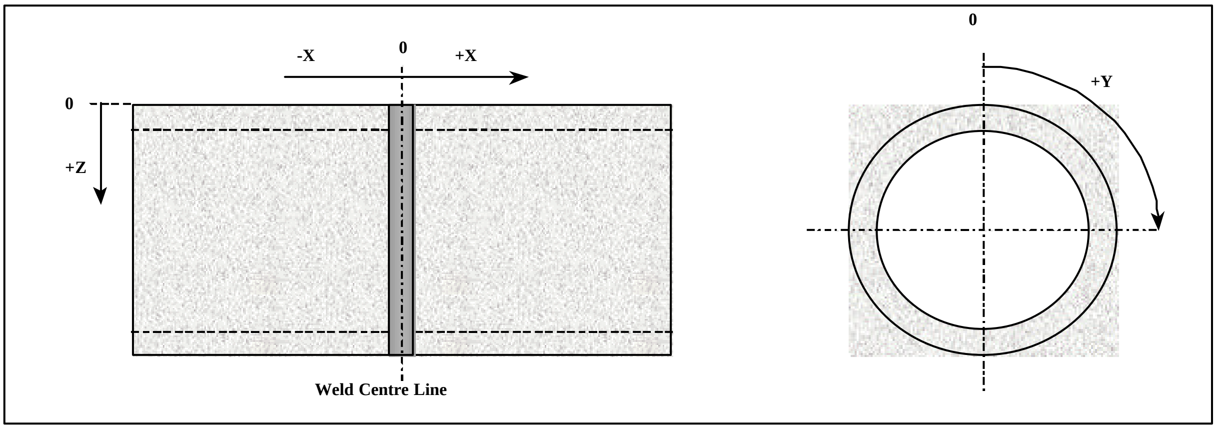


Figure 1: Reference co-ordinate system on the components for the ENIQ pilot study

All the components have clearly marked references in both the axial direction (X) and the circumferential direction (Y), the outside surface correspond to Z = 0 mm.

5. INSPECTION PERSONNEL

All inspectors must be qualified by a scheme meeting the requirements of EN 473 (see document 13.12). The inspector in charge of the inspection shall be qualified to Level III in ultrasonic techniques. He shall also be acquainted with the topics listed below for

Level II personnel. The inspection team shall consist of Level II personnel with formal training and in in-service inspection experience in the following the topics:

- Volumetric ultrasonic inspection of austenitic welds. This shall include a detailed knowledge of the application of compression wave probes for defect detection and sizing.
- The detection and evaluation of IGSCC indications.
- Application of the TOFD technique for measuring ligaments and for defect sizing.
- Knowledge of the generation and interpretation of B, C and D scans produced from RF ultrasonic data.
- Application of the inspection system and the pipe scanner.
- Application of the data acquisition and the data analysis software packages.

Comment: In a real industrial procedure should the requirements to the personnel be documented in a file and handed over to the qualifying body together with the inspection procedure and the technical justification.

6. CALIBRATION BLOCKS USED

The table below summarises the calibration and references blocks used in the ENIQ pilot study. Drawings of the austenitic calibration blocks A(1) and B and C can be found in appendix E.

Table 1: Table of calibration blocks to be used in the ENIQ pilot study

Id.	Name	Description	Material	Application
A(1)	"IIW 2" Calibration Block for Austenitic Steel	Rad. 25-50 mm, width 40 mm	AISI 304 L	Timebase, probe index calibration. Calibration check
A(2)	Standard IIW 2 Calibration Block	Rad. 25-50 mm, width 10 mm	Ferritic steel	Nominal angle on shear wave probes
B	Probe Charac-terisation Block	16 SDH's, 2 notches	AISI 304 L	Probe Characterisation
C	ENIQ 4 Reference test specimen	4 PISC type A notches, 6 SDH	AISI 304 L	TOFD calibration

6.1 Block A(1), The austenitic "IIW 2" calibration block

The block A(1)shall correspond to the specifications given in appendix E page 2 and shall be used as an aid for:

- determination of the probe index
- calibration of the time base
- calibration check of all probes (except for probe A, which shall be checked on Block C).

Comment: *The width of the calibration block A(1) is greater than a standard IIW2 block. This allows a better calibration of the TRL with their bigger probe shoes.*

6.2 Block A(2), Standard ferritic IIW 2 Block

Block A(2) shall be used to check the nominal angle of the shear wave probes.

6.3 Block B, The Probe Characterisation Block

The specification of calibration block B (The Probe Characterisation Block) shall correspond to the specification given in appendix E page 3, and shall be used to establish the:

- distance amplitude curve (DAC)
- check the nominal focal distance for the TRL probes
- check the nominal probe angle for the TRL probes
- calibration check of probe A.

6.4 Block C, Reference Test Specimen

The Reference Test Specimen (C) shall be used for TOFD calibration.

7. EQUIPMENT

The main characteristics of the inspection system are given on next page. A detailed description can be found in reference document ENIQ.PILOT(96)6.

7.1 Data Acquisition System

TOMOSCAN 12, 4 channel ultrasonic system with software version 3.4 Rev 16 manufactured by RD Tech.

7.2 Data Analysis System

TomoView analysis software version 1.0 manufactured by RD Tech.

7.3 Pipe Scanner Acquisition System

AWS-6 Magnetic wheel scanner, resolution better than 1.2 mm for the X axis and 1.8 mm for the Y axis manufactured by FORCE Institutes.

7.4 Scanner Control

WSC-2 scanner controller manufactured by FORCE Institutes:

- step length 0.2 mm to 9.9 mm
- probe movement 5 to 150 mm/s.

7.5 Pre-amplifier for TOFD measurements

TOFD Pre-amplifier manufactured by AEA Sonomatic

- gain + 20 dB
- bandwidth 0 - 10 MHz (+/- 3 dB).

7.6 Cables

Cables from inspection system to scanner:

2 x 50 m RG 58C/U, 50 Ohm	Connectors: BNC ⇒ LEMO 01

and cables from scanner to probe dependent on connector type on probe:

a. 2 x 1m RG 174A/U, 50 Ohm	Connectors: LEMO 01 ⇒ LEMO 00
b. 2 x 1m RG 174A/U, 50 Ohm	Connectors: LEMO 01 ⇒ SMA
c. 2 x 1m RG 174A/U, 50 Ohm	Connectors: LEMO 01 ⇒ SMB
d. 1 x 1m RG 174A/U, 50 Ohm	Connectors: LEMO 00 ⇒ LEMO 00

7.7 Probes

Table 2 shows a summary of the probes to be used in the ENIQ pilot study. All ultrasonic probes with a width exceeding 15 mm in width, except the probes J and K, shall be profiled to fit the OD of the 406 mm diameter reference test pieces (ENIQ 6).

Comment: Evidence is given in the Technical Justification to support the selected parameters for the probes (see reference document 13.1).

7.8 Couplant

The inspection shall be carried out with running water us couplant in an open or a closed circuit. A gel/oil based coupling media may be used as couplant during the TOFD measurements.

Table 2: Summary of the probes to be used in the ENIQ pilot study. See a complete list of the probes in appendix F.

Id.	Probe Type	Angle	Frequency [MHz]	Crystal Dimension [mm]	Probe Housing [mm]	Shoe shape	Probe Main Function
A	SEL	0º	5.0	ø 10	ø 25 mm	Flat	Detection
B	Shear	49º	2.0	8 x 9	13.5 x 24 x 22	Flat	Detection
C	Shear	60º	2.0	8 x 9	13.5 x 24 x 22	Flat	Detection
D	Shear	70º	2.0	8 x 9	13.5 x 24 x 22	Flat	Detection
E	TRL Focal depth = 18	45º (aust)	2.0	2(10 x 18)	30 x 30 x 30	Curved to OD 406 mm	Detection
F	TRL Focal depth = 30	45º (aust)	2.0	2(10 x 18)	30 x 30 x 30	Curved to OD 406 mm	Detection
G	TRL Focal depth = 20	60º (aust)	2.0	2(10 x 18)	30 x 30 x 30	Curved to OD 406 mm	Detection
H	TRL Focal depth = 12	70º (aust)	2.0	2(10 x 18)	30 x 30 x 30	Curved to OD 406 mm	Detection
2 x I	Longitudinal (TOFD)	0º	5.0	ø 6.25	Shoes: 16 x 30 x 15	Curved to OD 406 mm	Sizing: To be used with 45 and 60 degrees wedges for Time Of Flight Diffraction
J	Long-Long Tr 47º/ Re 31º	40-50º (effective angle)	3.0	2(10 x 10)	45 x 19 x 28	Flat	Sizing
K	Long-long Tr 68º/ Re 45º	55-65º (effective angle)	3.0	2(10 x 10)	45 x 19 x 28	Flat	Sizing

8. CALIBRATION

8.1 Equipment

a. The inspection system shall be checked and calibrated according to reference document 13.9. This shall minimum take place at an interval of once a year.

b. Before and after the inspection the vertical and horizontal linearity of the inspection system shall be checked, also the linearity of all available gain settings shall be checked according to the procedure given in reference document 13.10.

c. The accuracy of the scanner shall be checked before the inspection. This shall be done in accordance with the procedure given in reference document 13.11.

8.2 Probes

a. The probe index point for each probe shall be determined and clearly marked on the probe before the beginning of the inspection. The index point shall be checked at a regular interval (see section 10.3).

b. The time base calibration for each probe shall be performed before the beginning the inspection. The timebase settings for each probe are given in table 3. A detailed description of how to calibrate the timebase for all probes is given in the document 13.4 paragraph 6.3.

c. *O deg SEL (A):*

   No Distance Amplitude correction shall be used for the 0 degree probe

   Shear wave (B, C and D):

   A Distance Amplitude Curve (DAC) shall be recorded for all shear wave probes utilising the 3 mm SDH's on the calibration block B. A description of how to record a DAC curve is described in document 13.4 paragraph 6.5.

   TRL probes (E, F, G and H):

   the focal curve and nominal focal distance shall be determined on the calibration block B. A procedure how to do this is also given in document 13.4 paragraph 6.5. However, if the focal curve and nominal focal distance are supplied by the probe manufacturer on a specific numbered data sheet, which states the probe serial number, then these values can be used directly.

d. The nominal probe angle shall be recorded for all probes. The nominal angle of the shear wave probes shall be measured in ferritic steel on the A(2) calibration block. The nominal angle for the shear wave probes shall also be within a tolerance of ± 2 degrees.

   For TRL probes the nominal angles for the longitudinal wave component shall be recorded. This shall be done using the calibration reflector in calibration block B listed in table 3 for the specific TRL probe. The measured angle of the nominal angle shall be within a tolerance of ± 3 degrees.

e. TOFD set-up shall be calibrated on the ENIQ 4 reference test specimen. This shall be done on the 40% deep PISC type A notch in the base material.

8.3 System Calibration Check

8.3.1 Extent of calibration check

Calibration of the index point, the sensitivity settings and timebase adjustment shall be checked to insure that the inspection sensitivity not have changed from the original calibration. This shall be done at following regularly intervals:

- before the start of scanning on a new component
- after the ending of the inspection.

The calibration check shall be performed on the A(1) calibration block for all probes, except for probe A which shall be checked on block B. The check of the calibration shall be performed with the inspection equipment fully connected. The calibration check shall always be reported on the separate data sheet for calibration check (see appendix D).

8.3.2 Acceptance criteria for calibration check

Index point:

If the probe index deviates more than ± 2 mm from the original values, then all recorded data since last calibration shall be corrected to the correct position. The inspection system shall be re-calibrated with the new zero position.

Timebase:

If the time base settings deviates more than ± 10 % from the original values, then a investigation shall be conducted to clarify the reason for this change. The result of this investigation shall be reported on the data sheet for calibration check. All recorded data since last calibration check are not valid and shall be deleted. The relevant inspection areas shall be inspected again.

Sensitivity:

If the sensitivity deviates more than ± 3 dB from the original values, then the sensitivity settings shall be re-adjusted, and possible indications shall be re-calculated to their correct values.

If the sensitivity settings deviate more than ± 6 dB from the original values then a investigation shall try to clarify the reason for the change in sensitivity. The result of this investigation shall be reported on the data sheet for calibration check. All recorded data since last calibration check are not valid and shall be deleted. The relevant inspection areas shall be inspected again.

TOFD:

If the depth measurement on the calibration notch deviate more than ± 0.5 mm from the original value, then the data since last calibration check must be deleted. The system shall then be re-calibrated and all the deleted data must be acquired again.

9. ULTRASONIC TECHNIQUES

9.1 Calibration of the Scanner Position

Zero-set the equipment on the object according to figure 1, page 6. The weld centre line shall be 0 mm in the axial direction (X) during the inspection and the start in circumferential direction (Y) shall be 0°. Scanning directions shall be positive/negative in millimetres in the axial direction and increasing in degrees in the circumferential direction according to the given reference point on the component.

9.2 Scanning

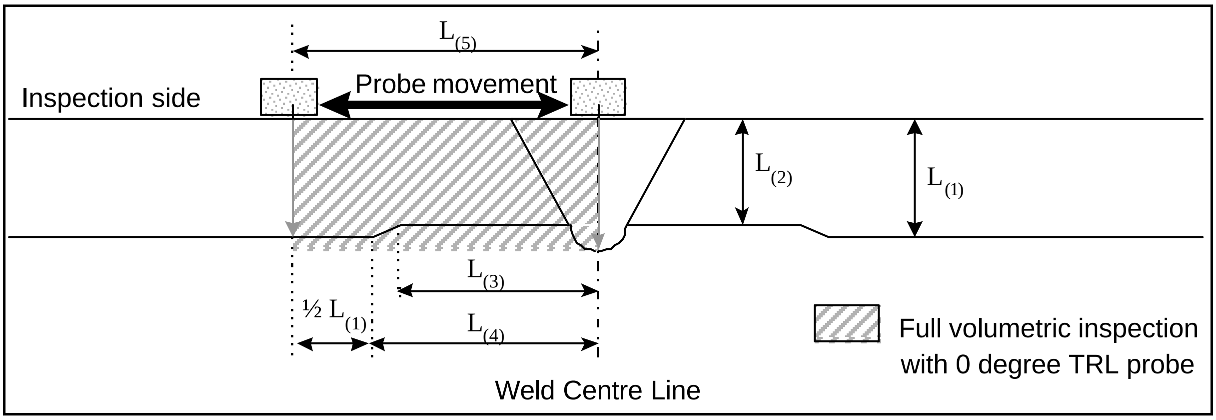
Data collection shall be performed by collecting a raster scan over the inspection area with the probe perpendicular to the main axis of the weld. Scanning shall be performed from both sides of the weld. If not so, it shall be clearly indicated in the reporting. The scanning of the components shall be performed with a step of less than 2 mm (in both X and Y direction), this ensures a overlap of 20 % of the sound beam in all conditions.
The volume to be inspected is from the weld centre line to the position of the counterbore plus ½T, where T is the wall thickness of the component. See figure 2, 3 and 4 (page 11-12) for the required inspection area for the different probes.
The inspection system shall be set to record the full-rectified A-scans, for the specified gate together with the position of the probe. The B, C and D scans can then be constructed at any time for further evaluation of the inspection data.

9.3 Scanning Areas

The following figures 2, 3 and 4 illustrate the required inspection area for the different probes. All the measurements $L_{(1)}$ to $L_{(9)}$ in the figures are given in appendix B.

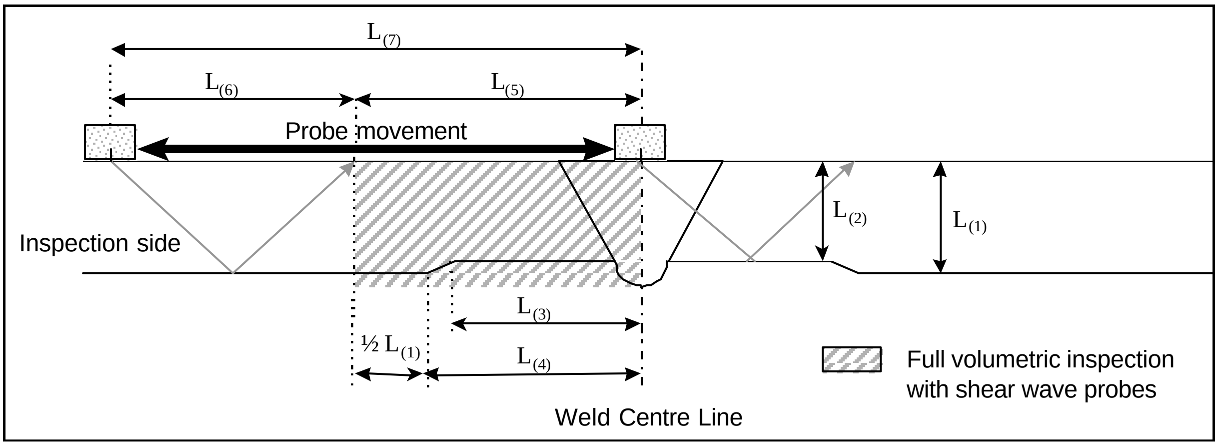
Scanning area for Probe A (0° SEL)

Figure 2: Scanning area and volume to be inspected from each side of the weld on all components with the 0° SEL probe (A).



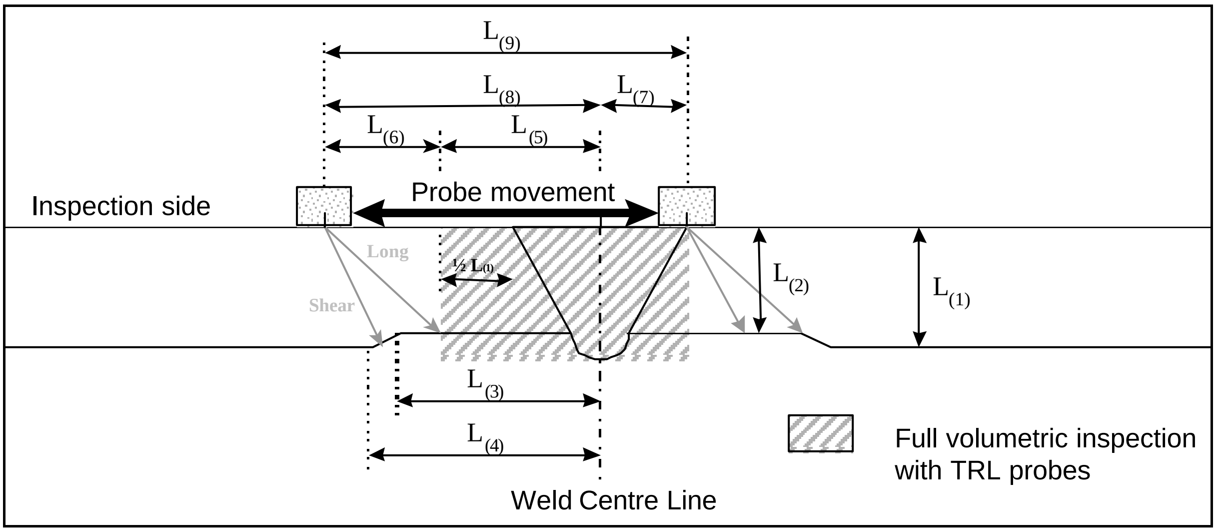
Scanning area for Probe B, C and D (Shear wave probes)

Figure 3: Scanning area and volume to be inspected from each side of the components with the shear wave probes (B,C and D)



Scanning area for Probe E, F, G and H (TRL probes)

Figure 4: Scanning area and volume to be inspected from each side of the components with the TRL probes (E, F, G and H)



The 0º probes (I) shall be used together with 45º and 60º wedges for TOFD measurement. The probes J and K shall be used for through wall sizing with the crack tip diffraction technique. These probes shall only be used for through wall sizing on already detected indications in accordance with the inspection sequence.

9.4 Instrument Settings

The inspection equipment shall be used in a single probe configuration. The general instruments settings are listed here below. Please refer to table 3 for individual settings for each probe.

Data acquisition system

Gain settings:		see table 3
Sampling frequency:		see table 3
Gate length:		see table 3
Pulse repetition frequency PRF:		2000 Hz
Band pass filter:		see table 3
Hardware averaging:	(TOFD)	16 times
	(all other probes)	4 times
Emitter pulse amplitude:		see table 3
Emitter pulse width:		see table 3

Scanner

Scanning Speed:	≤ 50 mm/s
Scan length in X direction:	depends on probe used (see appendix B)
Scan length in Y direction:	360° (length depends on component diameter)

Table 3: Table of the system settings for each probe in the ENIQ pilot study

[1] *FD = Focal Depth* [2] *T = The Wall Thickness*

Probe Id.	Probe Type	Angle	Required Gate Length	System Gain Settings (Recording Level)	Receiver Filter Settings	Sampling Frequency	Emitter Pulse Amplitude/Width
A	TRL	0º	½ skip Long. wave (1 x T at 5750 m/s)	ø 3mm SDH, 20 mm depth in Block B at FSH **+ 18 dB**	2 - 10 MHz	≥ 20.0 Mhz	300 V / 100 ns
B	Shear	49º	1 skip Shear wave (3 x T at 3150 m/s)	ø 3mm SDH, 10 mm depth in Block B at FSH **+ 0 dB** (with DAC curve)	1 - 5 MHz	≥ 10.0 Mhz	250 V / 225 ns
C	Shear	60º	1 skip Shear wave (4 x T at 3150 m/s)	ø 3mm SDH, 10 mm depth in block B at FSH **+ 0 dB** (with DAC curve)	1 - 5 MHz	≥ 10.0 Mhz	250 V / 225 ns
D	Shear	70º	1 skip Shear wave (6 x T at 3150 m/s)	ø 3mm SDH, 10 mm depth in block B at FSH **- 6 dB** (with DAC curve)	1 - 5 MHz	≥ 10.0 Mhz	250 V / 225 ns
E	TRL FD[1] = 18 mm	45º (austenitic steel)	½ skip for both Long. & Shear (2 x T at 5750 m/s)	ø 3mm SDH, 17.5 mm depth in block B at FSH **+ 12 dB**	1 - 5 MHz	≥ 10.0 Mhz	300 V / 225 ns
F	TRL FD[1] = 30 mm	45º (austenitic steel)	½ skip for both Long. & Shear (2 x T at 5750 m/s)	ø 3mm SDH, 30 mm depth in block B at FSH **+ 12 dB**	1 - 5 MHz	≥ 10.0 Mhz	300 V / 225 ns
G	TRL FD[1] = 20 mm	60º (austenitic steel)	½ skip for both Long. & Shear (2.1 x T at 5750 m/s)	ø 3mm SDH, 20 mm depth in block B at FSH **+ 9 dB**	1 - 5 MHz	≥ 10.0 Mhz	300 V / 225 ns
H	TRL FD[1] = 12 mm	70º (austenitic steel)	½ skip for both Long. & Shear (3 x T at 5750 m/s)	ø 3mm SDH, 12.5 mm depth in block B at FSH **+ 3 dB**	1 - 5 MHz	≥ 10.0 Mhz	300 V / 225 ns
I (x 2)	Longitudinal (TOFD)	T< 20 mm 60º wedges T> 20 mm 45º wedges	LL Back wall echo + 50 %	-	1 - 5 MHz	≥ 25.0 Mhz	200 V / 100 ns
J	Long-Long Tr 47º/ Re 31º	40-50º (effective angle)	½ skip Long. wave (1.5 x T at 5750 m/s)	ø 3mm SDH, 20 mm depth in block B at FSH **+ 12 dB**	1 - 5 MHz	≥ 15.0 Mhz	300 V / 175 ns
K	Long-long Tr 68º/ Re 45º	55-65º (effective angle)	½ skip Long. wave (2.5 x T at 5750 m/s)	ø 3mm SDH, 10 mm depth in block B at FSH **+ 12 dB**	1 - 5 MHz	≥ 15.0 Mhz	300 V / 175 ns

9.5 Probe Sequence

Probe Sequence for Detection and Length Sizing

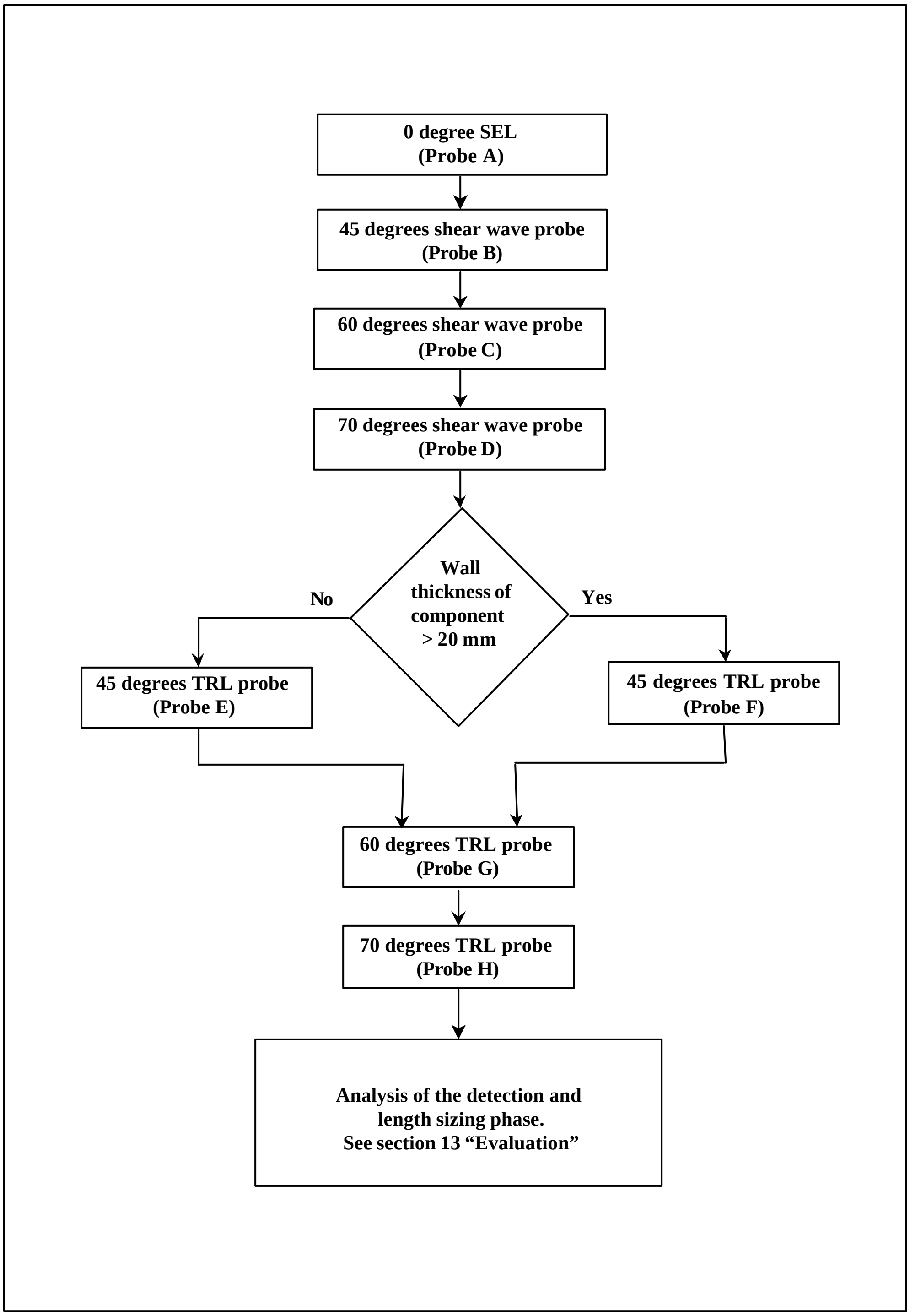


Figure 5: Inspection probe sequence for the detection and length sizing phases in the ENIQ pilot study

Probe Sequence for Through Wall Sizing

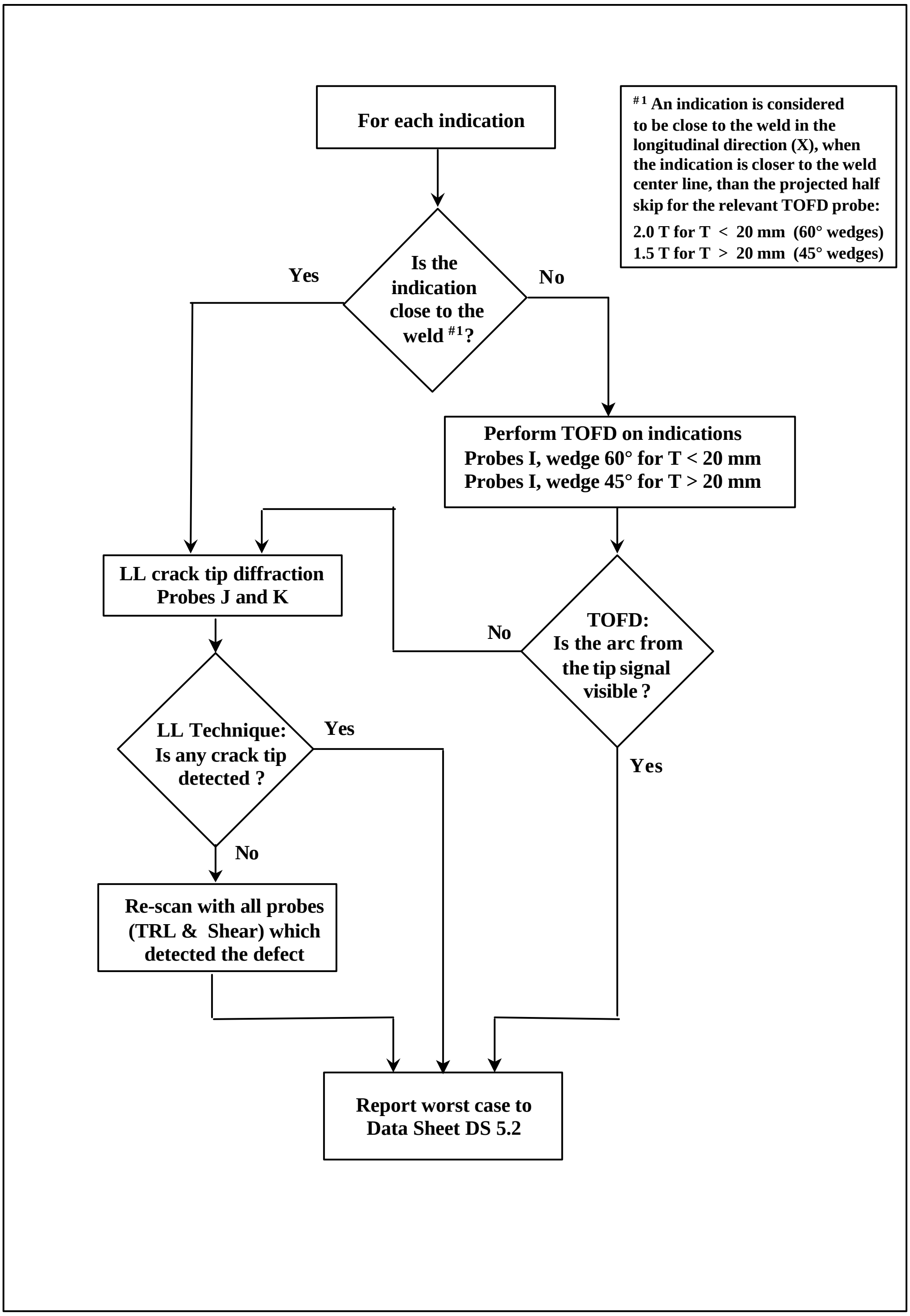


Figure 6: Inspection probe sequence for the Through Wall-Sizing phase in the ENIQ pilot study

9.6 Detection

The method used for flaw detection is the pulse echo technique using a variety of beam angles with both shear and compression waves: Table 3 summarises the instrument settings and the scanning area for each probe is described in appendix B.

9.7 Length Sizing

The method of length measurement of the indication shall be the 6 dB amplitude drop method (see reference document 13.5). If the signal from an indication is over- saturated (>100% FSH) then the length of the defect shall be reported at 50 % FSH. The final length to be reported is the combined worst case from the different probes, which have detected the defect.

9.8 Through Wall Sizing

The through-wall thickness of flaws in the base material, shall if possible, be measured using the time of flight diffraction technique (TOFD) as described in detail in reference document 13.6. The TOFD technique shall be applied if the indication is further away from the weld centre line than:

Min. distance from WCL before applying TOFD:	Component thickness:
2 T	**T < 20 mm**
1.5 T	**T > 20 mm**

The probes used are 5 MHz probes with Plexiglas wedges with an angle of 45° (60° for wall thickness less than 20 mm). The TOFD method shall always be applied focusing in a depth of 2/3 of the wall thickness of the component.

The through wall extent of defects in or close to the weld material shall be through wall extent sized using the LL technique. The technique is applied as normal crack tip diffraction, the only difference being the construction of the probe (see TJ for detailed description).

A crack tip signal shall at least be + 3 dB above the noise level to be considered. If a crack tip signal is detected with both transducers, then the worst case shall be reported onto Data Sheet DS 5.2

If a defect can not be sized using any of the above techniques then the defect shall be re-scanned at noise level (noise = 10 % FSH) with all the transducers which detected the defect. This shall be done to try to apply the crack tip diffraction method for the through wall sizing.

A crack tip signal shall at least be + 3 dB above the noise level to be considered. If a crack tip signal is detected with more than one transducer, then the worst case shall be reported onto Data Sheet DS 5.2.

9.9 Characterisation

The characterisation will consist in indicating the position of a defect (counterbore, weld, HAZ) and verifying whether a defect is surface breaking or embedded.

10. REPORTING LEVEL

All ultrasonic indications exceeding 50 % of full screen height of the recording level outlined in table 3 shall be reported. Analysis of each indication shall be done in accordance with the procedure described in section 11.

11. EVALUATION

The decision process for the evaluation of the inspection results consists of three phases:

Phase 1:

a. Detection and reporting of all indications onto Data Sheet DS 5.1 (one data sheet for each probe).

Phase 2:

b. Apply defect criteria to determine whether an indication is a defect.
c. Report axial probe position (X1, X2) and axial volumetric projected position (XP1, XP2) of defect onto Data Sheet DS 5.2.
d. Determine length of defect and report result onto Data Sheet DS 5.2 (Y1, Y2).

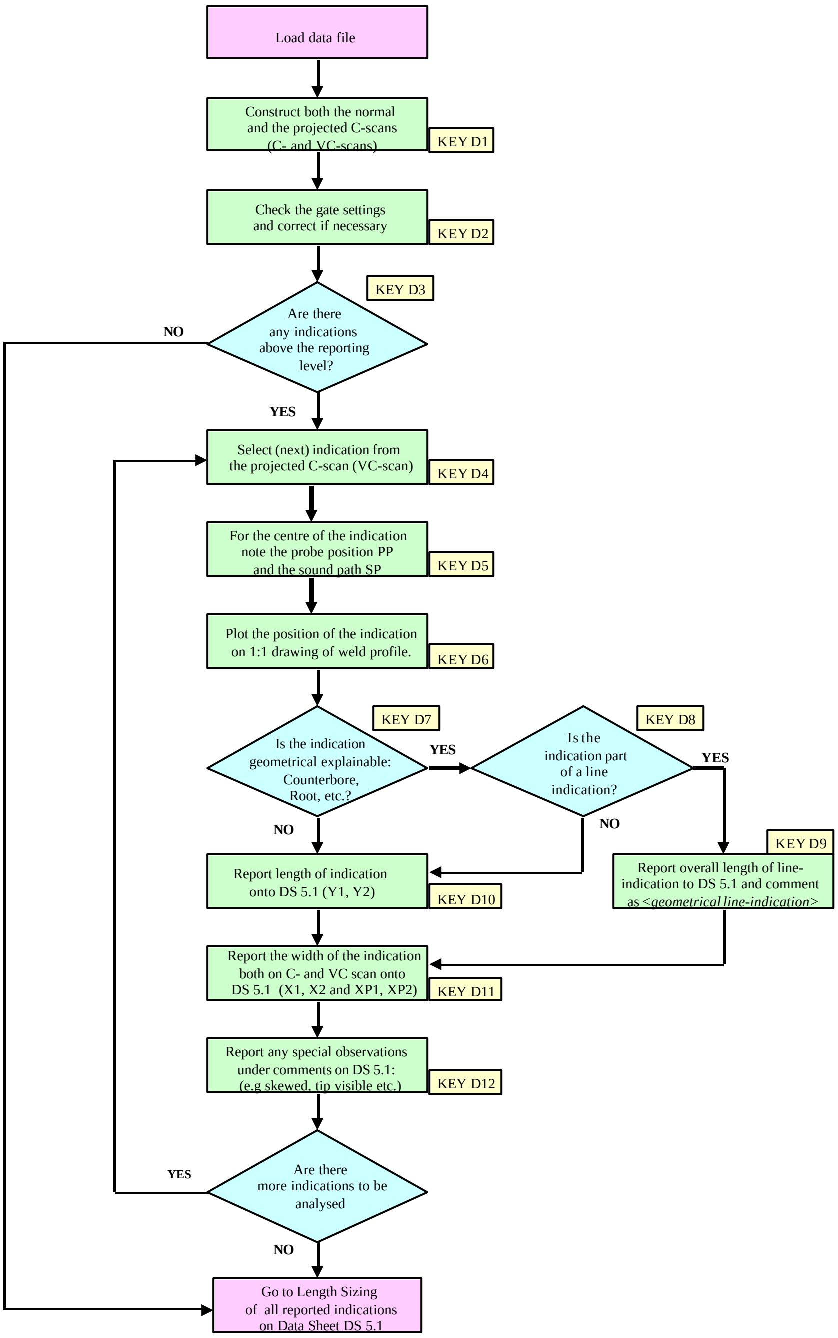
Phase 3:

e. Characterisation of reported defects and report result onto Data Sheet DS 5.2.
f. Sizing of Through Wall Extent (Z1, Z2) of reported defects and report result onto Data Sheet DS 5.2.

The decision process for the 3 phases is shown in detail the following pages. Each of the three phases has its own decision tree and are followed by a description of each decision step.

11.1 Evaluation scheme for detection

Figure 7: Decision tree for the evaluation of the inspection results for the ENIQ pilot study (detection)



Key D-1 Construct both normal and projected C-scans (C- and VC-scans):

For each scan check that the probe movement and scanning area correspond to the one given in Appendix B. Construct both the normal C-scan (C) and the projected volumetric C-scan (VC).. These scans will be used for the reporting of indications.
The C-scans obtained with the same probe, but from different sides of the weld shall be considered separately, and shall therefore also be reported on a separate data sheet DS 5.1.

Comment: The projected volumetric C-scan is a C-scan corrected for the angle of incidence thus showing the projected position of the indications.. It is calculated automatic by the analysis software.

Key D-2 Check if the gate settings are correct:

Set the gate width to the width given in Table 3, and set the reporting level to 50 %

Key D-3 Is there any indications above the reporting level?

The following indications have to be reported:

a. Indications on the C scan above the reporting level.

b. Any discontinuity in the line indications in the C-scan pattern shall be reported as a separate indication.

Key D-4 Select next indication from the projected C-scan:

This reporting has to be done for all indications exceeding 50 % FSH.

Key D-5 For the centre of the indication note the probe position PP and the sound path SP:

Following steps shall be used for each indication to determine the position of an indication:

a. Use the A-, B- and the C-scan to find the position where the A scan signal gives the maximum amplitude from the indication.

b. Use the position in a) to determine the position of the probe with respect to the weld centre line.

c. Use the A-scan signal in a) to determine the sound path from the probe to the indication.

Key D-6 Plot the position of the indication on a 1:1 drawing of the weld profile:

Then plot the probe position together with their corresponding sound path on a 1:1 drawing of the component to determine the position of the indication with maximum amplitude. The different wave components shall be taking into account for the TRL probes during the plotting of the indications.

Key D-7 Is the indication geometrical explainable (counterbore, root, etc.)?

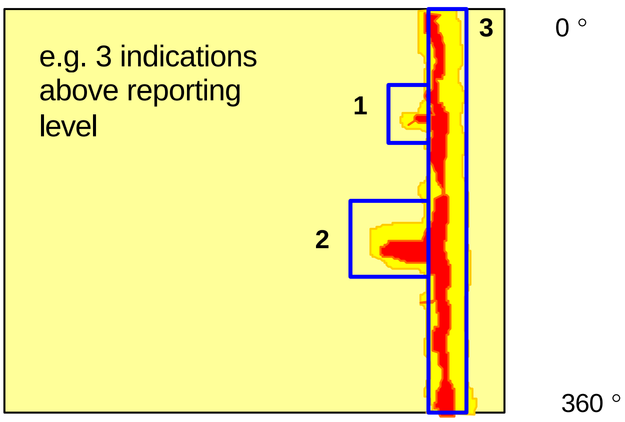
Use the plot from Key D-6 for the different indication to determine if an indication is due to a geometrical phenomena e.g. Root, Counterbore etc.

Key D-8 Is the indication part of a line indication?

YES: *(Line indications)*

An intermediate broken line indication on the C scan shall be reported as only one indication even though the amplitude in some parts of the line indication is smaller than the reporting level. The presence of such a line indication along the circumference shall then be verified using the A- and B-scans. Line indications that can be explained geometrically shall be reported on data sheet DS 5.1 with the comment *"geometrical line indication"*. These line-indications shall not be considered in the further evaluation process.
Geometrical line-indication can for the TRL probes show up twice on the C-scan, both as a longitudinal- and as a shear wave. Special attention shall be paid to indications, which appear between such two line-indication, because they are likely to be mode-converted signals from planer defects.

Figure 8: Example of reporting of indications from C-scan



NO: *(Other indications)*

Variation in the line indication patterns shall be reported as separate indications. An example with three indications is shown here above. Indication 3 is a continuous line indication from the root area along the whole circumference of the component.

Indication 1 and 2 are a discontinuity of this pattern, and shall therefore be reported separately.

Key D-9 Report overall length of the line-indication onto DS 5.1, and attach <geometrical line-indication> as comment for indication:

Report the over all length of the line indication onto Data Sheet DS 5.1 evens though the line-indication at some stages does not exceed the reporting level. These types of defect are often along the whole circumference. Indicate on the DS 5.1 that this indication is a geometrical line indication.

Key D-10 Report the length of indication onto DS 5.1 (Y1, Y2):

Report the length of the indication onto Data Sheet DS 5.1 using the 6 dB amplitude drop method (see reference document 13.5). If the signal from an indication exceeds the FSH (signal > 100% FSH) then the length of the indication shall be reported at 50 % FSH.

Key D-11 Report the width of the indication both on the C- and VC-scan onto DS 5.1 (X1, X2 and XP1, XP2):

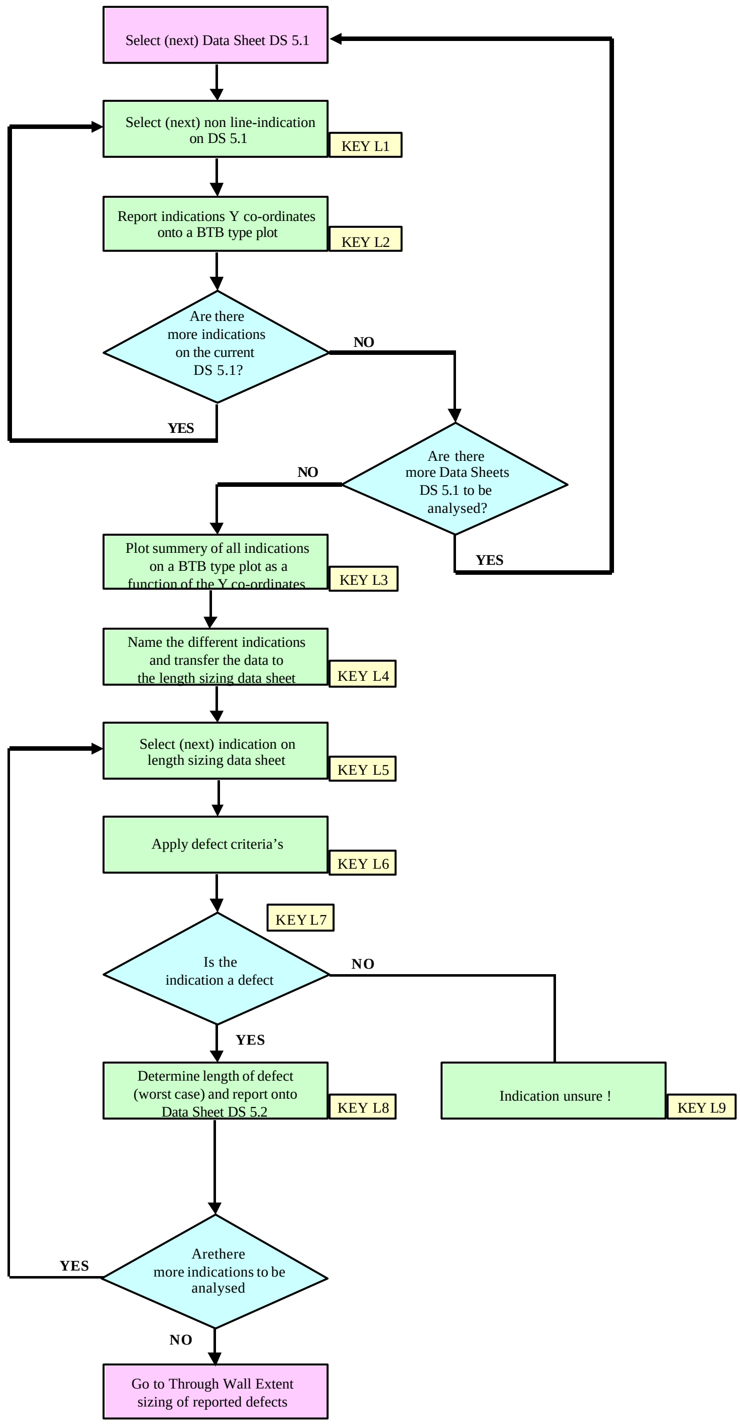
For each indication report the position of the indication in the axial direction (X) from both the normal C-scan (X1, X2) and the volumetric projected C-scan (XP1, XP2). Report the position of the indication onto Data Sheet DS 5.1 using the 6 dB amplitude drop method. If the signal from an indication is exceeds the FSH then the position of the indication shall be reported at 50 % FSH.

Key D-12 Report any special observations under comments on DS 5.1 (e.g. skewed, tip signal visible etc.):

Reports any special observations of the indication into the “comments” column on Data Sheet DS 5.1 (e.g. indication is skewed or a crack tip is visible).

11.2 Evaluation scheme for length sizing

Figure 9: Decision tree for the evaluation of the inspection results for the ENIQ pilot study (length sizing)



Key L-1 Select non-line indication on DS 5.1:

All indications, which were reported as line-indications, shall not be evaluated further. Select therefore the next *non* line-indication on the Data Sheet DS 5.1.

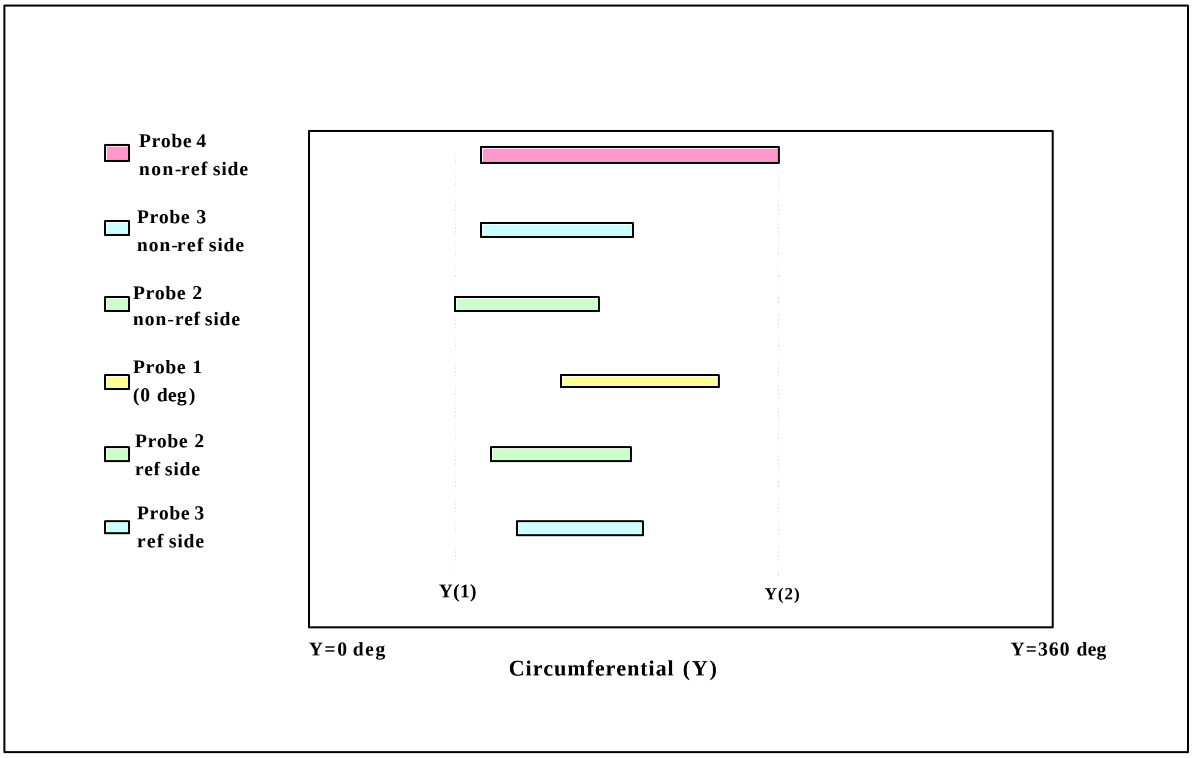
Key L-2 Report the indications Y co-ordinates onto a BTB type plot:

Report the Y co-ordinates for each non line-indication from key L-1 onto a spreadsheet preparing the data for a BTB-type plot showing the indications from different probes as a function the circumference (Y).

Key L-3 Plot summery of all indications on a BTB type plot as a function of the Y co-ordinate:

Plot the BTB-type plot showing the indications from different probes as a function the circumference (Y).
The decision whether indications from different probes and inspection directions are caused by the same origin, shall mainly be decided by comparing the circumferential Y co-ordinate for the different indications, but also the position of the indication along the axial direction (X) shall be considered. An indication positioned within 10 mm in the axial direction is considered to belong to the same reflector.
The decision taken shall be explained and accompanied with a BTB type plot of all the indications together. See example of BTB type plot here below:

Figure 10: Example of a BTB type plot summarising indications from both side of the weld



Key L-4 Name the different indications and transfer the data to the length sizing data sheet:

Name all the groups of indications and transfer the length measurements of all the indications from DS 5.1 to the Length sizing data sheet DS LS (see appendix A).

Key L-5 Select next indication on length sizing data sheet:

Select next indication to be evaluated from the Length Sizing Data Sheet DS LS.

Key L-6 Apply defect criteria:

The indication is considered to be in the base material when the distance between the indication and the weld centre line is bigger than:

a. 2 x Wall thickness for components with a wall thickness T smaller than 20 mm

b. 1.5 x Wall thickness for components with a wall thickness T greater than 20 mm

This criterion is the same as for when to apply the TOFD technique for Through Wall Extent sizing. For indications positioned closer to the weld in the axial position than above, the defect criteria for defects in the weld material and Heat Affected Zone (HAZ) area should be applied.

Defect criteria for indications in the base material

A indication is considered as a defects in the base material if is not explainable as a geometrical indication and at least one of the following two statements are true:

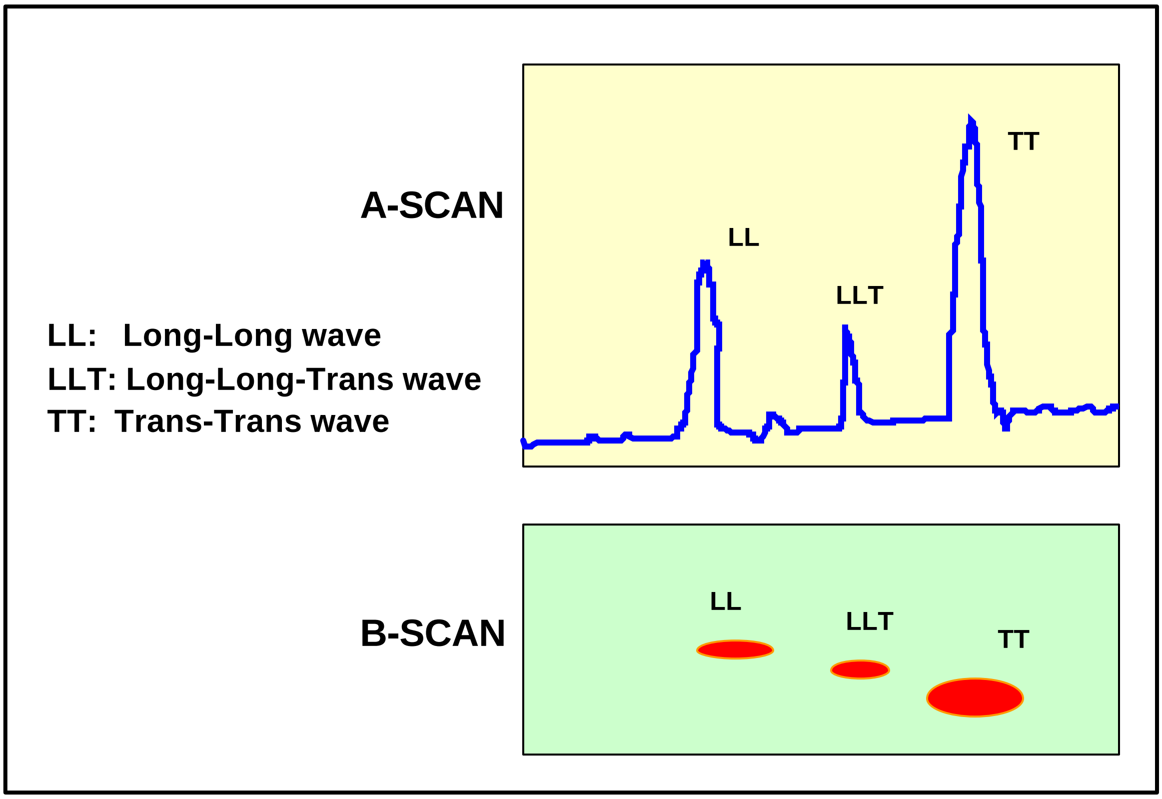
I. it is detected with more than one transducer,

II. if it is detected with the 0 degrees SEL probe.

Important points to be considered during the analysis of the indications from the TRL probes (see figure 10)

- A surface breaking defect on the inside of the component will normally give a distinguished signal pattern because of the mode conversions of the signals. An example of this pattern is shown below.
- The different wave modes will probably not always create signals exceeding 50 % FSH.
- Shear waves do generally not penetrate through the whole weld.
- Normally no LLT signal from the geometry (e.g. root).
- Normally no distinct LLT signal from 45 TRL.

Figure 11: Example of a typical pattern for a planer surface breaking defect for a TRL probe (only one of the components in the signal pattern will have to exceed the reporting level in order to consider the whole signal)



Defect criteria for indications in the weld material and the HAZ area:

An indication in the weld material is considered as a defect if it is detected by the 0 degree SEL probe or at least 2 of the 4 statements below are true:

I. The indication is detected with more than one TRL probe (45°, 60° and 70°)

II. The signal from any TRL show up the distinct LL/LLT/TT signal pattern as described

III. The indication is detected with at least one shear wave probe

IV. The indication is detected from both sides.

Key L-7 Is the indication a defect?

Determine by applying the defects criteria in *"Key L-6"* whether an indication is a defect.

Yes: Go to Key L-8

No: Go to Key L-9

Key L-8 Determine the length of the defect (worst case) and report the results onto data sheet DS 5.2:

Determine the length of the defect (Y1, Y2) by taking the overall worst case from all the reported sizes for an indication on the Length Sizing Data Sheet DS LS. See figure 9.

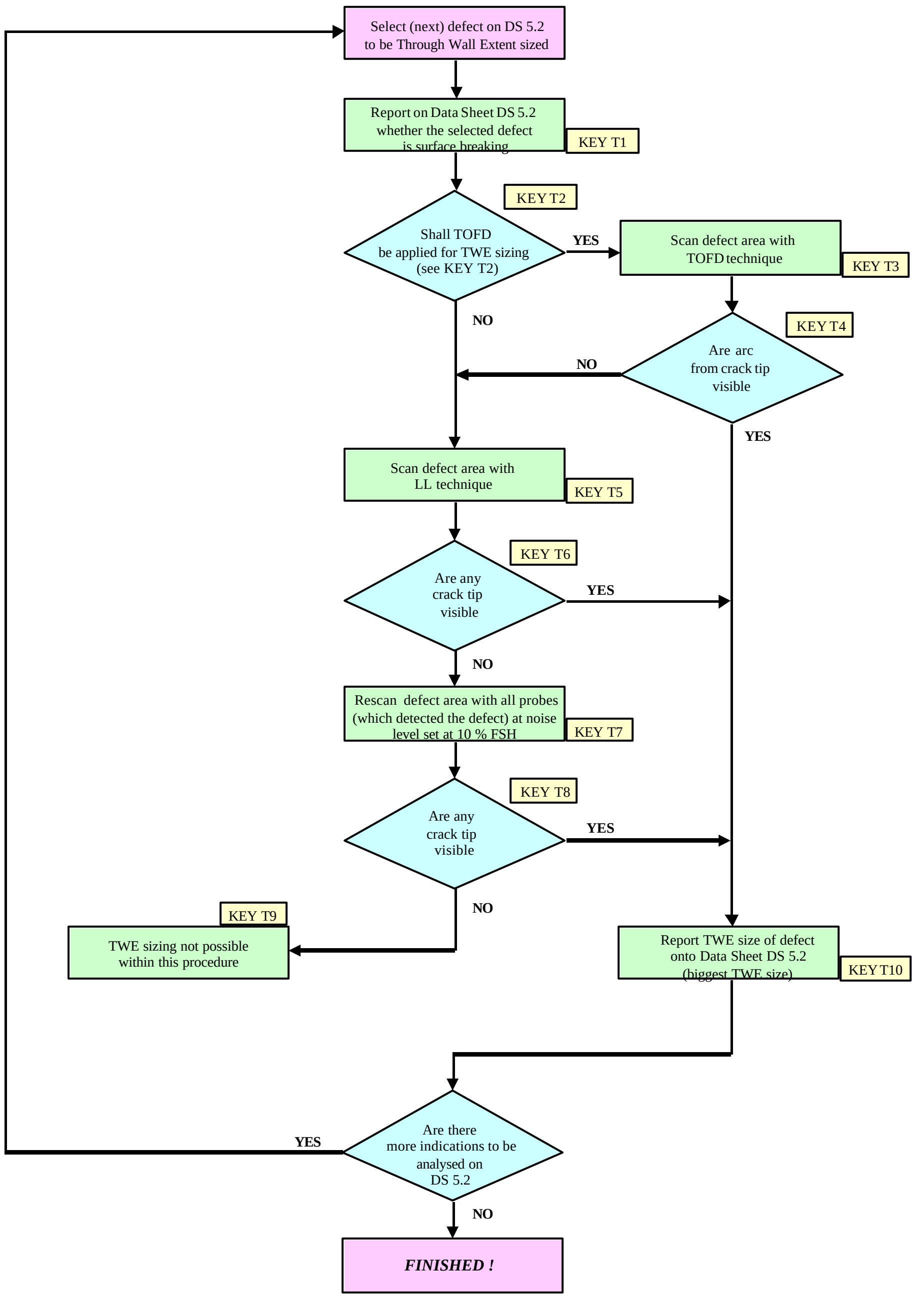
Key L-9 Determine the length of the defect (worst case) and report the results onto data sheet DS 5.2:

If an indication does not fulfils the defect criteria and can not be explained as a geometrical indication, then the indication shall be reported on a separate data sheet together with suggestion for further investigation of indications.

Comment: If any indications fall into this category, then it means that the inspection procedure is qualified for this type of indications/defects.

11.3 Evaluation scheme for through wall extent sizing and characterisation

Figure 12: Decision tree for the evaluation of the inspection results for the ENIQ pilot study (through wall extent sizing and characterisation)



Key T-1 Report onto data sheet DS 5.2 whether the selected defect is surface breaking:

Following steps shall be used for each defect to determine whether it is surface breaking:

a. Use the C-scan to find the position where the A scan signal gives the maximum amplitude from the defect.

b. Use the position in a) to determine the position of the probe with respect to the weld centre line.

c. Use the A-scan signal in a) to determine the sound path from the probe to the indication.

Then plot the probe position (PP) together with their corresponding sound path (SP) on a 1:1 drawing of the component to determine the position of the defect with maximum amplitude.

- If the defect is surface breaking will the position with the maximum amplitude be originating from the corner between the defect and the back-wall surface,
- If the defect not is surface breaking will the maximum amplitude from the defect be within the volume of the material.

Report the result onto Data Sheet DS 5.2

Key T-2 Is TOFD applied as TWE sizing technique:

The TOFD technique shall be applied if the indication is further away from the weld centre line than:

a. 2 x Wall thickness for components with a wall thickness T smaller than 20mm

b. 1.5 x Wall thickness for components with a wall thickness T greater than 20mm.

Key T-3 Evaluate TOFD data:

Apply TOFD evaluations on the B-scan. See reference document 13.6.

Key T-4 Is the arc from a tip signal visible?

Determine whether a crack tip signal is detected. A small point reflector from a crack tip will give a characteristic arc shaped signal positioned between the creeping wave along the surface and the back-wall echo.

Comment: This technique is converting the through wall extent measurement into a time measurement, and it is thereby not using the amplitude of the signal directly. The technique relies on the capability to recognise patterns. It is therefore not easy to *quantify a signal to noise ratio for the TOFD signal. Generally it could be said that the tip signal must be somewhat higher than the noise level.*

Key T-5 Evaluate LL-probe data for TWE sizing:

Scan the defect area with the instrument settings given in table 3.

Key T-6 Is the crack tip visible?

A crack tip must have a signal to noise ratio of at least + 3 dB to be considered for through wall sizing. If crack tips are detected then report the worst case onto Data Sheet DS 5.2.

Key T-7 Evaluate crack tip data for TWE sizing for probes which detected the defect:

Re-scan the defect area with all the probes, which detected the defect with the gain set at the noise level to 10 –15 % FSH.

Key T-8 Is the crack tip visible?

A crack tip must have a signal to noise ratio of at least + 3 dB to be considered for through wall sizing. If crack tips are detected then report the worst case onto Data Sheet DS 5.2.

Key T-9 TWE sizing not possible within this procedure!

Sizing is not possible within this procedure for this type of defect. Any defect in this category shall be filled into a separate sheet together with suggestions for further evaluation.

Comment: If any indications fall into this category, then it means that the inspection procedure is not qualified for TWE sizing this type of indications/defects.

12. REPORTING REQUIREMENTS

The reporting of the inspection results will be done in accordance with the rules used in the PISC programme. This will enable an easy evaluation of the inspection results, with evaluation tools such as the BTB code. The following is required for the reporting:

a. *DS 1: Co-ordinate system used:*
   Data sheet describing the co-ordinate system used to report the indications; the co-ordinate system proposed by the qualification body shall be used.

b. *DS 2: Inspection procedure:*
A full description of the inspection procedure will be given in document ENIQ.PILOT(96)5.

c. *DS 3: Equipment used:*

A full description of the equipment will be given in document ENIQ.PILOT(96)6.

d. *DS 4: Raw inspection data:*

All raw inspection data will be stored on disk. These data sheets will contain information concerning the filenames and the scanning conditions used during the inspection. DS 4 shall also contain all the data sheets from the calibration checks.

e. *DS 5: Inspection Results:*

- data sheet ENIQ DS 5.1: location and dimensions of the indications detected with one particular probe along the example given hereafter;
- data sheet ENIQ DS 5.2: final inspection results containing location and dimensions of all indications considering the whole procedure.

The difference between data sheets ENIQ DS 5.1 and ENIQ DS 5.2 is s follows:

- data sheet ENIQ DS 5.1 will only consider the inspection results of one of the probes to create a defect envelope. It is thus a table of results relative to one of the techniques only. Several sheets may be required, numbered data sheet ENIQ DS 5.1(x).
- data sheet ENIQ DS 5.2 gives the final results of the location and size of all flaws determined from the combination of measurements by several different techniques and probes.

The data requested in data sheet ENIQ DS 5.1 are (one for each probe used):

a. date of inspection
b. name of inspectors
c. technique used
d. limits of the inspected area
e. probe used
f. scanning direction
g. co-ordinates and dimensions of the envelope of each indication
h. maximum amplitude of the flaw signal
i. comments

The data requested in data sheet ENIQ DS 5.2 are (for full procedure):

a. limits of the inspected area
b. which data sheets ENIQ DS 5.1 are used to arrive to results in data sheet ENIQ DS 5.2
c. co-ordinates and dimensions of the envelope of each indication
d. the maximum amplitude of the flaw signal
e. comments

An example of data sheet ENIQ DS 5.1 and ENIQ DS 5.2 and an addendum to data sheet ENIQ DS 5.2 are given in appendix A.

Comment: During the open trials in the ENIQ pilot study some additional reporting is needed. Each step in the decision process must be fully documented. This means that a big amount of the chosen signals shall be printed to support the decision made. In a real qualification situation most of this type of documentation will not be needed on print, but will be explained to the invigilator from the qualifying body during the open trials.

Table 4: Additional reporting required in the Open Trials of the ENIQ pilot study

ENIQ sheet	Key from the decision tree	Description
DS 6.1	B	For each probe and each side of the weld make a print out of the C-scan with gate and gain set according to Table 3 and the reporting level set to 50 % FSH
DS 6.2	-	For each indication and each probe printout of the C-scan with the length of the indication
DS 6.3	C	Make a BTB type plot with all the indication pared together from the different data sheets DS 5.1. This data sheet shall also contain an explanation of why this set of indication was pared together.
DS 6.4	D, E and G	Make for each indication on the indication list a 1:1 drawing with position of the indications for each probe (one for each wave component for the TRL probes). This drawing shall be accompanied with a print out of the A-scan used for each probe containing: a. the position of the probe where the indication have maximum amplitude in relation to the weld centreline. b. the sound path from the probe to the position of the maximum amplitude of the indication.

DS 6.5	I	Possible explanation of the indication which is not to be considered as an defect or geometrical indication.
DS 6.6	J and K	This data sheet shall contain documentation for each defect for the through wall sizing: a. All TOFD B-scans, if an arc is visible from the crack tip on the indication. b. All the A- and B-scans of the crack tip signals, if applicable. c. C-scan used for the 6 dB drop method, if applicable.

13. REFERENCE DOCUMENTS

13.1 "Technical Justification" ENIQ.PILOT(96)9, 18th. November 1996 (draft).

13.2 "QA programme for the ENIQ pilot study" ENIQ.PILOT(95)2, 22nd. October 1996

13.3 "Description of input data to the ENIQ pilot study" ENIQ.PILOT(96)3, 8th October 1996.

13.4 "Handbook on the Ultrasonic Examination of Austenitic Welds", Commission V, IIW, 1986.

13.5 "Ultrasonic Examination of Welds. Part 1. Methods for Manual Examination of Fusion Welds in Ferritic Steels", BS 3923: Part 1, British Standards, 1986.

13.6 "Guide to Calibration and Setting Up of the Time of Flight Diffraction (TOFD) Technique for the Detection, Location and Sizing of Flaws", BS 7706, British Standards, 1993.

13.7 "TOMOSCAN user's manual" R.D. Tech, software version 3.4R, May 1995.

13.8 "TOMOLUIS software manual" R.D. Tech, software version 2.1, preliminary issue October 1994.

13.9 "Calibration procedure PTOMO34" rev B, R.D. Tech.

13.10 "Linearity check of UT-system" TI-11P-15, ABB-TRC 7th. April 1995

13.11 "Kalibreringskontroll AWS 6" TI-11P-30, ABB-TRC 27th. April 1995

13.12 "Qualification and Certification of NDT Personnel - General Principles", EN473, CEN, 1993.

APPENDIX A

Examples of data recording on data sheets “ENIQ DS 5.1” and “ENIQ DS 5.2” and the length sizing data sheet DS LS

EXAMPLE OF DATA RECORDING ON DATA SHEET "*ENIQ DS 5.1*":

This Data Sheet is to be produced for each technique/probe used.

FILE NAME:

PROBE USED:

SCANNING SIDE:.

DATE:

DATA ANALYSTS:

INSPECTORS:

INSPECTED VOLUME: X1= X2=
Y1= Y2=
Z1= Z2=

Indication number	Probe position P 1(mm)	Probe position P2 (mm)	X2 (mm)	X2 (mm)	Y1 (deg)	Y2 (deg)	Comment on indication
1							
2							
3							
4							
5							

EXAMPLE OF DATA RECORDING ON DATA SHEET "*ENIQ DS 5.2*":

This data sheet represent the final results, and is a summary of all the different ENIQ1 data sheets.

D.S. CONCERNED: **DATA ANALYST:** **INSPECTED VOLUME:** X1= X2=

INSPECTOR(S): Y1= Y2=

Z1= Z2=

Indication number	X1 (mm)	X2 (mm)	Y1 (deg)	Y2 (deg)	Z1 (mm)	Z2 (mm)	Comment on indication
1							
2							
3							
4							
5							

Addendum to the ENIQ DS 5.2 data sheet:

In order to allow a complete analysis at the level of techniques, the following questions will be answered for each indication given in the *ENIQ DS 5.2* data sheet.

- *Detection*
  1. With which techniques/probes were you able to detect this indication.
  2. Describe the decision process that led you to consider this indication as a defect.

- *Through Wall Sizing*
  1. With which techniques/probes were you able to size the through wall depth of this indication.
  2. Describe the decision process, which allowed you to arrive at the dimensions given in the *ENIQ DS 5.2* data sheet.

- *Length Sizing*
  1. With which techniques/probes were you able to size the length of this indication.
  2. Describe the decision process, which allowed you to arrive at the dimensions in the *ENIQ DS 5.2* data sheet.

Hereafter follow examples of tables of how this information could be given.

- *Detection*

	Detection technique 1	Detection technique 2	Detection technique 3	Detection technique 4	Decision process
Indication 1	detected	detected	detected	detected	see decision tree
Indication 2	not detected	not detected	not detected	detected	see decision tree
Indication 3	detected	not detected	detected	detected	see decision tree
Indication 4	detected	not detected	detected	detected	see decision tree
. . .	..	...	...	...	...

- *Through Wall Sizing*

	Through Wall Sizing technique 1	Through Wall Sizing technique 1	......	Decision process
Indication 1	Z1=15 mm Z2=25 mm	not able to size		maximum depth measured was reported (procedure p 26)
Indication 2	Z1=10 mm Z2=25 mm	Z1=12 mm Z2=25 mm		maximum depth measured was reported (procedure p 26)
Indication 3	not used	Z1=10 mm Z2=25 mm		maximum depth measured was reported (procedure p 26)
. .				

- *Length Sizing*

	Length sizing technique 1	Length sizing technique 2	......	Decision process
Indication 1	Y1=15 mm Y2=25 mm	Y1=17 mm Y2=28 mm		See reporting on indication list (procedure page 23)
Indication 2	Y1=10 mm Y2=25 mm	Y1=12 mm Y2=25 mm		See reporting on indication list (procedure page 23)
Indication 3	Y1=12 mm Y2=22mm	Y1=10 mm Y2=25 mm		See reporting on indication list (procedure page 23)
. .				

LENGTH SIZING

ADDENDUM TO ENIQ DS 5.2

ENIQ COMPONENT NO: _____

DATA ANALYSTS: _________

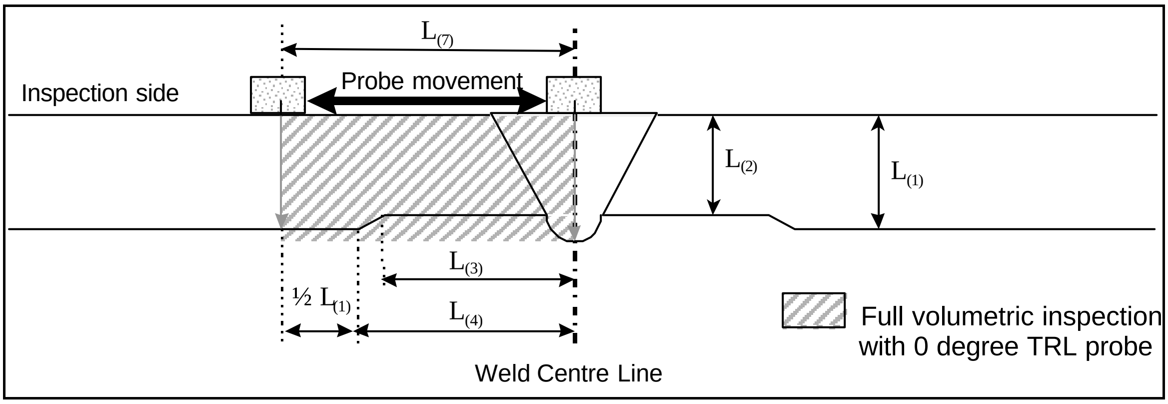
PROBE	**A**	**B**	**C**	**D**	**E/F**	**G**	**H**	**B**	**C**	**D**	**E/F**	**G**	**H**
INSP. SIDE	**-**	**REF**	**REF**	**REF**	**REF**	**REF**	**REF**	**NOT REF**	**NOT REF**	**NOT REF**	**NOT REF**	**NOT REF**	**NOT REF**
Indication no 1													
Indication no 2													
Indication no 3													
Indication no 4													
Indication no 5													
Indication no 6													
Indication no 7													
Indication no 8													
Indication no 9													
Indication no 10													

Y 1	**Y 2**	**COMMENT**
(DEG)	**(DEG)**	

APPENDIX B

Table of scanning areas for the different components

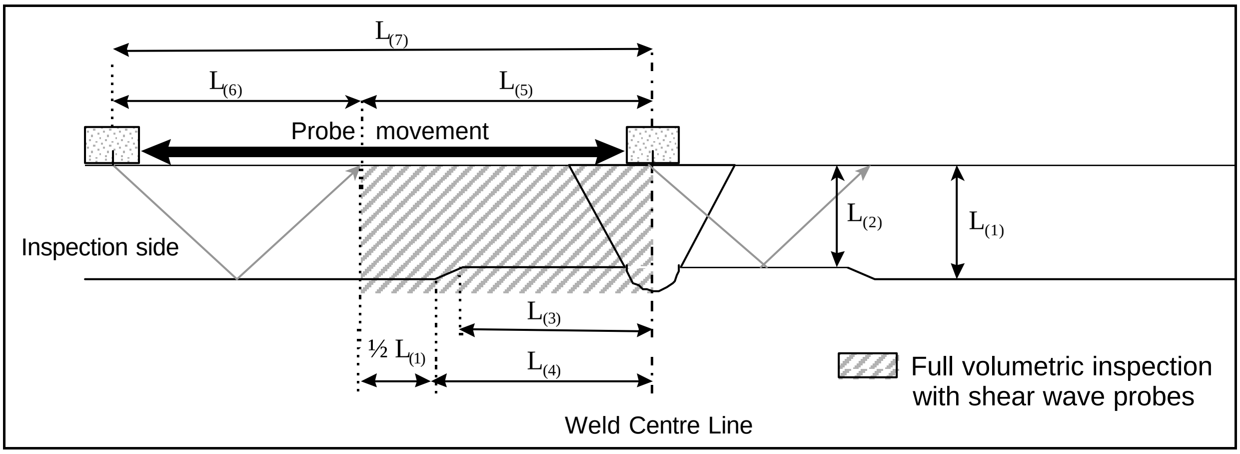
Figure 1: Scanning area and volume to be inspected from each side of the weld on all components with the 0° TRL probe (A). See measurements in the table bellow.



MEASUREMENTS FOR THE 0 DEGREE TRL PROBE

ENIQ Assembly	$L_{(1)}$ [mm]	$L_{(2)}$ [mm]	$L_{(3)}$ [mm]	$L_{(4)}$ [mm]	$L_{(5)}$ [mm]	$L_{(6)}$ [mm]	$L_{(7)}$ [mm]
1	26	26	10	10	-	-	23
2	26	26	10	10	-	-	23
3	19	19	10	10	-	-	20
4	26	24	79	86	-	-	99
5	16	16	10	10	-	-	19
6	30	27	85	96	-	-	111
7	30	27	90	96	-	-	111
8	18	18	10	110	-	-	19
9	26	26	10	10	-	-	23

Figure 2: Scanning area and volume to be inspected from each side of the weld on all components with the shear wave probes (B, C and D). See measurements in the following tables.



MEASUREMENTS FOR THE 45 DEGREE SHEAR WAVE PROBE

ENIQ Assembly	$L_{(1)}$ [mm]	$L_{(2)}$ [mm]	$L_{(3)}$ [mm]	$L_{(4)}$ [mm]	$L_{(5)}$ [mm]	$L_{(6)}$ [mm]	$L_{(7)}$ [mm]
1	26	26	10	10	23	52	75
2	26	26	10	10	23	52	75
3	19	19	10	10	20	38	58
4	26	24	79	86	99	52	151
5	16	16	10	10	19	31	50
6	30	27	85	96	111	58	169
7	30	27	90	96	111	60	171
8	18	18	10	110	19	36	55
9	26	26	10	10	23	50	73

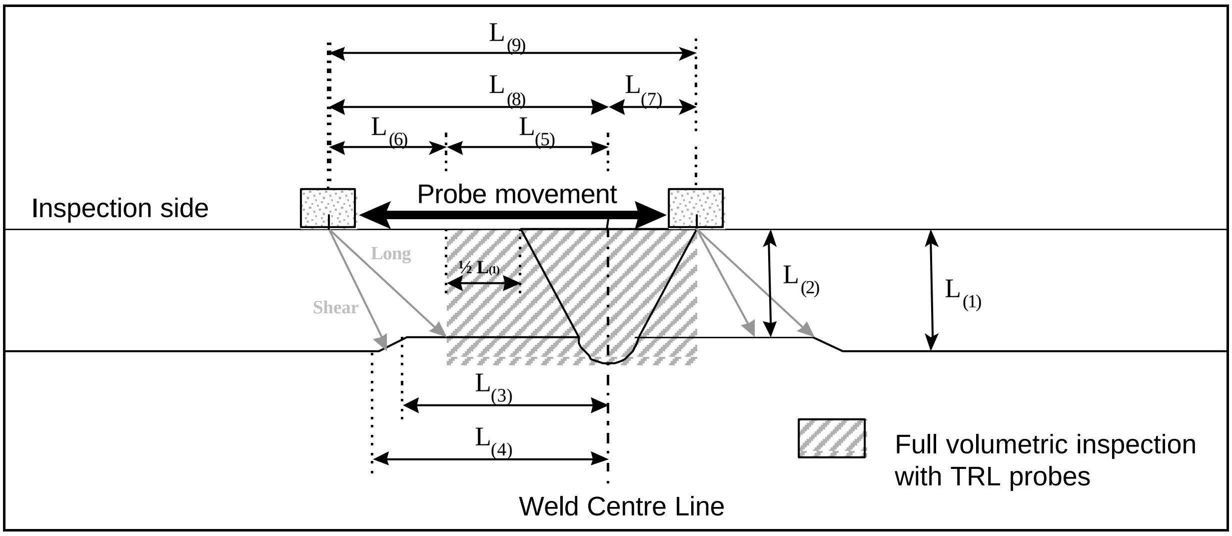
MEASUREMENTS FOR THE 60 DEGREE SHEAR WAVE PROBE

ENIQ Assembly	$L_{(1)}$ [mm]	$L_{(2)}$ [mm]	$L_{(3)}$ [mm]	$L_{(4)}$ [mm]	$L_{(5)}$ [mm]	$L_{(6)}$ [mm]	$L_{(7)}$ [mm]
1	26	26	10	10	23	90	113
2	26	26	10	10	23	90	113
3	19	19	10	10	20	66	86
4	26	24	79	86	99	90	189
5	16	16	10	10	19	55	74
6	30	27	85	96	111	104	215
7	30	27	90	96	111	104	215
8	18	18	10	110	19	62	81
9	26	26	10	10	23	90	113

MEASUREMENTS FOR THE 70 DEGREE SHEAR WAVE PROBE

ENIQ Assembly	$L_{(1)}$ [mm]	$L_{(2)}$ [mm]	$L_{(3)}$ [mm]	$L_{(4)}$ [mm]	$L_{(5)}$ [mm]	$L_{(6)}$ [mm]	$L_{(7)}$ [mm]
1	26	26	10	10	23	143	166
2	26	26	10	10	23	143	166
3	19	19	10	10	20	104	124
4	26	24	79	86	99	143	242
5	16	16	10	10	19	88	107
6	30	27	85	96	111	165	276
7	30	27	90	96	111	165	276
8	18	18	10	110	19	99	118
9	26	26	10	10	23	143	166

Figure 3: Scanning area and volume to be inspected from each side of the weld on all components with the TRL probes (E, F, G and H). See measurements in the following tables.



MEASUREMENTS FOR THE 45 DEGREE TRL PROBE

ENIQ No:	$L_{(1)}$ [mm]	$L_{(2)}$ [mm]	$L_{(3)}$ [mm]	$L_{(4)}$ [mm]	$L_{(5)}$ [mm]	$L_{(6)}$ [mm]	$L_{(7)}$ [mm]	$L_{(8)}$ [mm]	$L_{(9)}$ [mm]
1	26	26	10	10	26	26	13	52	65
2	26	26	10	10	26	26	13	52	65
3	19	19	10	10	19	19	10	38	48
4	26	24	79	86	26	26	13	52	65
5	16	16	10	10	16	16	8	32	40
6	30	27	85	96	30	30	15	60	75
7	30	27	90	96	30	30	15	60	75
8	18	18	10	110	18	18	9	36	45
9	26	26	10	10	26	26	13	52	65

MEASUREMENTS FOR THE 60 DEGREE TRL PROBE

ENIQ No:	$L_{(1)}$ [mm]	$L_{(2)}$ [mm]	$L_{(3)}$ [mm]	$L_{(4)}$ [mm]	$L_{(5)}$ [mm]	$L_{(6)}$ [mm]	$L_{(7)}$ [mm]	$L_{(8)}$ [mm]	$L_{(9)}$ [mm]
1	26	26	10	10	26	45	13	71	84
2	26	26	10	10	26	45	13	71	84
3	19	19	10	10	19	33	10	52	62
4	26	24	79	86	26	45	13	71	84
5	16	16	10	10	16	28	8	44	52
6	30	27	85	96	30	52	15	82	97
7	30	27	90	96	30	52	15	82	97
8	18	18	10	110	18	31	9	49	58
9	26	26	10	10	26	45	13	71	84

MEASUREMENTS FOR THE 70 DEGREE TRL PROBE

ENIQ No:	$L_{(1)}$ [mm]	$L_{(2)}$ [mm]	$L_{(3)}$ [mm]	$L_{(4)}$ [mm]	$L_{(5)}$ [mm]	$L_{(6)}$ [mm]	$L_{(7)}$ [mm]	$L_{(8)}$ [mm]	$L_{(9)}$ [mm]
1	26	26	10	10	26	71	13	97	110
2	26	26	10	10	26	71	13	97	110
3	19	19	10	10	19	52	10	71	81
4	26	24	79	86	26	71	13	97	110
5	16	16	10	10	16	44	8	60	68
6	30	27	85	96	30	82	15	112	127
7	30	27	90	96	30	82	15	112	127
8	18	18	10	110	18	49	9	67	76
9	26	26	10	10	26	71	13	97	110

APPENDIX C

List of essential parameters

Table 1: Essential parameters of the input group related to the component

Essential parameter	**Nr.**	**Additional evidence**	**Type of essential parameter**	**Range of variability/comments**
Geometry of component; double sided inspection	C1		Tolerance	Inspection from both sides
Surface roughness	C2		Tolerance	< 6.3 µm R_a
Weld crown configuration: - presence of macroscopic undulations - ground	C3	To be done: PTR/C3, RME/C3 and EDE/C3	Range	Less than 3 mm over a surface of 50 mm x 50 mm
Weld root configuration	C4	To be done: PTR/C4 and RME/C4	Range	– not ground: - length: 0- 30 mm - through-wall extent: 0-4 mm – profiles as given in Appendix 1
Wall thickness	C5	To be done: PTR/C5 and RME/C5	Range	13.5 - 30 mm
Pipe diameter	C6		Range	320 - 700 mm
Counterbore taper angle	C7	Available: EDE/C7	Range	< 30 degrees
Position of counterbore along pipe axis	C8	Available: Measurement of internal profile	Range	5 and 85 mm
Weld mismatch (bad adjustment or ovalisation)	C9		Tolerance	It is postulated that no weld mismatch is present for this case
Macrostructure base material	C10	- to be documented as far as possible - destructive examination a posteriori - to be done: PTR/C10	Range	Grain size and macrostructure to be determined a posteriori through DE
Macrostructure weld	C11	- to be documented as far as possible - destructive examination a posteriori - to be done: PTR/C11	Range	Grain size and macrostructure to be determined a posteriori through DE

Table 2: Essential parameters of the input group related to the defects

Essential parameter	**Nr.**	**Additional evidence**	**Type of parameter**	**Range of variability/comments**
Defect shape	D1	available: EDE/D1	Range	Smallest aspect ratio considered is 1 to 1 (postulated)
Defect size	D2		Range	- 3 mm - 100 % through-wall extent - qualification defect size is 50 % TWE (fixed by fracture mechanics and safety factor)
Defect position along through-wall extent of pipe and ligament	D3		Range	Fatigue defects starting from pre-existing manufacturing defects
Defect position with respect to weld centre line	D4	Available: EDE/D4	Range	- fatigue cracks: weld - IGSCC: HAZ and base material - limit case: partially HAZ and weld
Tilt angle	D5	- available: EDE/5.1 and EDE/5.2 - to be done: RME/D5	Range	< 30°
Skew angle	D6	- available: RME/D6 and EDE/D6 - to be done: RME/D6	Range	< 10°
Roughness/ branching	D7	To be done: EDE/D7, PTR/D7	Range	- determined by defect type - limit case of smooth planar defect is to be considered
Presence of compressive stresses	D8	Available: EDE/D8	Tolerance	Considered to be small in this component
Defect position in plan	D9		Tolerance	No obstructions limiting the circumferential scanning

Table 3: Procedure essential parameters

Essential parameter	Nr.	Characteristics	Type of essential parameter	Range/comments
General features	P1	- type of waves: shear and/or compression - twin or single crystal	Tolerance	– fixed in the inspection procedure – justify choice in the TJ
Dimensions probe	P2	For width larger than 15 mm will be profiled to 406 mm reference specimen	Tolerance	– fixed in the inspection procedure – justify choice in the TJ
Frequency	P3	Defined using reference specimens: – detection: - 2 MHz for twin crystal compression wave probes - 2MHz for shear wave probes – sizing: - TOFD: 5 MHz (base material) - LL: 3 MHz - pulse-echo: 2 MHz	Tolerance	– choice and range to be fixed in the inspection procedure and to be justified in the TJ – range: taken equal to tolerance of parameter T1 (± 10 % of the central frequency)
Beam angle	P4	▪ detection: 45º, 60º and 70º ▪ sizing: – TOFD: - T < 20 mm: 45º - T > 20 mm: 60º – LL: - Tr 47º, Re 31° - Tr 68º, Re 45º	Tolerance	– Choice and range to be fixed in the inspection procedure and to be justified in the TJ – range: taken equal to tolerance of parameter: T3: - shear wave probes: ± 2° - twin crystal probes (detection + LL): ± 3° - TOFD probes: ± 3°
Pulse length	P5	– pulse echo (detection and sizing) +LL: < 5 cycles – TOFD: < 200 ns	Tolerance	– choice and range to be fixed in the inspection procedure and to be justified in the TJ – range: see characteristics

Beam focal characteristics of twin crystal probes	P6	▪ focal depth: – detection: - 45°: 25-35 mm - 60°: 15-25 mm - 70°: 10-15 mm – LL: - 47º/31°: 25 -30 mm - 68º/45º: 10-15 mm	Tolerance	– choice and range to be fixed in the inspection procedure and to be justified in the TJ – range: taken equal to tolerance for parameter T5 - focal depth: ± 5 mm - focal spot: ± 3 mm
Sensitivity used for recording and reporting level and analysis	P7	Probe dependent: - recording level defined in table 3 of ENIQ.PILOT(96)5 - reporting level is 50 % of recording level - analysis (depth sizing) is done at noise level	Tolerance	– choice to be fixed in the inspection procedure and to be justified in the TJ – range: ± 3 dB (see Table 3 of ENIQ.PILOT(96)5), to be checked before the inspection of each weld
Scanning step	P8	smaller than 2 mm	Tolerance	– choice to be fixed in the inspection procedure and to be justified in the TJ – range: see characteristics
Scanning speed	P9	smaller than 50 mm/sec	Tolerance	– choice to be fixed in the inspection procedure and to be justified in the TJ – range: see characteristics
Personnel training, experience and qualification	P10	– certification along EN 473 – appropriate experience and training – pass with success qualification	Range	– justify choice in technical justification – performance to be verified during blind trials – range: not applicable
Sizing method	P11	– TOFD – LL-probes – pulse echo	Range	– to be specified fully in NDT procedure – justify choice in technical justification – performance to be verified during open trials

Table 4: Equipment essential parameters related to data acquisition hardware and software, probes and scanner (it is to be noted that all measurement methods specifications will no be made available in the framework of this pilot study)

Essential parameter	**Nr.**	**Type of essential parameter**	**Additional evidence/ measurement methods**	**Tolerance/comments**
Vertical linearity	E1	Tolerance	- available: EDE/E1.1 and EDE/E1.2 - MMS/E1-14	- fixed, should be better than 1% - calibration along TRC procedure: TI-11P-15 before each inspection
Horizontal linearity	E2	Tolerance	MMS/E1-14	- fixed, should be better than 1% - calibration along TRC procedure: TI-11P-15 before each inspection
Resolution of digitiser	E3	Tolerance	MMS/E1-14	Fixed at 8 bit
Sampling rate	E4	Tolerance	MMS/E1-14	Frequency dependent, fixed in the inspection procedure, see table 3 of ENIQ.PILOT (96)5
Averaging rate	E5	Tolerance	MMS/E1-14	Detection: rate fixed at 4 TOFD: rate fixed at 16
Points per A-scan sampling	E6	Tolerance	MMS/E1-14	Fixed, maximum number depends on sampling rate and gate length
Pulse amplitude of the emitter	E7	Tolerance	MMS/E1-14	Probe dependent, fixed in the inspection procedure, see table 3 of ENIQ.PILOT (96)5
Pulse width of the emitter	E8	Tolerance	MMS/E1-14	Probe dependent, fixed in the inspection procedure, see table 3 of ENIQ.PILOT (96)5
Pulse fall time	E9	Tolerance	MMS/E1-14	Fixed at 7 ns
Pulse rise time	E10	Tolerance	MMS/E1-14	Fixed at 15 ns
Band width of receiver	E11	Tolerance	MMS/E1-14	Fixed, 35 MHz

Available gain of receiver	E12	Tolerance	MMS/E1-14	0 – 92 dB
Band pass filter of receiver	E13	Tolerance	MMS/E1-14	Fixed in the inspection procedure, see table 3 of ENIQ.PILOT (96)5
Time base setting pulse echo probes	E14	Tolerance	MMS/E1-14	± 10 % of original value (to be checked before the inspection of each weld)
Time base setting TOFD probes	E15	Tolerance	MMS/E1-15	± 0.5 mm (to be checked before the inspection of each weld)
Sampling gate	E16	Tolerance		Probe dependent, defined in table 3 of ENIQ.PILOT(96)5
Cable length	L1	Tolerance		Fixed length
Cable impedance	L2	Tolerance	MMS/L2	± 5 Ohms
Probe frequency	T1	Tolerance (see P3)	MMS/T1	± 10 % of the central frequency
Probe index	T2	Tolerance	MMS/T2	± 2 mm
Probe shoe angle	T3	Tolerance	MMS/T3	*Detection:* - ± 2 degrees for shear wave probes - varies along depth for twin crystal probes; should be known within ± 3 degrees *TOFD:* tolerance of ± 3 °
Probe shoe squint angle	T4	Tolerance	MMS/T4	± 2°
Twin crystal probe focal characteristics	T5	Tolerance (see P6)	- to be done: EDE/T5 and PTR/T5 - MMS/T5	Focal depth: ± 5 mm Focal spot: ± 3 mm
Linearity of scanner	S1	Tolerance	MMS/S1	Calibration along TRC procedure TI-11P-30
Data display and analysis system	D1	Tolerance		Images to be looked at during analysis of the data to be fixed in inspection procedure: - recording of A-scans - possibility to construct B-,C- and D-scans - measurement possibilities on images - possibilities of selection of gates

Table 5: Parameters related to real in-service conditions (environmental factors)

Essential parameter	Characteristics	Essential in this case	Range of variability
Environmental factors	- time restrictions - restrictions due to radiation - - limited access	Yes	To be fixed in the input information

APPENDIX D

Calibration and verification of data sheet

GENRAL INFORMATION:

Project: ENIQ Pilot Study	**Place:** JRC, Petten (NL)
Procedure: ENIQ.PILOT(96)5	**Calibration file:**
Objects: Qualification assemblies	**Comment:**

EQUIPMENT:

UT Equipment: TOMOSCAN 12, Software 3.4 rev 16.	**Cable:** 50m RG58C/U + 1m RG174A/U (50 Ohms)
Emitter pulse amplitude:	**Emitter pulse width:**

PROBE:

Identification number:	**Type/ Angle (e.g. TRL 45°):**
Frequency [MHz]:	**Delay:**
Size of crystal:	**Wedge identification:**

Calibration Block:

Calibration Block:	**Reference reflector type (e.g. SDH):**
Examination side:	**Reference reflector size (e.g. ø 2 mm):**
Velocity [m/s]:	**Verification block:**

Calibration:

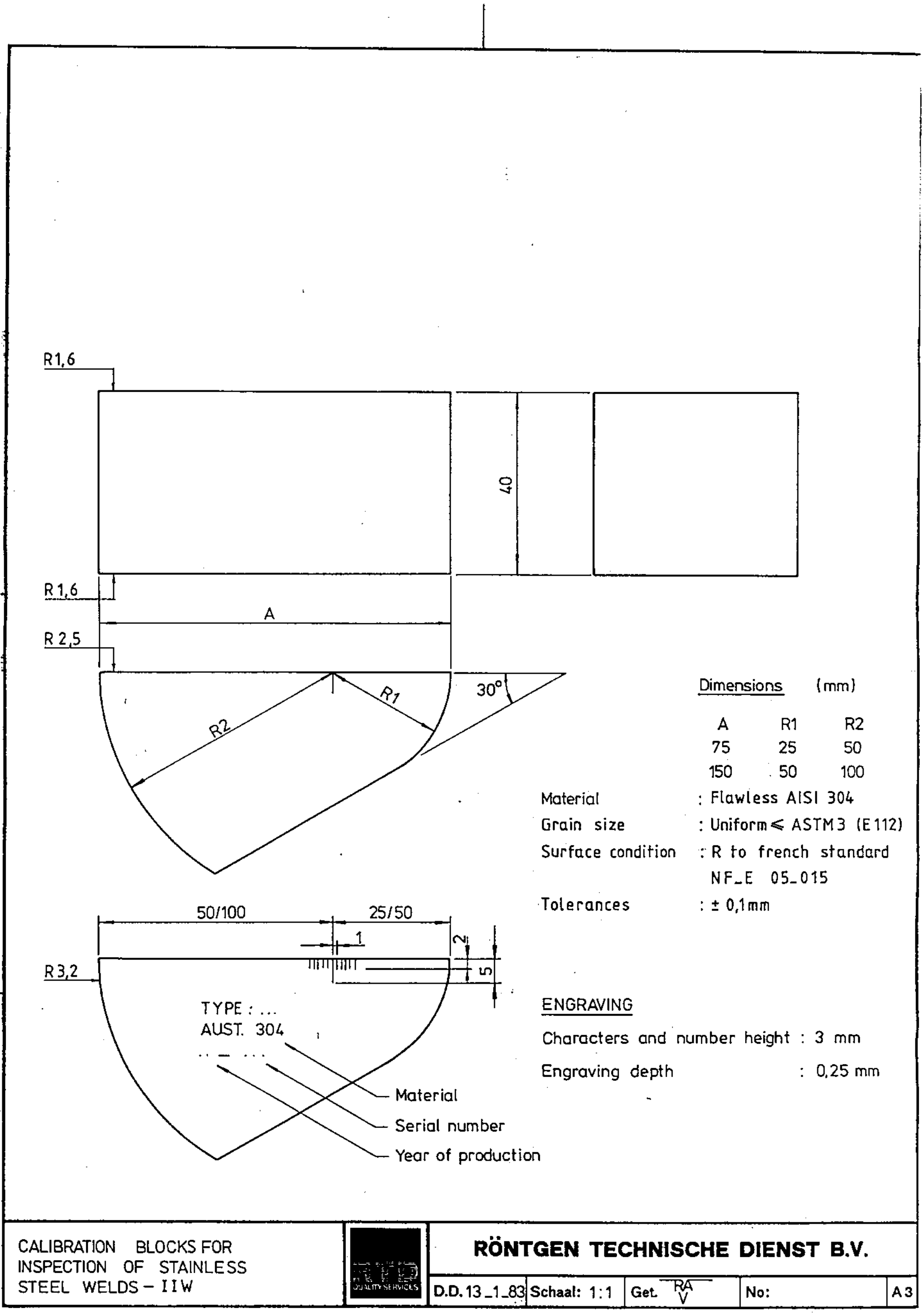
Reference reflector	Reflector depth[mm]	Meas. sound path [dB]	Gain [dB]	Date / Signature	Comments:

Verification:

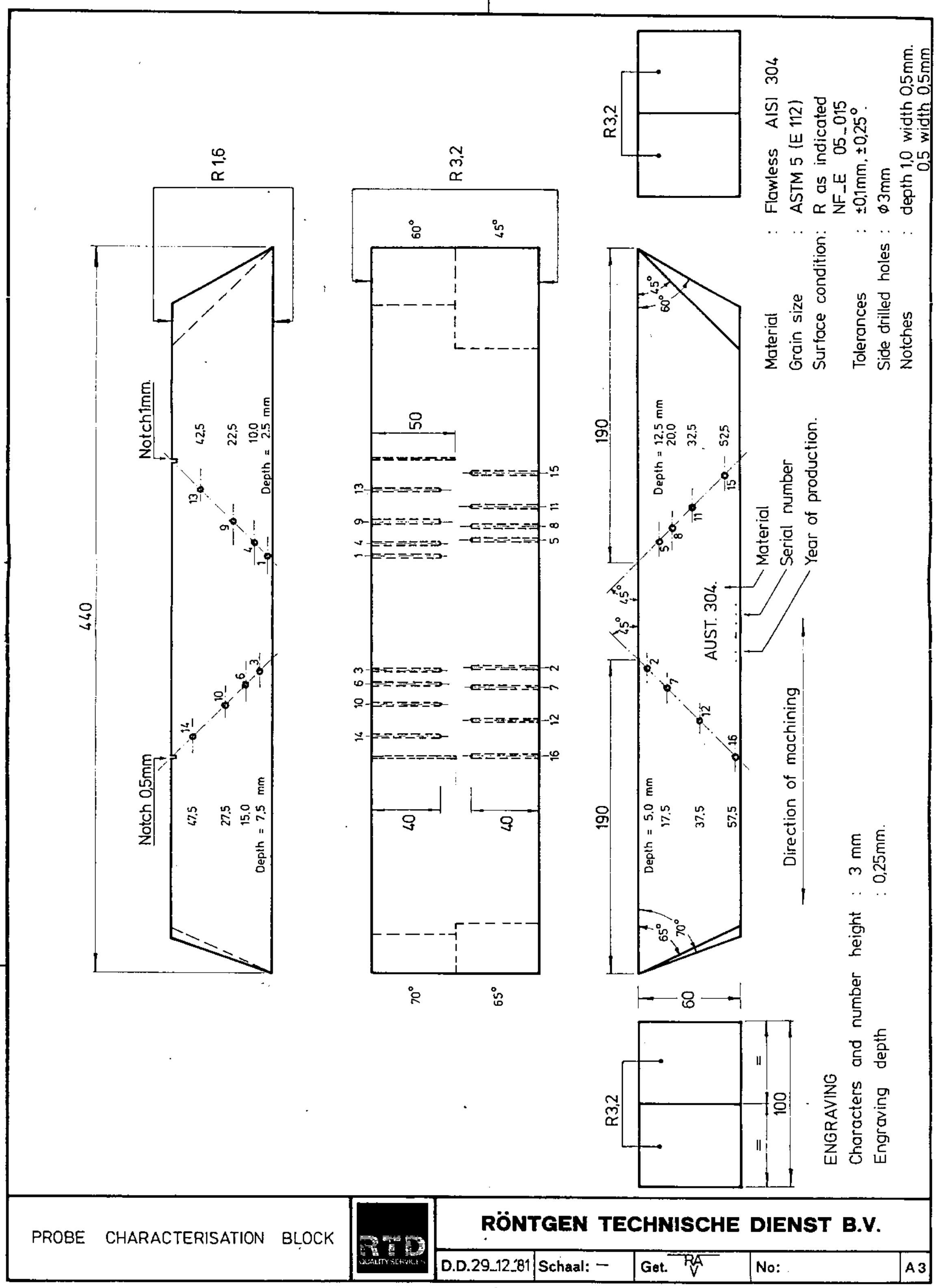
Verification Block	Verification reflector	Meas. sound path [dB]	Gain [dB]	Date / Signature	Correction:	Comments:

APPENDIX E

Drawings of austenitic calibration blocks


R1,6
40
R 1,6
A
R 2,5
30°
R1
R2
Dimensions (mm)
A R1 R2
75 25 50
150 50 100
Material : Flawless AISI 304
Grain size : Uniform ≤ ASTM 3 (E 112)
Surface condition : R to french standard NF_E 05_015
Tolerances : ± 0,1 mm
50/100
25/50
1
2
5
R 3,2
TYPE : ...
AUST. 304
.. — ...
Material
Serial number
Year of production
ENGRAVING
Characters and number height : 3 mm
Engraving depth : 0,25 mm
CALIBRATION BLOCKS FOR INSPECTION OF STAINLESS STEEL WELDS – IIW
RÖNTGEN TECHNISCHE DIENST B.V.
D.D. 13_1_83
Schaal: 1:1
Get. RA V
No:
A3

2 of 3


R 1,6
R 3,2
R3,2
Notch1mm.
Notch 0,5mm
440
190
190
50
40
40
60
100
Depth = 2,5 mm
10,0
22,5
42,5
Depth = 7,5 mm
15,0
27,5
47,5
Depth = 12,5 mm
20,0
32,5
52,5
Depth = 5,0 mm
17,5
37,5
57,5
AUST. 304.
Material
Serial number
Year of production.
Direction of machining
Material : Flawless AISI 304
Grain size : ASTM 5 (E 112)
Surface condition : R as indicated NF_E 05_015
Tolerances : ±0,1mm, ±0,25°.
Side drilled holes : ϕ3mm
Notches : depth 1,0 width 0,5mm. 0,5 width 0,5mm
ENGRAVING
Characters and number height : 3 mm
Engraving depth : 0,25mm.
PROBE CHARACTERISATION BLOCK
RÖNTGEN TECHNISCHE DIENST B.V.
D.D.29_12_'81
Schaal: —
Get.
No:
A 3

3 of 3

APPENDIX F

Full list of probes to be used

Identification in inspection procedure	Manufacturer	Type	Wave mode	Angle	Frequency [MHz]	Crystal Dimension [mm]	Probe Housing [mm]	Shoe shape
A	Krautkramer	DA 201	TRL	0º	5.0	ø 10	ø 25 mm	Flat
B	Krautkramer	W49-K2	Shear	49º	2.0	8 x 9	13.5 x 24 x 22	Flat
C	Krautkramer	MWB60-2	Shear	60º	2.0	8 x 9	13.5 x 24 x 22	Flat
D	Krautkramer	MWB60-2	Shear	70º	2.0	8 x 9	13.5 x 24 x 22	Flat
E	RTD	TRL45-FS25	TRL Focal depth = 18	45º (aust)	2.0	2(10 x 18)	30 x 30 x 30	Curved to OD 406 mm
F	RTD	TRL45-FS45	TRL Focal depth = 30	45º (aust)	2.0	2(10 x 18)	30 x 30 x 30	Curved to OD 406 mm
G	RTD	TRL60-FS40	TRL Focal depth = 20	60º (aust)	2.0	2(10 x 18)	30 x 30 x 30	Curved to OD 406 mm
H	RTD	TRL70-FS35	TRL Focal depth = 12	70º (aust)	2.0	2(10 x 18)	30 x 30 x 30	Curved to OD 406 mm
2 x I	Panametrics	V.535	Longitudinal (TOFD)	0º	5.0	ø 6.25 (ø 0.25”)	Shoes: 16 x 30 x 15	Wedges curved to OD 406 mm
J	Amdata	1T65	Long-Long Tr 47º/ Re 31º	40-50º (effective angle)	3.0	2(10 x 10)	45 x 19 x 28	Flat
K	Amdata	1T75	Long-long Tr 68º/ Re 45º	50-60º (effective angle)	3.0	2(10 x 10)	45 x 19 x 28	Flat

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ABSTRACT

One of the major achievements of the European Network for Inspection Qualification (ENIQ), composed of European nuclear plant operators, service vendors, qualification bodies and manufacturers, was the approval of the European methodology for qualification of non-destructive tests.
The first issue of this document was published in March 1995 and the second issue was published in February 1997. The ENIQ European methodology document describes inspection qualification as the sum of the following items: practical assessment (blind or non-blind) – conducted on simplified or representative test pieces resembling the component to be inspected and technical justification, which involves assembling all evidence on the effectiveness of the test, including previous experience of its application – experimental studies, mathematical modelling, physical reasoning (qualitative assessment) and so on.
In the European methodology, only general principles are provided on how to do inspection qualification. It does not contain detailed guidelines of how to do inspection qualification for a specific component. That is why, within the framework of ENIQ, it was decided to conduct a pilot study in order to explore ways of how to apply the European methodology allowing at the same time to test its feasibility for implementation.
This report contains the inspection procedure, which was used during the practical trials and the ISI simulation of the first ENIQ Pilot Study on wrought stainless steel.