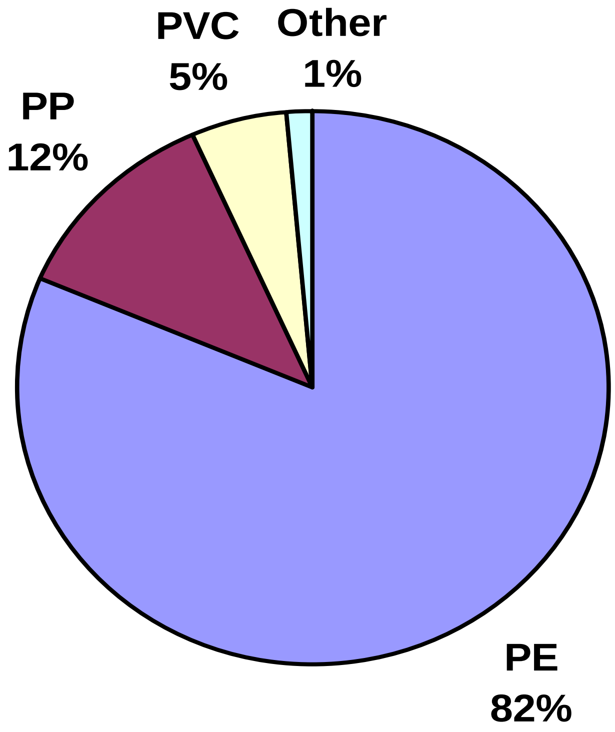


Figure 1 Pipe materials of interest to the plastics pipes industry.

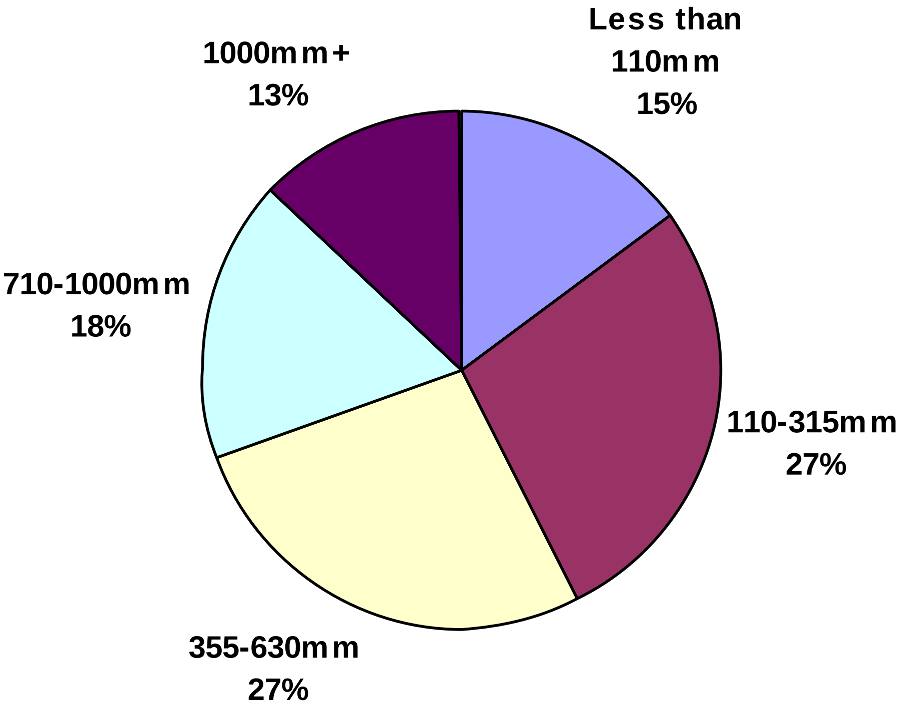


Figure 2 Pipe sizes of interest to the plastics pipes industry.

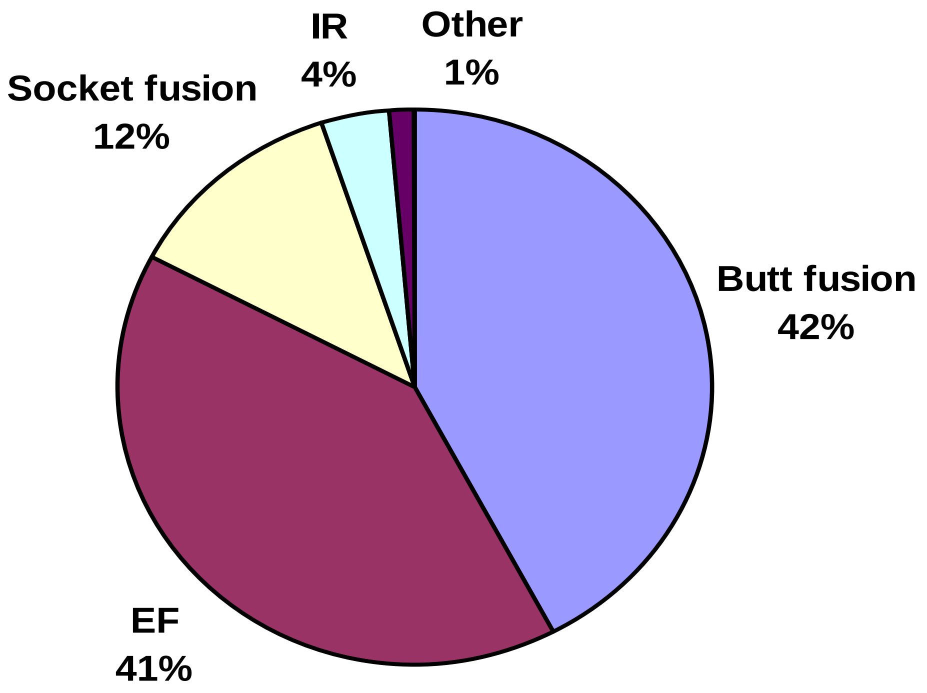


Figure 3 Welding processes of interest to the plastics pipes industry.

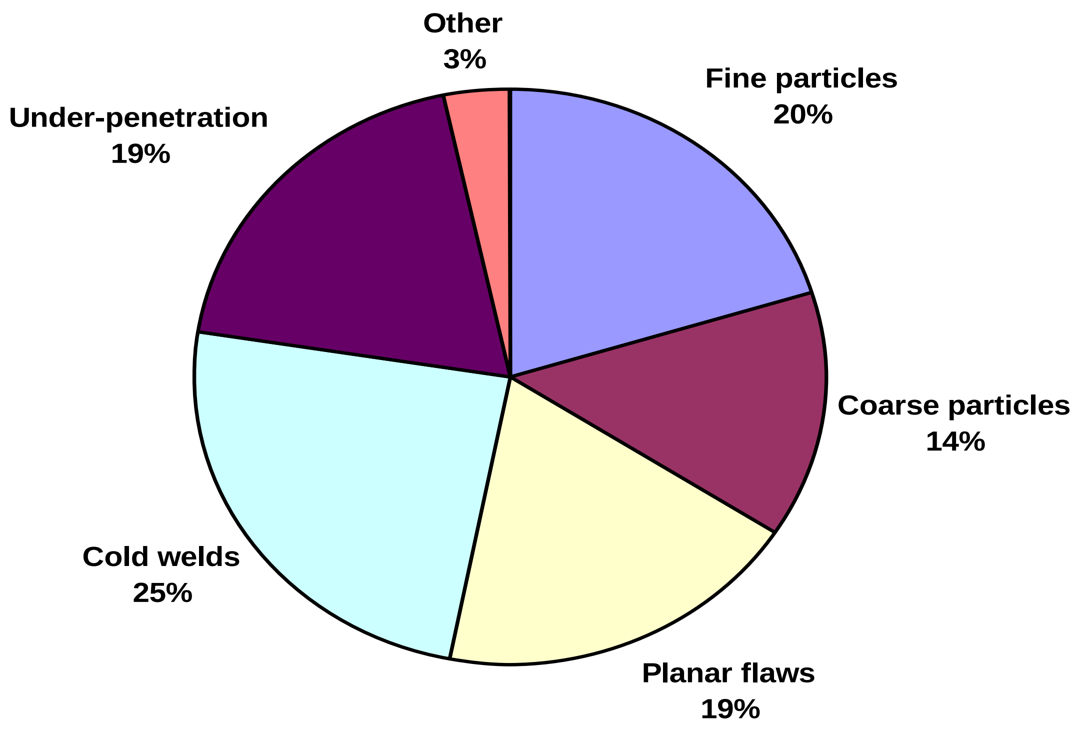


Figure 4 Types of flaw of interest to the plastics pipes industry.

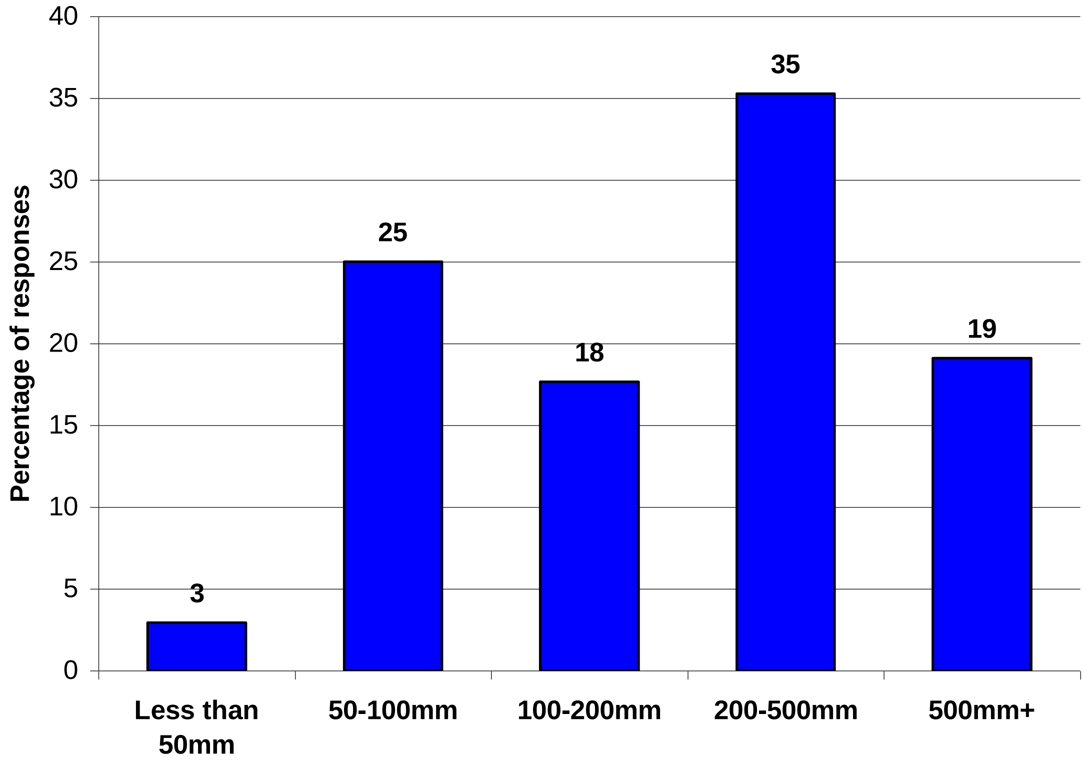


Figure 5 Minimum working distance around the pipe joint according to the plastics pipes industry.

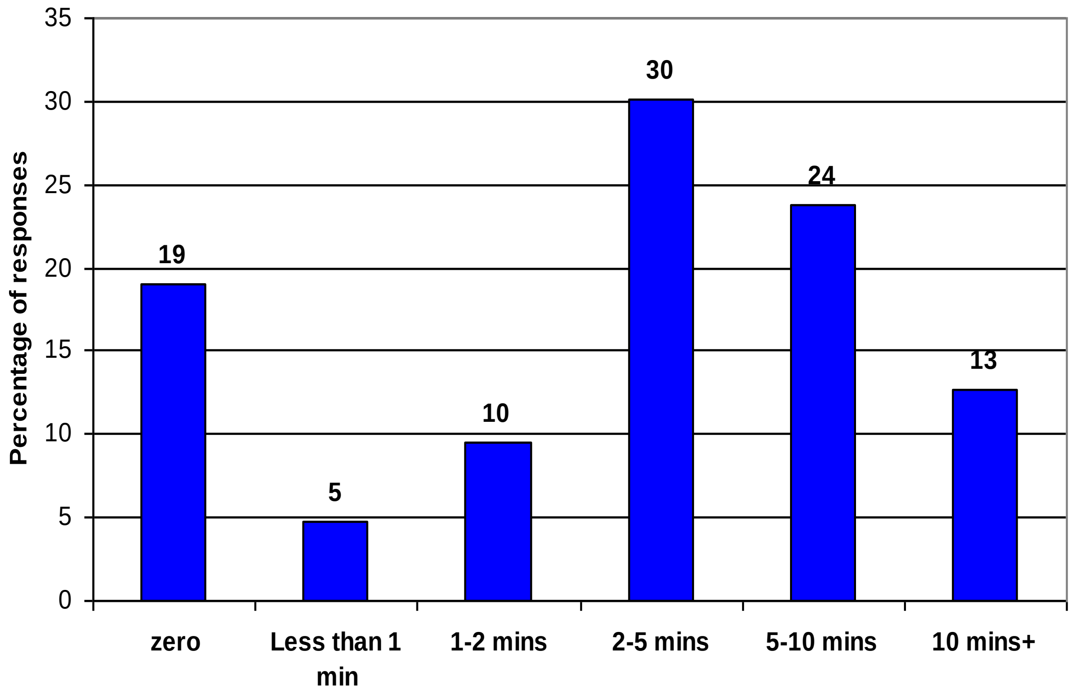


Figure 6 Maximum time after welding cycle for inspection according to the plastics pipes industry.

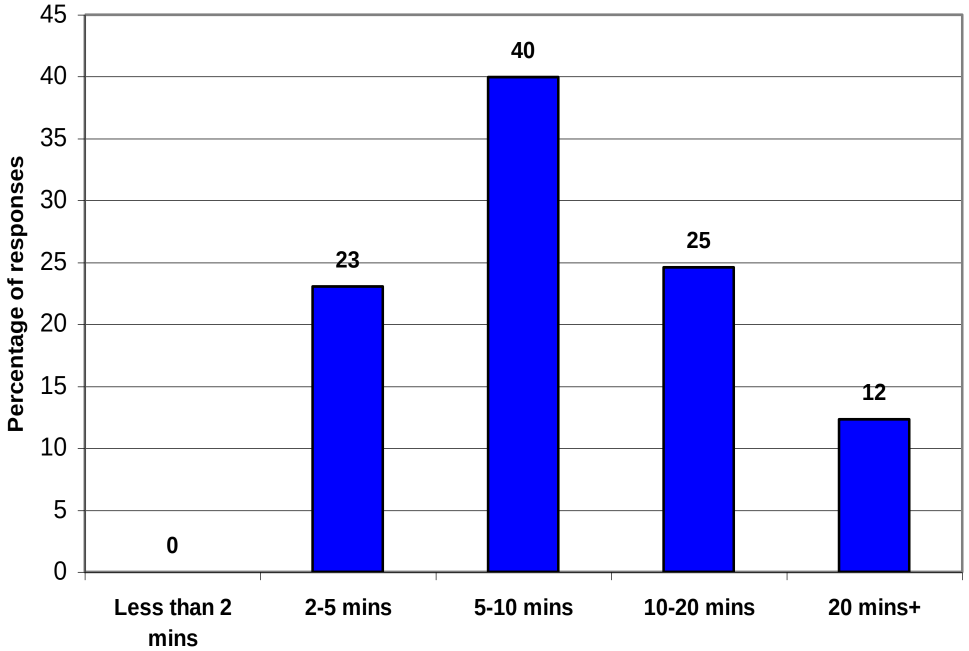


Figure 7 Maximum time for retrospective inspection according to the plastics pipes industry.

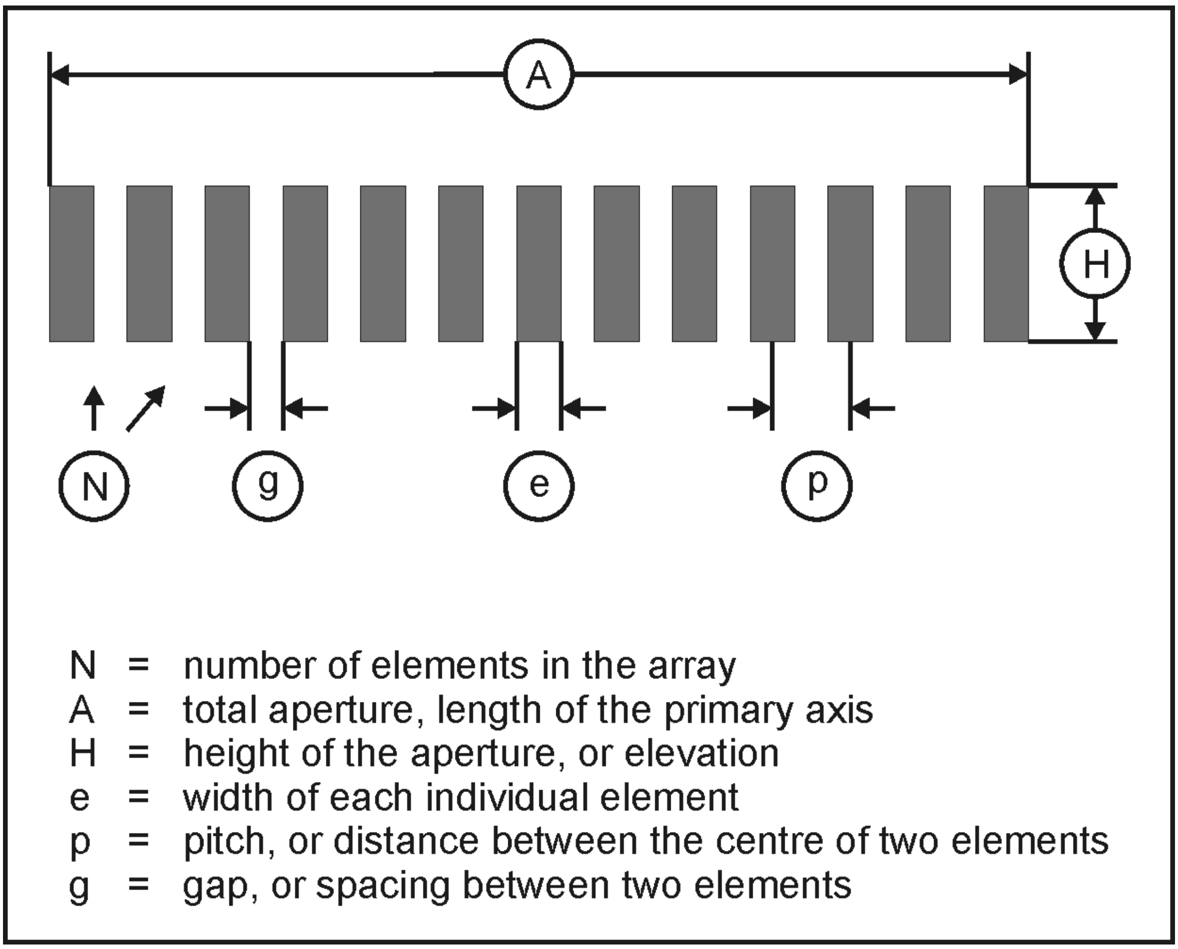


Figure 8 The dimensional parameters of a linear phased array.

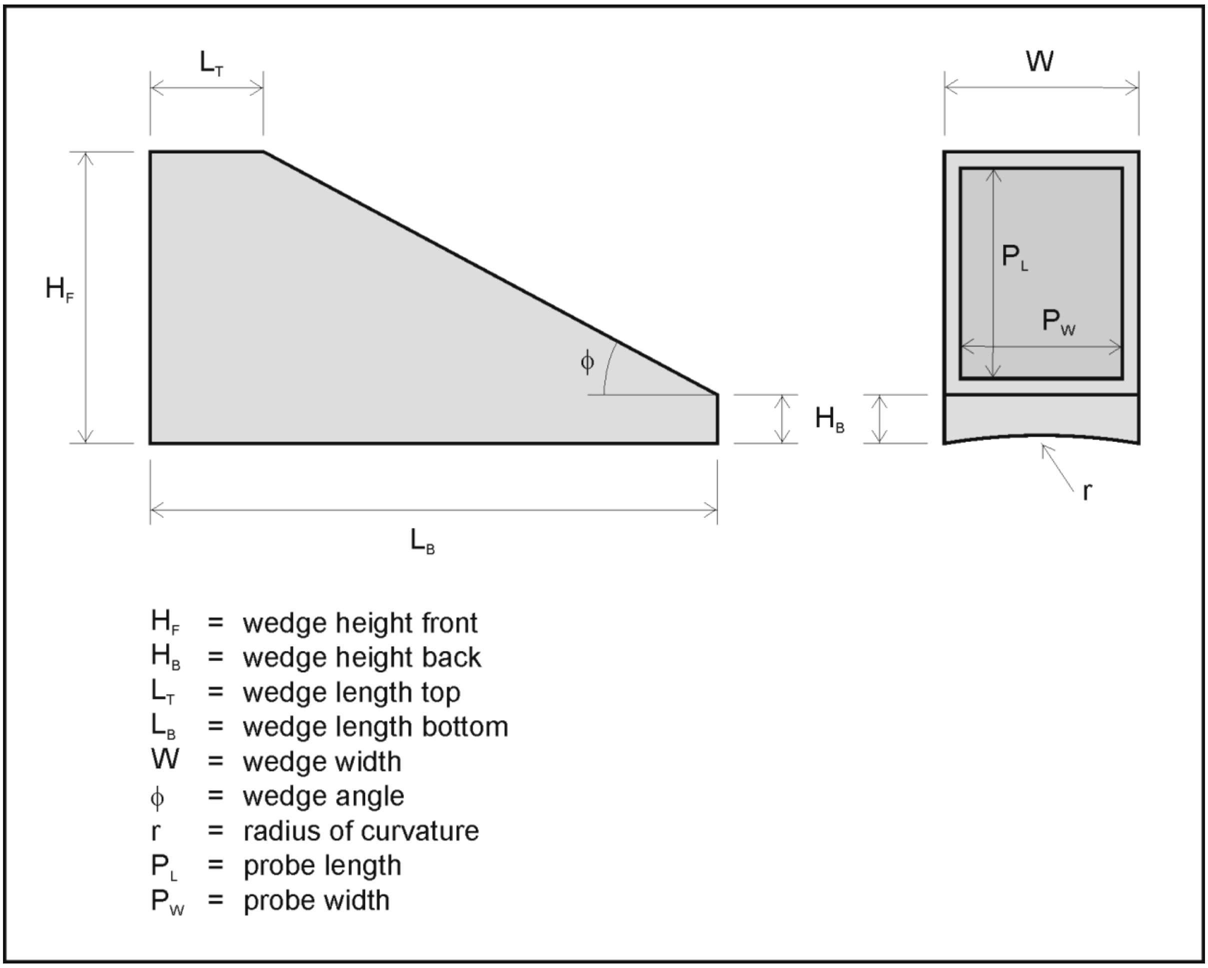


Figure 9 Schematic of a wedge for the inspection of butt fusion joints, showing the dimension parameters.

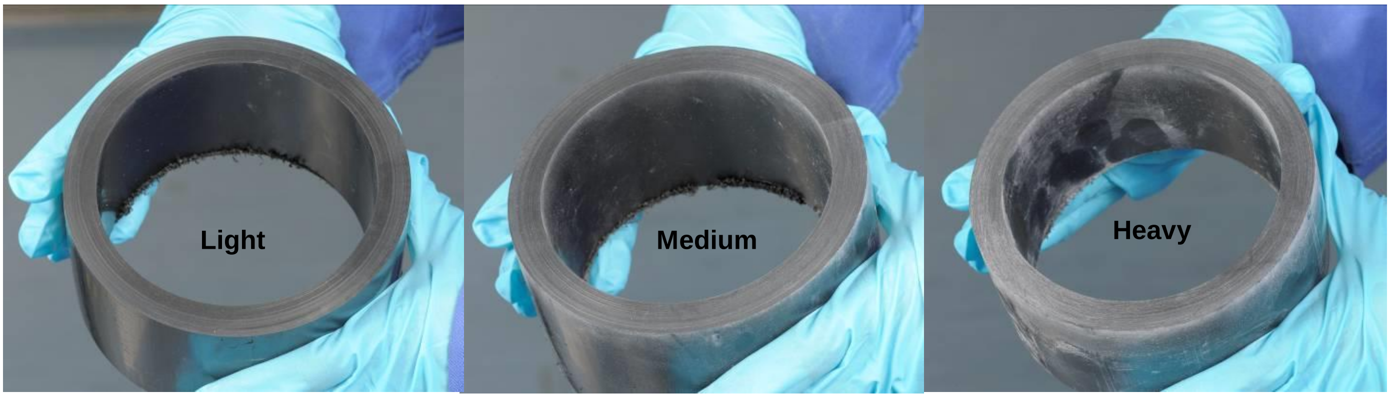


Figure 10 Standard talc-contaminated pipe samples for butt fusion welding.

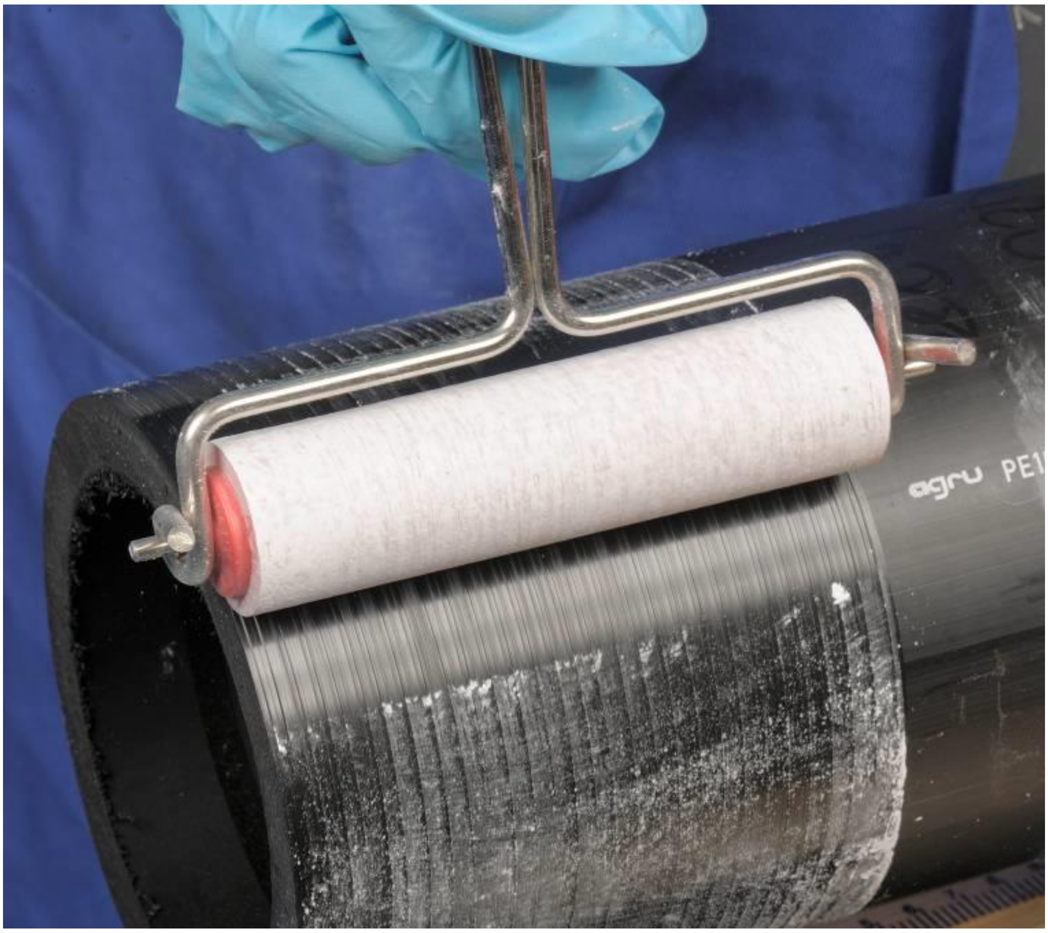


Figure 11 Application of talc on to the pipe surface for EF welding.

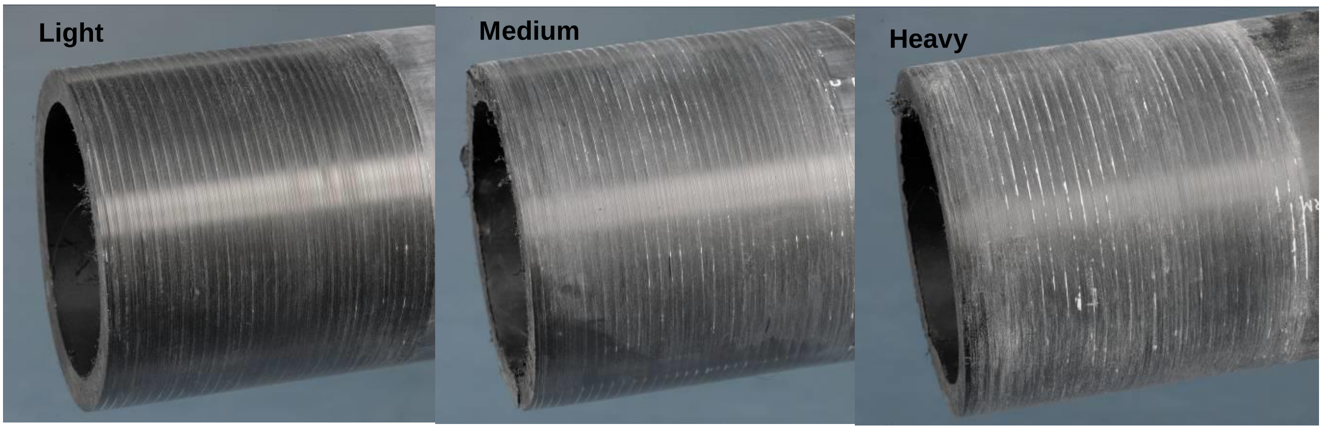


Figure 12 Standard talc-contaminated pipe samples for EF welding.

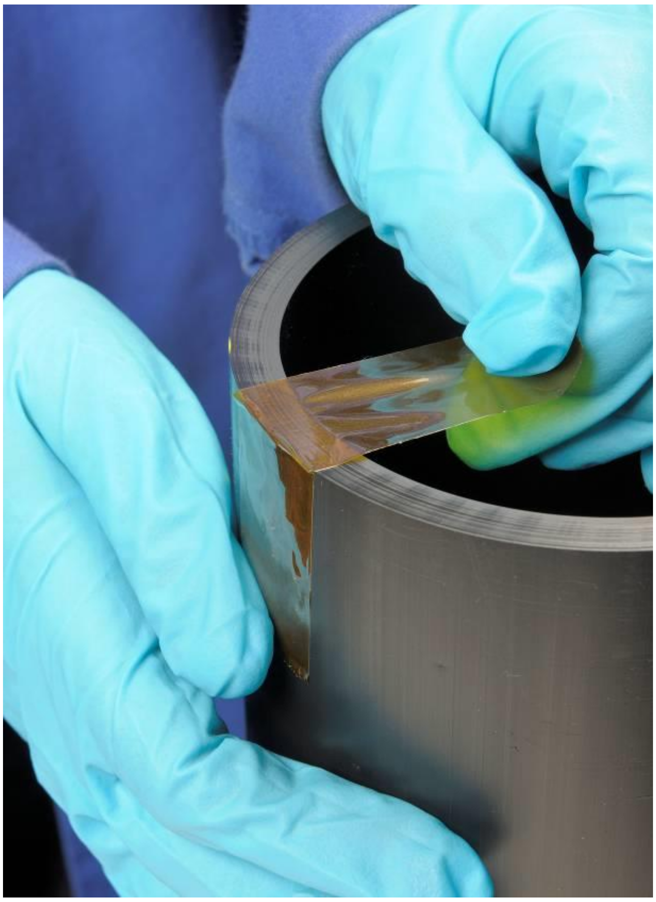


Figure 13 Application of polyimide tape to the trimmed end of a PE pipe.

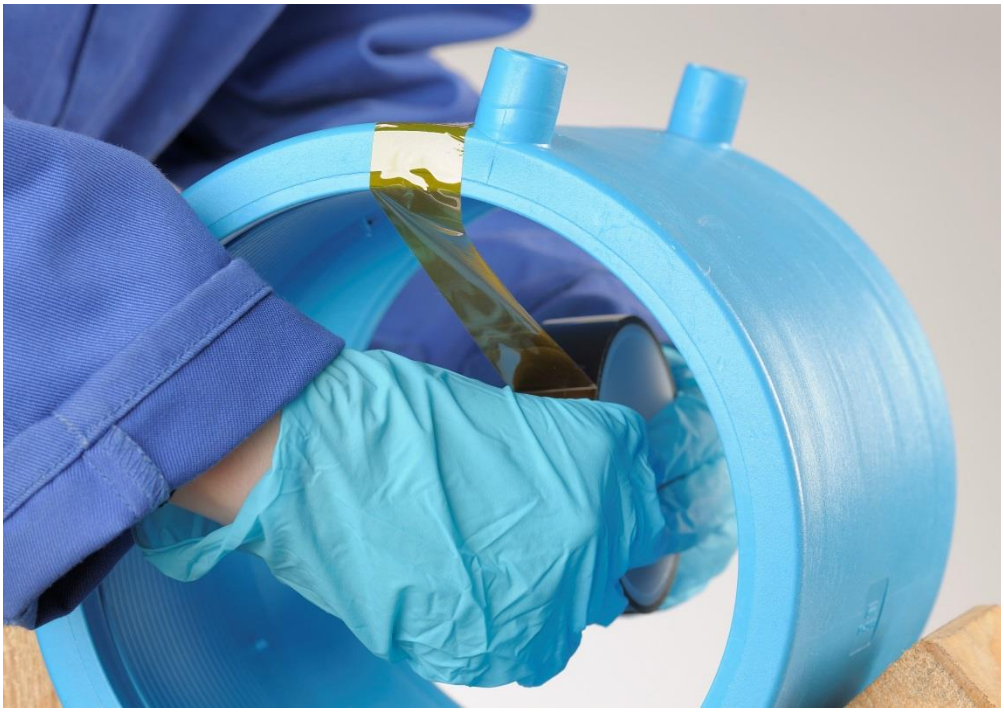


Figure 14 Application of polyimide tape to an EF coupler.

Figure 15 Applying sand contamination to the pipe end using a fluidised bed.

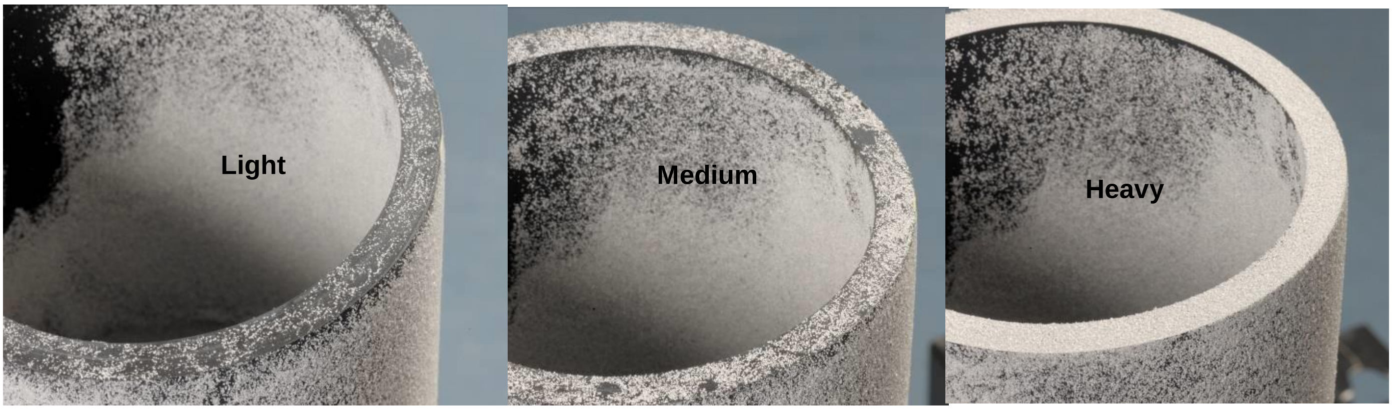


Figure 16 Standard sand-contaminated pipe samples for butt fusion welding.

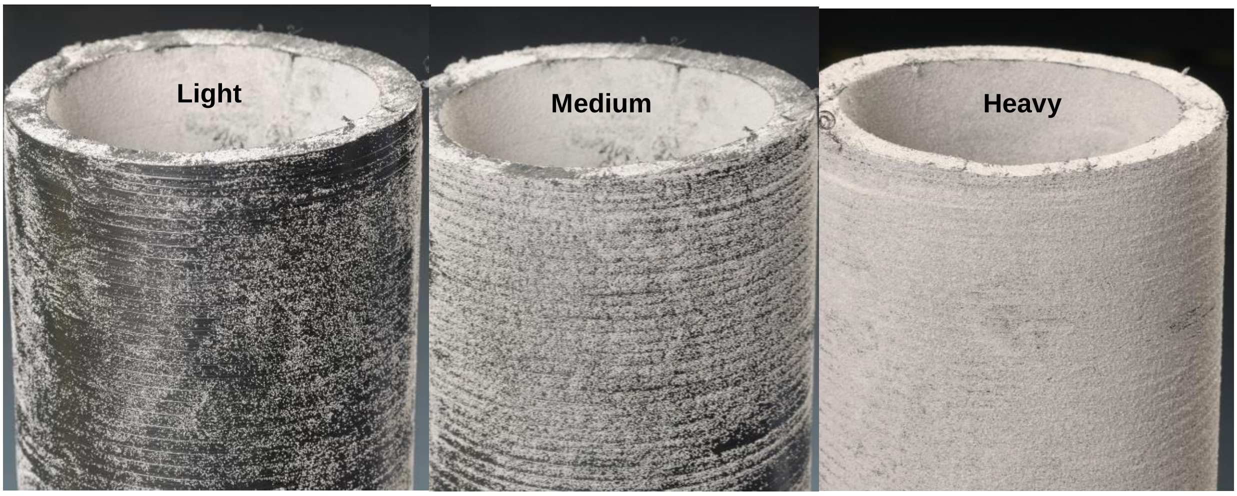


Figure 17 Standard sand-contaminated pipe samples for EF welding.

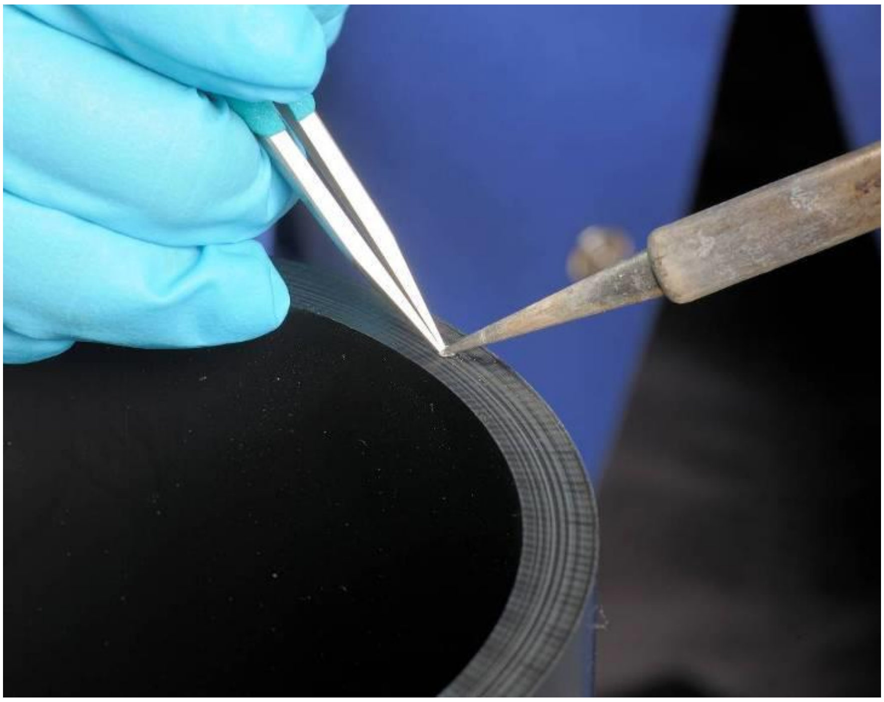


Figure 18 Heat staking aluminium disc to the trimmed end of a pipe for butt fusion welding.

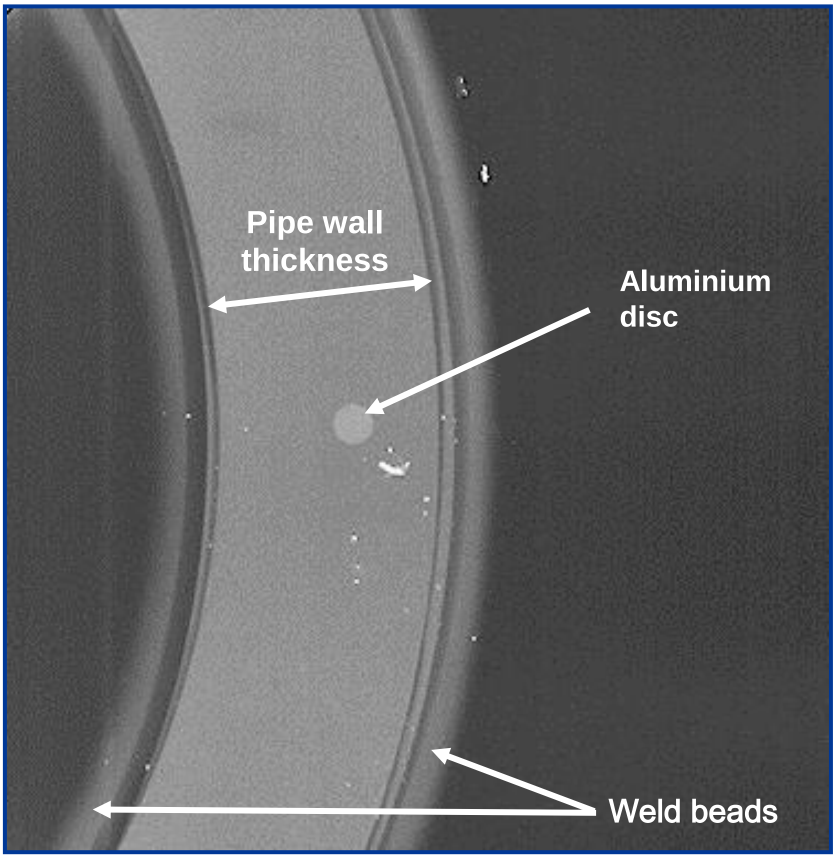


Figure 19 X-ray radiograph of butt fusion weld containing an aluminium disc.

Figure 20 Heat staking aluminium disc to the scraped surface of a pipe for EF welding.

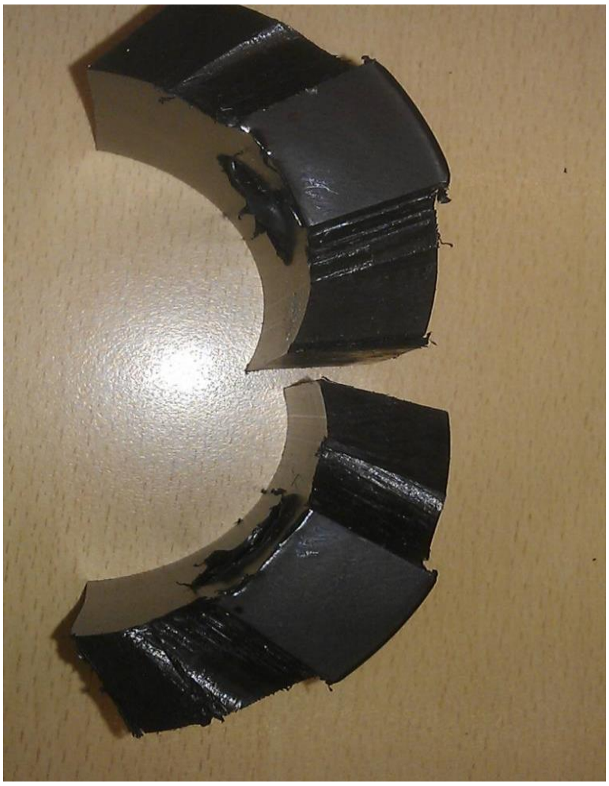


Figure 21 Brittle failure in a tensile test specimen due to a cold weld in a butt fusion joint.

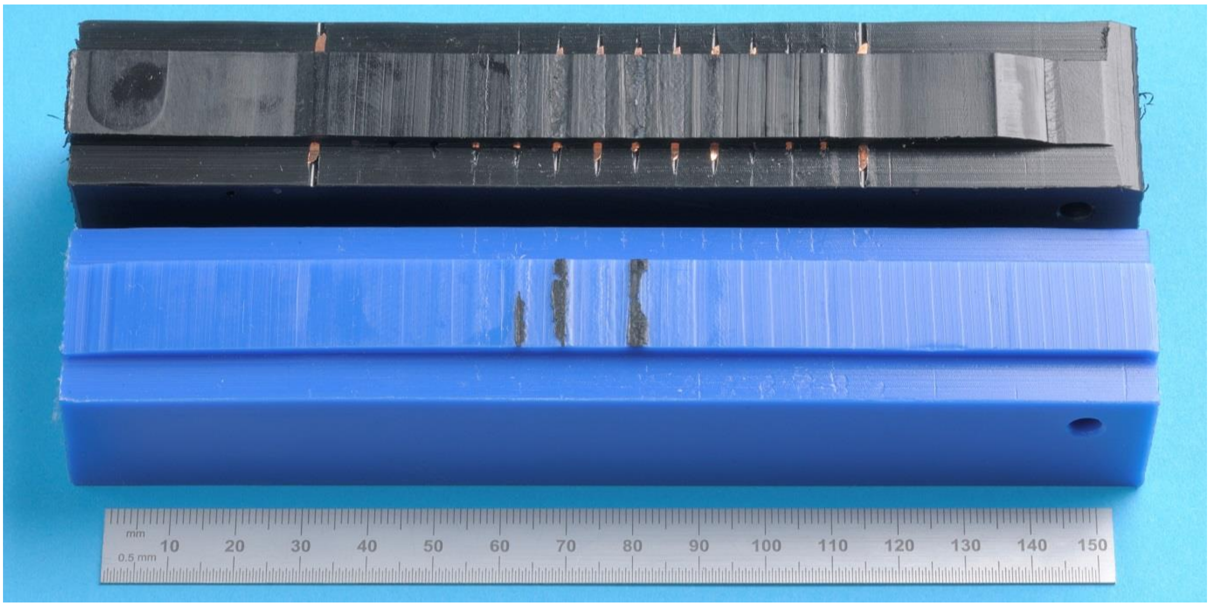


Figure 22 Brittle failure in a peel decohesion test specimen due to a cold weld in an EF joint.

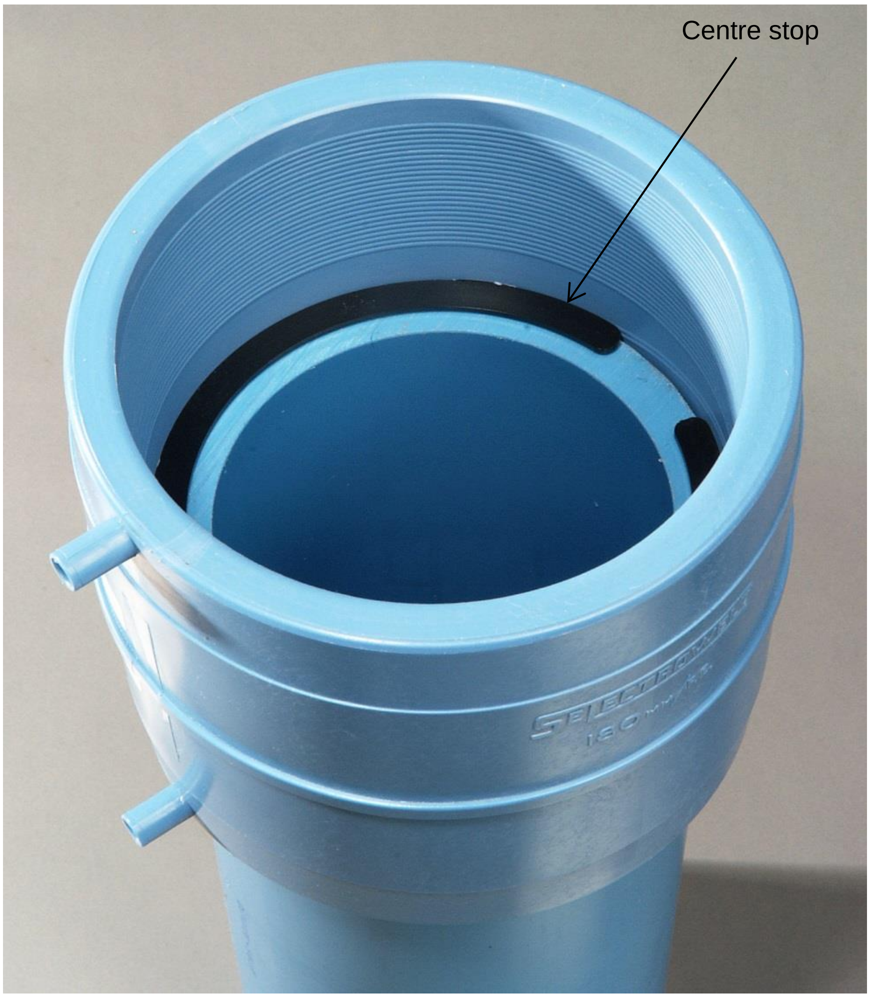


Figure 23 EF coupler showing the centre stop.

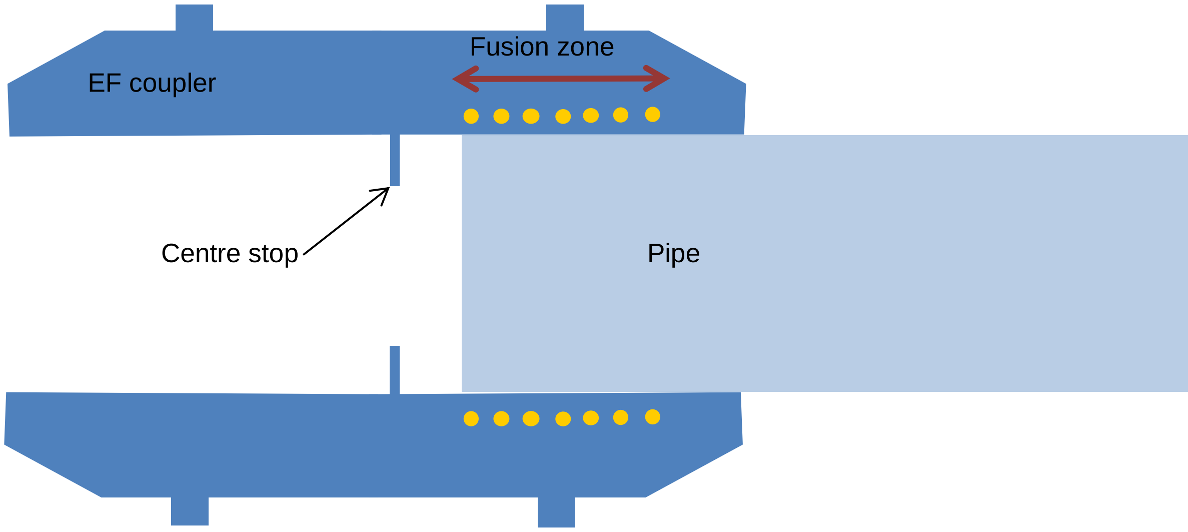


Figure 24 Pipe under-penetration Level A.

Figure 25 180mm and 225mm electrofusion joints made in the project.

Table 1 Welds made in the project

Pipe size / material	Flaw type	No. of welds	
		Butt fusion	Electrofusion
180mm SDR17 PE80	None	4	1
	Light talc	3	1
	Medium talc	3	1
	Heavy talc	3	1
	Light sand	3	1
	Medium sand	3	1
	Heavy sand	3	1
	Cold weld	3	5
	Aluminium discs	0	8
	Pipe under-penetration A	-	6
	Pipe under-penetration B	-	5
	Pipe under-penetration C	-	5
225mm SDR11 PE100	None	1	1
	Light talc	1	1
	Medium talc	1	1
	Heavy talc	1	1
	Light sand	1	1
	Medium sand	1	1
	Heavy sand	1	1
	Cold weld	1	5
	Aluminium discs	1	8
	Pipe under-penetration A	-	5
	Pipe under-penetration B	-	5
	Pipe under-penetration C	-	5
355mm SDR11 PE80	None	2	1
	Light talc	1	-
	Medium talc	1	-
	Heavy talc	1	-
	Cold weld	1	1
	Aluminium discs	1	4
	Pipe under-penetration A	-	1
	Pipe under-penetration B	-	1
	Pipe under-penetration C	-	1
450mm SDR17 PE100	None	1	1
	Light talc	1	0
	Medium talc	1	0
	Heavy talc	1	0
	Cold weld	0	1
	Aluminium discs	1	6
	Pipe under-penetration A	-	1
	Pipe under-penetration B	-	1
	Pipe under-penetration C	-	1
710mm SDR17 PE100	None	2	1
	Light talc	1	0
	Medium talc	1	0
	Heavy talc	1	0
	Cold weld	0	1
	Aluminium discs	1	0
	Pipe under-penetration A	-	1
	Pipe under-penetration B	-	1

Figure 26 450mm electrofusion joints made in the project.

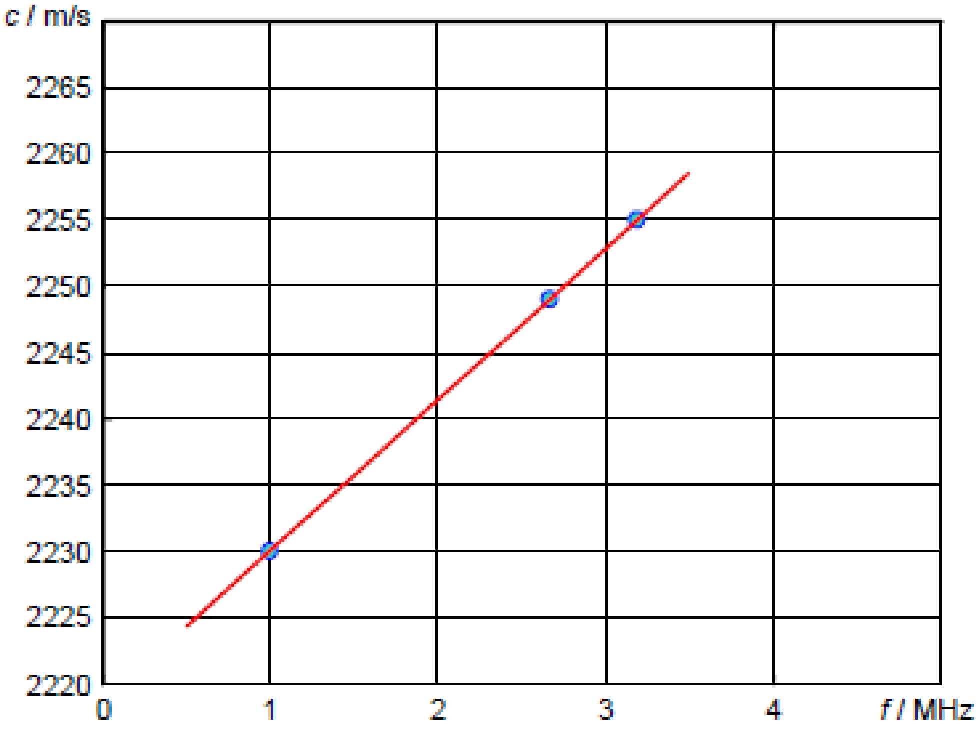


Figure 27 Ultrasonic longitudinal wave velocity dependency of frequency in PE80.

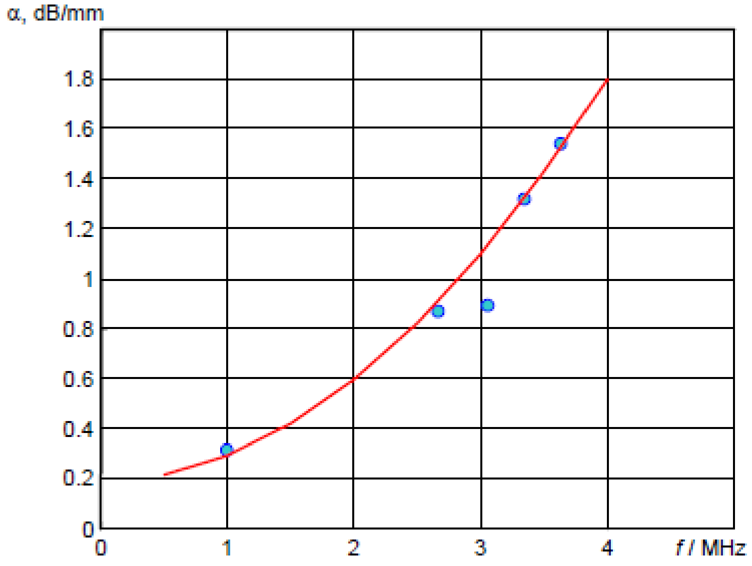


Figure 28 The ultrasonic longitudinal wave attenuation per propagation distance dependency of frequency in PE80.

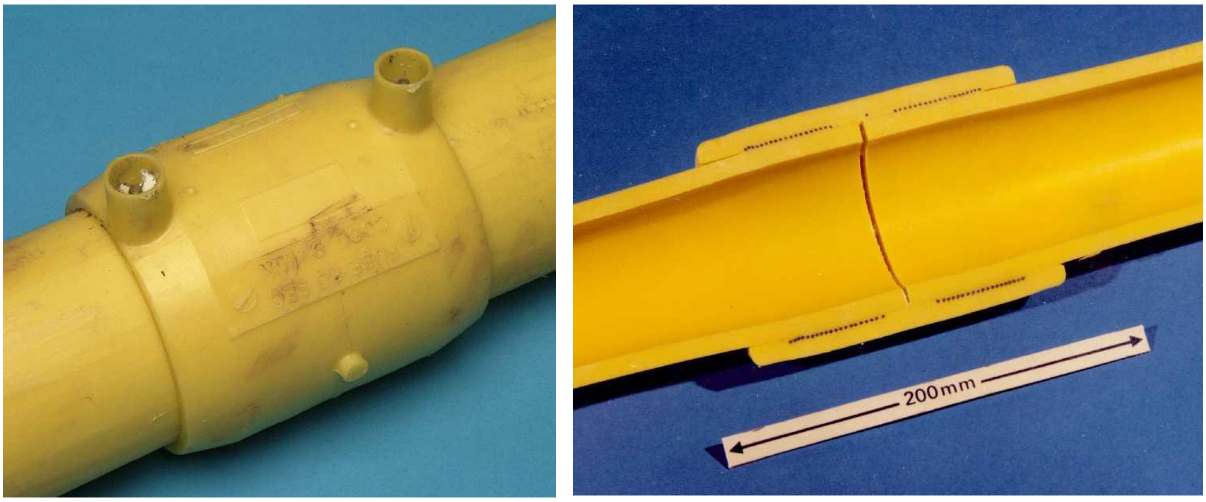


Figure 29 Photographs of an electrofusion joint: a) external; b) cross-section through the joint.

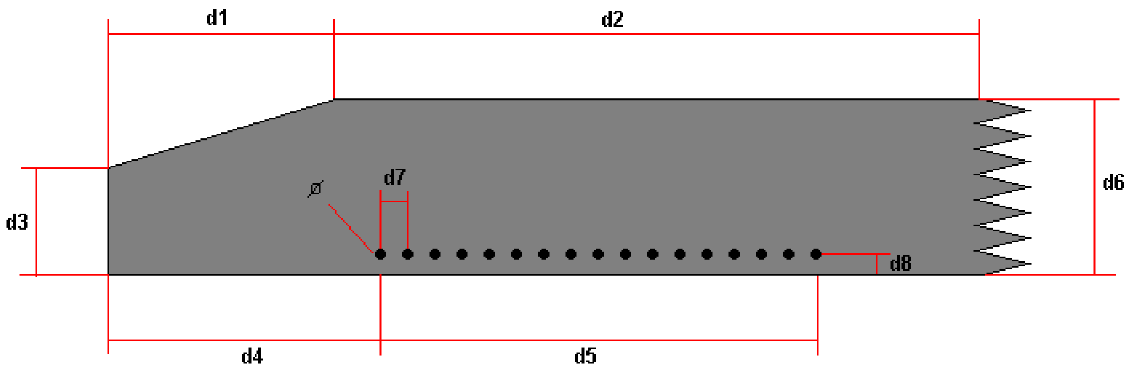


Figure 30 Key dimensional parameters for an electrofusion fitting.

Figure 31 Butt fusion welding of PE pipes.

Figure 32 Butt fusion weld beads.

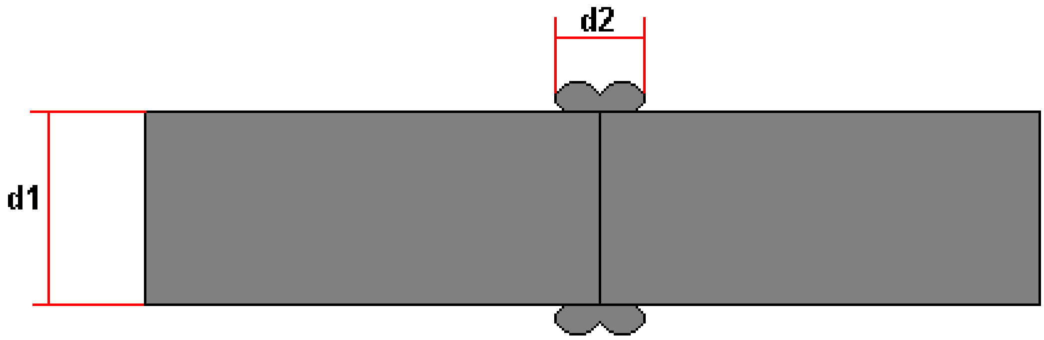


Figure 33 Key dimensional parameters for a butt fusion joint.

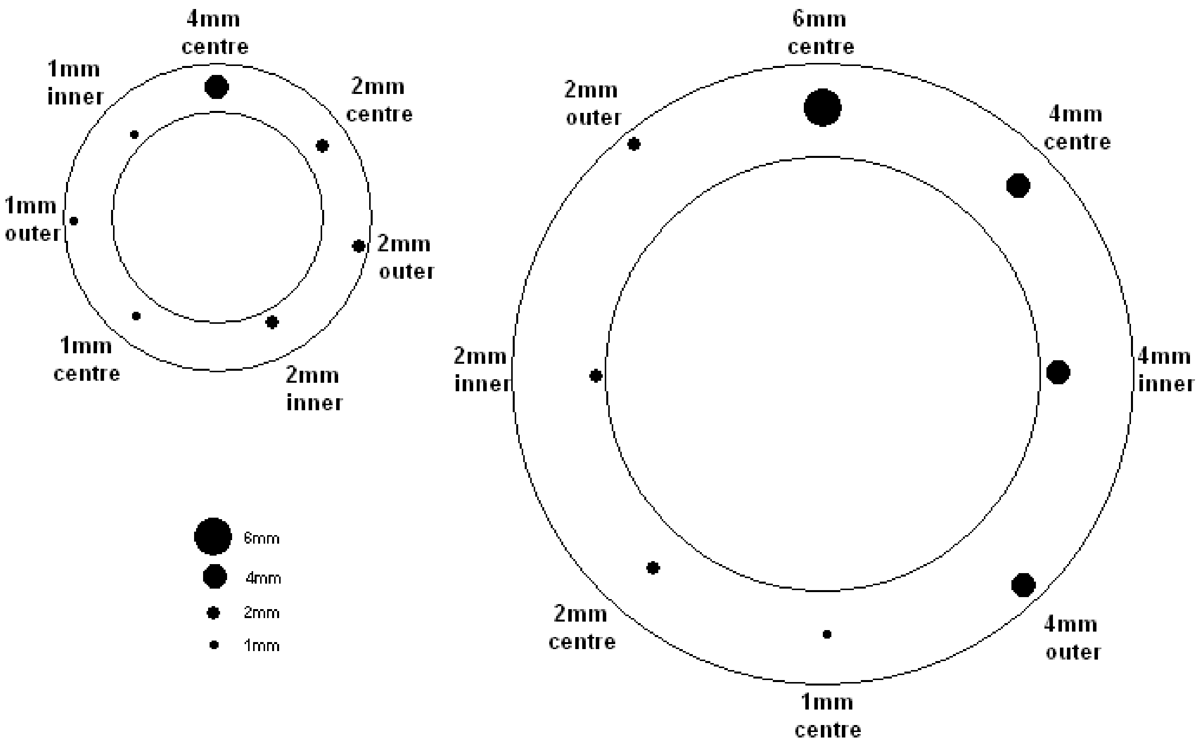


Figure 34 Examples of FBHs in 100mm diameter (left) and 200mm (right) diameter PE pipes.

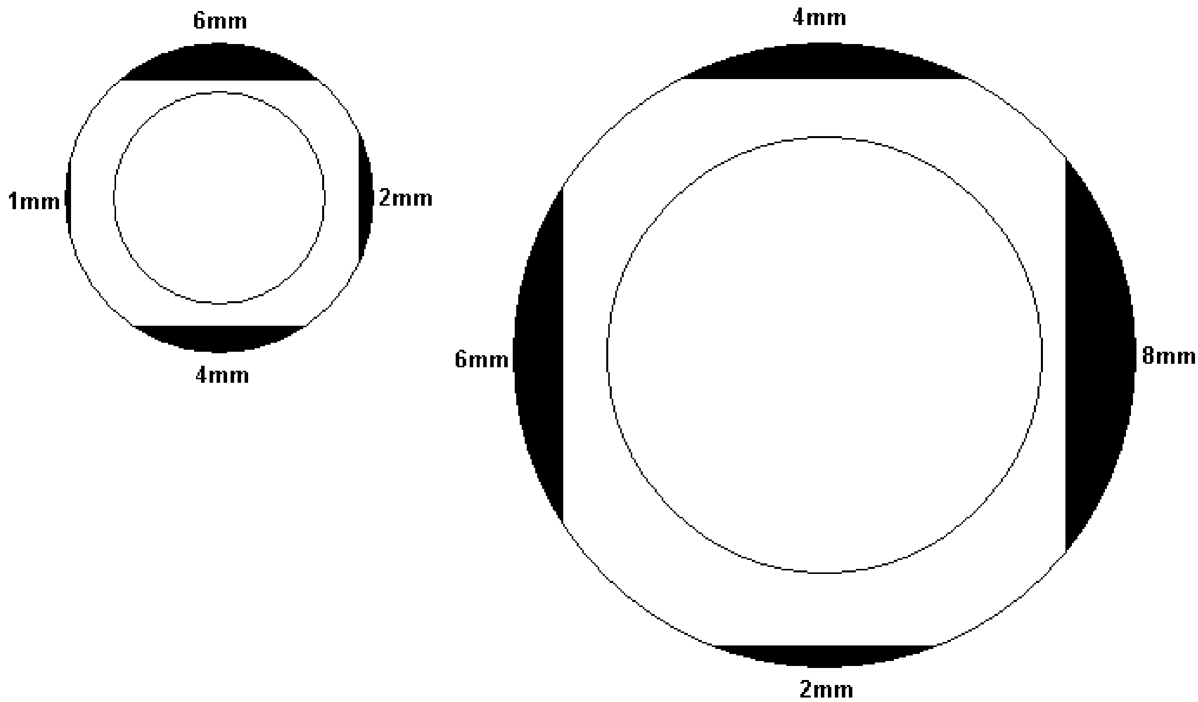


Figure 35 Examples of slots in 100mm diameter (left) and 200mm diameter (right) pipes.

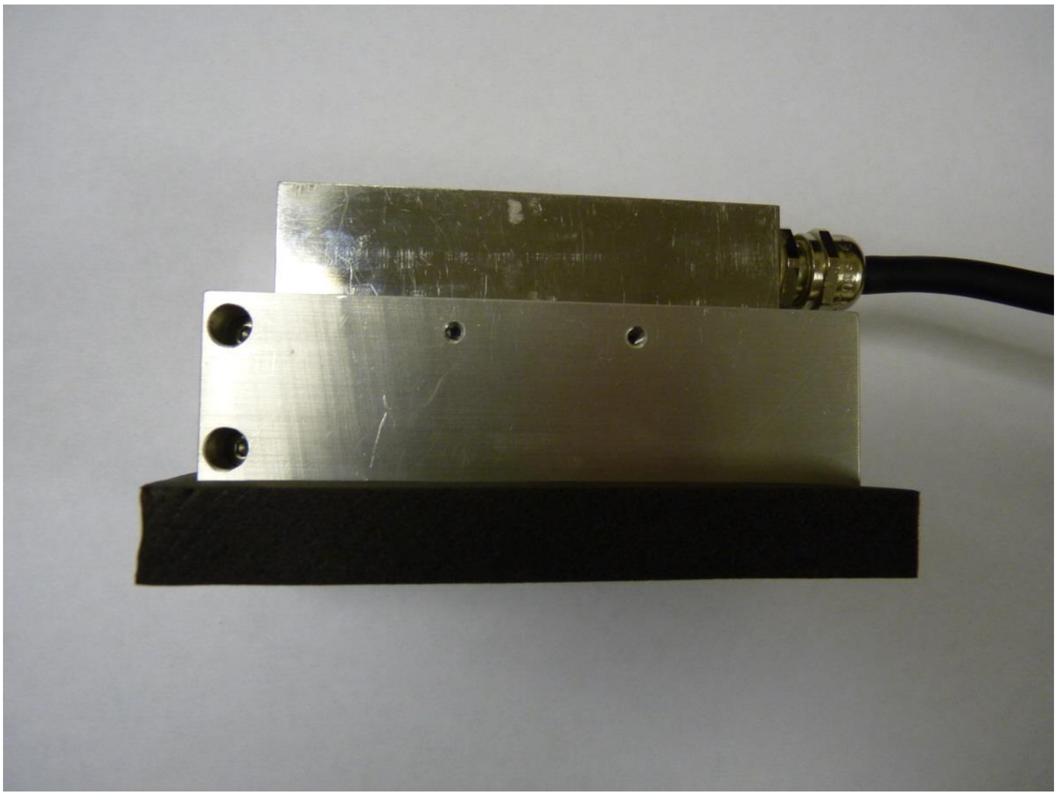


Figure 36 0° water wedge for inspecting EF joints, with phased array probe and sealing skirt attached.

Figure 37 Angled water wedge for inspecting butt fusion joints, with phased array probe and sealing skirt attached.

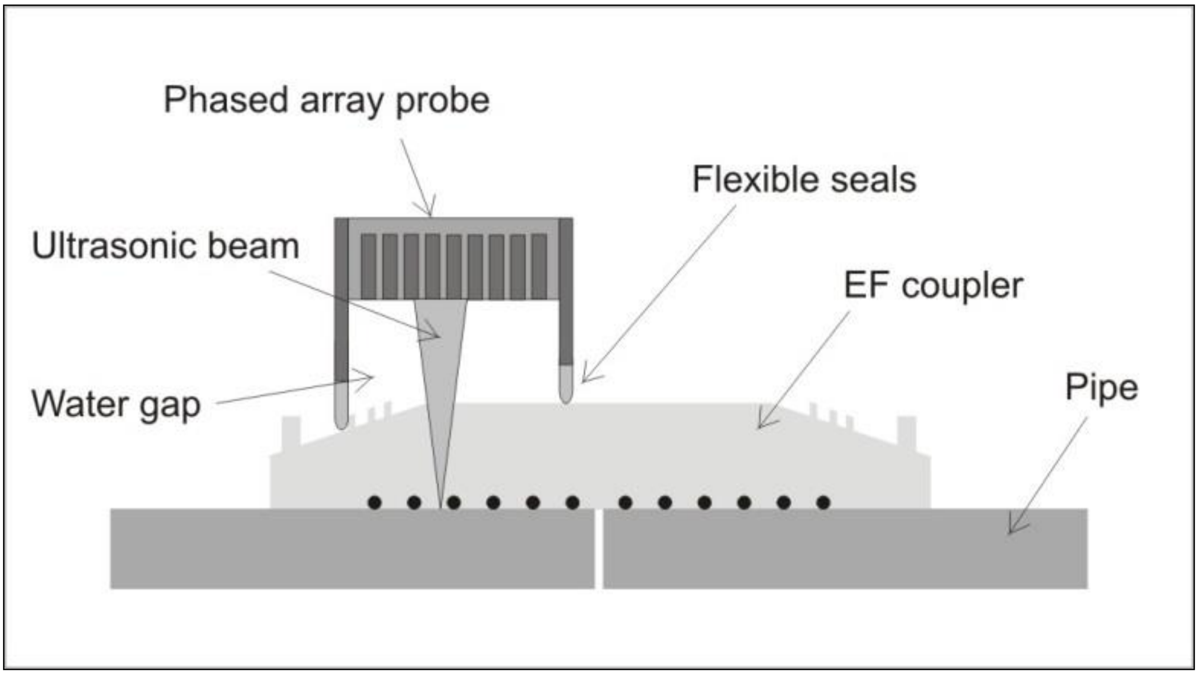


Figure 38 Schematic of the inspection technique for EF joints.

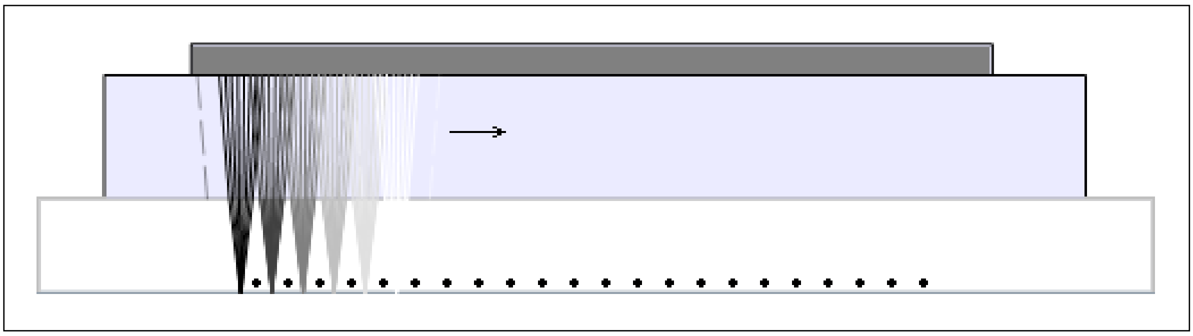


Figure 39 Normal 0° configuration for an EF joint. The beam is focused at the fusion zone and is electronically steered for left to right.

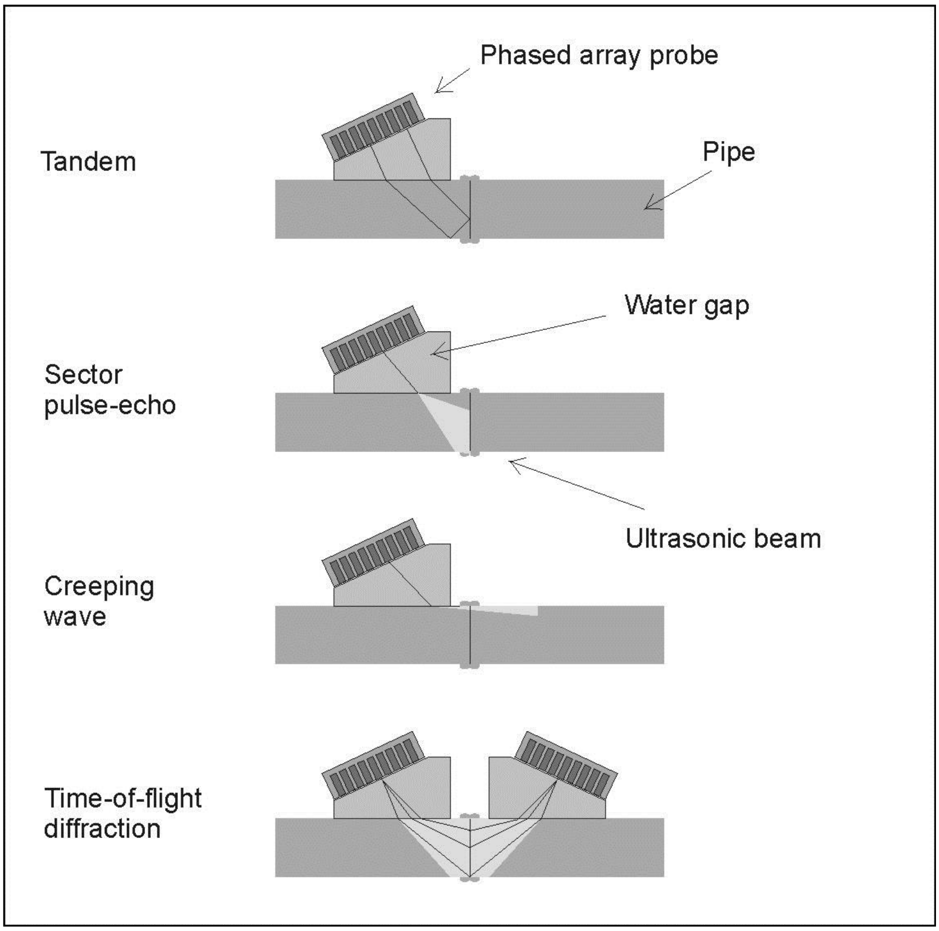


Figure 40 Schematic drawings of the inspection techniques used for butt fusion welds.

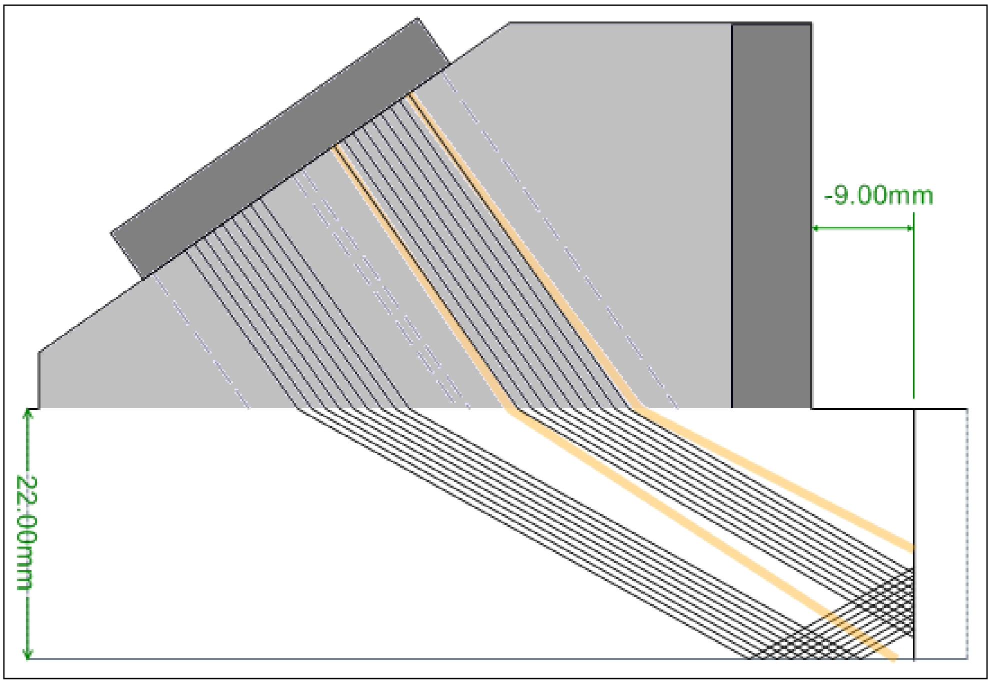


Figure 41 The self-tandem configuration for a 225mm SDR11 pipe with a wall thickness of 22mm. The yellow lines are the beam spread of the transmitted sound. The light grey area is the water inside the wedge and the dark grey area in the front of the wedge is the wedge wall.

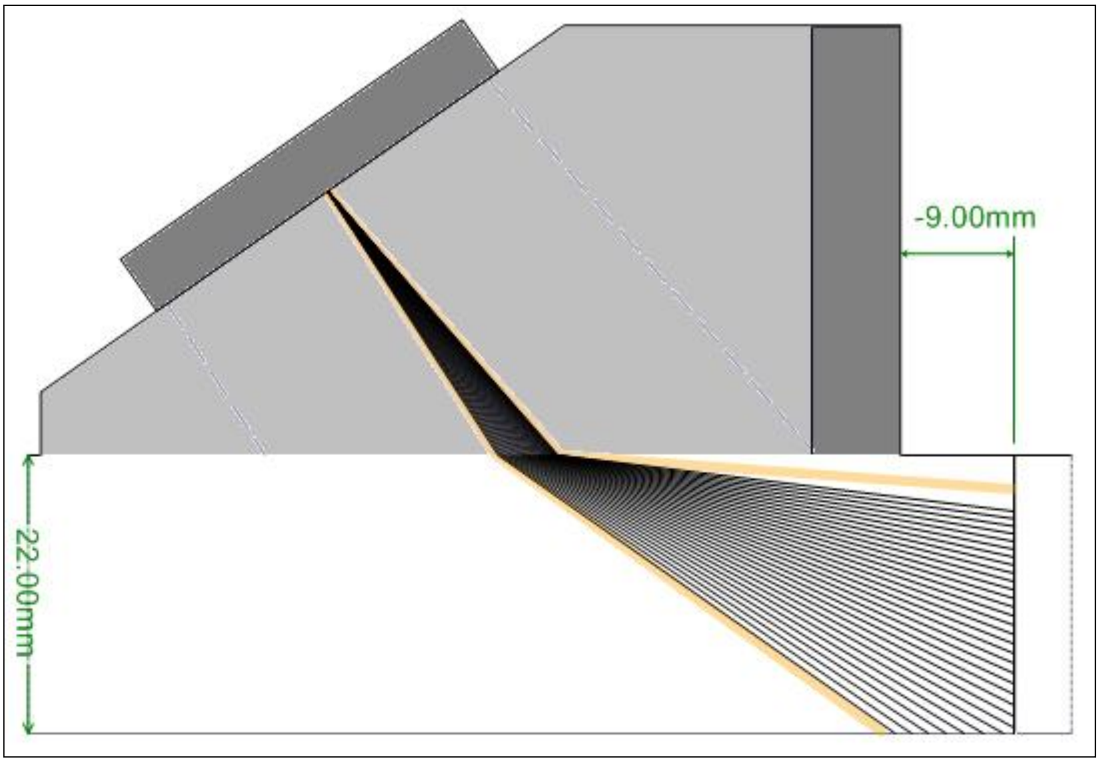


Figure 42 The sector pulse-echo configuration for a 225mm SDR11 pipe with wall thickness of 22mm. The yellow lines are the beam spread of the transmitted sound.

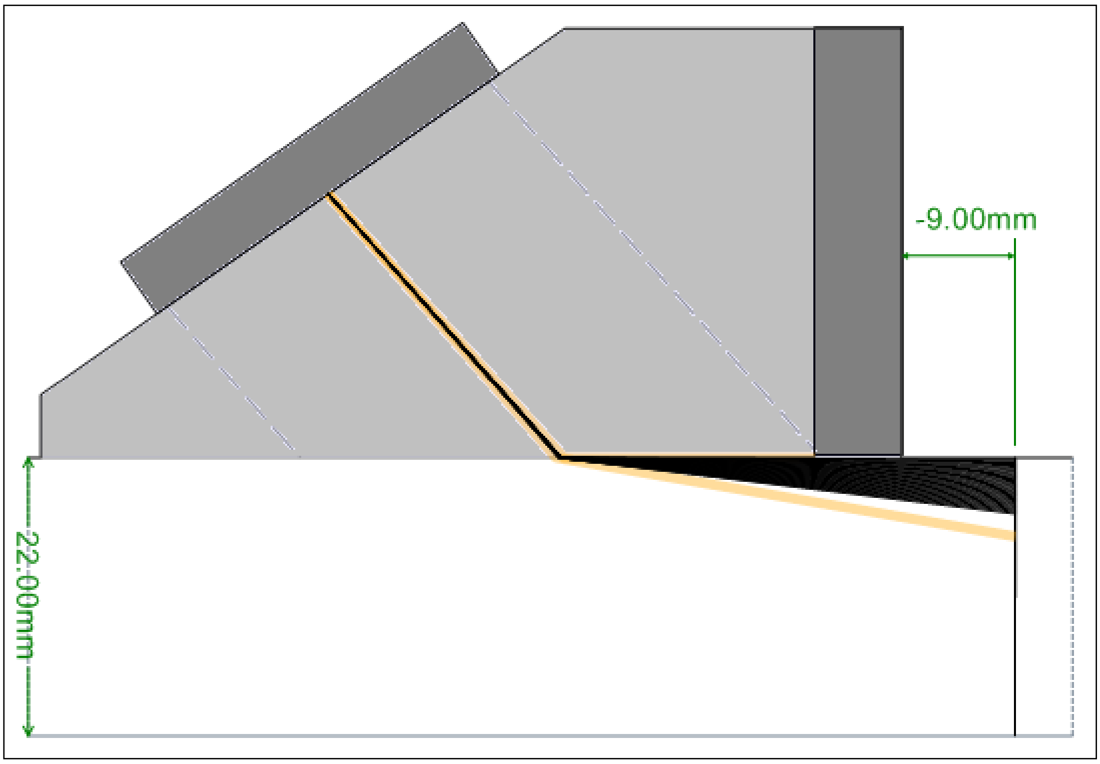


Figure 43 The creeping wave configuration on a 225mm SDR11 pipe with a wall thickness of 22mm. The yellow line is the beam spread of the transmitted sound.

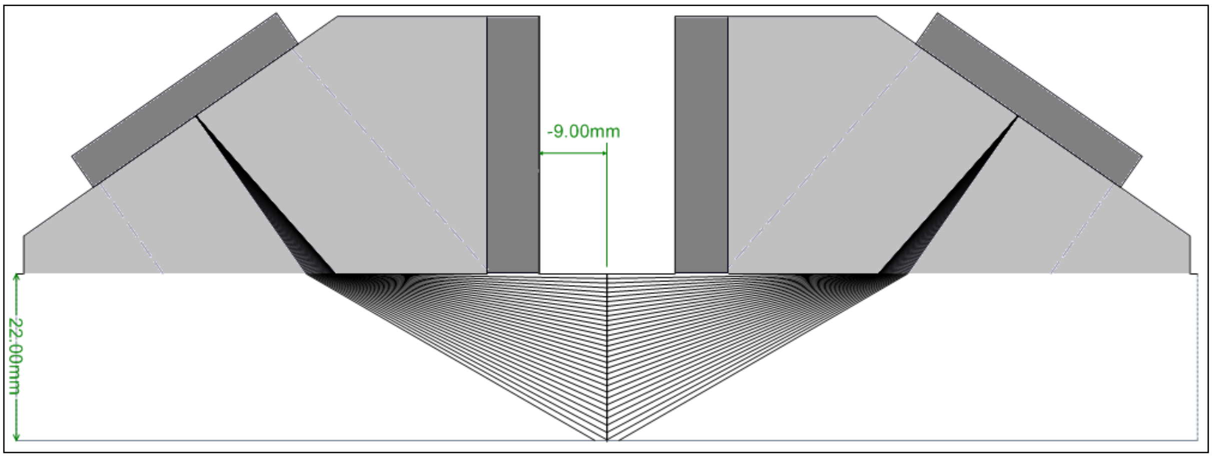


Figure 44 The TOFD configuration for a 225mm SDR11 pipe with a wall thickness of 22mm. The angles of the scan cover the entire fusion zone.

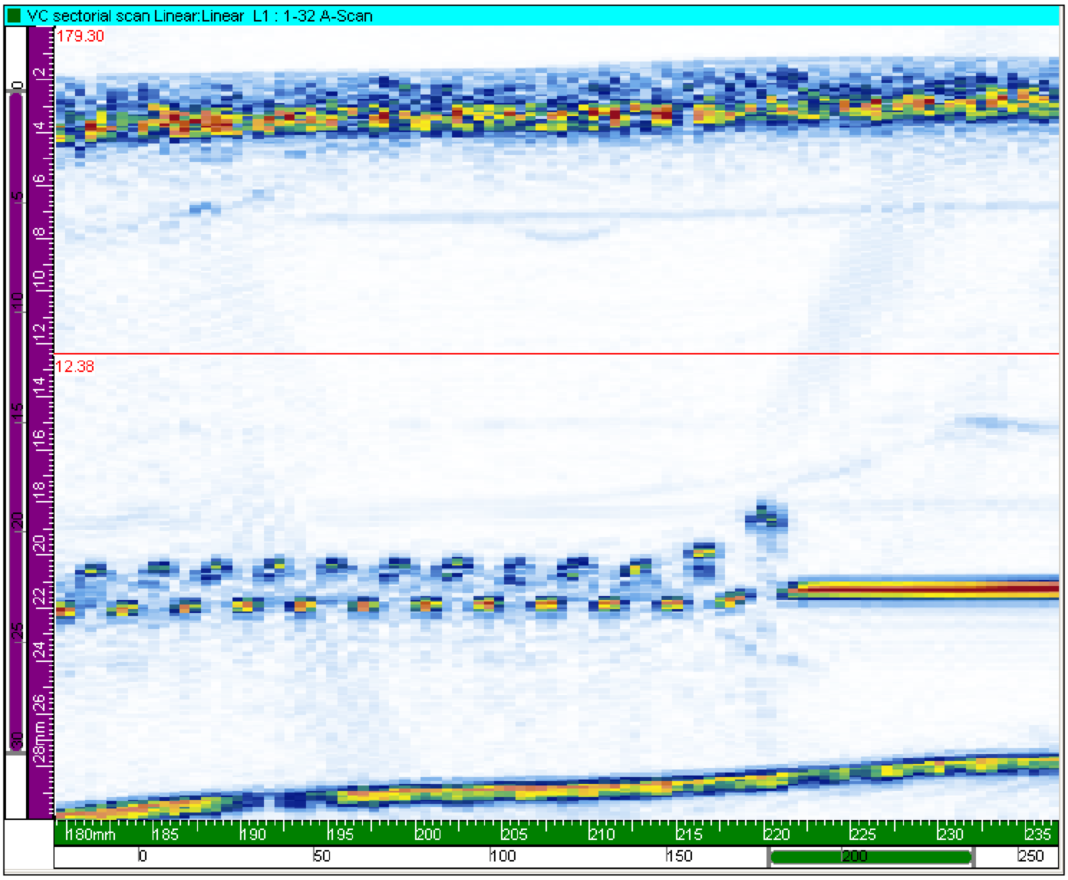


Figure 45 The electronic scan at one circumferential position of a 180mm EF coupler using a 7MHz linear phased array probe. The line at the bottom of the figure is the first repeat of the water path in the wedge, showing the top surface of the fitting.

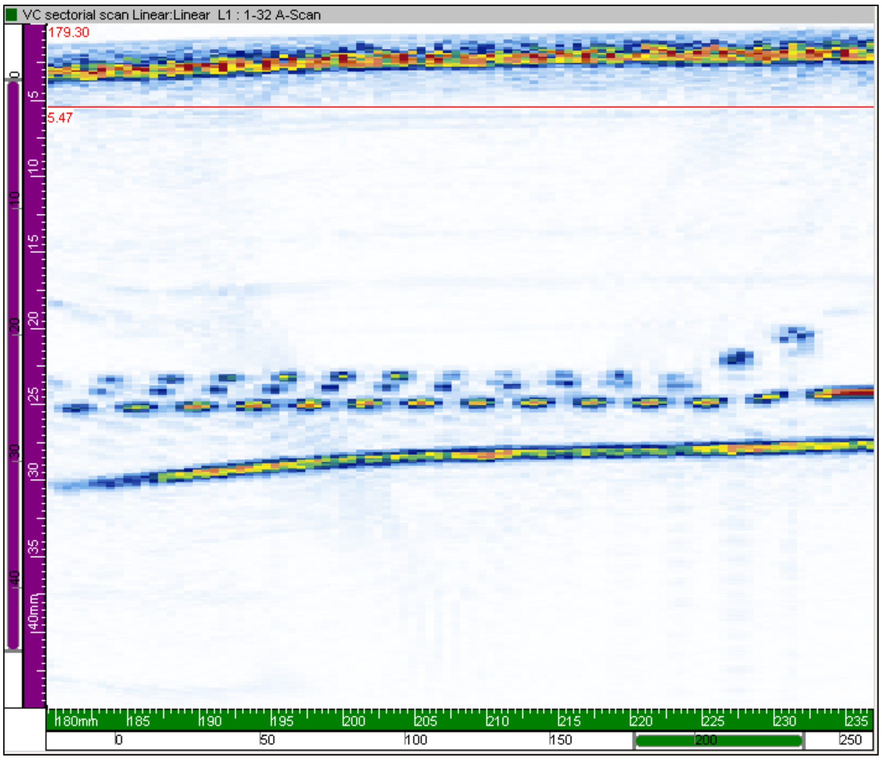


Figure 46 The electronic scan at one circumferential position of a 225mm EF coupler using a 7MHz linear phased array probe. The lower line is the first repeat of the water path in the wedge, showing the top surface of the fitting.

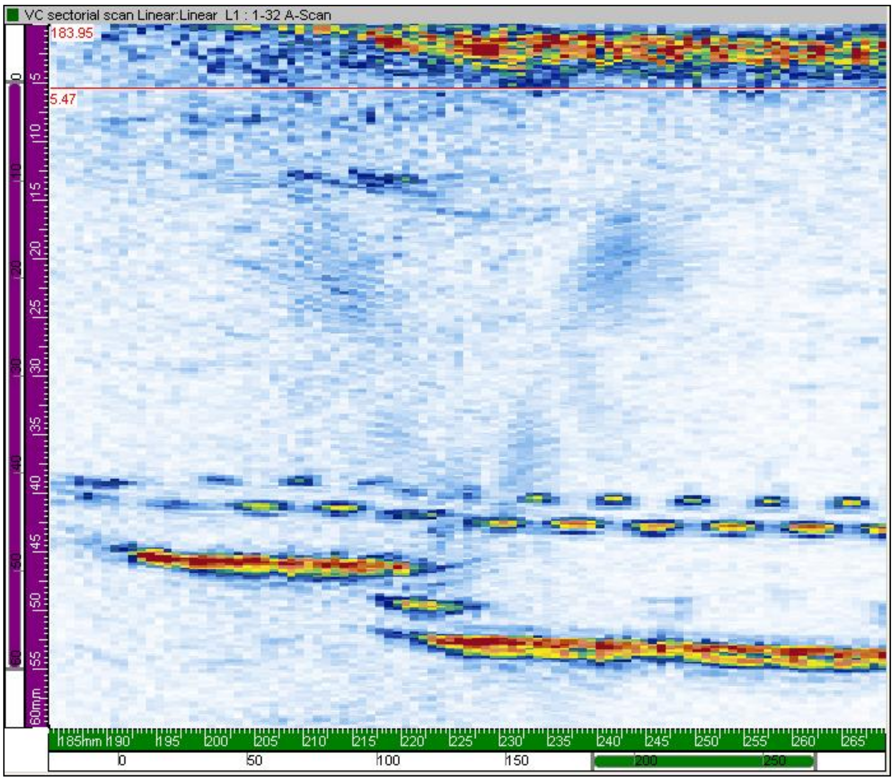


Figure 47 The electronic scan at one circumferential position of a 710mm EF coupler using a 5MHz linear phased array probe.

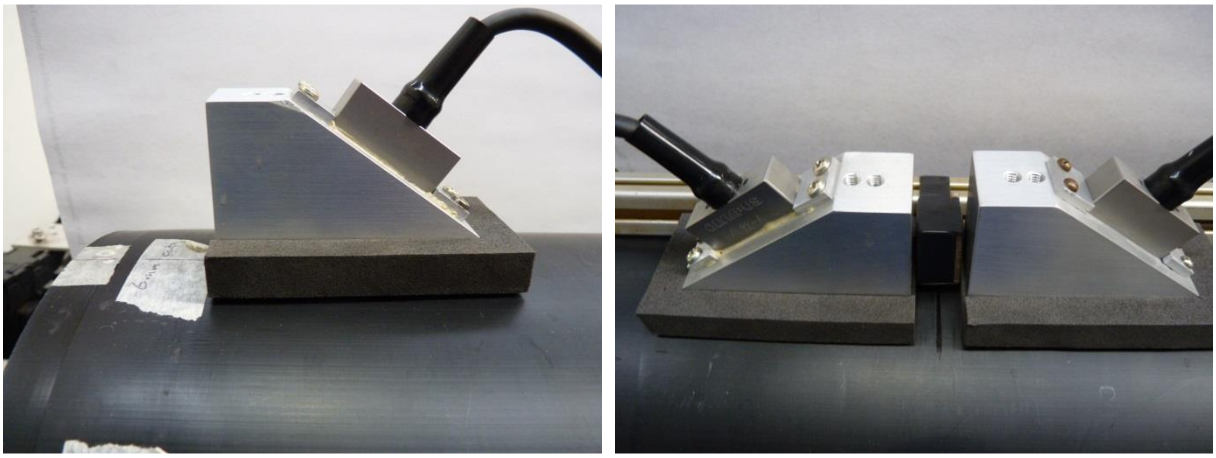


Figure 48 The experimental set-ups for evaluating the butt fusion inspection techniques: a) for tandem and sector pulse-echo, and b) for TOFD and creeping wave.

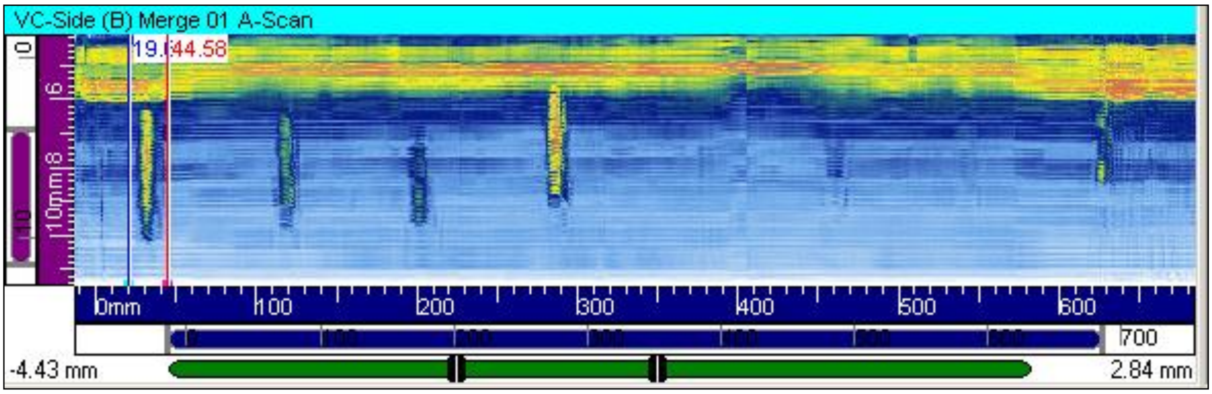


Figure 49 Tandem B-scan of FBHs in 200mm pipe. The 6mm FBH in the centre of the pipe wall is marked.

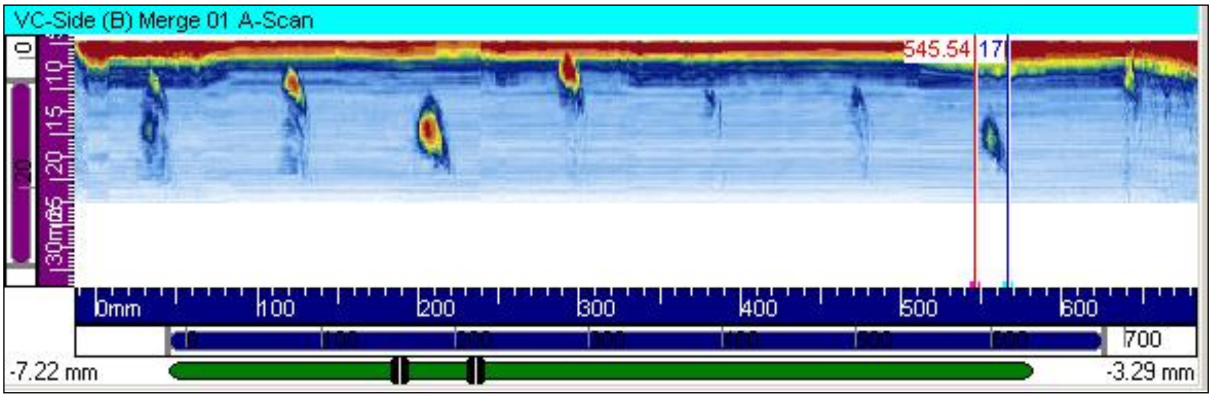


Figure 50 Sector pulse-echo B-scan of FBHs in 200mm pipe. The axis on the left reveals at what depths the FBHs are located. The 2mm FBH close to the inner surface of the pipe wall is marked.

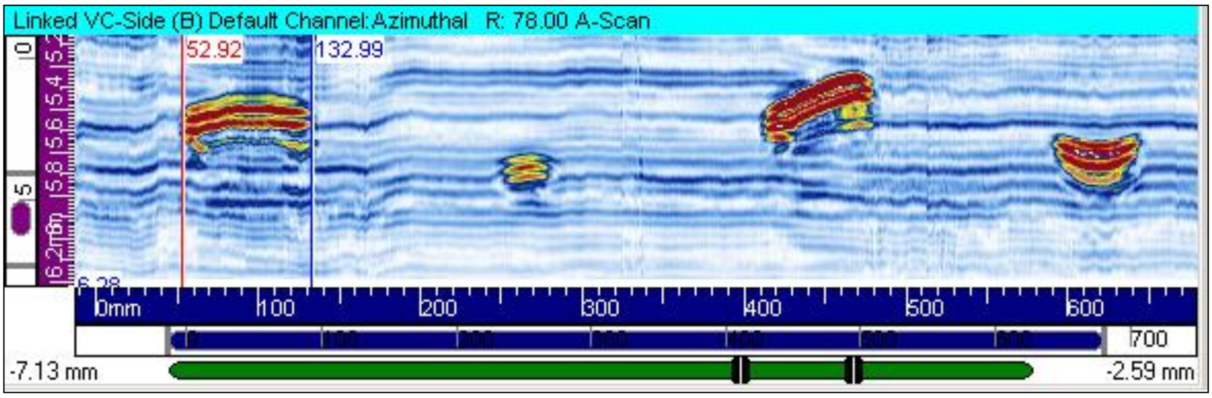


Figure 51 Creeping wave B-scan of slots in 200mm pipe.

Table 2 Comparisons between the physical measurement (PM) and the ultrasonic creeping wave measurement (UM) of the location and size of the slots in the circumferential direction in 200mm pipe. All distances are in millimetres.

	8mm slot		2mm slot		6mm slot		4mm slot	
	PM	UM	PM	UM	PM	UM	PM	UM
Location	51	53	247	252	408	411	589	590
Size	84	80	38	26	75	68	58	53

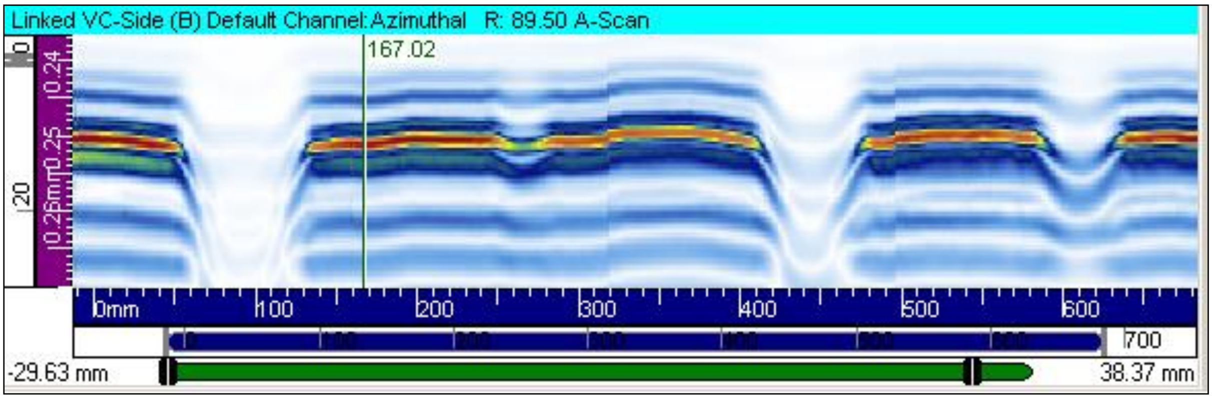


Figure 52 TOFD B-scan of slots in 200mm pipe.

Table 3 Comparisons between the physical measurement (PM) and the ultrasonic TOFD measurement (UM) of the location and size of the slots in the circumferential direction in 200mm pipe. All distances are in millimetres.

	8mm slot		2mm slot		6mm slot		4mm slot	
	PM	UM	PM	UM	PM	UM	PM	UM
Location	51	52	247	250	408	409	589	585
Size	84	80	38	28	75	78	58	49

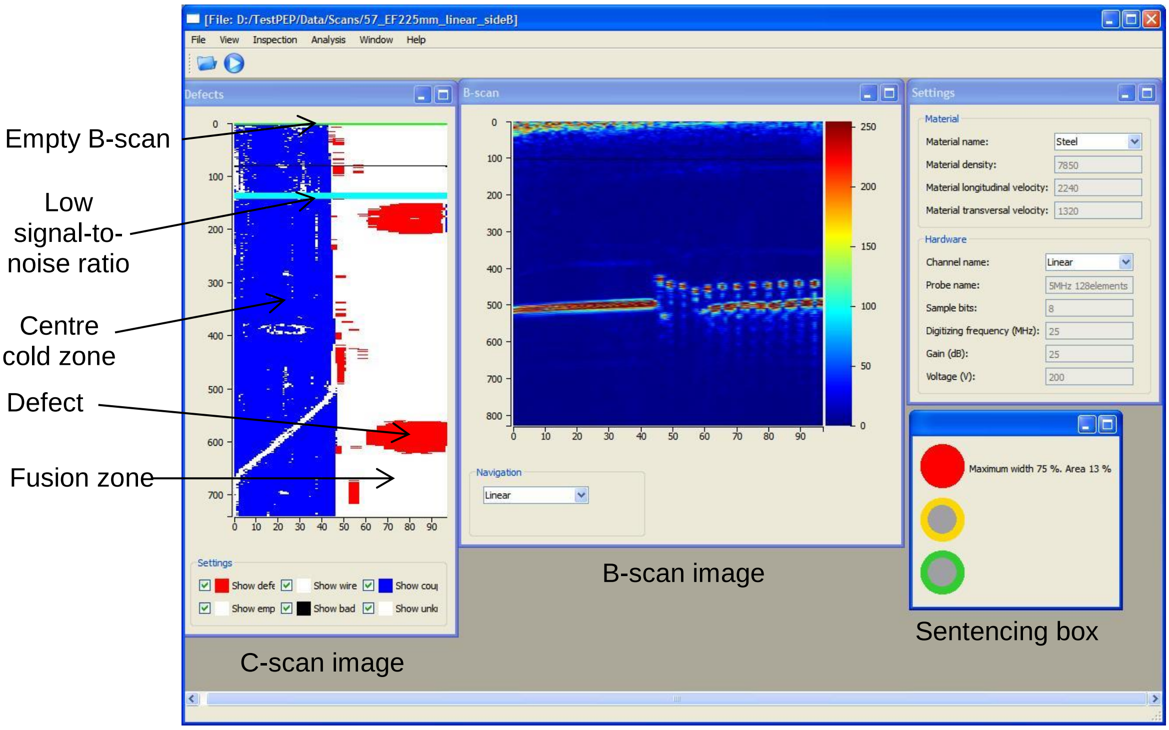


Figure 53 Typical display from the data analysis software.

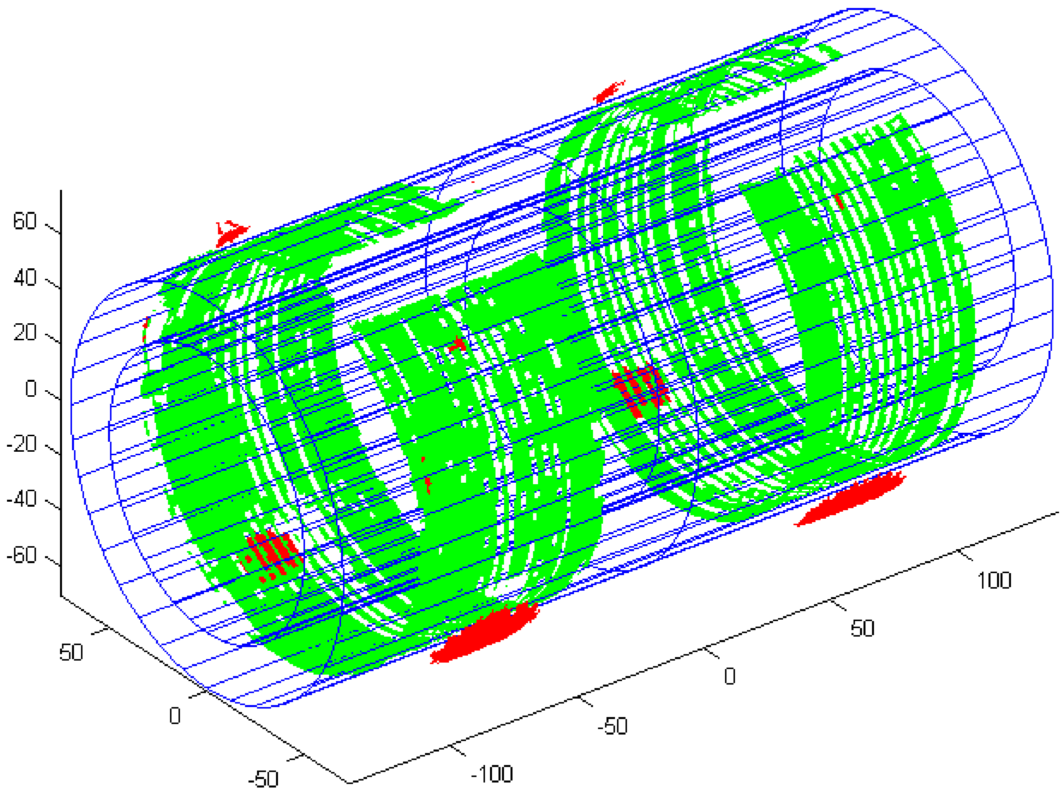


Figure 54 3-D image of electrofusion joint from the data analysis software, showing the indications from the heating wires (green) and defects (red).

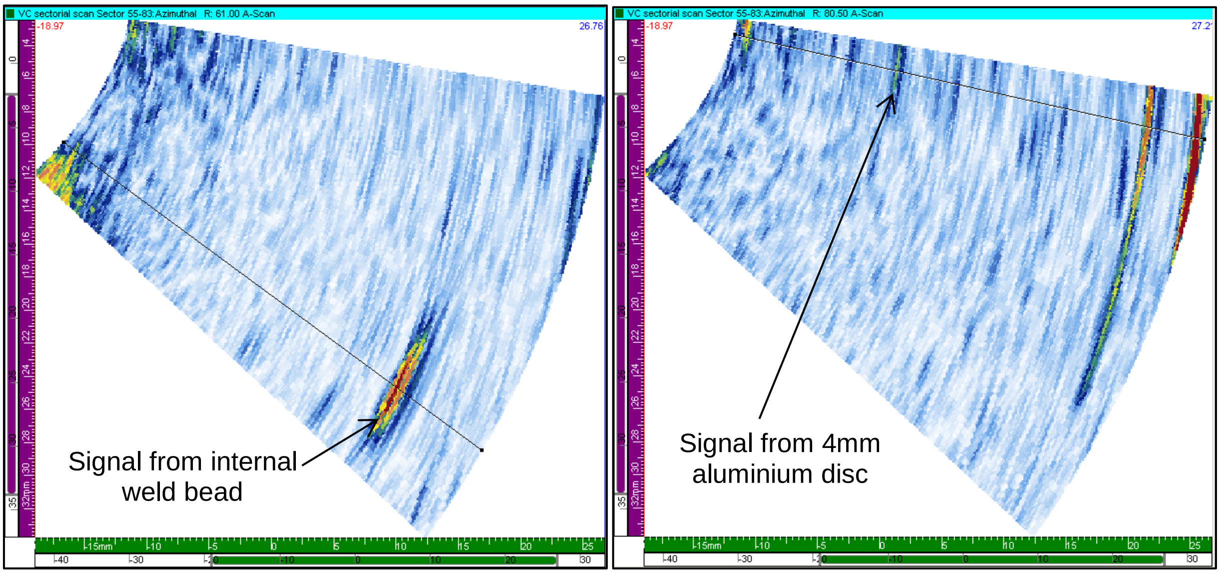


Figure 55 B-scan images of butt fusion welds in 225mm PE pipes: unflawed weld (left), and weld containing a 4mm aluminium disc (right).

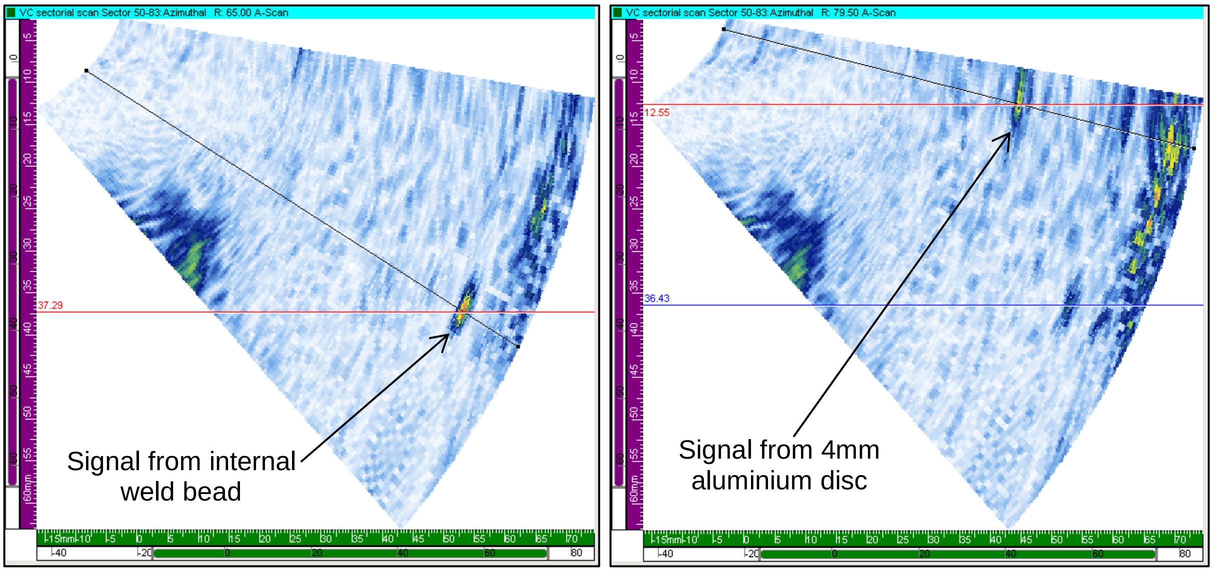


Figure 56 B-scan images of butt fusion welds in 355mm PE pipes: unflawed weld (left), and weld containing a 4mm aluminium disc (right).

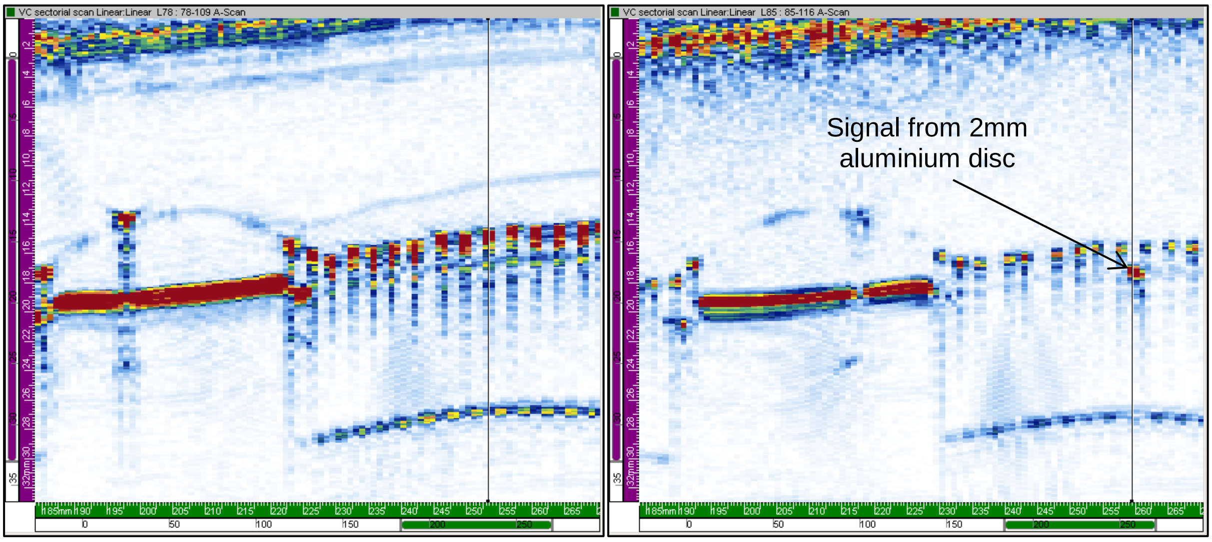


Figure 57 B-scan images of electrofusion welds in 180mm PE pipes: unflawed weld (left), and weld containing a 2mm aluminium disc (right).

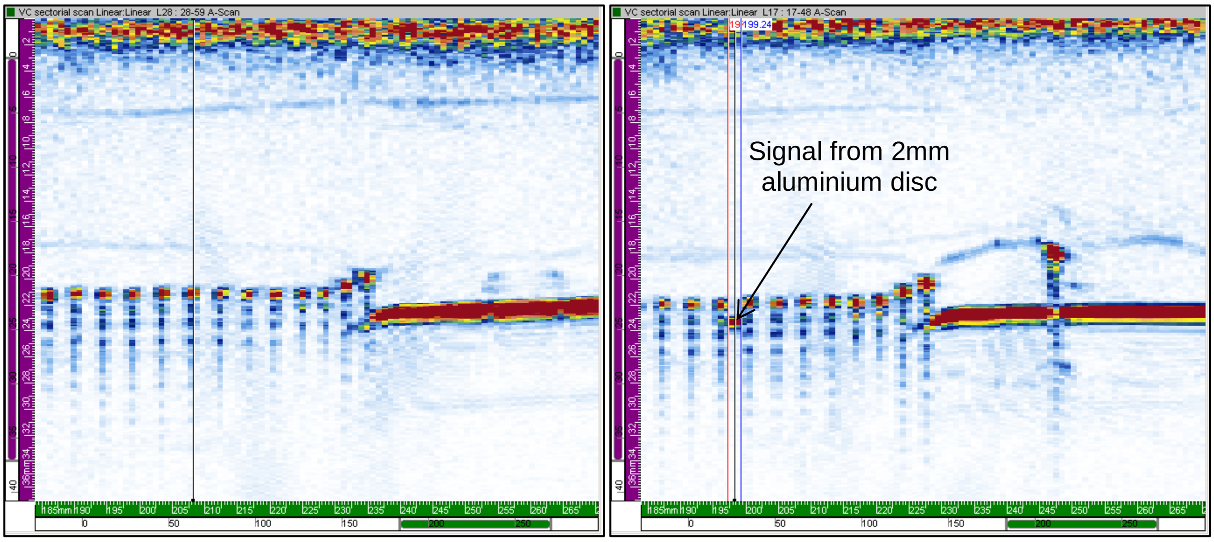


Figure 58 B-scan images of electrofusion welds in 225mm PE pipes: unflawed weld (left), and weld containing a 2mm aluminium disc (right).

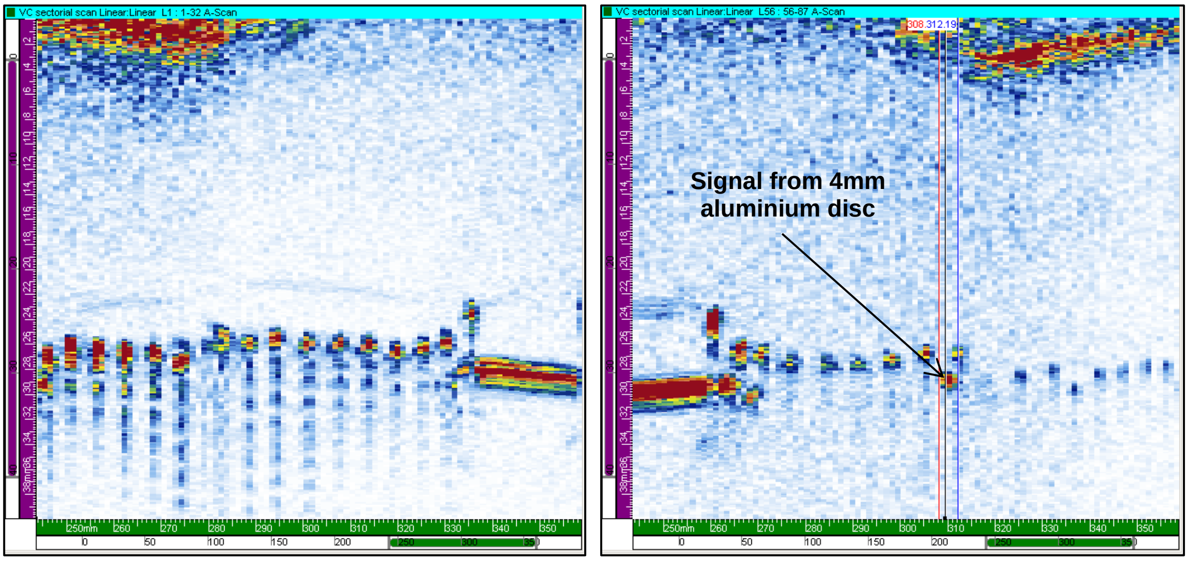


Figure 59 B-scan images of electrofusion welds in 450mm PE pipes: unflawed weld (left), and weld containing a 4mm aluminium disc (right).

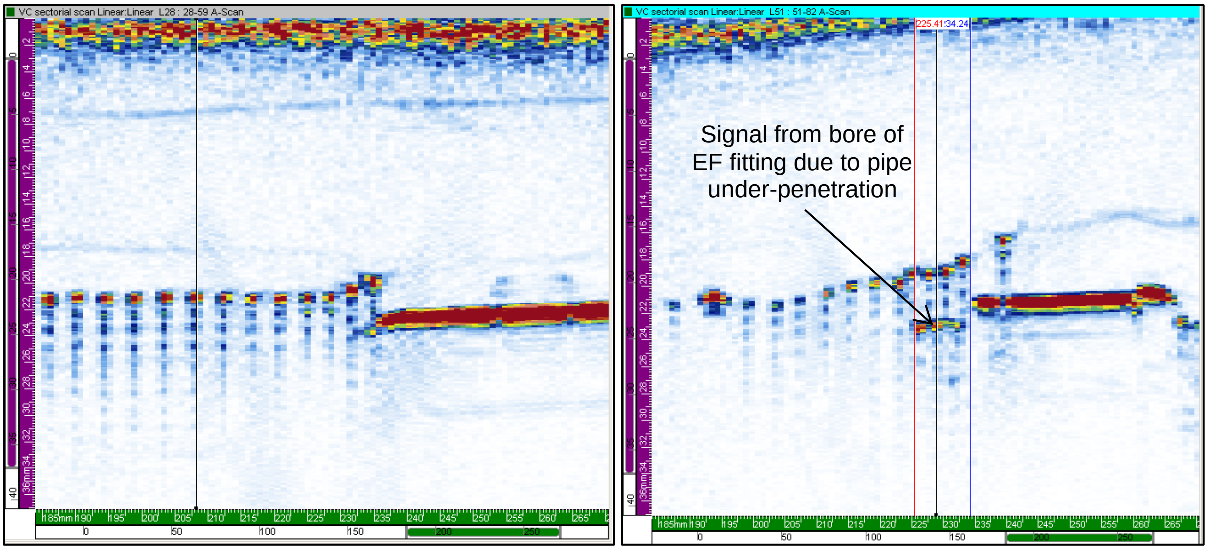


Figure 60 B-scan images of electrofusion welds in 225mm PE pipes: unflawed weld (left), and weld with pipe under-penetration level A (right).

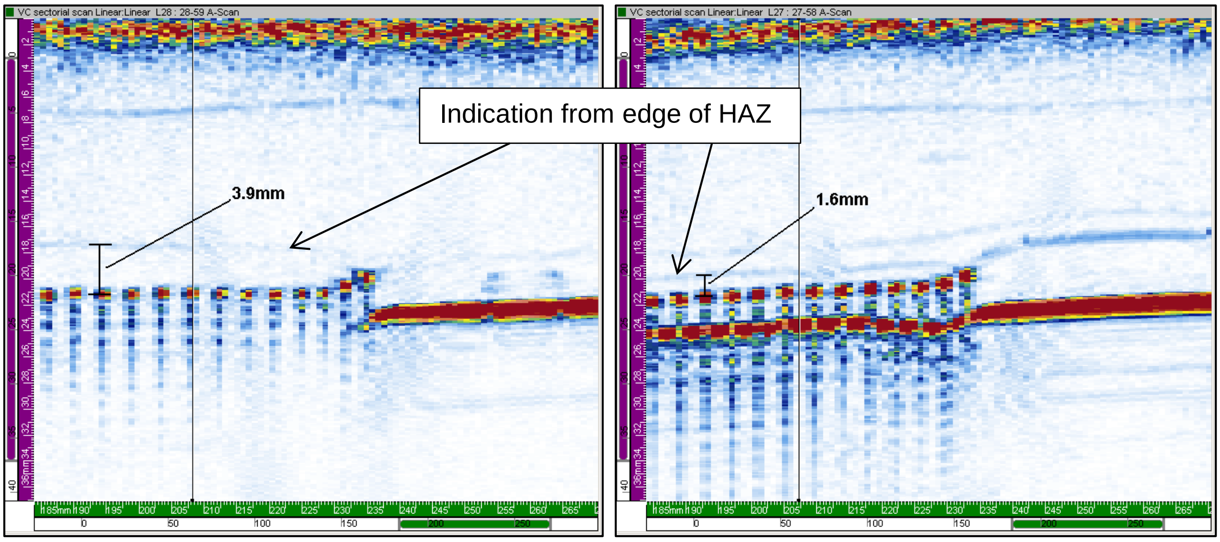


Figure 61 B-scan images of electrofusion welds in 225mm PE pipes: weld made using standard heating time (left), and weld made using reduced heating time (right).

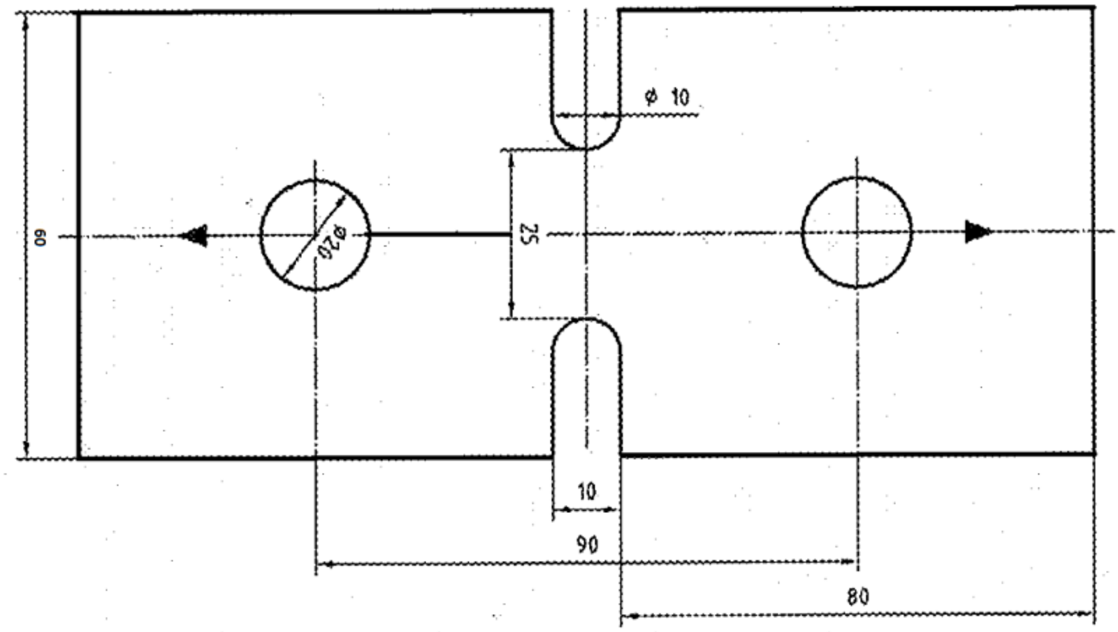


Figure 62 Waisted tensile test specimen geometry.

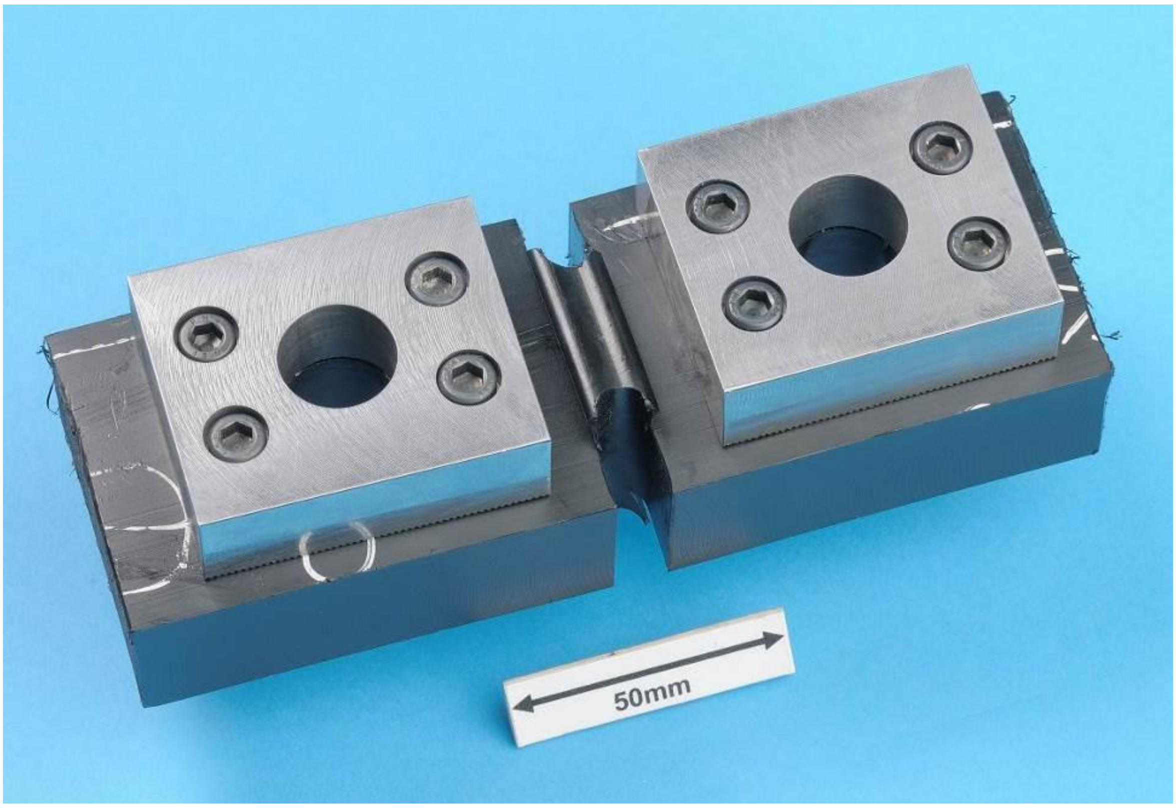


Figure 63 Waisted tensile test specimen with side plates attached.

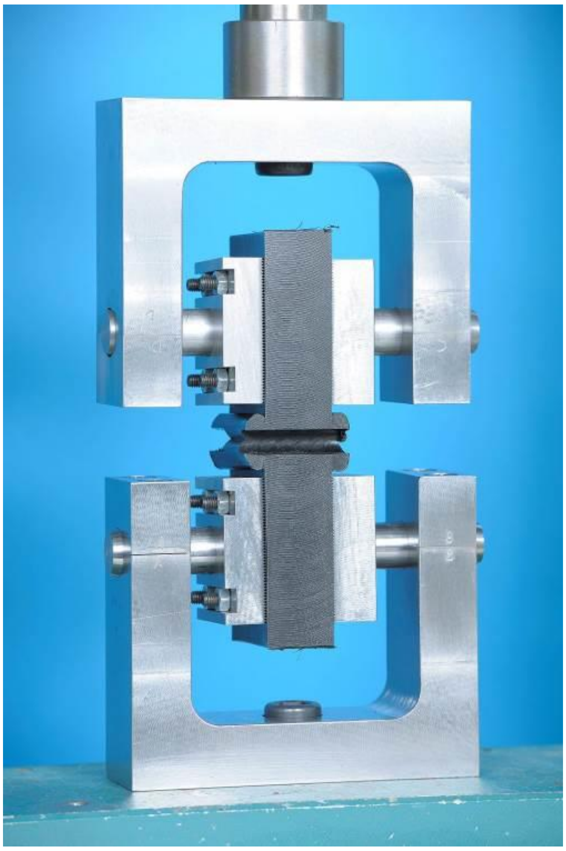


Figure 64 Tensile test set-up.

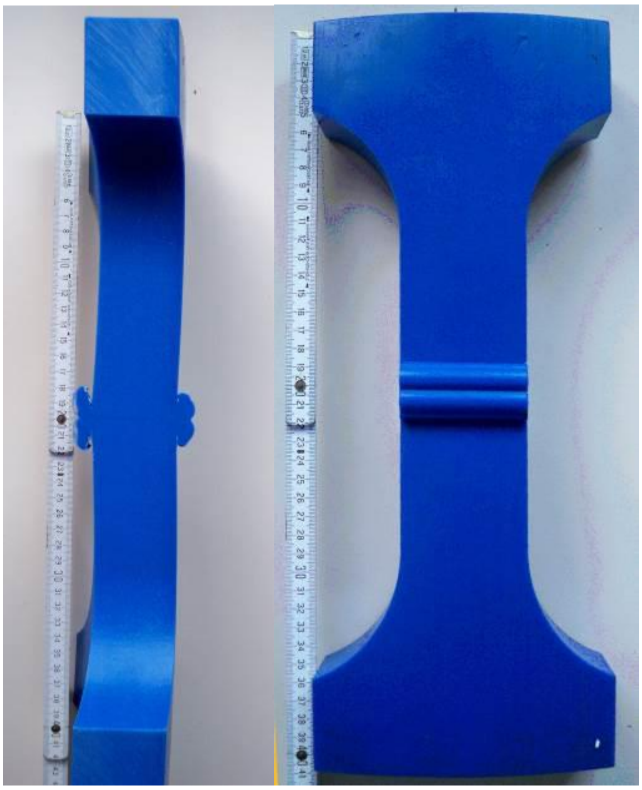


Figure 65 Specimen for tensile creep rupture test on butt fusion welds.

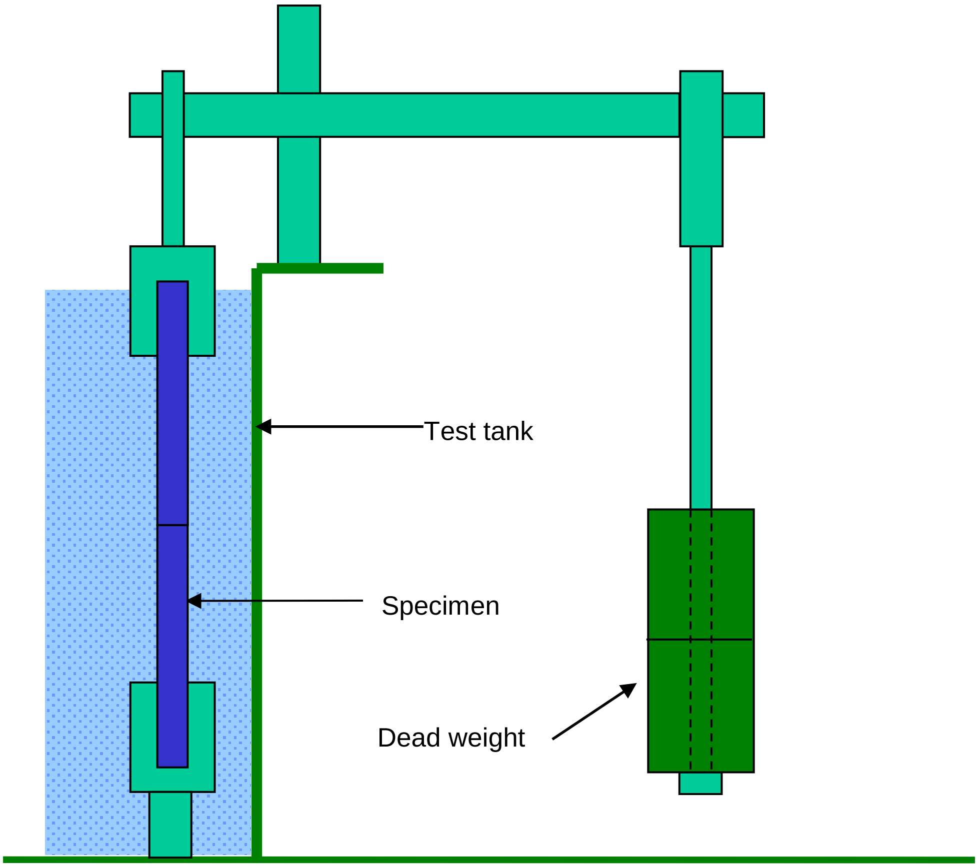


Figure 66 Specimen creep rupture test set-up.

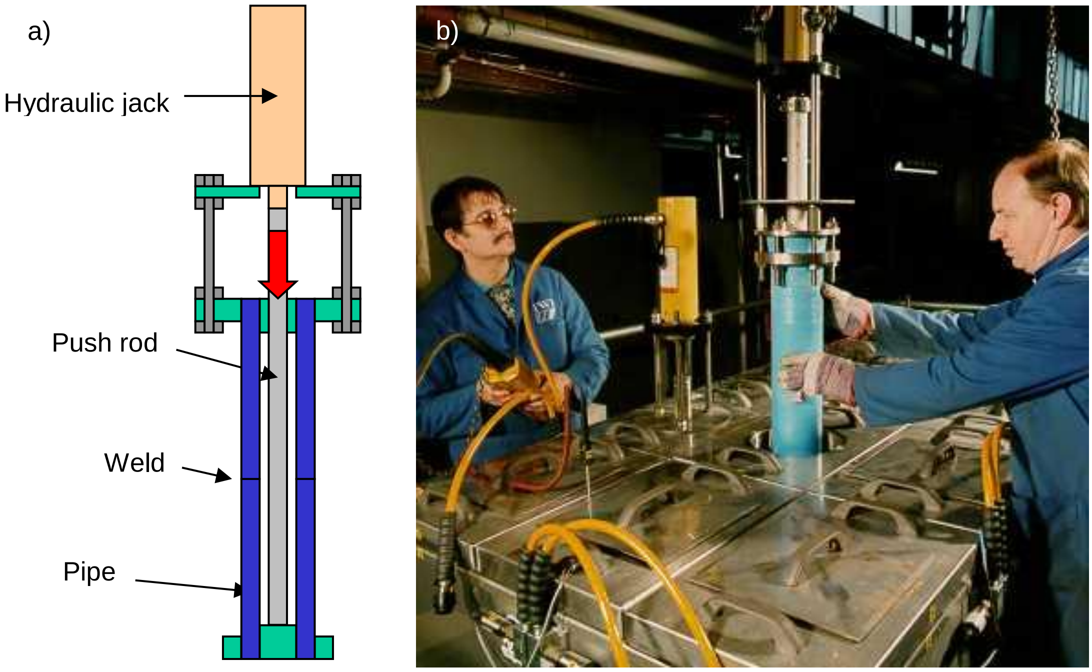


Figure 67 Whole pipe tensile creep rupture test: a) diagram of loading arrangement, b) photograph of the test rig.

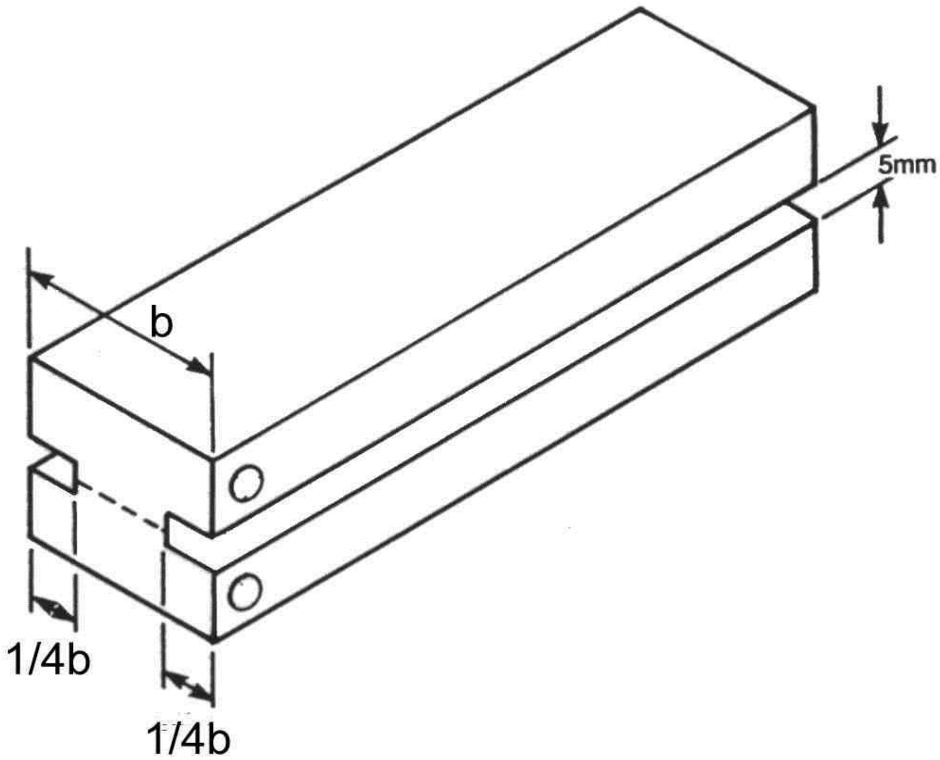


Figure 68 Peel decohesion test specimen.

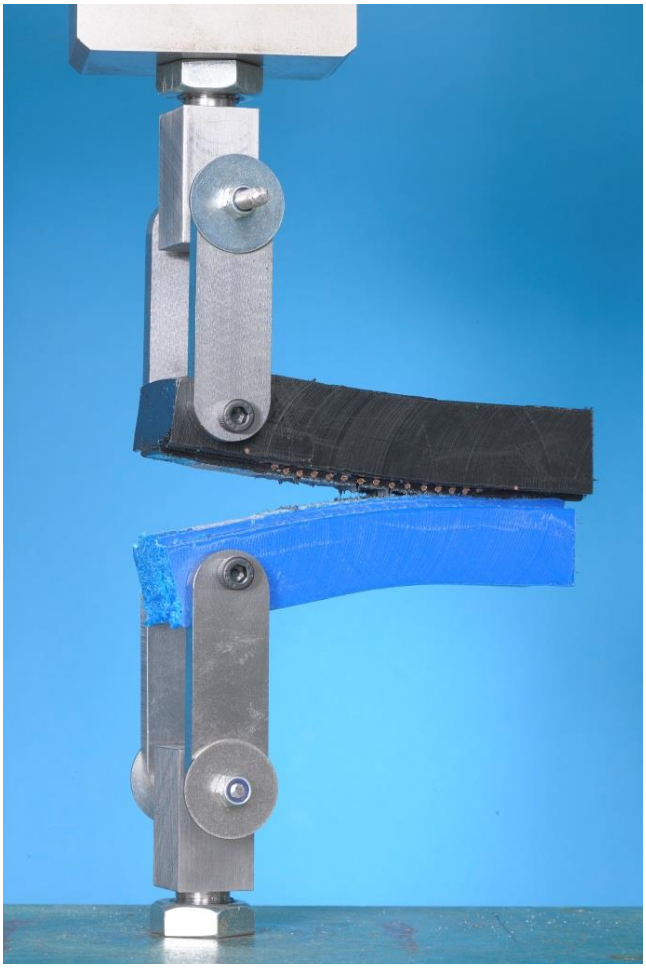
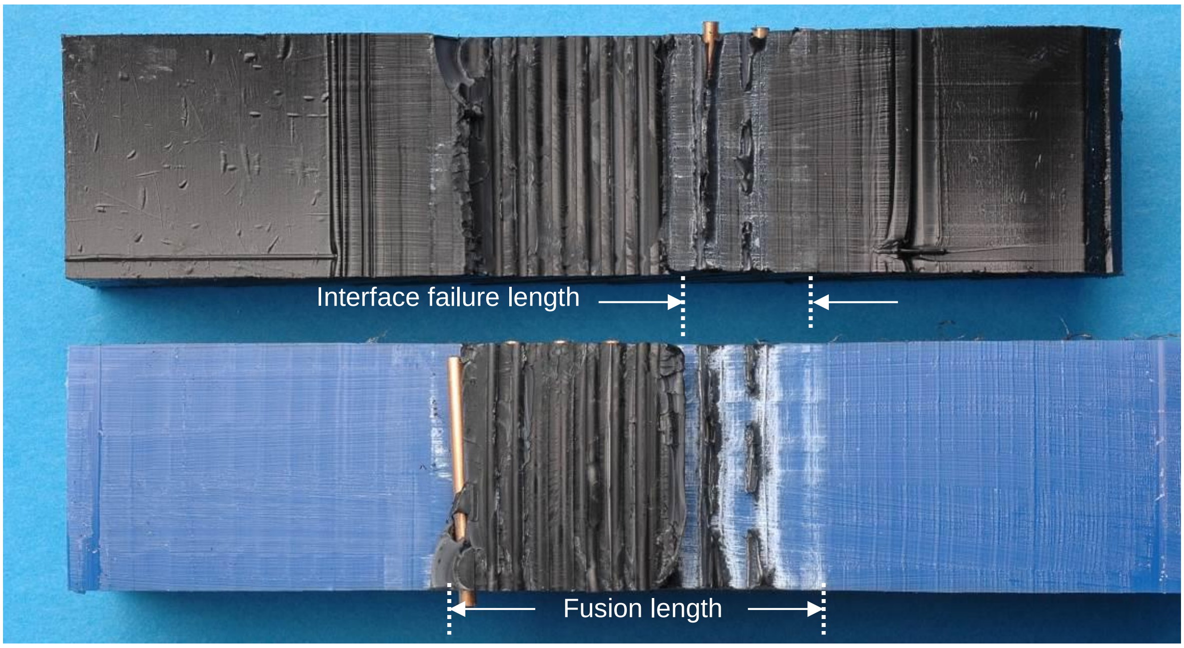


Figure 69 Peel decohesion test.



% interface failure = (Length of failure through the interface)/(Fusion length)

Figure 70 Calculation of percentage interface failure in peel decohesion test.

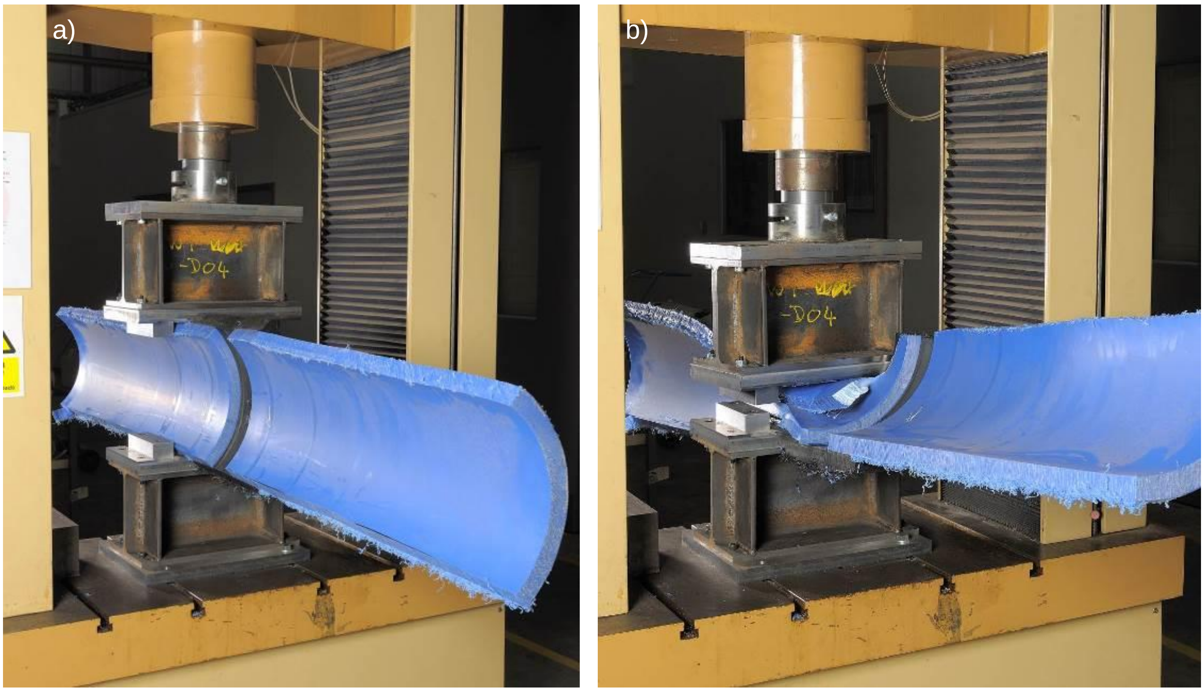
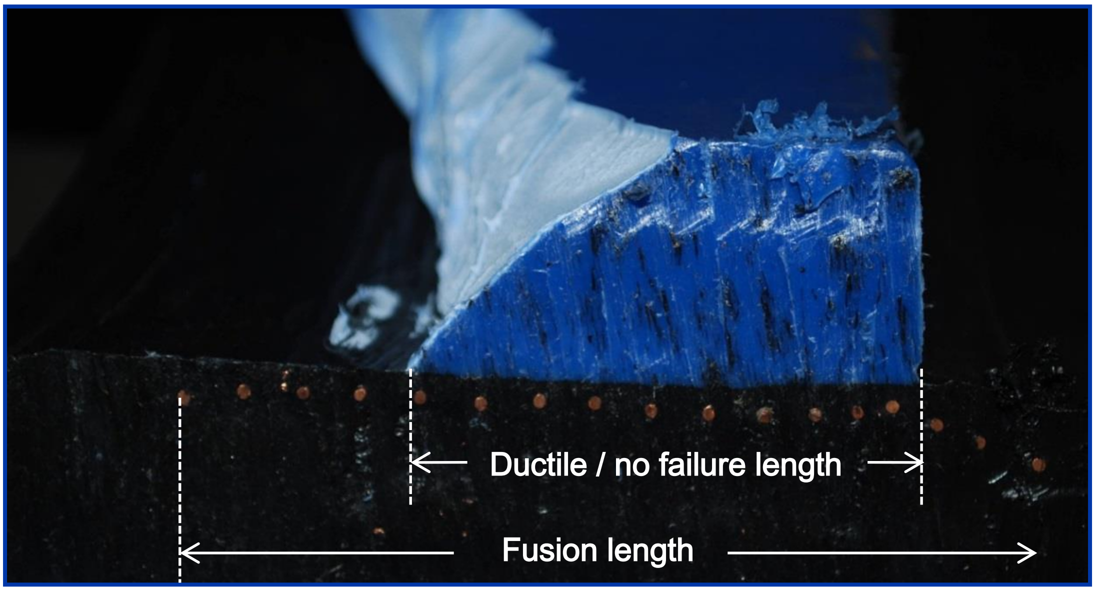


Figure 71 Crushing decohesion test: a) at start of test, and b) at end of test.



% ductile or no failure = (ductile/no failure length)/(fusion length)

Figure 72 Calculation of percentage ductile or no failure in crushing decohesion test.

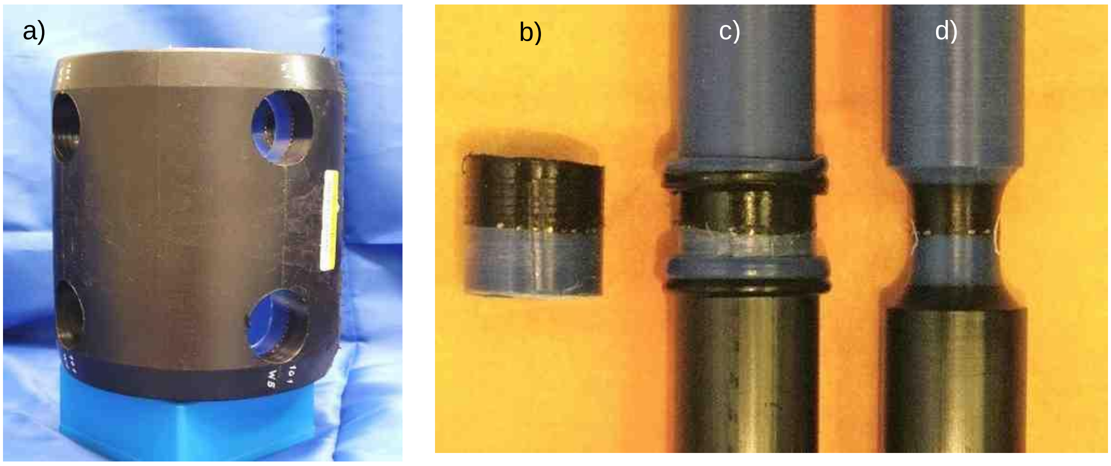


Figure 73 Preparation of specimens for the tensile creep test: a) welded EF joint showing positions from where "cork" specimens were cut; b) cork specimen; c) extension bars hot plate welded to cork specimens; d) final specimen waisted at the EF weld interface.

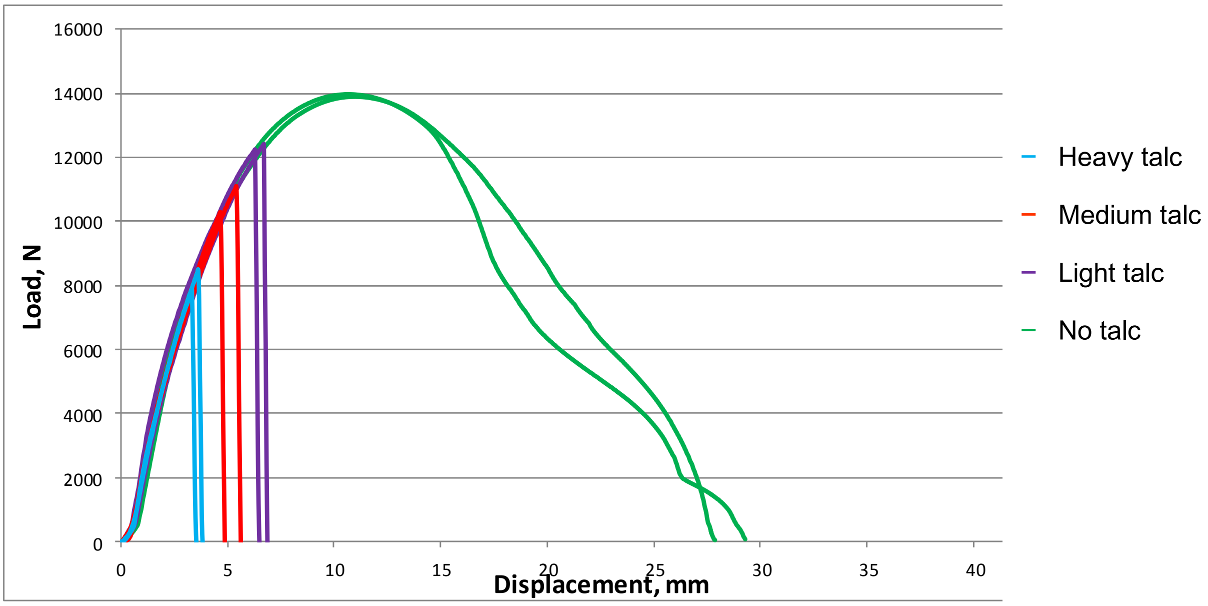


Figure 74 Load vs displacement curves for short-term tensile tests on uncontaminated and talc contaminated butt fusion welds in 225mm diameter pipes.

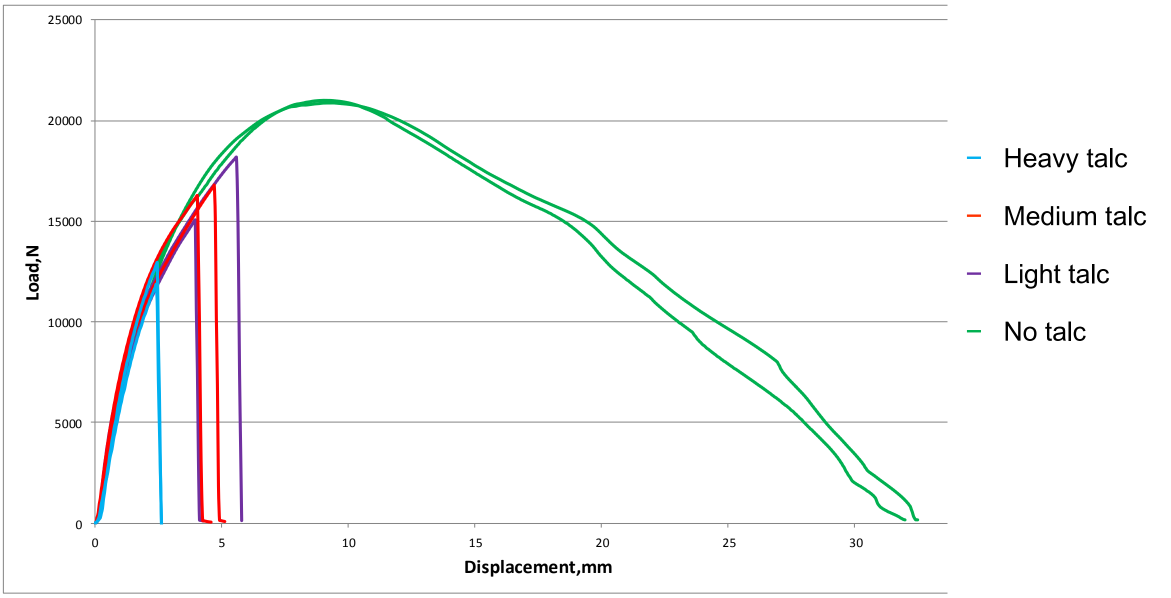


Figure 75 Load vs displacement curves for short-term tensile tests on uncontaminated and talc contaminated butt fusion welds in 450mm diameter pipes.

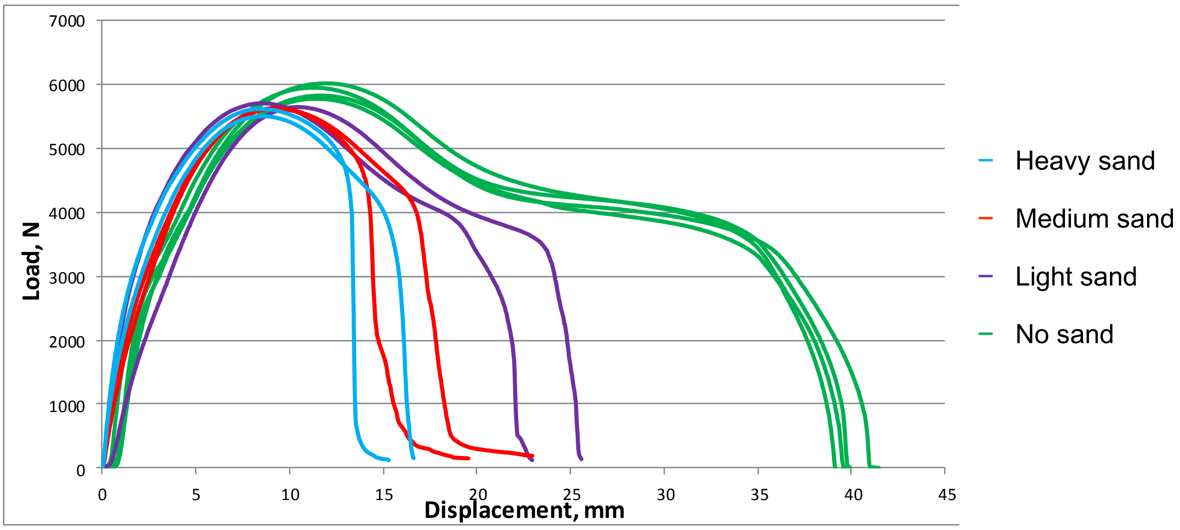


Figure 76 Load vs displacement curves for short-term tensile tests on uncontaminated and sand contaminated butt fusion welds in 180mm diameter pipes.

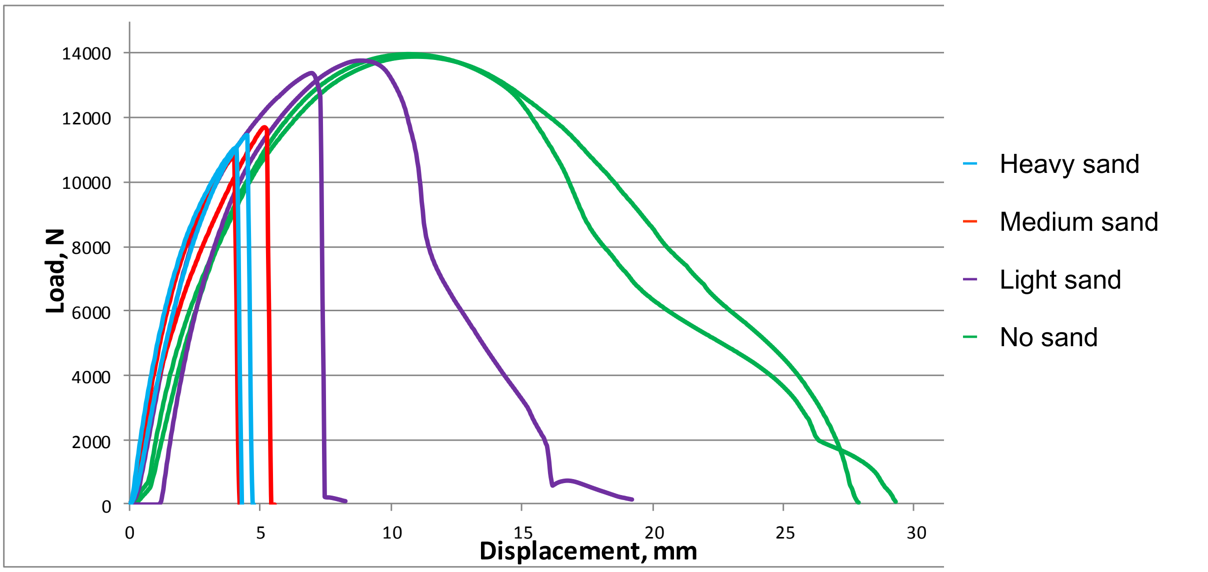


Figure 77 Load vs displacement curves for short-term tensile tests on sand contaminated butt fusion welds in 225mm diameter pipes.

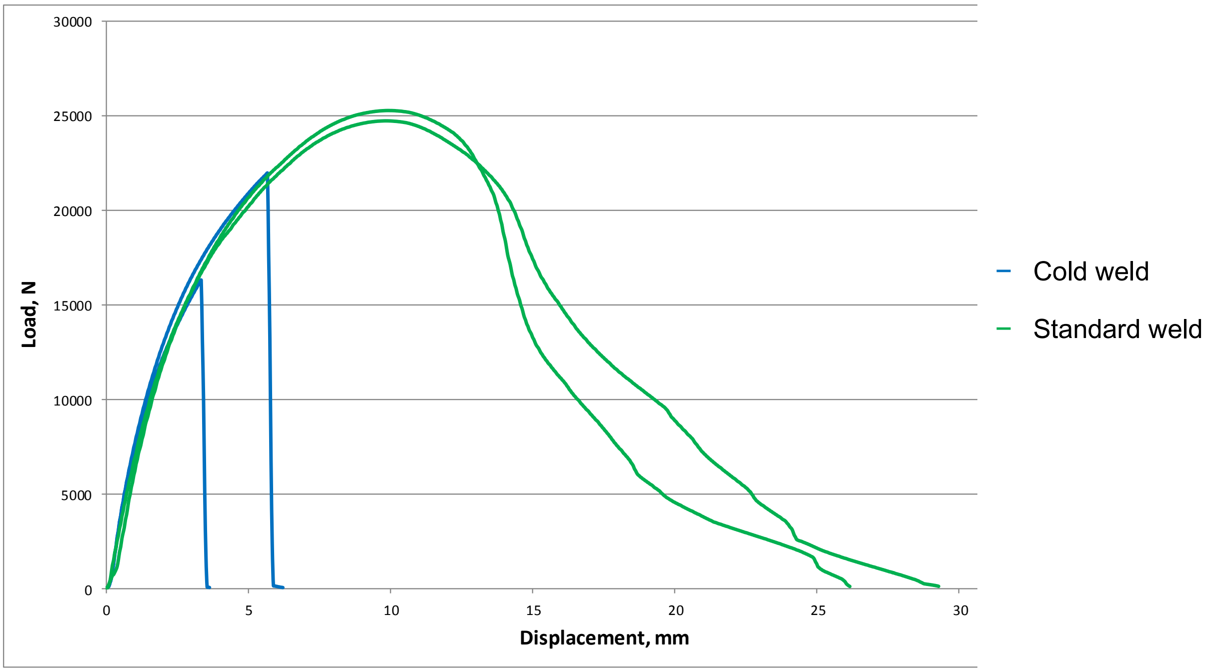


Figure 78 Load vs displacement curves for standard and cold welds in 355mm diameter pipes.

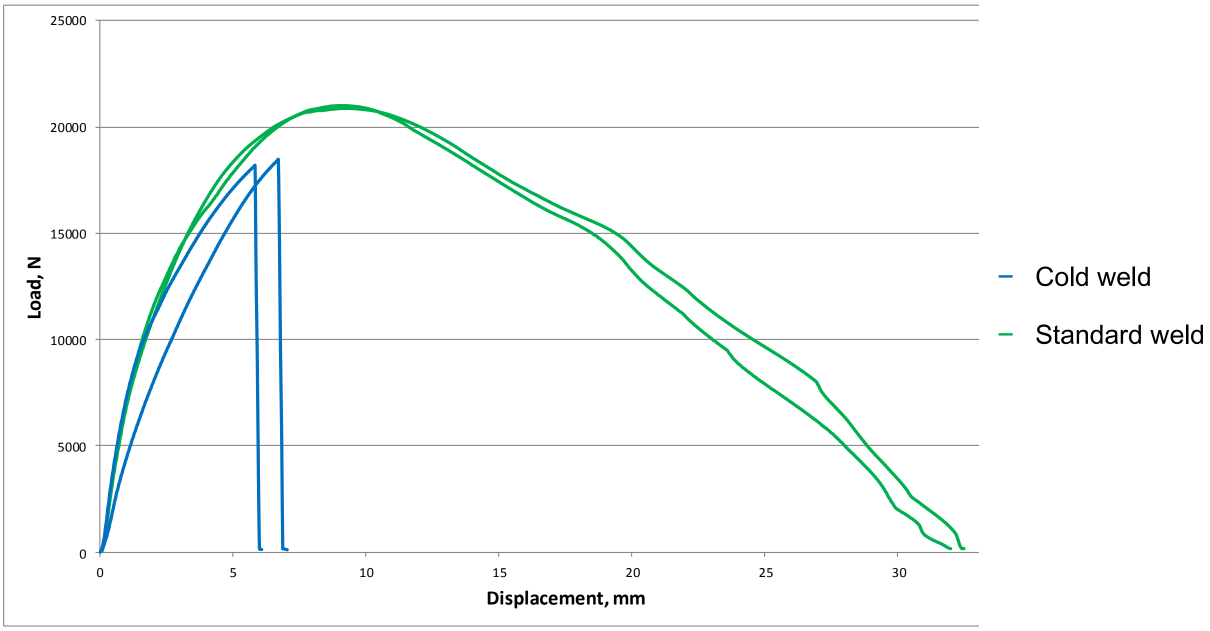


Figure 79 Load vs displacement curves for standard and cold welds in 450mm diameter pipes.

Table 4 Summary of results of creep rupture tests on specimens from butt fusion welds

Pipe size / material	Flaw description	Geometric mean time to failure, hours	Failure position
180mm / PE80	None	267.7	Outside fusion plane
	Light talc	161.6	Outside fusion plane
	Medium talc	50.5	In fusion plane
	Heavy talc	113.4	In fusion plane
	Light sand	149.0	Outside fusion plane
	Medium sand	79.4	In fusion plane
	Heavy sand	79.6	In fusion plane
225mm / PE100	None	171.6	Outside fusion plane
	Light talc	12.2	In fusion plane
	Medium talc	7.2	In fusion plane
	Heavy talc	5.5	In fusion plane
	Light sand	47.5	In fusion plane
	Medium sand	21.5	In fusion plane
	Heavy sand	19.7	In fusion plane
355mm/ PE80	None	55.9	Outside fusion plane
	Light talc	28.0	In fusion plane
	Medium talc	24.8	In fusion plane
	Heavy talc	6.8	In fusion plane
	Cold weld	4.8	In fusion plane
450mm / PE100	None	187.4	Outside fusion plane
	Light talc	136.6	Mixed
	Medium talc	14.3	In fusion plane
	Heavy talc	5.8	In fusion plane
	Cold weld	0.03	In fusion plane
710mm / PE100	None	181.8	Outside fusion plane
	Light talc	189.7	Mixed
	Medium talc	28.4	In fusion plane
	Heavy talc	18.4	In fusion plane

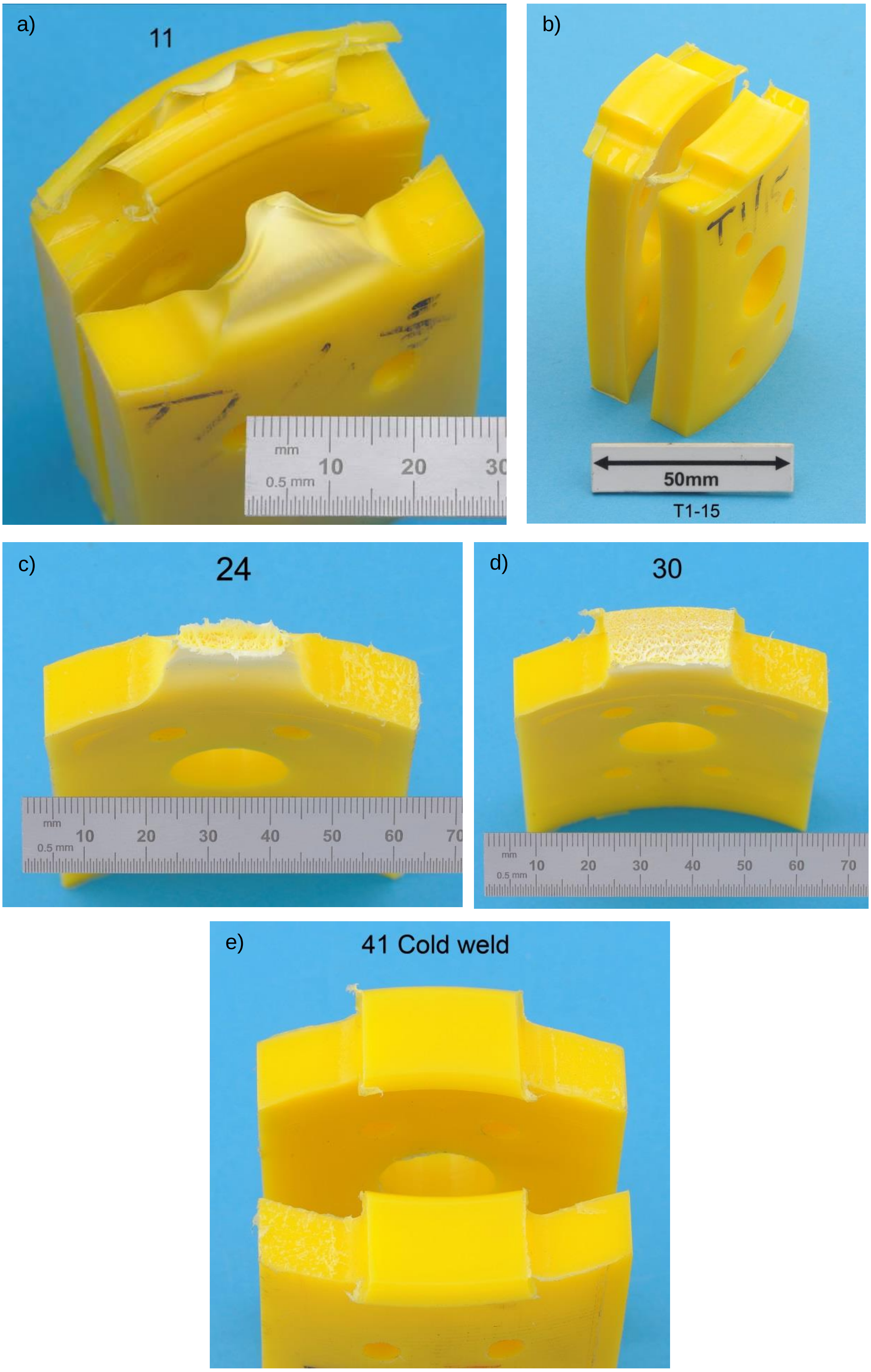


Figure 80 Fracture surfaces of tensile specimens from butt fusion welds in 180mm pipe containing: a) no flaws; b) light talc contamination; c) light sand contamination; d) heavy sand contamination; and e) cold weld.

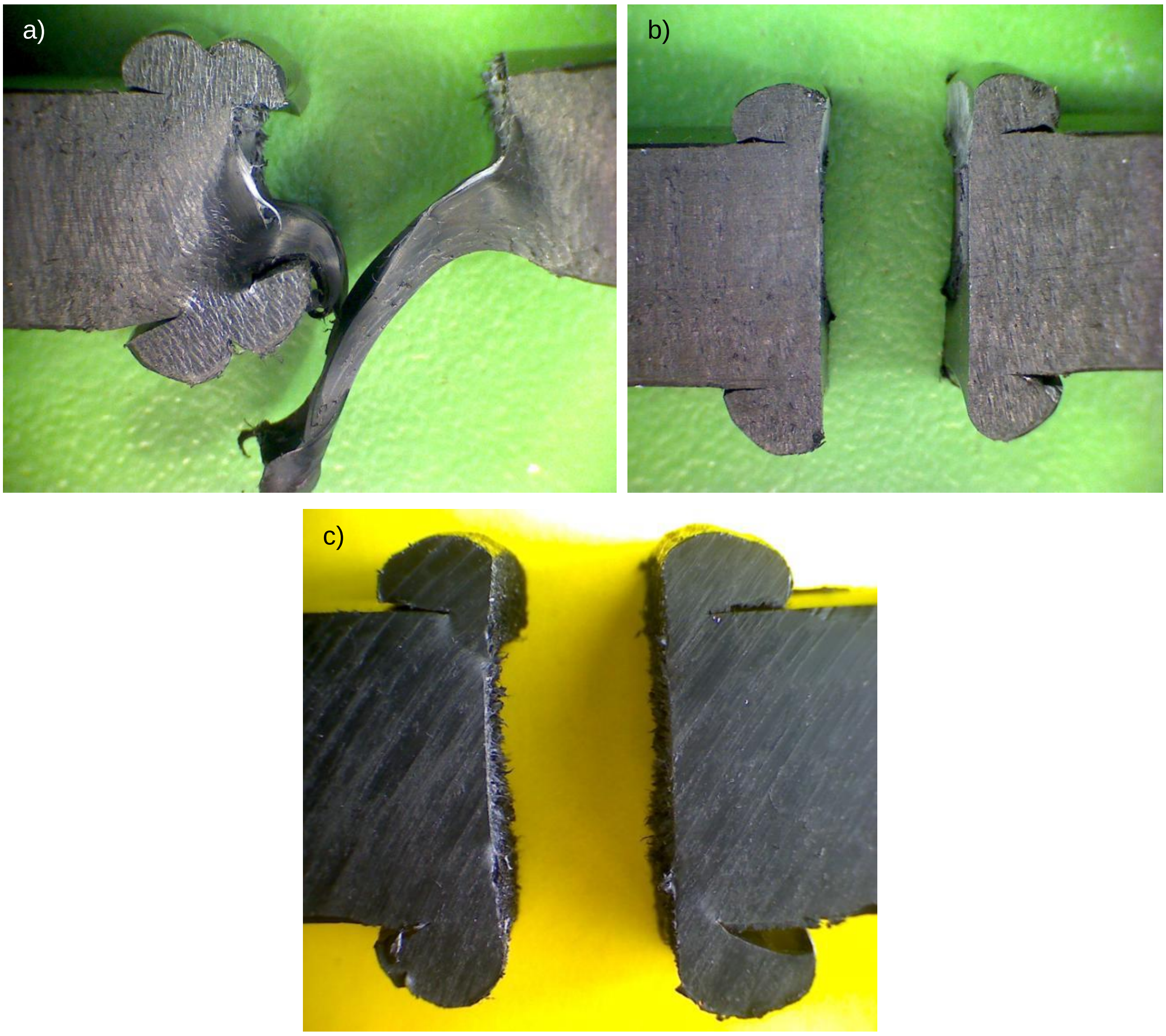


Figure 81 Fracture surfaces of tensile creep rupture specimens from butt fusion welds in 225mm pipe containing: a) no flaws; b) light talc contamination; and c) medium sand contamination.

Table 5 Results of whole pipe tensile creep rupture tests on butt fusion joints in 180mm PE80 pipes

Weld No.	Flaw description	Time to failure, hrs	Failure mode
13	None	3500	Test ongoing
16	Light talc	100	Test ongoing
19	Medium talc	717.7	Brittle
20	Medium talc	1200	Test ongoing
22	Heavy talc	160.8	Brittle
23	Heavy talc	111.5	Brittle
39	Cold weld	0*	Brittle

* failed before test load reached

Table 6 Results of peel decohesion tests

Material/ Pipe size	Flaw description	Specimen No.	Side	% interface failure
PE100 / 225mm	Light sand	49-1	A	100
		49-2	A	100
		49-3	A	100
		49-4	A	81
	Medium sand	50-1	A	100
		50-2	A	100
		50-3	A	100
		50-4	A	100
	Heavy sand	51-1	A	100
		51-2	A	100
		51-3	B	100
		51-4	B	100
	Cold weld	60-1	A	100
		60-2	A	31
		60-3	B	100
		60-4	B	100
PE80 / 355mm	Light sand	162-1	A	19
		162-2	A	73
	Heavy sand	162-3	B	100
		162-4	B	100
	Cold weld	167-1	A	100
		167-2	A	100
		167-3	B	100
		167-4	B	100
PE100 / 450mm	Cold weld	155-1	A	100
		155-2	A	100
		155-3	B	100
		155-4	B	100

Table 7 Results of crushing decohesion tests

Pipe size / Material	Flaw description	Average % ductile / no failure
180mm PE80	2mm aluminium disc	92
	4mm aluminium disc	94
	8mm aluminium disc	93
	15mm aluminium disc	96
	25mm aluminium disc	92
	50mm aluminium disc	92
	Under-penetration A	79
	Under-penetration B	76
	Under-penetration C	69
225mm PE100	2mm aluminium disc	94
	4mm aluminium disc	92
	8mm aluminium disc	94
	15mm aluminium disc	95
	25mm aluminium disc	93
	50mm aluminium disc	94
	Under-penetration A	76
	Under-penetration B	69
	Under-penetration C	62
355mm PE 80	2mm aluminium disc	89
	8mm aluminium disc	95
	Under-penetration A	88
	Under-penetration B	86
	Under-penetration C	72
450mm PE100	2mm aluminium disc	94
	4mm aluminium disc	98
	8mm aluminium disc	97
	15mm aluminium disc	97
	25mm aluminium disc	97
	50mm aluminium disc	96
	Under-penetration A	84
	Under-penetration B	75
	Under-penetration C	71

Table 8 Summary of results of creep rupture tests on specimens from EF welds

Pipe size / material	Flaw description	Geometric mean time to failure, hours	Failure position
180mm / PE80	None	34.7	Plane of heating wires
	Light talc	1.6	Fusion plane
	Medium talc	0.1	Fusion plane
	Heavy talc	0.01*	Fusion plane
	Light sand	17.0	Plane of heating wires
	Medium sand	3.2	Fusion plane
	Heavy sand	0.01*	Fusion plane
	Cold weld	0.01*	Fusion plane
225mm / PE100	None	53.5	Plane of heating wires
	Light talc	22.1	Fusion plane
	Medium talc	5.0	Fusion plane
	Heavy talc	1.1	Fusion plane
	Light sand	28.8	Mixed
	Medium sand	0.01*	Fusion plane
	Heavy sand	0.01*	Fusion plane
	Cold weld	0.01*	Fusion plane
355mm/ PE80	None	41.3	Plane of heating wires
	Light sand	0.5	Fusion plane
	Heavy sand	0.01*	Fusion plane
	Cold weld	1.0	Mixed
450mm / PE100	Cold weld	0.01*	Fusion plane
710mm / PE100	None	20.2	Mixed
	Cold weld	0.01*	Fusion plane

(* ruptured during loading)

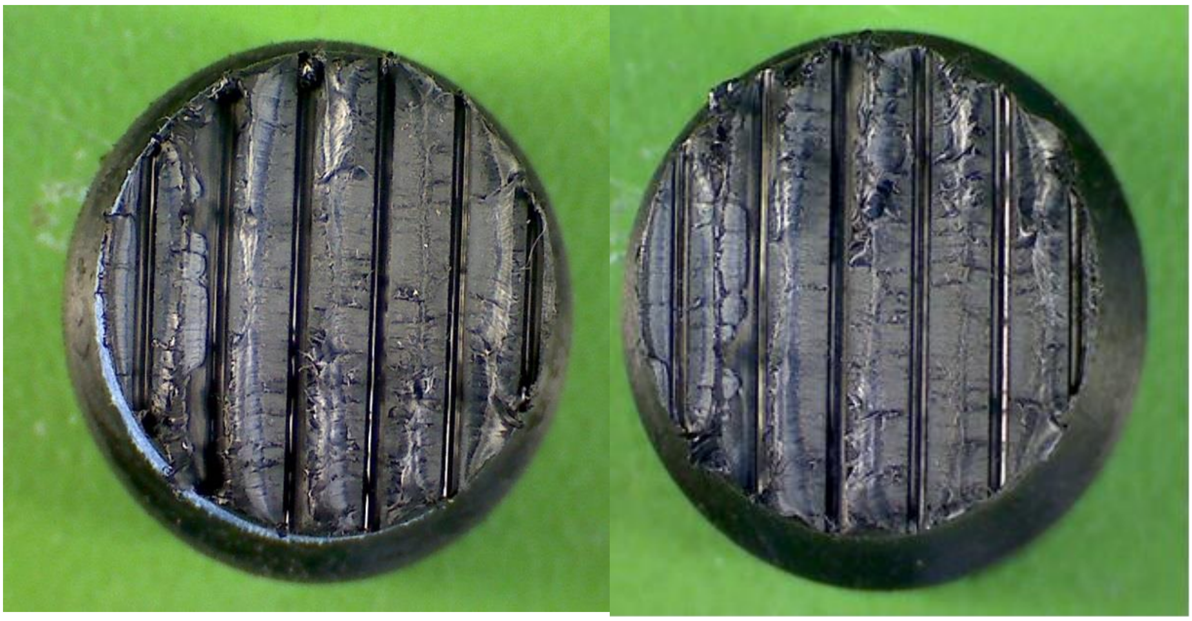


Figure 82 Typical fracture surface of an EF tensile creep rupture test specimens where rupture has occurred in the plane of the heating wires.

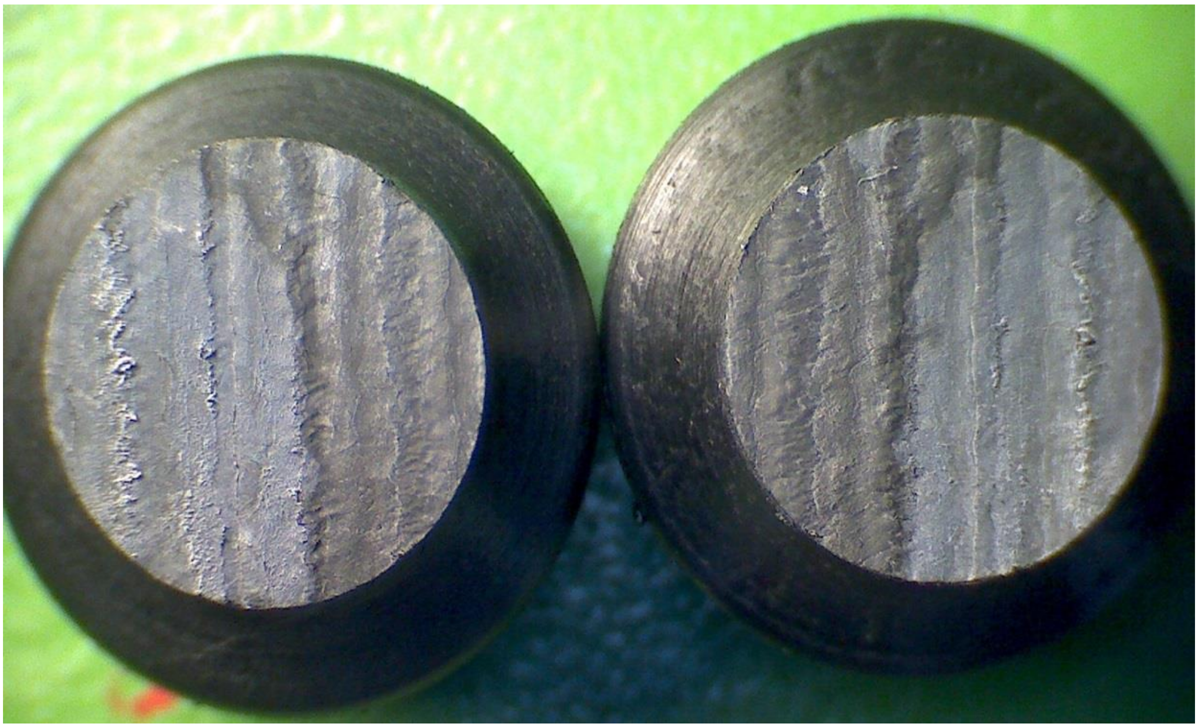


Figure 83 Typical appearance of an EF tensile creep rupture test specimens where rupture has occurred in the fusion plane due to talc contamination.

Figure 84 Typical appearance of an EF tensile creep rupture test specimens where rupture has occurred in the fusion plane due to sand contamination.

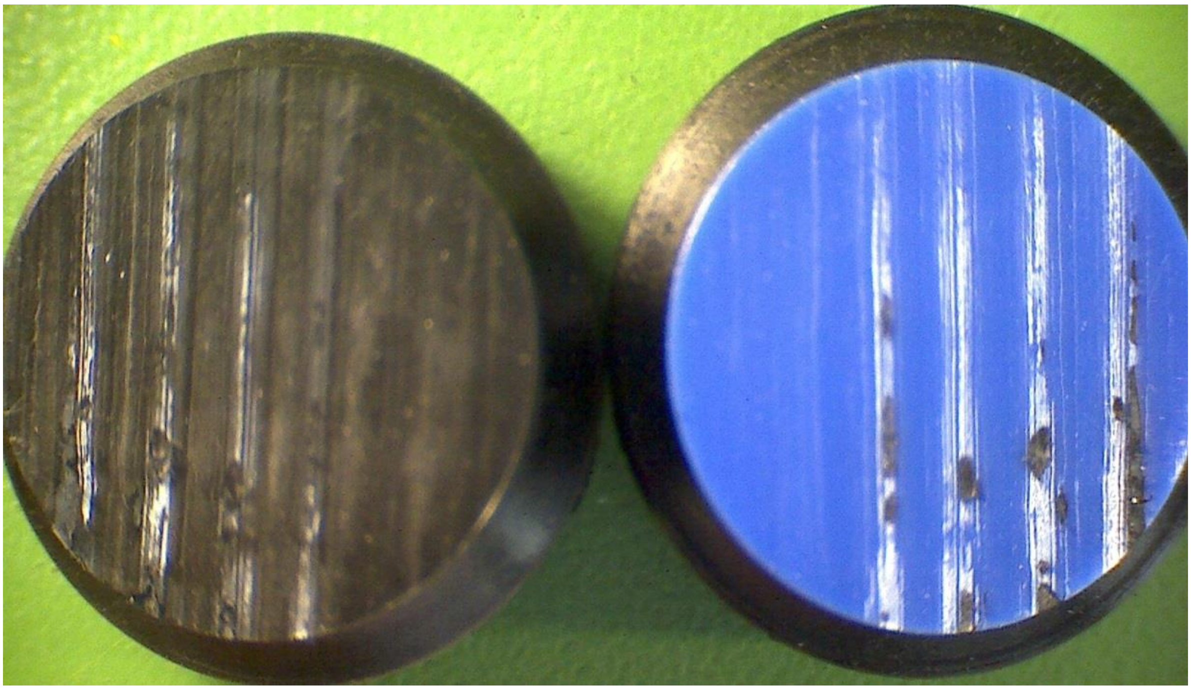


Figure 85 Typical appearance of a tensile creep rupture test specimens from a cold EF weld.

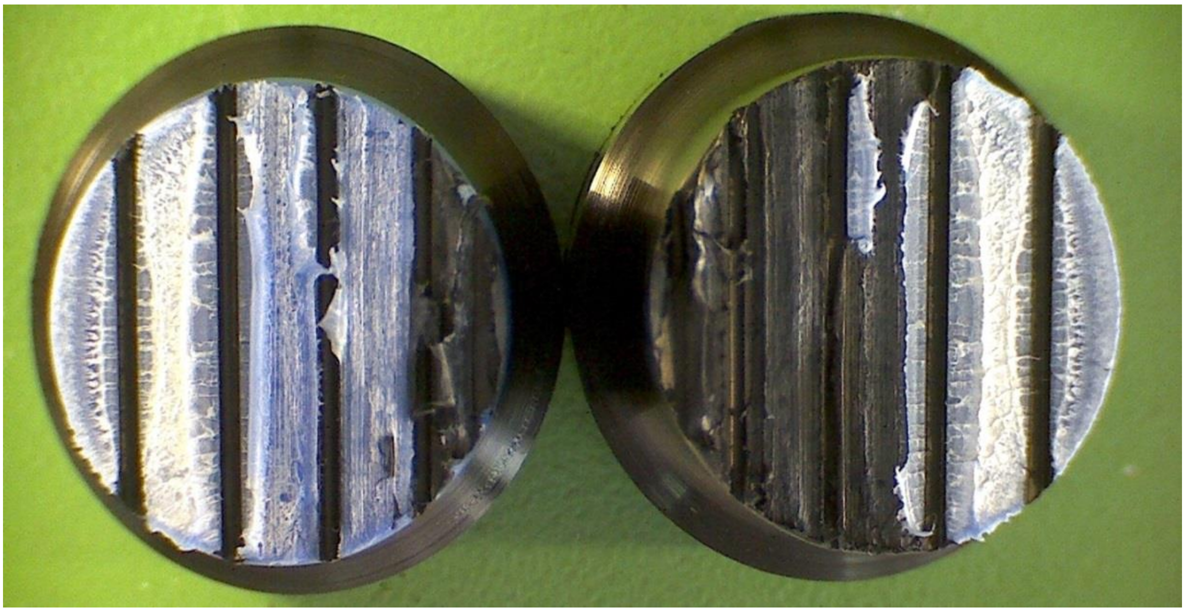


Figure 86 Fracture surface of a tensile creep rupture test specimen from the 710mm EF joint containing no flaws.

Table 9 Summary of results of hydrostatic pressure tests at 80°C on EF welds

Pipe size / material	Flaw description	Geometric mean time to failure, hours	Failure position
180mm / PE80	Cold weld	0	Failed during filling
	50mm Al disc	>5360	No failure, test stopped
	Under-penetration A	>5360	
	Under-penetration B	>5360	
	Under-penetration C	>5360	
225mm / PE100	Cold weld	0	Failed during filling
	50mm Al disc	1988	Circumferential crack in EF coupler
	Under-penetration A	523	
	Under-penetration B	827	
	Under-penetration C	673	

(* ruptured during loading)

Table 10 Summary of percentage contamination levels in butt fusion welds from the XPS analysis

Pipe size / Material	Flaw description	Average % contamination
180mm SDR17 / PE80	Light talc	8.7
	Medium talc	9.1
	Heavy talc	9.4
	Light sand	3.2
	Medium sand	0.8
	Heavy sand	2.1
225mm SDR11 / PE100	Light talc	10.9
	Medium talc	14.1
	Heavy talc	22.3
	Light sand	1.7
	Medium sand	2.7
	Heavy sand	6.7
355mm SDR11 / PE80	Light talc	1.4
	Medium talc	1.3
	Heavy talc	4.0
450mm SDR17 / PE100	Light talc	5.5
	Medium talc	7.5
	Heavy talc	18.0
710mm SDR17 / PE100	Light talc	1.0
	Medium talc	1.3
	Heavy talc	1.8

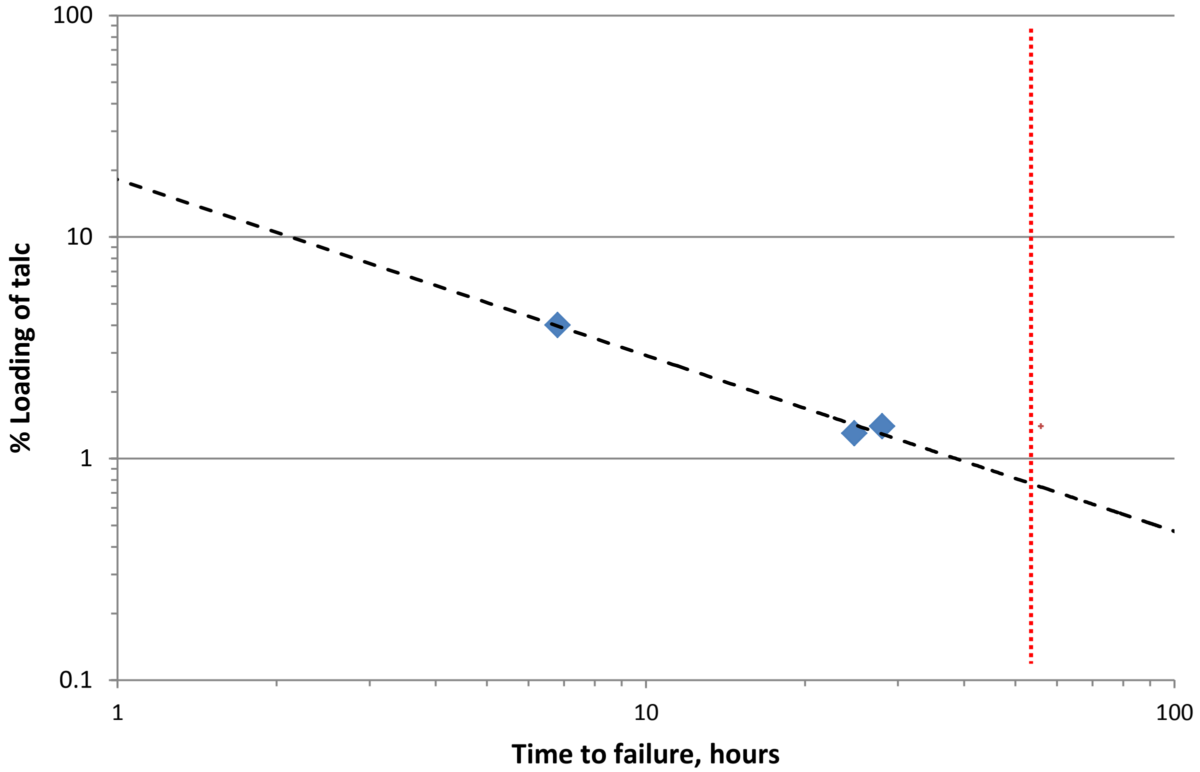


Figure 87 Graph of percentage talc contamination level against time to failure in the specimen creep rupture tests on butt fusion welds in 355mm PE pipes.

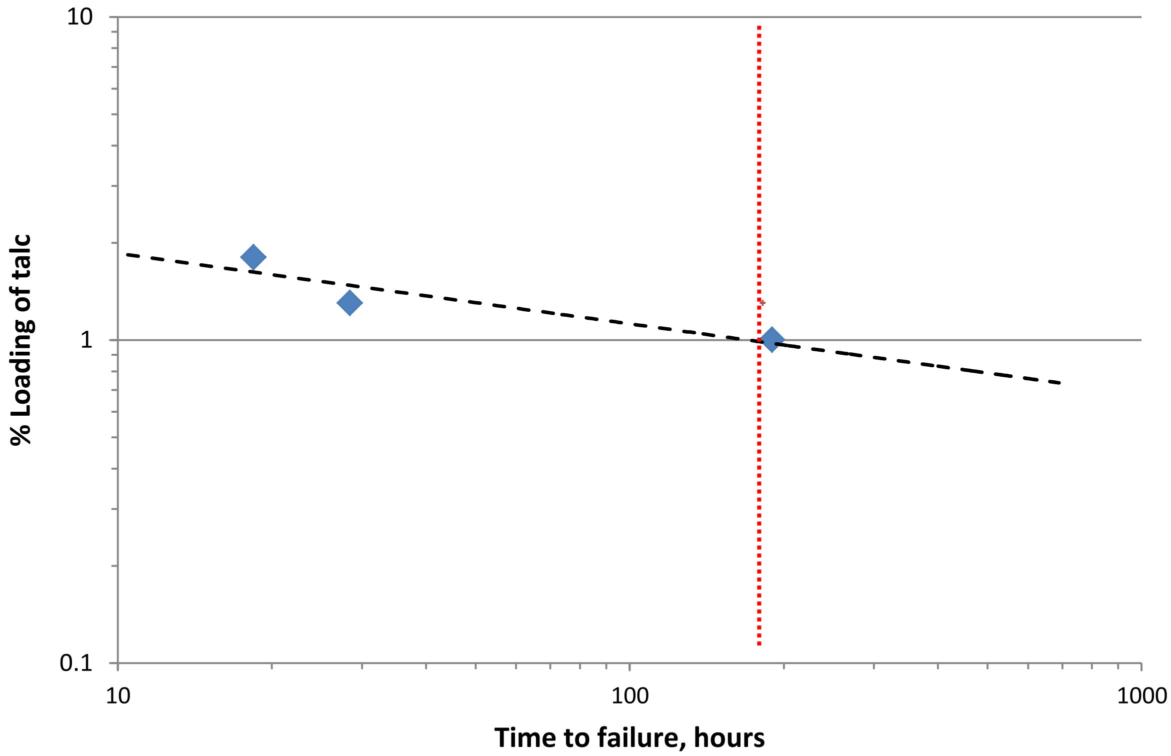


Figure 88 Graph of percentage talc contamination level against time to failure in the specimen creep rupture tests on butt fusion welds in 710mm PE pipes.

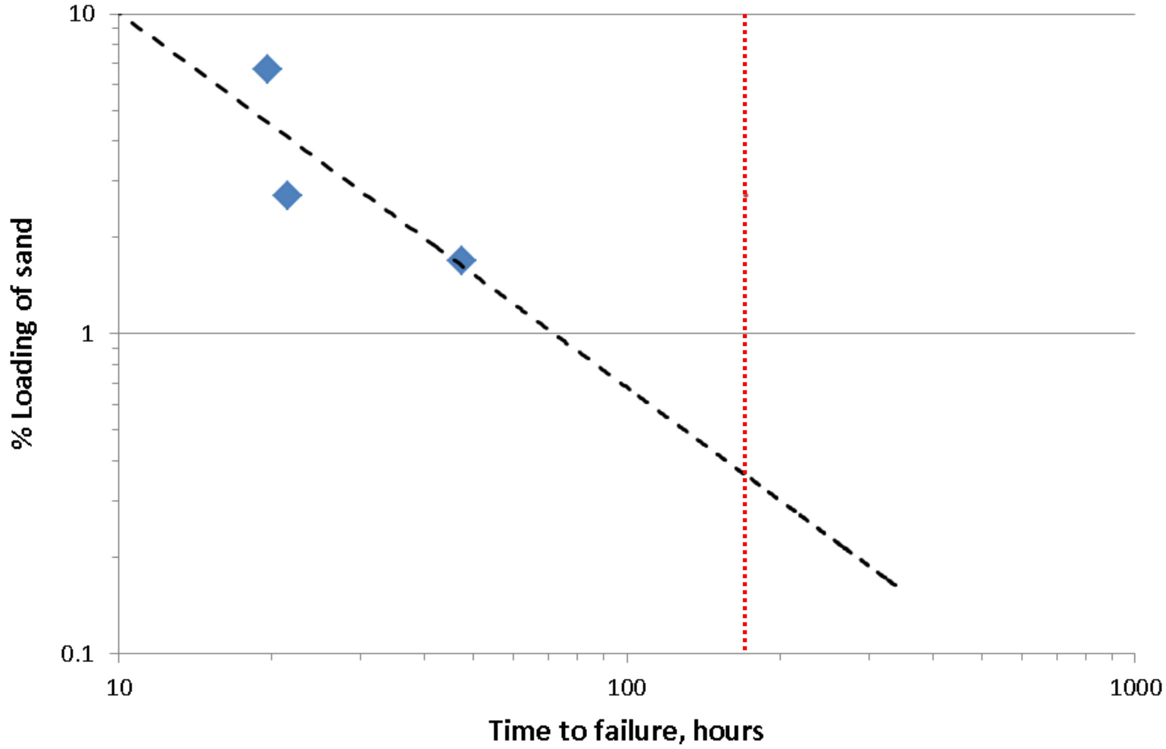


Figure 89 Graph of percentage sand contamination level against time to failure in the specimen creep rupture tests on butt fusion welds in 225mm PE pipes.

Table 11 Summary of critical flaw sizes and contamination levels

Joint type	Flaw type	Pipe size / material	Critical value
Butt fusion	Talc	180mm PE80	< 8.7%
		225mm PE100	1.2%
		355mm PE80	0.8%
		450mm PE100	4.6%
		710mm PE100	1.0%
	Sand	180mm PE80	< 3.2%
		225mm PE100	0.4%
	Cold weld	180mm PE80	Not acceptable
		225mm PE100	Not acceptable
		355mm PE80	Not acceptable
		450mm PE100	Not acceptable
Electrofusion	Talc	180mm PE80	< 8.7%
		225mm PE100	< 10.9%
	Sand	180mm PE80	0.8 – 3.2%
		225mm PE100	< 1.7%
	Al disc	180mm PE80	> 50mm diameter
		225mm PE100	> 50mm diameter
		355mm PE80	> 8mm diameter
		450mm PE100	> 50mm diameter
	Pipe under-penetration	180mm PE80	> 20% into fusion zone
		225mm PE100	< 0% into fusion zone
		355mm PE80	20% into fusion zone
		450mm PE100	20% into fusion zone

Figure 90 CAD design of the prototype ultrasonic instrument.

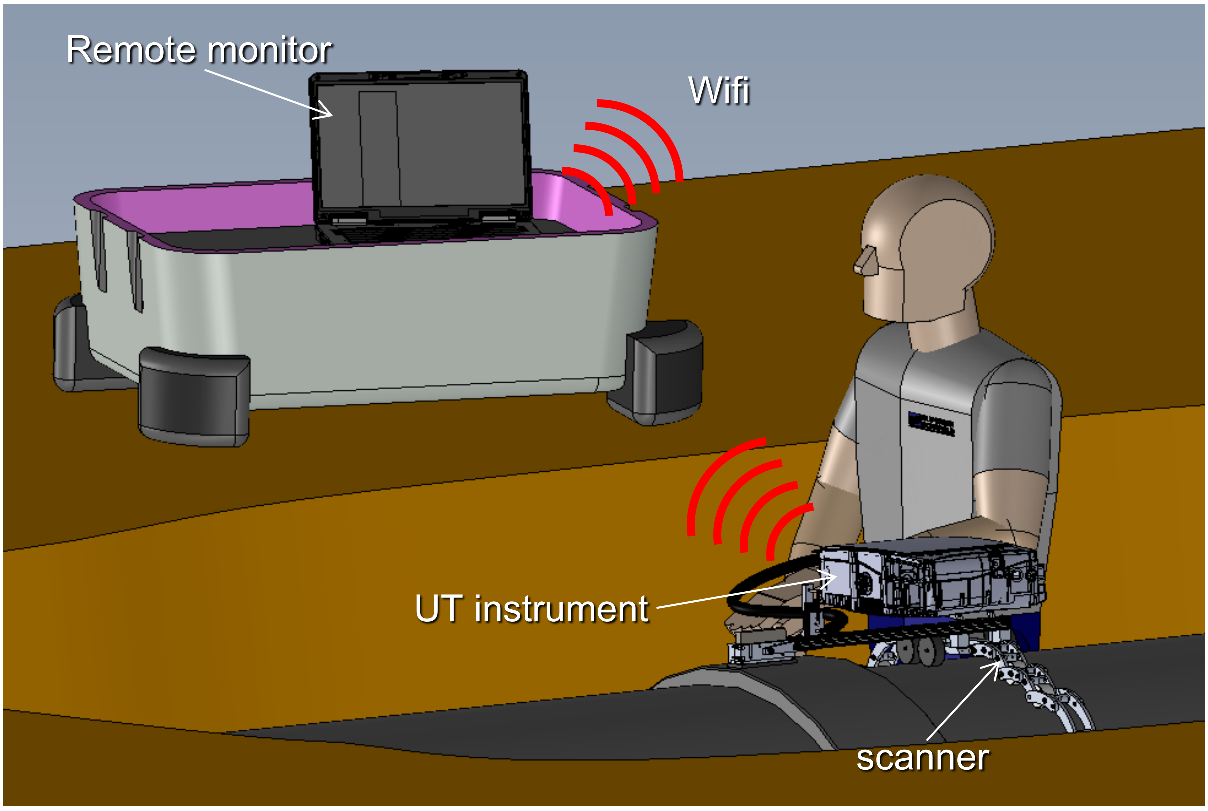


Figure 91 Proposed inspection set-up with the UT instrument attached directly to the scanner.

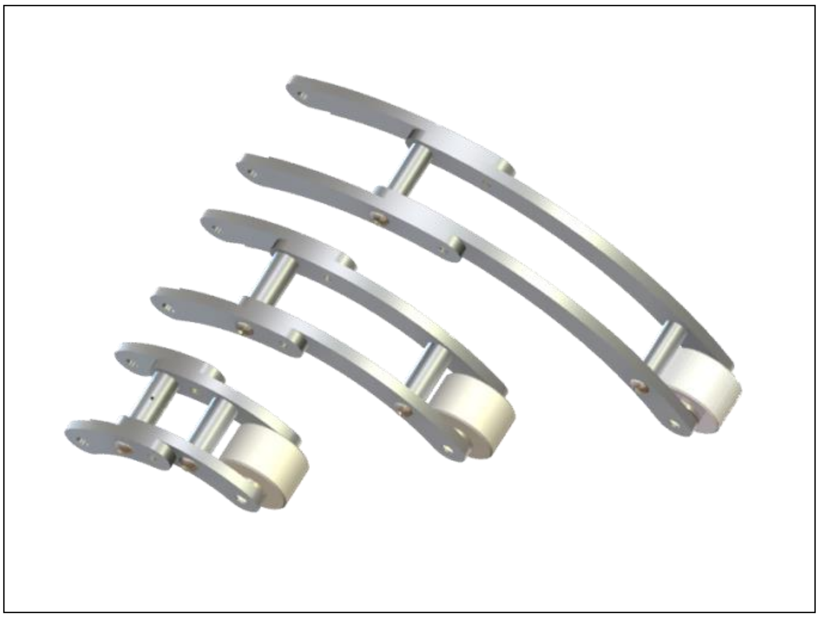


Figure 92 Three sizes of chain links for the scanning system.

Table 12 Number of different links required for each pipe size

	Number of links		
Pipe outside diameter, mm	**Small**	**Medium**	**Long**
180	2	2	-
225	-	4	-
355	-	-	4
450	-	2	4
710	2	-	8

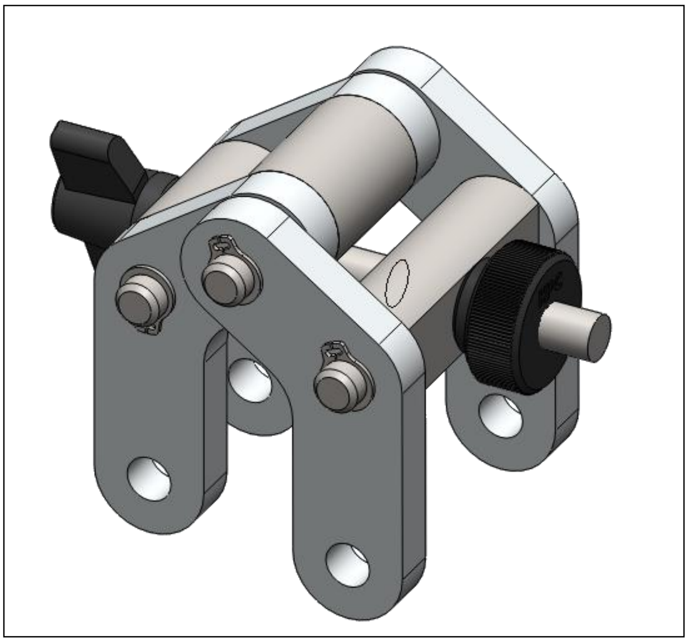


Figure 93 Tightening mechanism for the scanning system.

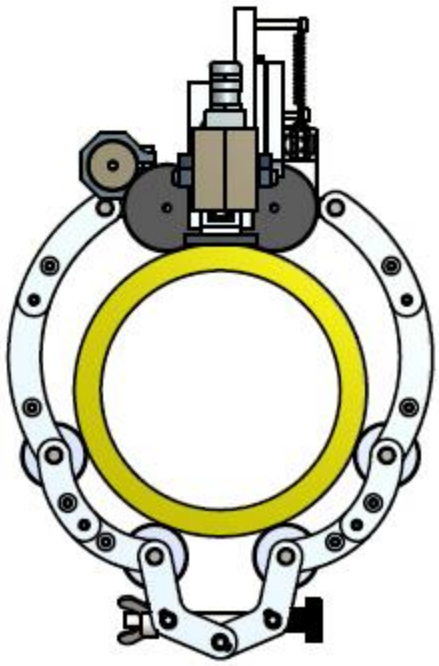


Figure 94 Scanner mounted on a 180mm diameter pipe.

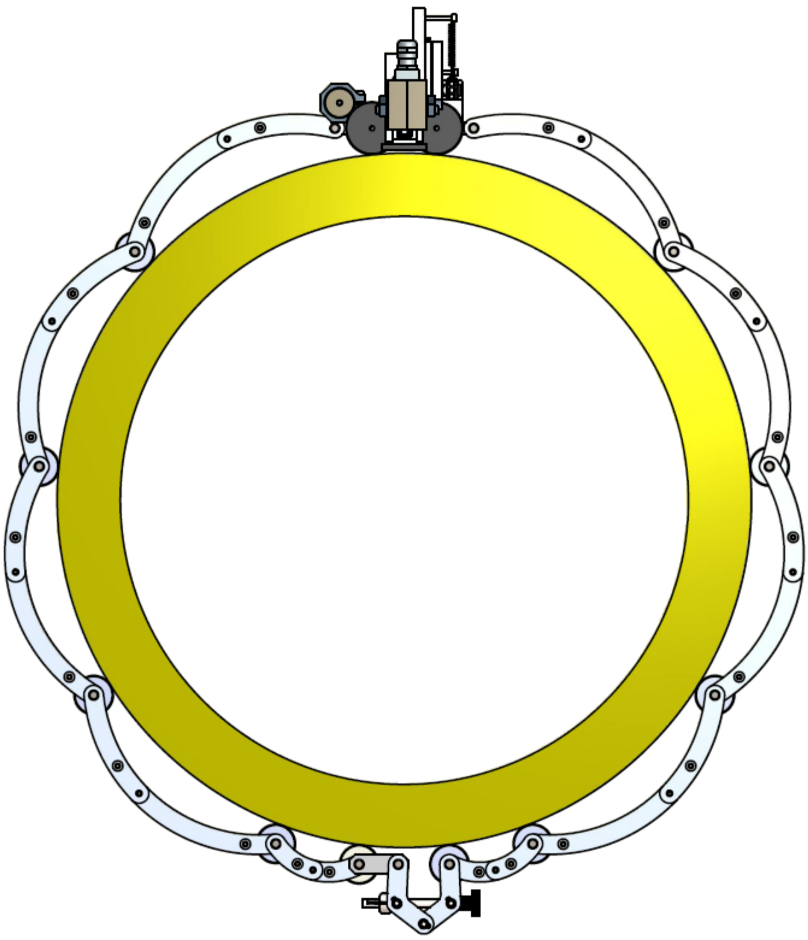


Figure 95 Scanner mounted on a 710mm diameter pipe.

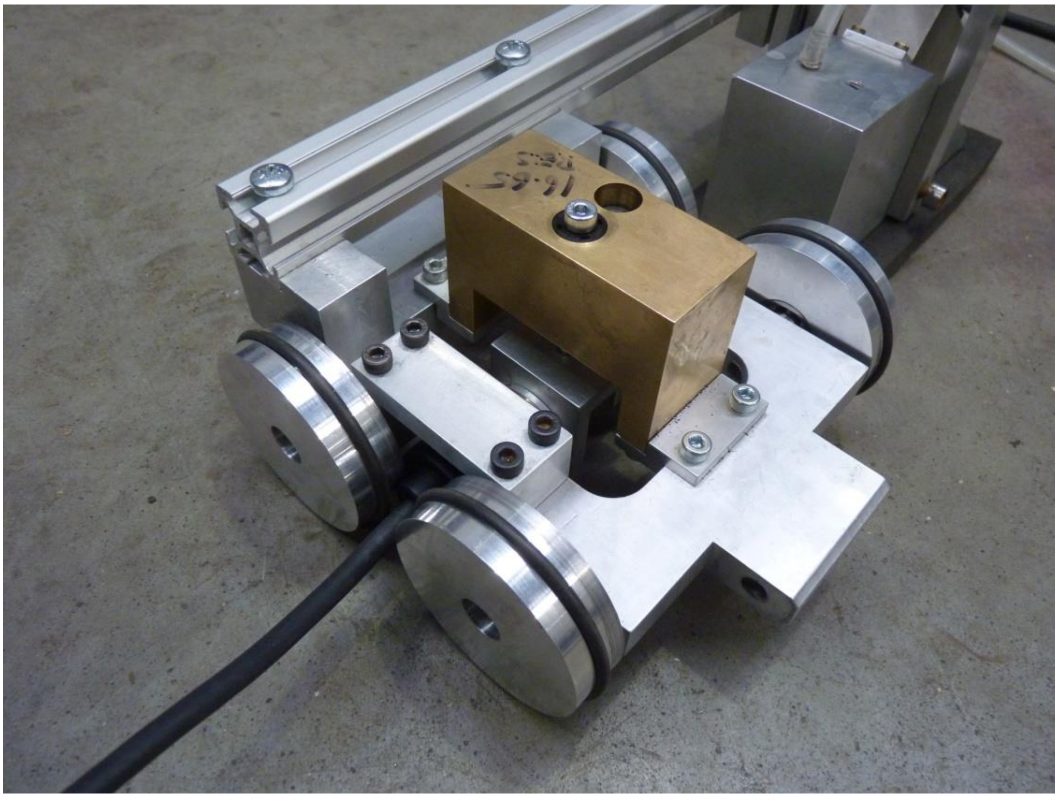


Figure 96 Carriage for inspecting small diameter pipes.

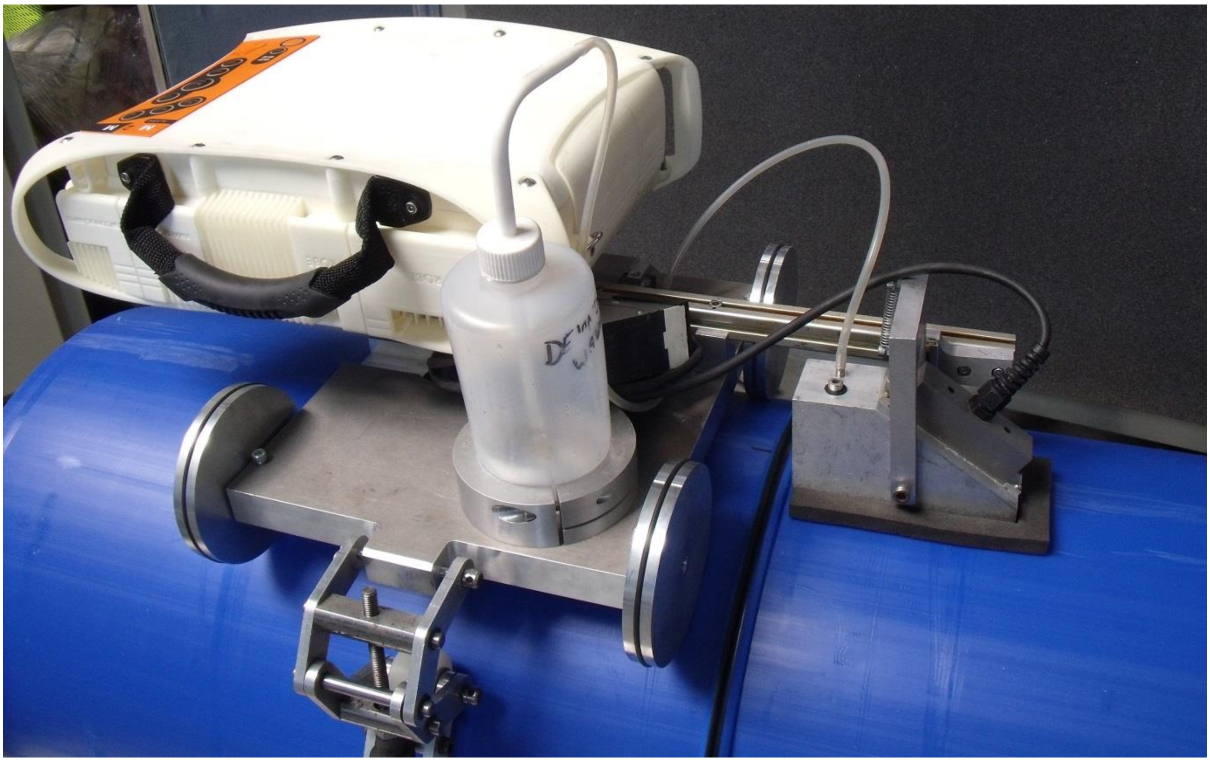


Figure 97 Carriage for inspecting large diameter pipes, with ultrasonic instrument and water reservoir attached.

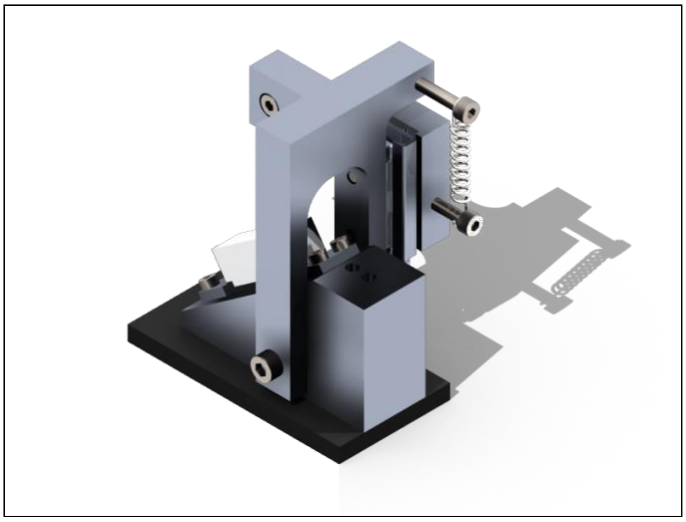


Figure 98 Probe holder for butt fusion joints, with the probe/wedge assembly attached.

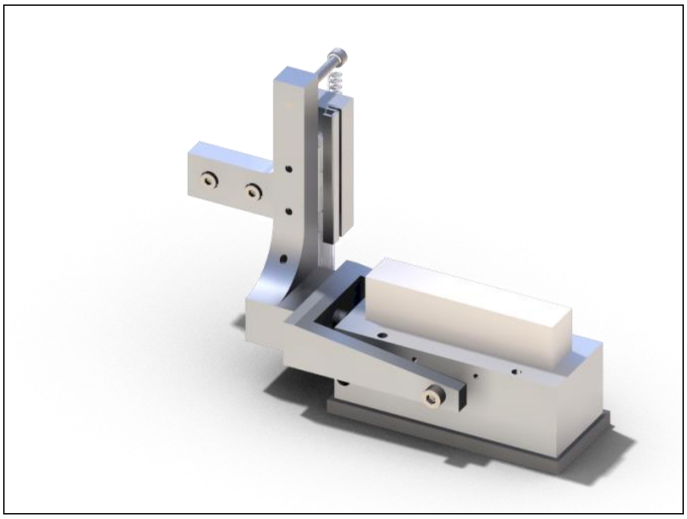


Figure 99 Probe holder for EF joints, with the probe/wedge assembly attached.

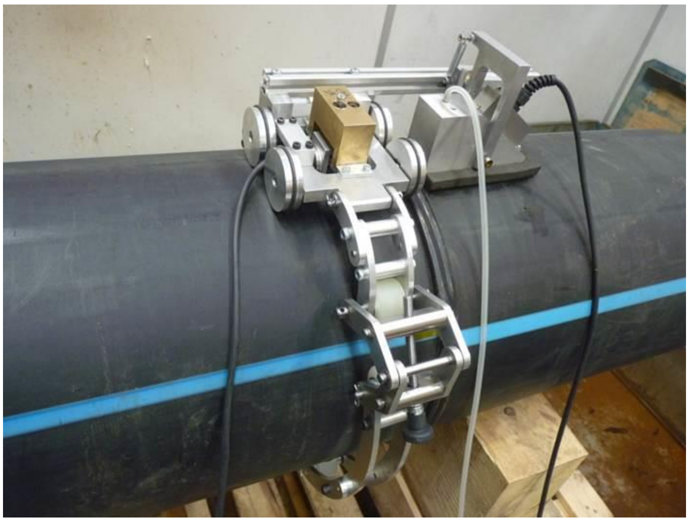


Figure 100 Final inspection system for small diameter pipes.

Phased array inspection report				250mmOD	
Date:	16/10/2012				
Pipe	16				
Side B					
Defect no.	Wire(s)	Start circumferential (mm)	Stop circumferential (mm)	Type of defect	Comment
1	6 to 9	45	88	Void	
2	4	116	142	Void	
3	5	138	171	Void	
4	5	205	227	Void	
5	8	236	265	Void	
6	5 to 7	301	310	Scatter/Planar	Below wires
7	2 to 9	310	243	Wire disp.	Radial
8	6 to 8	343	391	Scatter/Planar	Below wires
9	5	420	430	Void	
10	6 to 8	467	556	Scatter/Planar	Below wires
11	6	588	678	Void	
12	3 to 7	678	751	Wire disp.	Radial
13	7	906	911	Void	

Figure 101 Typical inspection report from the assessment trials at Radius Systems.

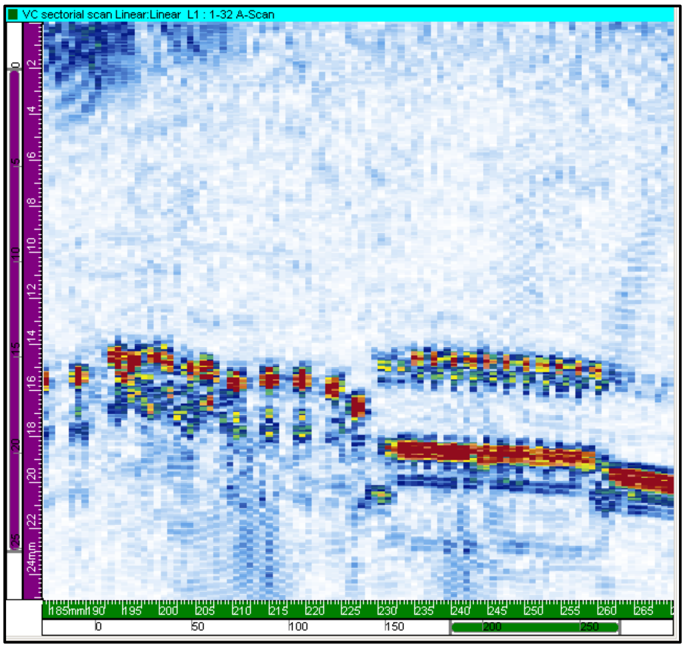


Figure 102 Typical image of an EF joint from the assessment trials at Radius Systems, showing a flaw indication below the heating wires.

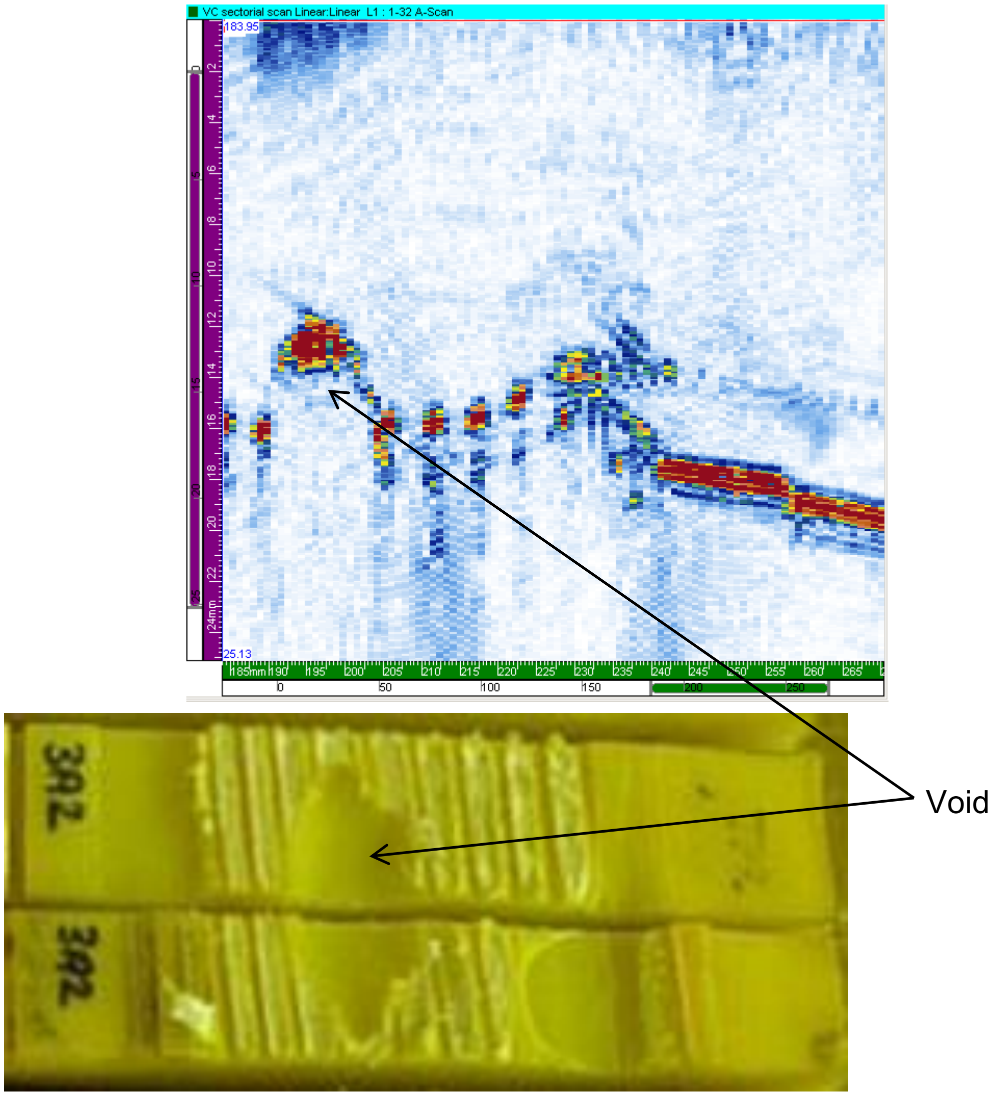


Figure 103 Example of a comparison between the ultrasonic image and the fracture surface of a peel test specimen from an EF joint supplied by Radius Systems.

Figure 104 Inspection of a butt fusion joint at Plasflow.

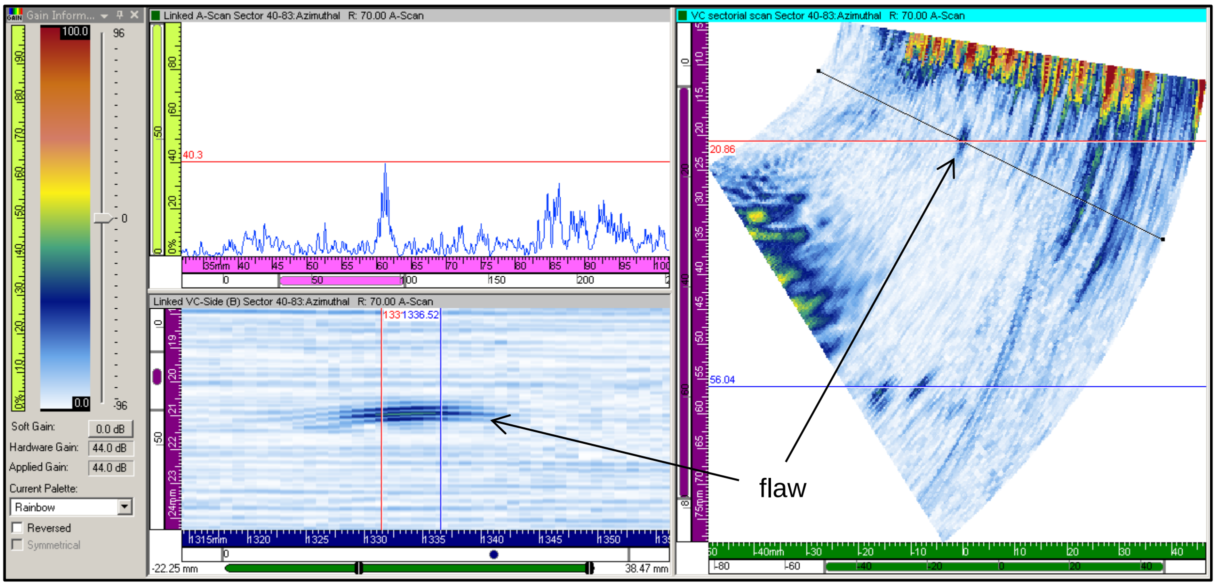


Figure 105 Indication of a flaw in a butt fusion weld at Plasflow.

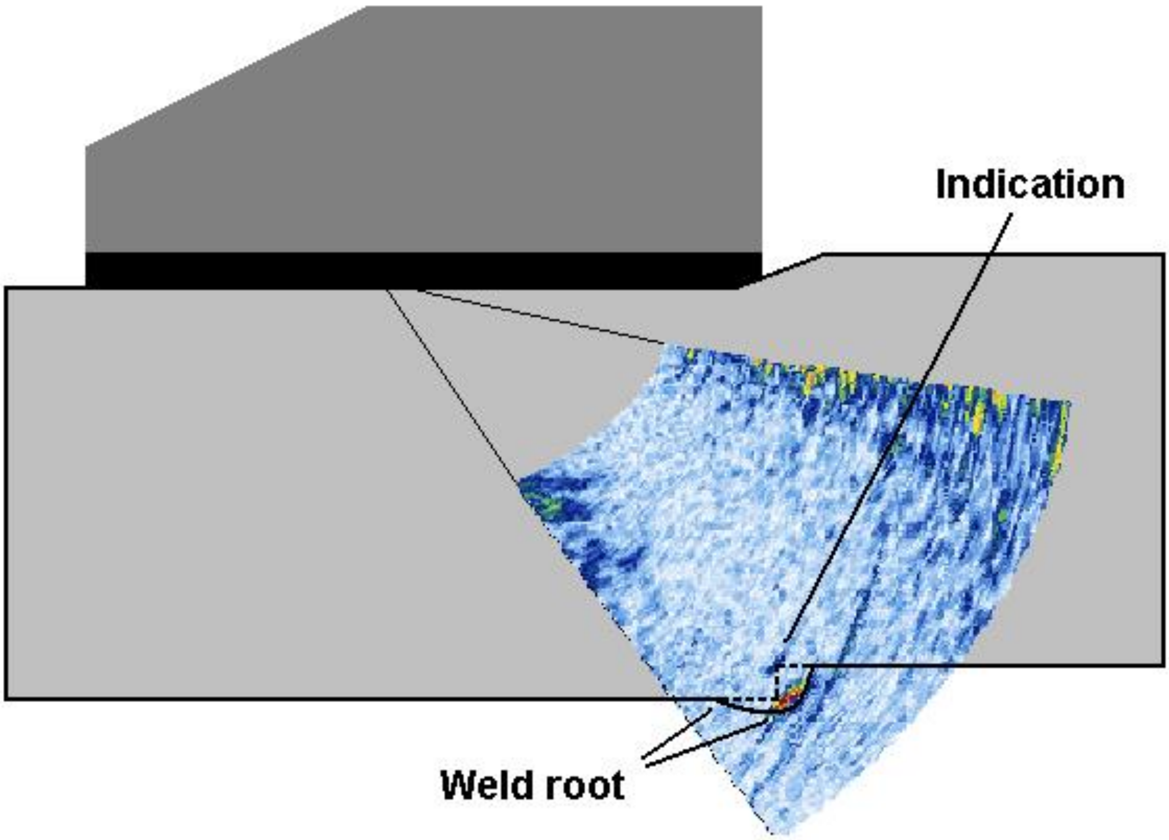


Figure 106 Indication from the step in the internal pipe surfaces in an axially misaligned butt fusion weld.

Figure 107 Inspection trials of EF welds at E.ON Ruhrgas.

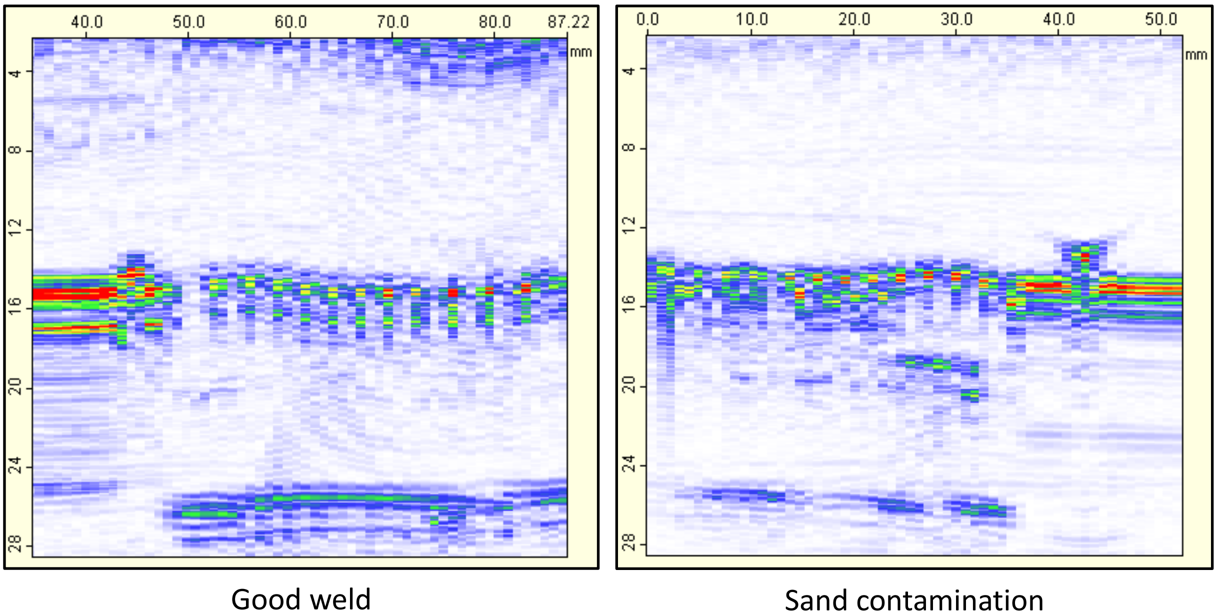


Figure 108 Comparison of ultrasonic images of a good weld and a sand contaminated weld in 110mm EF joints at E.ON Ruhrgas.

Figure 109 Field trial at a hydroelectric power station in Bethesda, UK.

Figure 110 Field trial at a gas pipe installation in Sheffield, UK.

Table 13 Training hours per subject for each programme

Subject	Hours of Training		
	Programme 1	**Programme 2**	**Programme 3**
1. General knowledge	-	3	2
2. Terminology, physical principles and fundamentals of ultrasonics and PAUT	-	8	6
3. Testing techniques and their limitations for electrofusion and butt fusion welds in PE pipes	4	10	10
4. Equipment and accessories	3	5	5
5. Calibration of the testing system	3	3	3
6. Procedures and acceptance criteria	3	6	6
7. Recording and evaluation of results	3	5	5
TOTAL	16	40	37

Figure 111 TestPEP project logo.

DEVELOPMENT & VALIDATION OF AN AUTOMATED NON-DESTRUCTIVE EVALUATION (NDE) APPROACH FOR TESTING WELDED JOINTS IN PLASTIC PIPES

TestPEP

The TestPEP Project addresses the global plastic pipeline distribution industry sector for gas and water and also the large potential market of civil nuclear power generation and reprocessing.

TestPep is a 36-month project involving several organisations from United Kingdom, Germany, Portugal, Lithuania, Spain, Italy and France.

The best method of alleviating the risk of leaks and maintaining the quality of welded joints in plastics pipes is to inspect them prior to service. However, there is no accepted NDE method for the examination of plastic pipes.

This has caused a risk to both the public and the plastic pipe industry. Furthermore, the environmental risks, with leaks of effluent, gas and water are severe.

There is a clear industrial need for a device to inspect all varieties of plastic pipes, fittings and sizes in order to detect defects and use this data to predict the life of welded pipe joints

www.ewf.be/TestPep.aspx

DEVELOPMENT & VALIDATION OF AN AUTOMATED NON-DESTRUCTIVE EVALUATION (NDE) APPROACH FOR TESTING WELDED JOINTS IN PLASTIC PIPES

TYPICAL SITE CONDITIONS FOR INSTALLING PLASTIC PIPES.

OBJECTIVES

Development and validation of automated non-destructive(NDE) System for testing welded joints in plastic pipes

THE TECHNICAL PROBLEM

Being relatively new structural materials, NDE of plastics is challenging, due to high attenuation and low ultrasonic velocity of the material.

INDUSTRIAL NEED

The industrial need is clear for a device that can inspect all manner of plastic pipes, detecting defects and predict life of welded pipe joints.

THE PROPOSED SOLUTION

Development of phased array ultrasonic NDE procedures, techniques and equipment for volumetric examination of welded joints in plastic pipes of diameters up to 1m.

An automated inspection system able to inspect pipe-to-pipe and pipe-to-fitting butt and socket joints will also be developed.

In parallel, the significance of flaw size and quantity will be established in relation to service requirements. This will be achieved by long-term mechanical testing of joints containing known flaws, and comparison with results for welds containing no flaws.

PARTNERS:

"This Project has received funding from the European Community's Seventh Framework Programme managed by REA – Research Executive Agency (FP7-SME-2008-2) under grant agreement no. 243791. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein."

Figure 112 TestPEP flyer (in English).

DEVELOPMENT & VALIDATION OF AN AUTOMATED

NON-DESTRUCTIVE

EVALUATION (NDE) APPROACH FOR TESTING

WELDED JOINTS IN PLASTIC PIPES

TestPEP

TestPEP è un Progetto Europeo, finanziato dalla UE nell'ambito del 7° Programma Quadro, rivolto in particolare al settore del trasporto e distribuzione di acqua e gas nonché al potenziale mercato dell'impiantistica industriale quali la generazione di energia e l'industria chimica e petrolchimica

Il Progetto ha la durata di 3 anni e si avvale della partecipazione di diverse organizzazioni di Regno Unito, Germania, Portogallo, Lithuania, Spagna, Francia e Italia

Le tubazioni in plastica trovano generalmente un largo impiego nelle reti di distribuzione di acqua e gas, dove eventuali perdite di fluido, seppur dannose, non comportano gravi danni per l'ambiente e rischi per la sicurezza. L' utilizzo in condizioni più severe come il trasporto di fluidi ad alto rischio (infiammabilità, , esplosività, corrosività, alte pressioni, etc) richiede, oltre ad idonei standard costruttivi, la disponibilità di metodi di Controllo non Distruttivo altamente affidabili e di standardizzati criteri di accettazione dei difetti, entrambi attualmente non disponibili o internazionalmente non riconosciuti.

Il sistema sviluppato dal progetto consente l'effettuazione del controllo non distruttivo delle giunzioni nel corso della messa in opera delle tubazioni, e attraverso i criteri di accettabilità messi a punto, la valutazione del grado di integrità strutturale delle giunzioni, favorendo la riduzione del rischio di perdite nel tempo e l'estensione della vita dell'impianto. Tali potenzialità possono incentivare la diversificazione di impiego delle tubazioni in plastica con indubbi benefici per il settore e per l'industria in generale.

DEVELOPMENT & VALIDATION OF AN AUTOMATED NON-DESTRUCTIVE EVALUATION (NDE) APPROACH FOR TESTING WELDED JOINTS IN PLASTIC PIPES

TYPICAL SITE CONDITIONS FOR INSTALLING PLASTIC PIPES

Obiettivo

Sviluppo e validazione di un sistema automatico per il controllo di giunti saldati in tubazioni di materiale plastico

La problematica

Le tubazioni in plastica offrono, per un vasto range di applicazioni indubbi vantaggi rispetto ai materiali tradizionalmente utilizzati, in particolare per il trasporto e distribuzione di gas , acqua e liquidi corrosivi. Il ridotto peso ed una certa flessibilità comporta una riduzione dei costi sia di fabbricazione che di messa in opera.
Il loro uso è però tuttora limitato a quei settori con indici di rischio bassi a causa della mancanza di affidabili metodologie di controllo dei giunti saldati.
L'utilizzo di tecniche ultrasonore risulta problematico a causa della forte attenuazione e la bassa velocità di propagazione degli ultrasuoni nel materiale. Questo progetto affronta quindi una sfida tecnologica con aspetti innovativi nel campo dei Controlli Non Distruttivi portando significativi benefici a vari settori industriali.

Soluzione proposta

Sviluppo di un sistema automatico, basato sulla tecnica UT phased array, per l' ispezione di giunzioni testa-testa e fittings e di una procedura automatica, per l' esame volumetrico on-line di giunti saldati di tubazioni in plastica di diametro fino a 1m.
Prove di laboratorio saranno condotte su giunti contenenti difetti conosciuti al fine di valutarne l'evoluzione nel tempo nelle reali condizioni di esercizio.

PARTNERS:

AEND, British Energy, Catania Ricerche, e.on Ruhrgas, CWI, HESSEL Ingenieurtechnik, TWI, Plastflow, Vermon

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Figure 113 TestPEP flyer (in Italian).

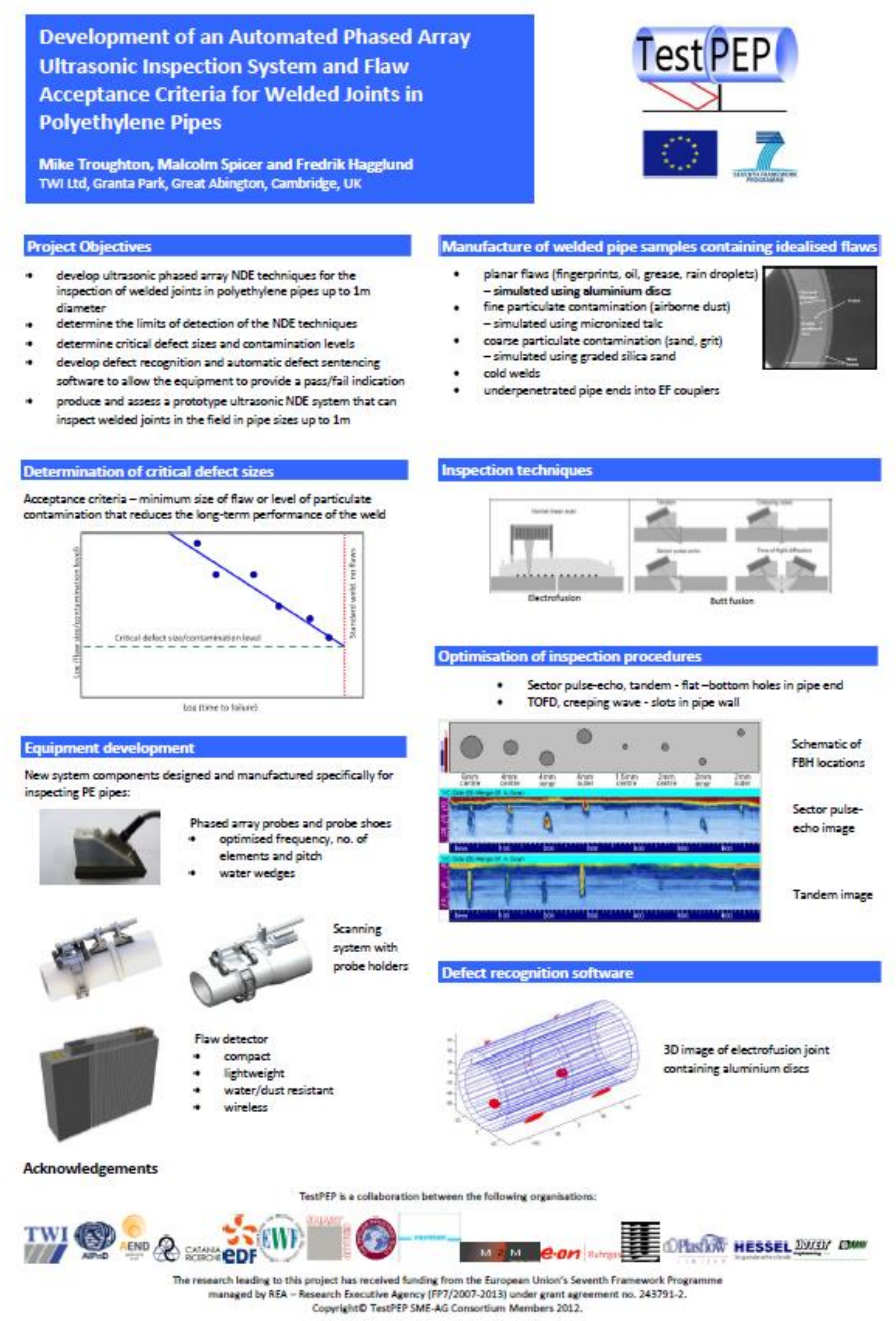

Figure 114 TestPEP poster (in English).

Figure 115 TestPEP poster (in Spanish).