EXPERTISE REPORT no. 11081

Requested by	:	STOCKHOLM VATTEN AB Mr. Tomas HELENIUS LM Torsgatan 26 S-106 36 STOCKHOLM
At the expense of	:	idem
Copy to	:	tomas.helenius@stockholmvatten.se
Subject	:	Evaluation of PE electrofusion couplers ø250 mm, ø560 mm and ø630 mm. Your order by e-mail of 9 January 2012.
Our reference	:	BEC 9206 and PV120007.doc
Invoice no.	:	20120152
Date of the report	:	23 February 2012
This report contains	:	18 pages + photos in annex

General remark

The test results are exclusively related to the products submitted to the tests and this report may, in no case, be considered as an approval of this product.
To warrant that the results would be representative of the product, as it is delivered or applied, conformity of the test pieces to the product should be assured.
The measurement uncertainty is known and available on request.
The test pieces are at your disposition during two months after the date of the report.
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EVALUATION OF PE ELECTROFUSION COUPLERS
ø250 MM, ø 560 MM AND ø 630 MM

1 Received material and references

The following PE electrofusion couplers and PE pipes were delivered by Stockholm-Vatten (Sweden) to Becetel on January 17th 2012.

Assembly no. 1: ø250 mm SDR 11 - ELOFIT

Marking:

- pipe : ... L 250x14,8 =16=
- coupler: IIP UNI 8 10 ELOFIT 250 PE100 SDR11 GAS EN 1555 WATER EN 12201 FUSION RANGE SDR 7,4 SDR 17,6

Colour of pipes: black and blue stripes;

Total length of assembly: 60 cm.

Assembly no. 2: ø560 mm SDR 11 - ELOFIT

Marking:

- Hand writing on the assembly: 11-110 Sv 1 13.23-13.40 Sv 2 13.40-14.51 CT 90 min
- pipe : ... code 1 11 =190111 ...
- coupler : Geco fusion system marker ..... Elofit
- sticker on endcap : STAR PE100 dia 560/100 Art no 44502561 SDR17

Colour of pipes: black with orange stripes;

Total length of assembly: 75 cm.

Assembly no. 3: ø630 mm SDR 17 - FRIALEN

Marking:

- pipe: -
- Coupler : FRIALEN safety fitting
- Hand writing on the assembly: G: Nynäsvägen

Colour of pipes: black with blue stripes;

Total length of assembly: 180 cm.

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2 Introduction

2.1 Order request no. 1 from Stockholm Vatten for investigation of an electrofusion coupler

2.1.1 Background

A water leak occurred in a five year old DN 630 SDR 17 PE pipe.
The installation was done by a contractor who has made many similar jobs. The leak occurred between the electrofusion coupler and one tube for unknown reasons.
The contractor has used a FRIATEC electrofusion coupler to rub together two cable ends. Before the pipeline was put into operation a pressure test was carried out without remarks. The pipeline is exposed to water pressure 6-8 bar during normal operation. The leak occurred in December 2011 and was repaired immediately.
The fusion coupler and pipes could be secured for examination.

2.1.2 Examination requirements

We want answers to the question why the leak occurred and how this electrofusion coupler could leak after five years of operation?
We want an investigation whether there is a problem with the electrofusion coupler or whether errors have been made during the welding.
We request a study within the framework of ISO 13954:1997 and a summary report on the cause of failure, written in English. The report will be sent via e-mail in the Word-format to our contact person.

Photo A

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2.2 Order Request no. 2 from Stockholm Vatten for investigation of fusion coupler

2.2.1 Background

A contractor has realized joints in sizes DN 250 and DN 560 on water pipes PE SDR 11. The contractor has (under his own initiative) used a rotating peel scraper. One can not see that the scraping passes beyond the sleeve edge. We observe also that the contractor has scraped with sandpaper.

2.2.2 Examination requirements

We want answers to the question if the contractor's welds will last as long as the PE tube, in this case, for a lifespan of 150 years.

We send over the fused pipes (with the electrofusion couplers) to you for examination. When you sent a confirmation to Mr. Thomas Helenius that you can complete the survey, we want you to give some time and pay the costs of this survey.

Photo B

Photo C

Contact person - coordinates
Mr. Tomas Helenius (Tel. +46 739142124)
E-mail. tomas.helenius @ stockholmvatten.se

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3 Realised tests

ISO 13954: "Plastics pipes and fittings – Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal diameter greater than or equal to 90 mm", has been used as guidance for the evaluation of the electrofusion couplers.

Besides these decohesion tests, the remaining thickness of the pipes, after scraping, has been measured and the thickness of the chips has been calculated. Moreover, the distance of the wires of the electrofusion coupler has been measured.

3.1 Peel decohesion test

3.1.1 Test conditions

- ISO 13954 "Plastics pipes and fittings – Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal diameter greater than or equal to 90 mm";
- Assemblies:
  - PE100 pipe ø 250 - electrofusion coupler ELOFIT ø250 mm - PE100 pipe ø 250 mm;
  - PE100 pipe ø 560 - electrofusion coupler ELOFIT ø560 mm - PE100 pipe ø 560 mm;
  - PE100 pipe ø 630 - electrofusion coupler FRIALEN ø630 mm - PE100 pipe ø630 mm;
- The electrofusion joints were realised on the construction site. Fusion conditions were read from the barcode present on the electrofusion couplers.
- The free length of the assembly measured is at least the length of the coupler increased with 250 mm along both sides of the coupler.
- Parallel samples of 25 mm width were milled alongside the assembly.
- Specification according NBN EN 12201-3 "Plastics piping systems for water supply and for drainage and sewerage under pressure - Polyethylene (PE) - Part 3: Fittings";
- Allowed percentage of brittle decohesion: ≤ 33 %;
- Conditioning: minimum 24 h in air at (23±2) °C;
- Test temperature: 23 °C; R.H.: 50 %;
- Tensile speed: 25 mm/min;
- Date of tests: 1st - 3rd February 2012.

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3.1.2 Principle of decohesion test (dimensions in mm)

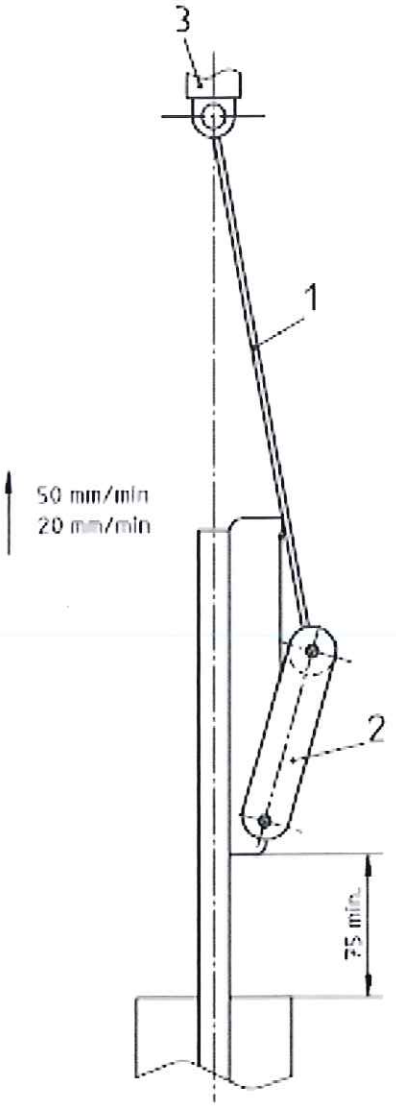

Figure 1: Peel test assembly

1 Tensioning chain or wire rope (minimum length 300 mm)
2 Shackle-type link
3 Tensile-testing machine

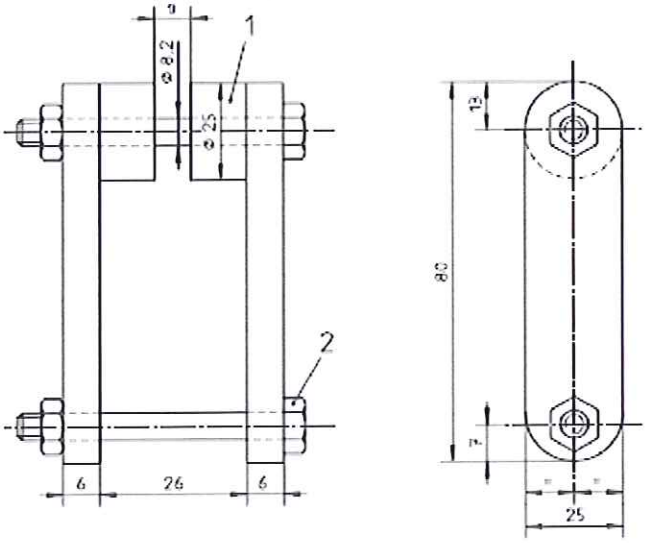

Figure 2: Shackle-type link

1 Spacer
2 Bolt, designed to fit the hole in the test piece (see figures 1 and 3)

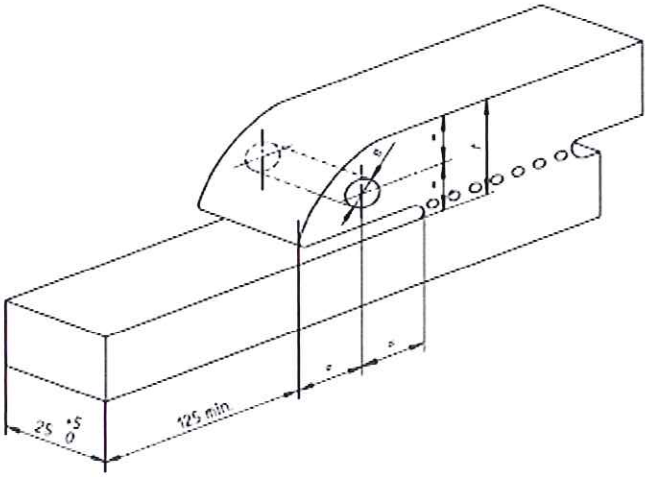

Figure 3: Dimensions and shape of test piece

1) hole, diameter t/5 with a minimum of 3 mm, for bolt of shackle-type link

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3.1.3 Test piece ø 250 mm

3.1.3.1 Measurement of the scraping depth of the pipe

The wall thickness (e_1) of the test specimen next to the scraped zone and the wall thickness of the test specimen in the scraped zone (e_2) have been used to calculate the effective thickness of the chips.

Legend: Side A and side B: see photos no. 11 and no. 12.

Measurement of the scraping depth of the pipe ø250 mm			
Reference of test piece	Measurement of wall thickness of the pipe next to the scraped zone e_1 (mm)	Measurement of wall thickness of the pipe in the scraped zone e_2 (mm)	e_1 - e_2 (mm)
Side A no. 1	15,21	15,13	0,08
	15,19	15,12	0,07
Side A no. 2	15,31	15,22	0,09
	15,41	15,33	0,08
Side A no. 3	15,25	15,18	0,07
	15,17	15,03	0,14
Side A no. 4	15,11	15,08	0,03
	15,14	15,09	0,05
Side A no. 5	15,11	15,11	0,00
	15,08	14,96	0,12
Side A no. 6	15,18	15,10	0,08
	15,22	15,18	0,04
Side A no. 7	15,15	15,14	0,01
	15,12	15,12	0,00
Side A no. 8	15,17	15,16	0,01
	15,22	15,18	0,04
Mean scraping depth			0,06
Side B no. 1	15,21	15,20	0,01
	15,19	15,17	0,02
Side B no. 2	15,31	15,30	0,01
	15,41	15,40	0,01
Side B no. 3	15,25	15,25	0,00
	15,17	1514	0,03
Side B no. 4	15,11	15,11	0,00
	15,14	15,14	0,00
Side B no. 5	15,11	15,08	0,03
	15,08	15,07	0,01
Side B no. 6	15,18	15,16	0,02
	15,22	15,19	0,03

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Measurement of the scraping depth of the pipe ø250 mm			
Reference of test piece	Measurement of wall thickness of the pipe next to the scraped zone e_1 (mm)	Measurement of wall thickness of the pipe in the scraped zone e_2 (mm)	e_1 - e_2 (mm)
Side B no. 7	15,15	15,15	0,00
	15,12	15,10	0,02
Side B no. 8	15,17	15,13	0,04
	15,22	15,20	0,02
Mean scraping depth			0,02

3.1.3.2 Peel decohesion test results

Legend: Side A and side B: see photos no. 11 and no. 12.

Evaluation of decohesion resistance of the pipe ø250 mm				
Reference of test piece	Position of test piece	Maximum load (N)	Failure	% brittle decohesion
Side A no. 1	Zone with wires at constant (normal) distance	3002	Ductile	0
Side A no. 2	Zone with wires at constant (normal) distance	1680	Brittle	100
Side A no. 3	Zone with wires at constant (normal) distance	1844	Brittle	100
Side A no. 4	Zone with wires at constant (normal) distance	1859	Brittle	100
Side B no. 1	Zone with wires at constant (normal) distance	1401	Brittle	100
Side B no. 2	Zone with wires at constant (normal) distance	1680	Brittle	100
Side B no.3	Zone with wires at constant (normal) distance	1720	Brittle	100
Side B no. 4	Zone with wires at constant (normal) distance	3153	Ductile	0

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3.1.4 Test piece ø560 mm

3.1.4.1 Measurement of the scraping depth of the pipe

Legend: Side A and side B: see photo no. 5

Measurement of the scraping depth of the pipe ø560 mm			
Reference of test piece	Measurement of wall thickness of test specimen next to the scraped zone e_1 (mm)	Measurement of wall thickness of test specimen in the scraped zone e_2 (mm)	$e_1 - e_2$ (mm)
Side A no. 1	35,68	35,22	0,46
	35,72	35,28	0,44
	35,67	35,25	0,42
Side A no. 2	35,73	35,24	0,49
	35,81	35,44	0,37
	35,72	35,40	0,32
Side A no. 3	34,65	34,30	0,35
	34,75	34,40	0,35
	34,80	34,49	0,31
Side A no. 4	35,48	35,03	0,45
	35,52	35,01	0,51
	35,45	35,04	0,41
Side A no. 5	35,27	34,92	0,35
	35,40	34,99	0,41
	35,51	35,03	0,48
Mean scraping depth			0,41
Side B no.1	34,79	34,64	0,15
	34,67	34,57	0,10
	34,60	34,43	0,17
Side B no.2	35,65	35,16	0,49
	35,84	35,32	0,52
	35,84	35,33	0,51
Side B no.3	35,10	34,61	0,49
	35,10	34,62	0,48
	35,07	34,59	0,48
Side B no. 4	35,33	34,83	0,50
	35,32	34,84	0,48
	35,53	34,99	0,54
Side B no. 5	34,64	34,18	0,46
	34,72	34,24	0,48
	34,83	34,34	0,49
Side B no. 6	34,52	34,2	0,23
	34,54	34,20	0,34
	34,6	34,18	0,47
Mean scraping depth			0,41

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3.1.4.2 Peel decohesion test results

Legend: Side A and side B: see photo no. 5.

Evaluation of decohesion resistance of the pipe ø560 mm				
Reference of test piece	Side of test piece	Maximum load (N)	Failure	% brittle decohesion
Side A no. 1	Zone with wires at constant (normal) distance	6675	Ductile	0
Side A no. 2	Zone with wires at constant (normal) distance	6748	Ductile	0
Side A no. 3	Zone with wires at constant (normal) distance	2703	Brittle	100
Side A no. 4	Zone with wires at constant (normal) distance	7418	Ductile	0
Side A no. 5	Zone with wires at constant (normal) distance	8851	Ductile/brittle	0
Side B no. 1	Zone with wires at constant (normal) distance	2402	Ductile/brittle	50
Side B no. 2	Zone with wires at constant (normal) distance	5210	Ductile	0
Side B no. 3	Zone with wires at constant (normal) distance	6306	50 % brittle	50
Side B no. 4	Zone with wires at constant (normal) distance	6611	Ductile	0
Side B no. 5	Zone with wires at constant (normal) distance	8831	Ductile	0
Side B no. 6	Zone with wires at constant (normal) distance	6293	Ductile	0

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3.1.5 Test piece ø630 mm

Legend: Side A and side B: see photo no. 1.

3.1.5.1 Measurement of the scraping depth of the pipe

Measurement of the scraping depth of the pipe ø630 mm			
Reference of test piece	Measurement of wall thickness of test specimen next to the scraped zone e_1 (mm)	Measurement of wall thickness of test specimen in the scraped zone e_2 (mm)	$e_1 - e_2$ (mm)
Side A no. 1	39,11	39,05	0,06
	39,29	39,22	0,07
Side A no. 2	39,13	38,83	0,30
	38,87	38,64	0,23
Side A no. 3	38,62	38,38	0,24
	38,59	3441	0,18
Side A no. 4	38,86	38,62	0,24
	39,07	38,74	0,33
Mean scraping depth			0,21
Side B no. 1	39,35	39,23	0,12
	39,92	39,75	0,17
Side B no. 2	39,37	39,27	0,10
	39,82	39,71	0,11
Side B no. 3	39,76	39,64	0,12
	39,08	38,95	0,13
Side B no. 4	39,40	38,27	0,13
	39,63	39,54	0,09
Mean scraping depth			0,12

3.1.5.2 Peel decohesion test results

Evaluation of decohesion resistance of the pipe ø630 mm				
Reference of test piece	Side of test piece	Maximum load (N)	Failure	% brittle decohesion
Side A no.1	Zone with wires at constant (normal) distance	3741	Brittle	100
Side A no.2	Zone with wires at constant (normal) distance	3105	Brittle	100
Side A no.3	Zone with wires at constant (normal) distance	4041	Brittle	100
Side A no.4	Zone with wires at constant (normal) distance	1820	Brittle	100

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Evaluation of decohesion resistance of the pipe ø630 mm				
Reference of test piece	Side of test piece	Maximum load (N)	Failure	% brittle decohesion
Side B no. 1	Zone with wires at constant (normal) distance	3128	Brittle	100
Side B no. 2	Zone with wires at constant (normal) distance	2297	Brittle	100
Side B no. 3	Zone with wires at constant (normal) distance	3971	Brittle	100
Side B no. 4	Zone with wires at constant (normal) distance	2581	Brittle	100

3.1.6 Pictures

Pictures of the brittle and ductile failures of the test pieces are included in annex 3, P21 till P26.

3.1.7 Discussion

The decohesion tests demonstrate very clearly that a lack of adequate scraping (and cleaning of the surfaces of pipe and fitting) is the main cause of the occurrence of leakages of the assemblies ø250 mm and ø630 mm. Indeed the maximum force obtained by decohesion testing on ductile test pieces and brittle ones is significantly different as well as their percentage of brittle decohesion, which is limited to 33 % according to ISO 13954.

The decohesion tests on ø560 perform much better (higher maximum loads) as the mean scraping depth is much higher than these of the assemblies ø250 mm and ø630 mm, resulting in high decohesion forces and a low percentage of brittle decohesion (lower than 33 %).

Hereafter a summary of the recommended preparation and fusion procedure is summarized. Also the corresponding deficiency observed in the assemblies is reported.

Preparation of the pipe

- Remove obvious dirt particles from the pipe surface to be scraped (using for example a clean, grease free piece of cloth).
- Determine the area to be scraped. For slide over couplers: coupler length, otherwise insertion depth of the coupler + 5 mm.
- In order to be able to better control the seamless removal of the pipe surface by scraping, axially orientated marking lines may be noted on the surface to be treated.

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Note: It is obvious that very rough, irregular scraped pipe surfaces, causing non-seamless scraped surfaces, can cause in many cases zones were oxidation occurs during fusion, which can result in bad fused (brittle) zones. In several cases this can cause delaminations, leakages, etc., e.g. when (small) vibrations, ground settlements or small earthquakes, occur, etc..

It is highly recommended to use a rotating peel scraper which eliminates the oxydised surface (skin: minimum 0,2 mm) and creates a smooth pipe surface without seams. This request can not be fulfilled when hand scraping is used. In the latter irregularly pipe surfaces are obtained, which can bad fusions, provoking leakages, brittle failures, delaminations,...
It is appropriate to follow the manufacturer's instructions for the installation of the scraping tool on the pipe and the utilisation of the scraper (e.g. mounting of the scraper tool, utilisation of the scraping tool, lifetime of scraping blades – in function of the pipe diameter, number of pipes to be scraped, ...).
Research related to scraping has demonstrated that only properly prepared assemblies have a corresponding lifetime to the PE-pipes (100 years – according to the state of the art).
It should be noted that PE 100 pipes are somewhat more difficult to scrape (by hand) than corresponding PE 80 pipes due to a difference in hardness.

Remarks:
Before fusion the pipe must be cleaned using a PE cleaning agent and absorbent, non-fibrous and non coloured paper.
In several manuals a minimum of 0,15 mm scraping depth is recommended.
Practise however, has demonstrated that this is only valid if a rotating peel scraper is used which generate PE-layers (also called chips, shavings or swarf) with a constant thickness.
Decohesion tests however have demonstrated that scraping depths of minimum 0,20 mm gives improved ductile behaviour. Apparently optimum decohesion results are reached when chips have a thickness of approximately 0,30 mm (to 0,4 mm), especially for larger diameter pipes.
On the other hand, the welding surface of the electrofusion coupler needs only to be cleaned (elimination of dust, impurities, fatty products,...) and not to be scraped as this inner surface (welding surface) is normally not oxidised during the production process or is in some cases removed due to the production method.
If marking has not been completely removed, the scraping process has to be repeated locally with a hand scraper, if necessary. If the oxidised skin is not completely removed a fused joint which is not homogeneous fused may leak.
Damages to the pipe surface as e.g. axial grooves or scratches may not be located within the fusion zone after scraping. Rescraping could evoke fitting problems between pipe and fitting.
It is obvious that the removal of an excessively large amount of material can leave a large annular gap which cannot be closed, or completely closed, during the fusion proces.

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3.2 Distance between electrofusion wires

3.2.1 Test conditions

The distances between the wires were measured with a microscope (x 25).

3.2.2 Test results

Side	Distance between wires (mm)		
	Coupler ø250	Coupler ø560	Coupler ø630
Zone with wires at constant (normal) distance.	4,5		5,2
2 zones with 4 wires at constant distance (5,5 mm) mid zone with 3 wires at constant distance 6,8 mm.		5,5 6,8	

The wire-distance for each coupler is in agreement with the manufacturers' production scheme.

3.3 Determination of the infrared spectrum

In order to verify the base material quality of the pipe (PE) or of the fitting (PE) the infrared spectrum has been recorded.

3.3.1 Test conditions

The IR spectrum is determined in reflection mode directly on the received material by means of a Perkin-Elmer Spectrum One apparatus with ATR function.
Date of test: 8 February 2012.

3.3.2 Test results (see also graphs in annex 1)

The IR spectrum of the different assemblies (ø250 mm, ø560 mm and ø630mm) composed of pipes and electrofusion fittings, is shown in Annex 1, graphs no. 1 till 6.
The different IR-spectra of the assemblies demonstrate that the base PE-material shows no deviation of the PE 100 (polyethylene) normally used for the distribution of (potable) water.

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3.4 Determination of oxidation induction time (OIT)

3.4.1 Introduction

In order to verify the basis quality of the pipe material (PE) or the fitting material (PE) the OIT has been determined on the different assemblies according to ISO 11357-6.

ISO 11357-6 describes a method for measuring the oxidation induction time in oxygen, at a specified temperature, of polyolefin materials, for or from pipes or fittings.
It may be used for assessing the thermal stability of either raw materials or finished products.

It is assumed that a polyolefin material for manufacture of pipe and/or fittings will incorporate an additive package which includes one or more antioxidants or other stabilizers.
The time for which the material, with its additive package consisting of antioxidant, stabilizers and other additives present in a test piece, inhibits oxidation is measured while the test piece is held isothermally at a specified temperature in a stream of oxygen.

The progress of the oxidation is monitored by measuring the difference in energy flow or temperature (ΔT) between the test piece pan and reference pan of a thermal analyser and recording this difference against time.

The oxidation induction time (OIT) is then derived from this record as the period during which the difference of energy flow or temperature remains constant between the test piece pan and reference pan.

This time can be indicative of the effective residual antioxidant level and reflects the time the test piece can be exposed in pure oxygen at the test temperature before the onset of thermal degradation. In normal atmospheric conditions this time will be longer.

Depending upon the material and the pipe or fitting processing, dimensions and service conditions, the methods of sample and test piece preparation may be crucial to the consistency of the results and their significance.

It is recommended to choose a temperature which normally results in induction times of at least 10 min.

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3.4.2 Test conditions

- ISO 11357-6 "Plastics — Differential scanning calorimetry (DSC) – Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT)";
- DSC Mettler-Toledo 821e, with STAR^e software version 6.0;
- Test temperature: 200 °C;
- Mass of test piece: (15±2) mg, taken from the inner and outer pipe surface, the brittle fusion zone and the inside and outside of the electrofusion coupler.
- The time necessary for the oxidation of the test piece was measured, while the test piece was kept in a stream of oxygen at 200 °C. The test piece and the reference were held at the same temperature, the difference in energy flow was recorded. The OIT of the test piece was the time taken from the introduction of oxygen to the intercept of the extended baseline and the tangent drawn to the exotherm at the point of maximum slope on the thermogram (tangent method). The recorded energy flow was included in the graph in annex, graphs 7 till 12.
- Number of test pieces: 3 per pipe size;
- Date of test: 10 February 2012.

3.4.3 Test results (see also graphs in annex 2)

3.4.3.1 PE assembly ø250 mm

Pipe

Test piece no.	Position	Graph no. 7	Mass of test piece (mg)	OIT at 200 °C (min.)	Test piece appearance
1	Brittle fusion zone	Black line	13,2	> 60	No change
2	Outside surface	Red line	15,5	> 60	No change
3	Inner surface	Blue line	15,2	> 60	No change

Fitting

Test piece no.	Position	Graph no. 8	Mass of test piece (mg)	OIT at 200 °C (min.)	Test piece appearance
1	Outside surface	Black line	15,2	50,8	No change
2	Inner surface	Red line	13,9	> 60	No change

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3.4.3.2 *PE assembly ø560 mm*

Pipe

Test piece no.	Position	Graph no. 9	Mass of test piece (mg)	OIT at 200 °C (min.)	Test piece appearance
1	Brittle fusion zone	Black line	16,1	> 60	No change
2	Outside surface	Red line	13,3	> 60	No change
3	Inner surface	Blue line	15,9	> 60	No change

Fitting

Test piece no.	Position	Graph no. 10	Mass of test piece (mg)	OIT at 200 °C (min.)	Test piece appearance
1	Outside surface	Black line	16,3	> 55	No change
2	Inner surface	Red line	14,1	> 60	No change

3.4.3.3 *PE assembly ø630 mm*

Pipe

Test piece no.	Position	Graph no. 11	Mass of test piece (mg)	OIT at 200 °C (min.)	Test piece appearance
1	Brittle fusion zone	Black line	13,3	> 60	No change
2	Outside surface	Red line	16,5	55,7	No change
3	Inner surface	Blue line	16,5	55,5	No change

Fitting

Test piece no.	Position	Graph no. 12	Mass of test piece (mg)	OIT at 200 °C (min.)	Test piece appearance
1	Outside surface	Black line	15,8	50,8	No change
2	Inner surface	Red line	11,2	> 60	No change

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4 Conclusions

The decohesion tests reveal very clearly that the poorly fused assemblies are due to an insufficient scraping and inadequate preparation (cleaning) of the surfaces to be fused.
Indeed, two of the three fused assemblies are obviously full of such several shortcomings and are cursed with the same defects.

In summary only the insufficient preparation of the surfaces to be welded are fully responsible for the leakage in the pipe/fitting assemblies ø250 mm and ø560 mm.

Remark: The above mentioned tests (except §3.2) belong to the domain of accreditation according to NBN EN ISO/IEC 17025 (Belac certificate no. 181-Test).

Melle, 23 February 2012

Prof. ir. Ph. VANSPEYBROECK
General Director

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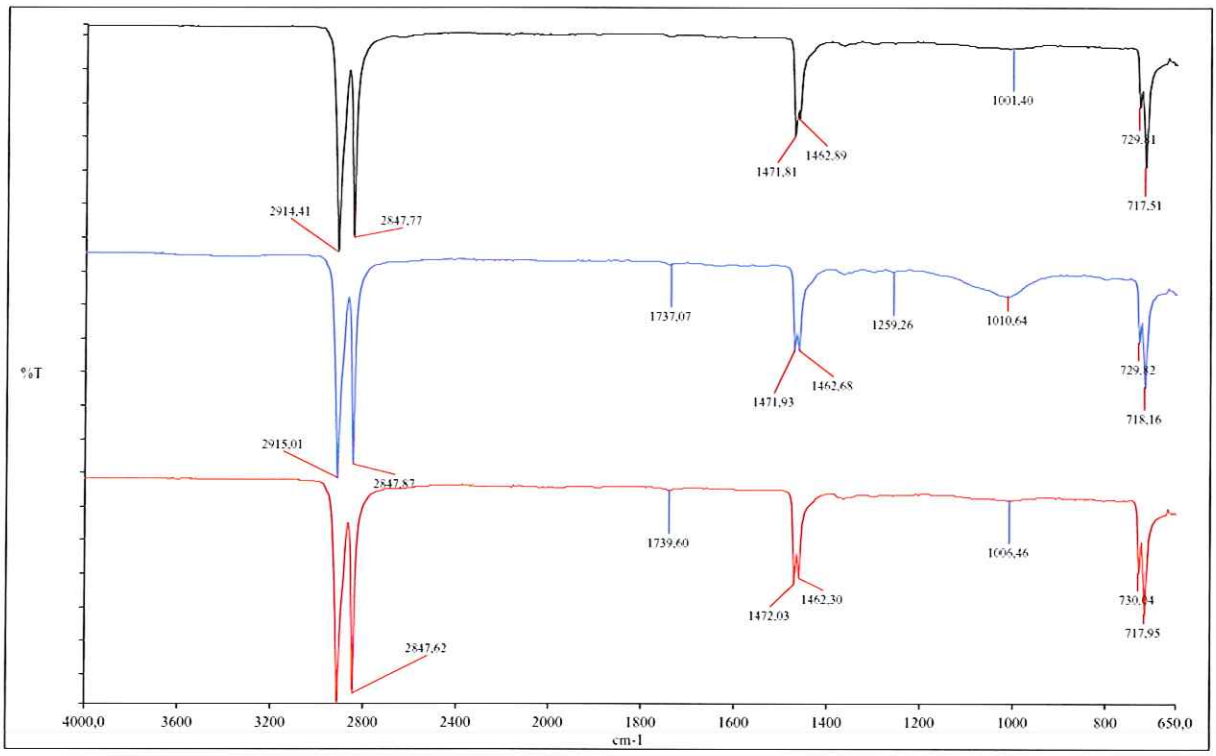
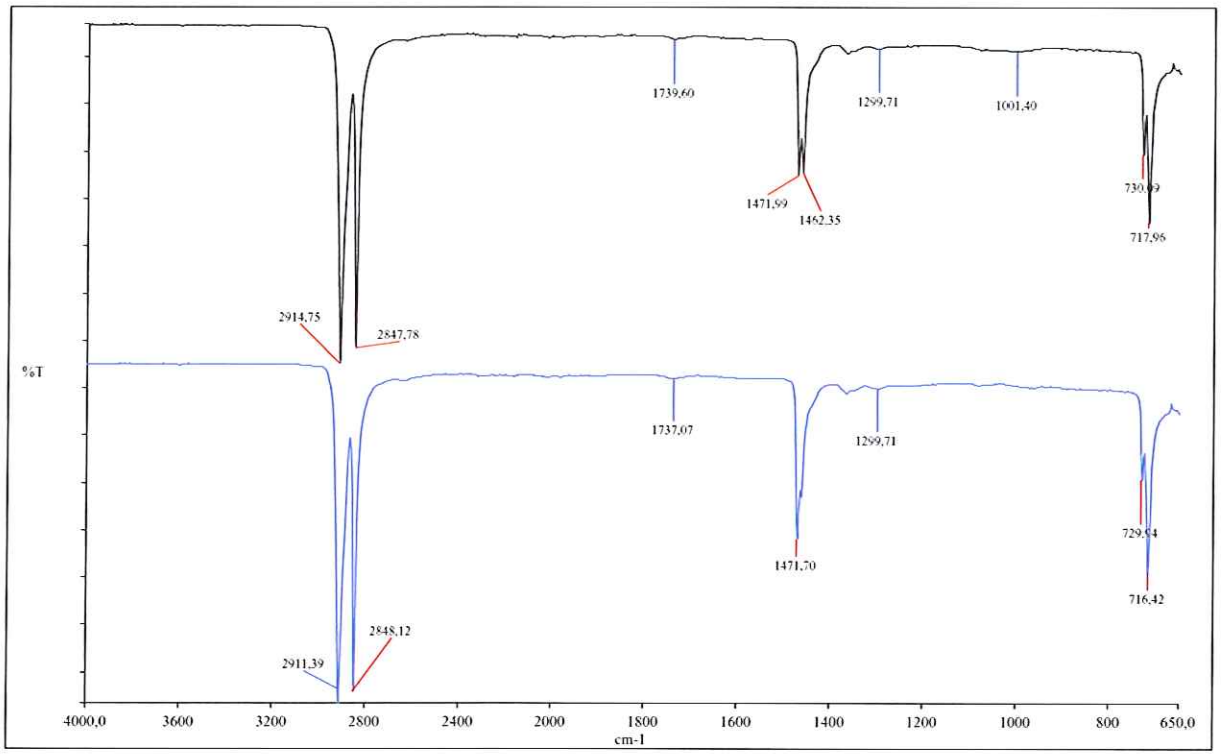
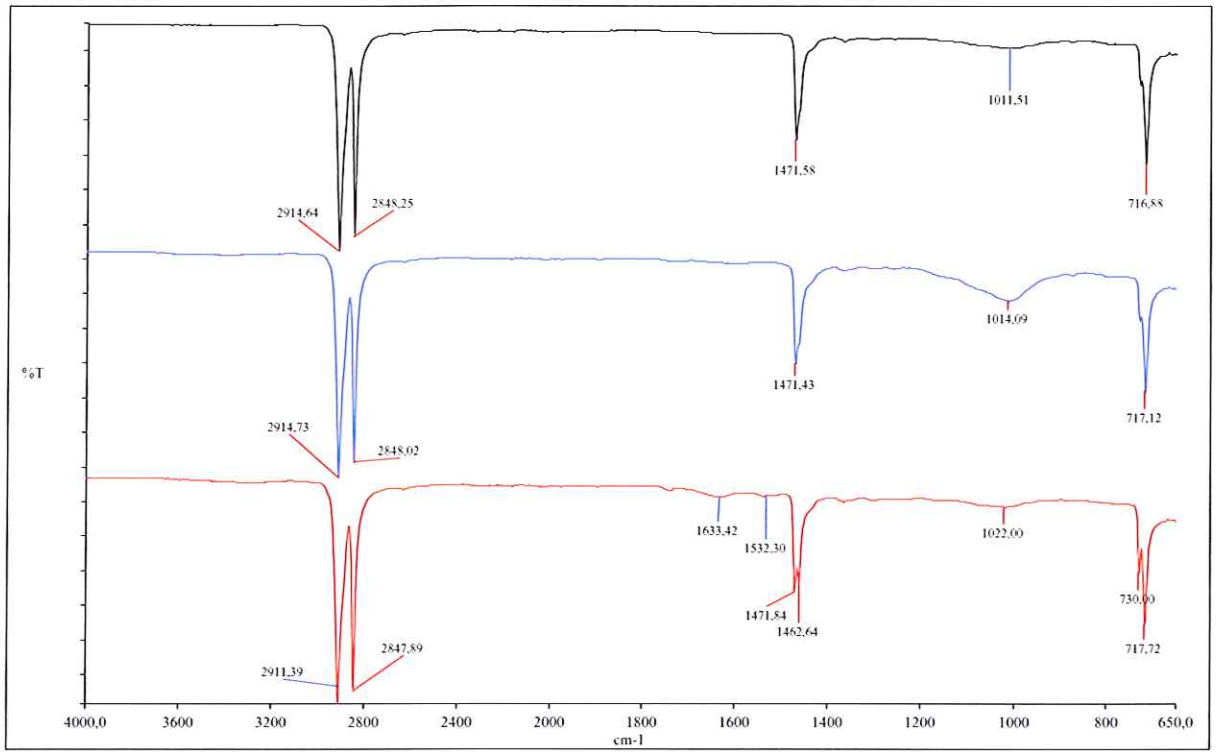
Annex 1 : Infrared Spectra



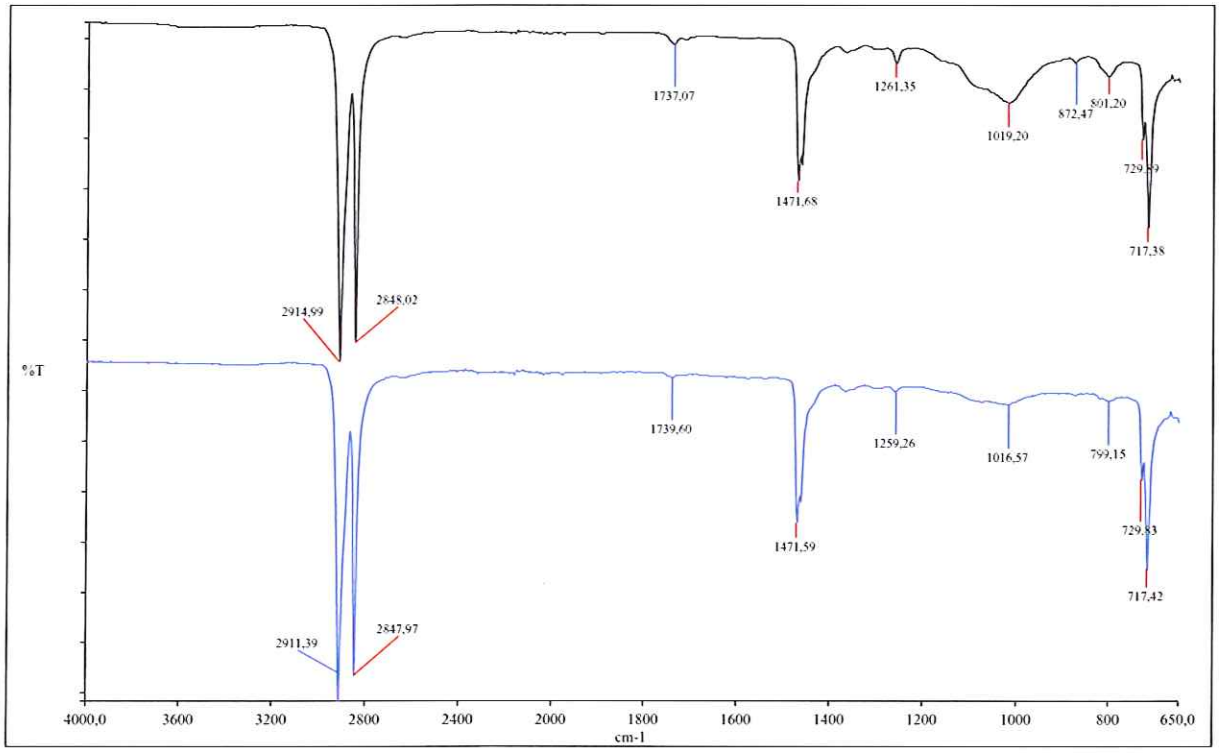
Graph no. 1: ø250 mm - pipe
upper: brittle fusion zone - middle: outside surface - under: inner surface



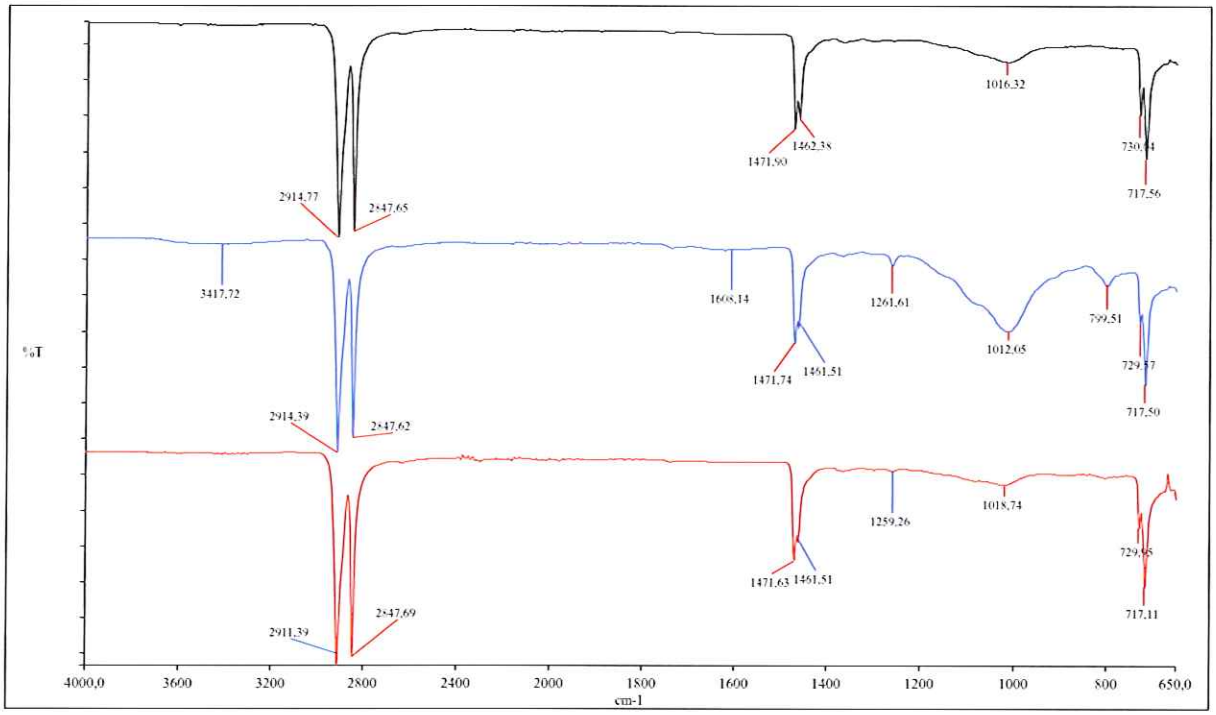
Graph no. 2: ø250 mm - coupler
upper: outside surface - under: inner surface



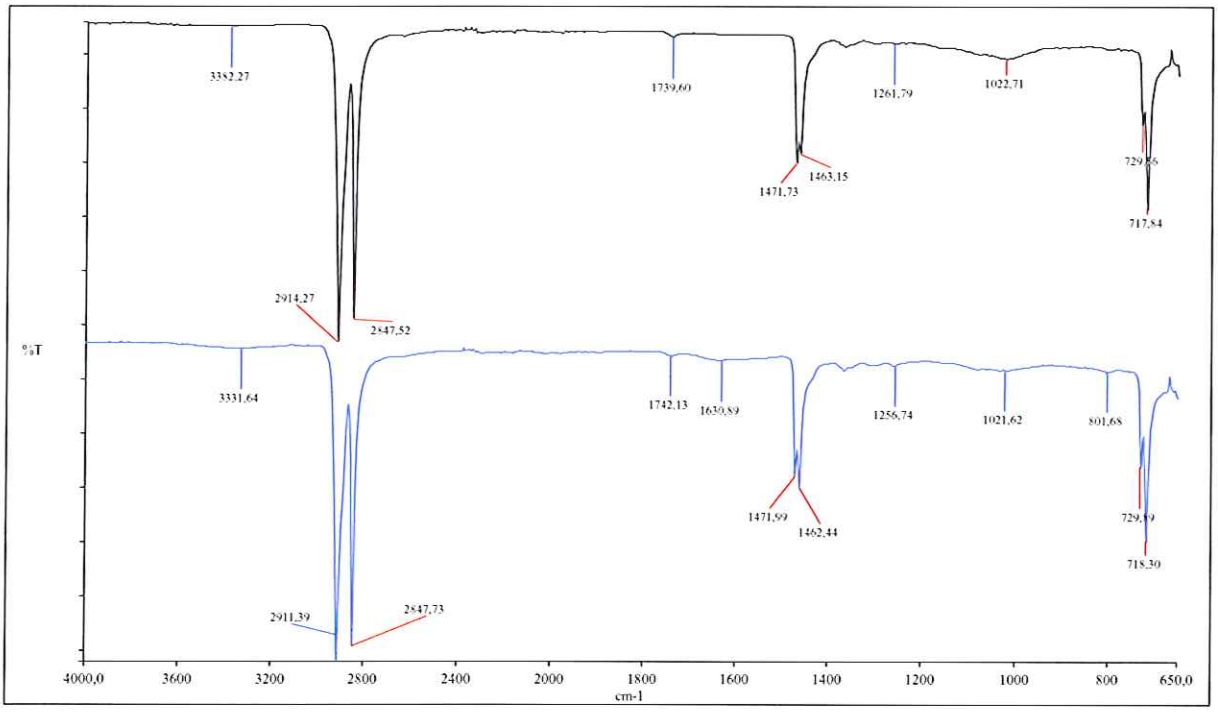
Graph no. 3: ø560 mm - pipe
upper: brittle fusion zone - middle: outside surface - under: inner surface



Graph no. 4: ø560 mm - coupler
upper: outside surface - under: inner surface

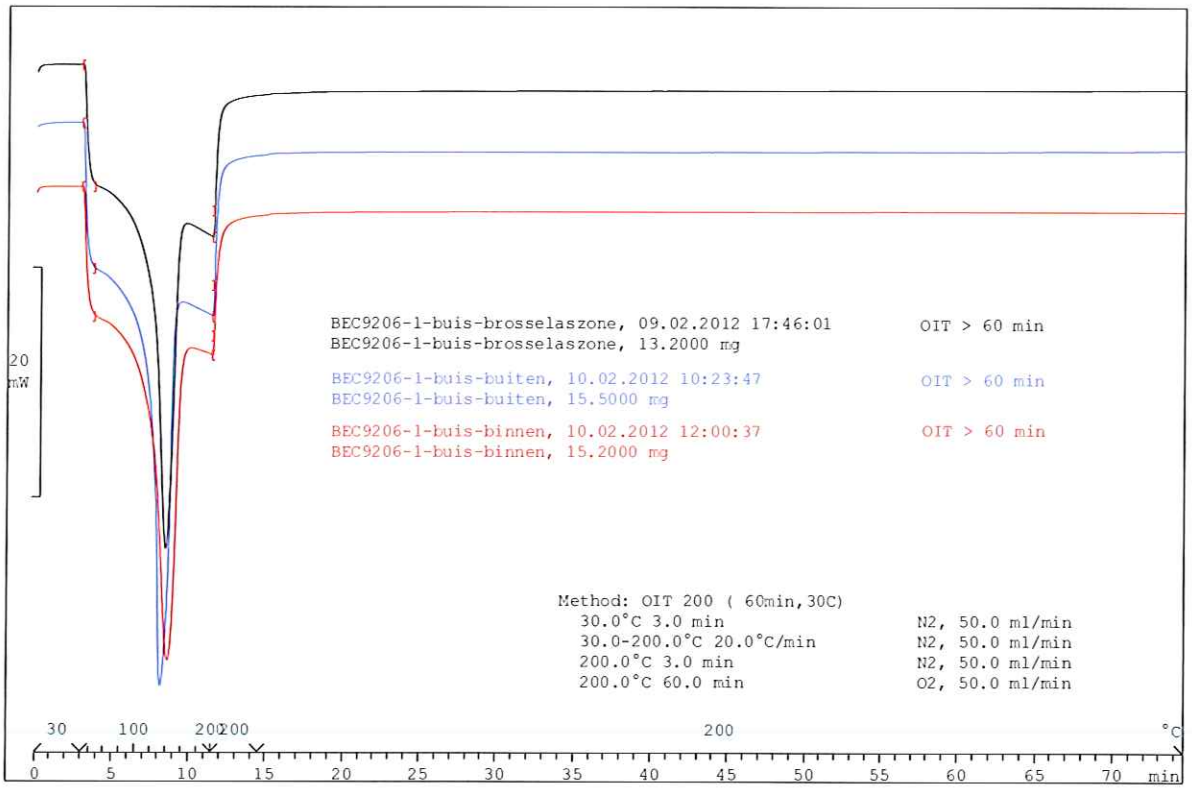


Graph no. 5: ø630 mm - pipe
upper: brittle fusion zone - middle: outside surface - under: inner pipe

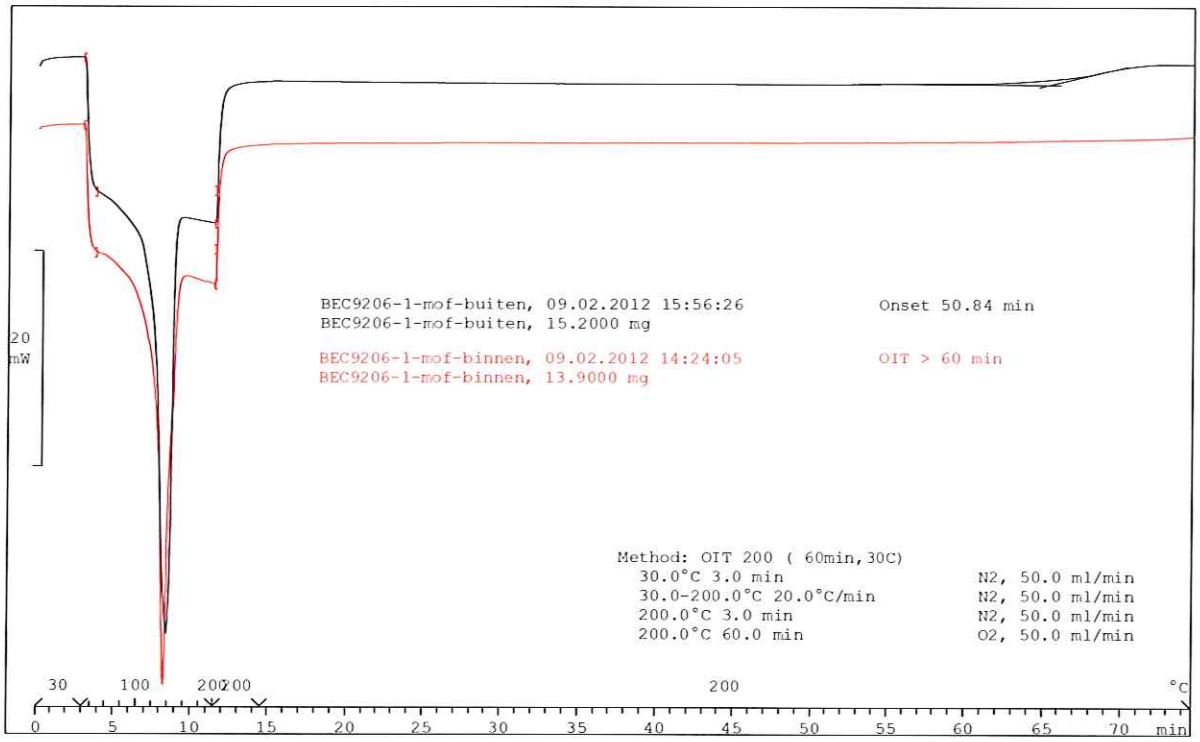


Graph no. 6: ø630 mm - coupler
upper: outside surface - down: inner surface

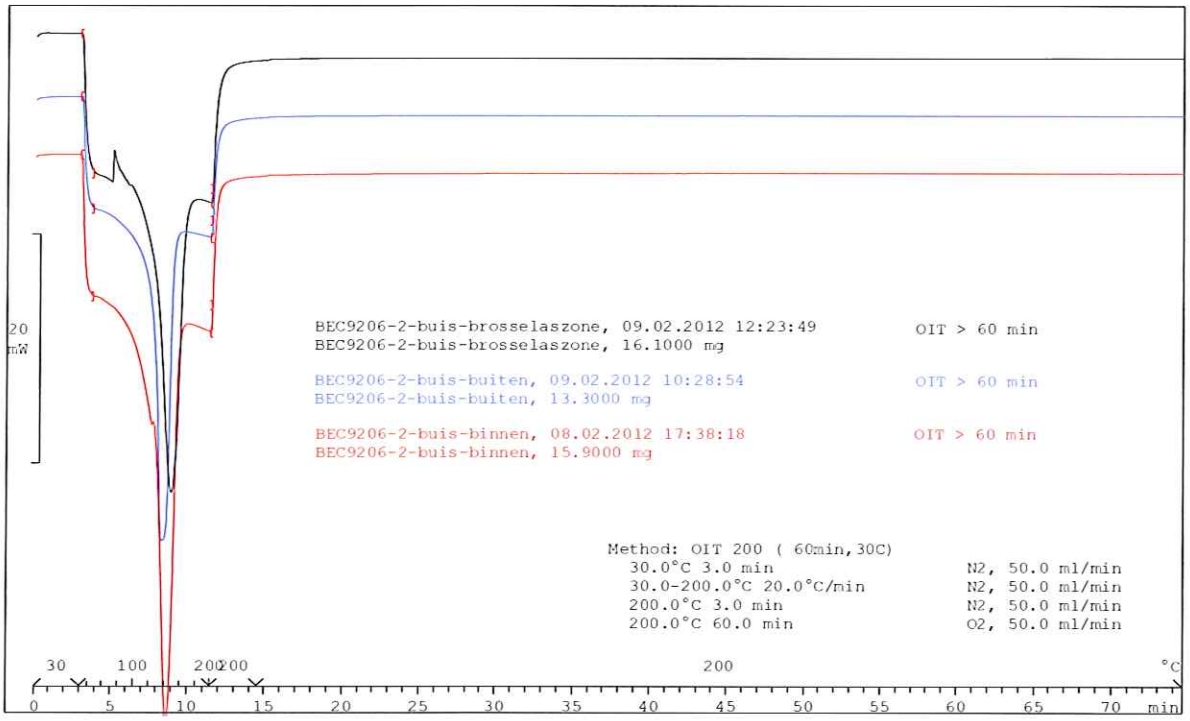
Annex 2 : OIT graphs



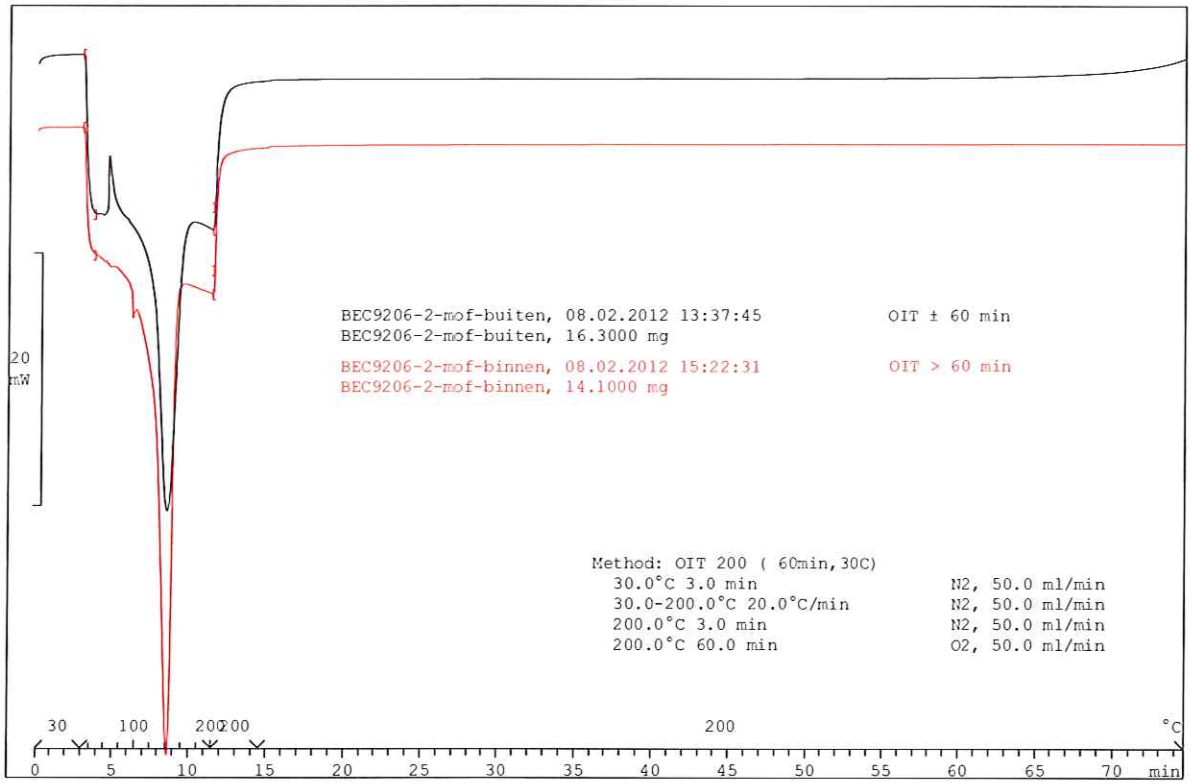
Graph no. 7: OIT of PE pipe ø250 mm
(upper graph: brittle fusion zone – middle: outside surface – under: inner surface)



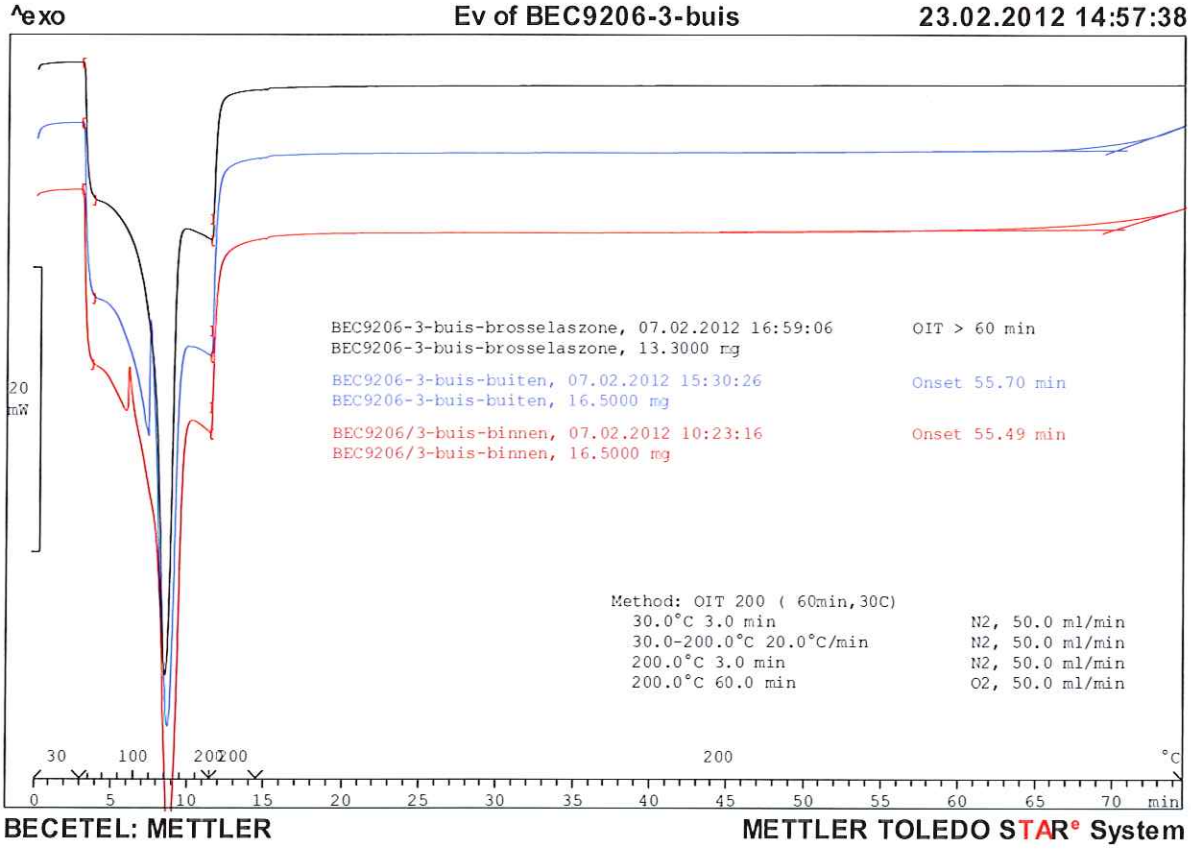
Graph no. 8: OIT of PE electrofusion coupler ø250 mm
(upper graph: outside surface – lower graph: inner surface)



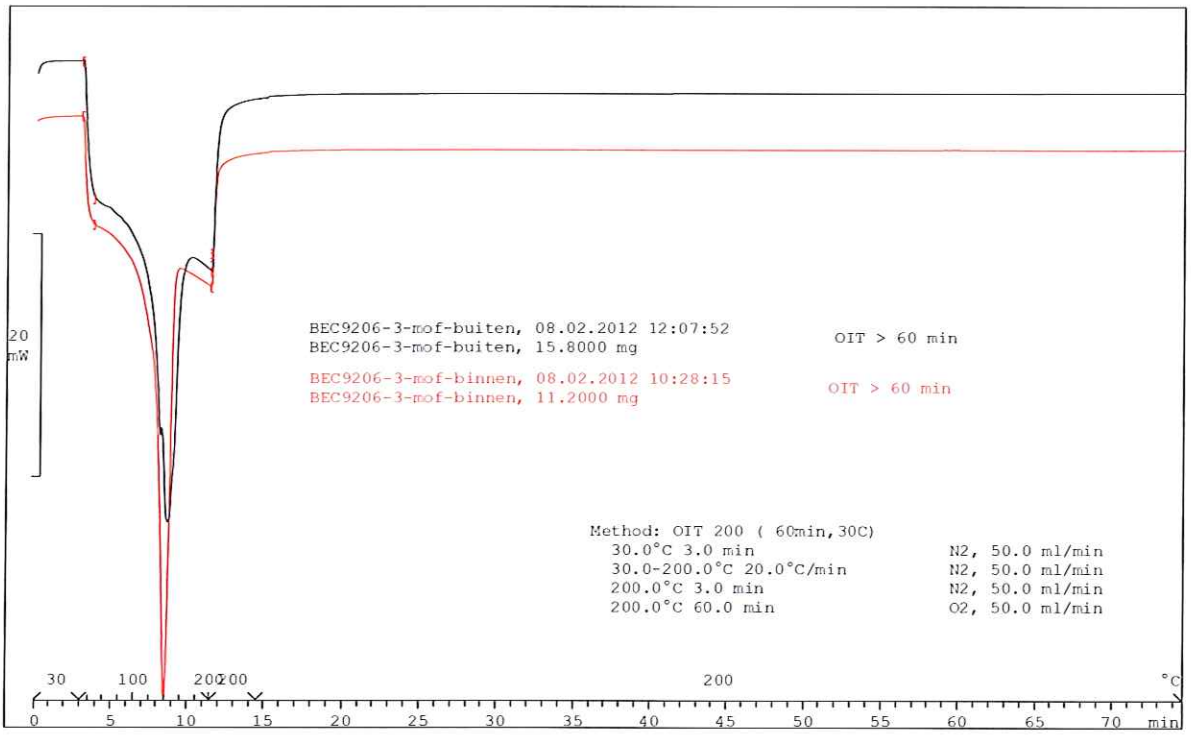
Graph no. 9: OIT of PE pipe ø560 mm
(upper graph: brittle fusion zone – middle: outside surface – under: inner surface)



Graph no. 10: OIT of PE electrofusion coupler ø560 mm
(upper graph: outside surface – lower graph: inner surface)



Graph no. 11 : OIT of PE pipe ø630 mm
(upper graph: brittle fusion zone – middle : outside surface – under : inner surface)

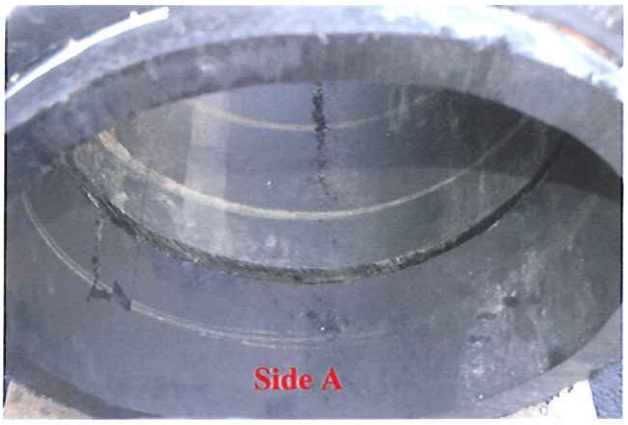


Graph no. 12 : OIT of PE electrofusion coupler ø630 mm
(upper graph: outside surface – lower graph: inner surface)

ANNEX 3 : PHOTOS

P1: Test assembly DN630 mm

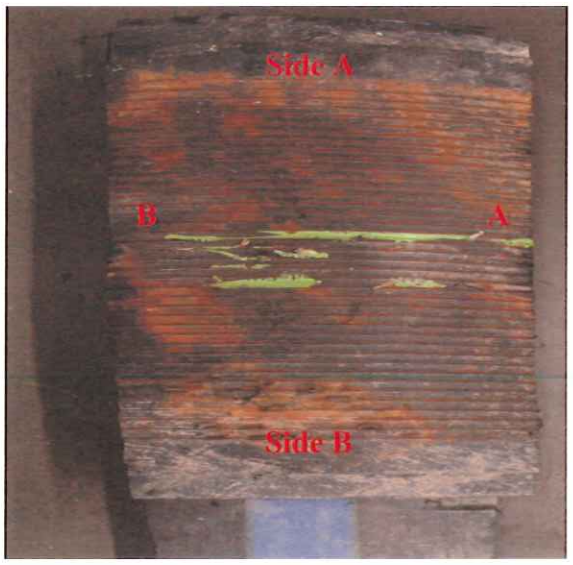
P2: Test assembly DN630 mm (rear view of previous photo).



P3: Test assembly DN630 mm (inside view)

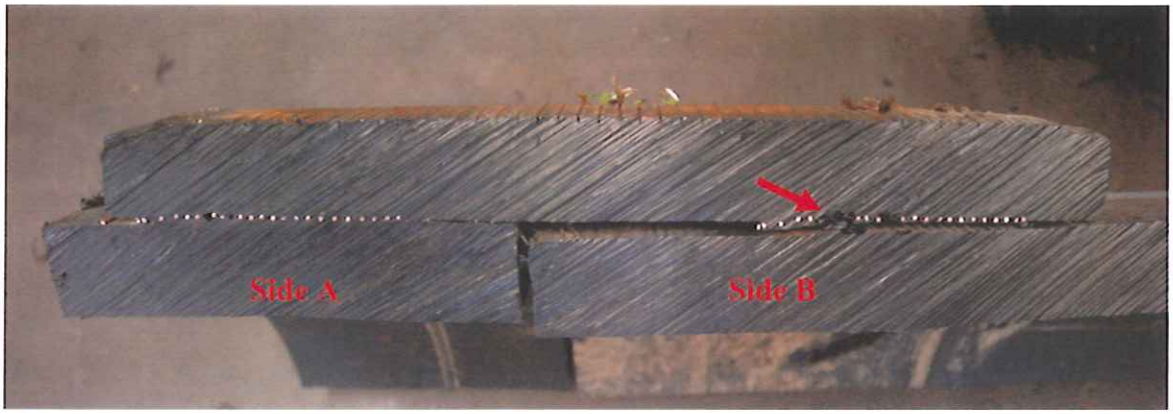
P4: Detail of the green ribbon of DN 630

P5: Test assembly DN630 mm. No scraping visible on the pipe section (side B) next to the electrofusion coupler.



P6: A piece was cut out of the assembly DN630.

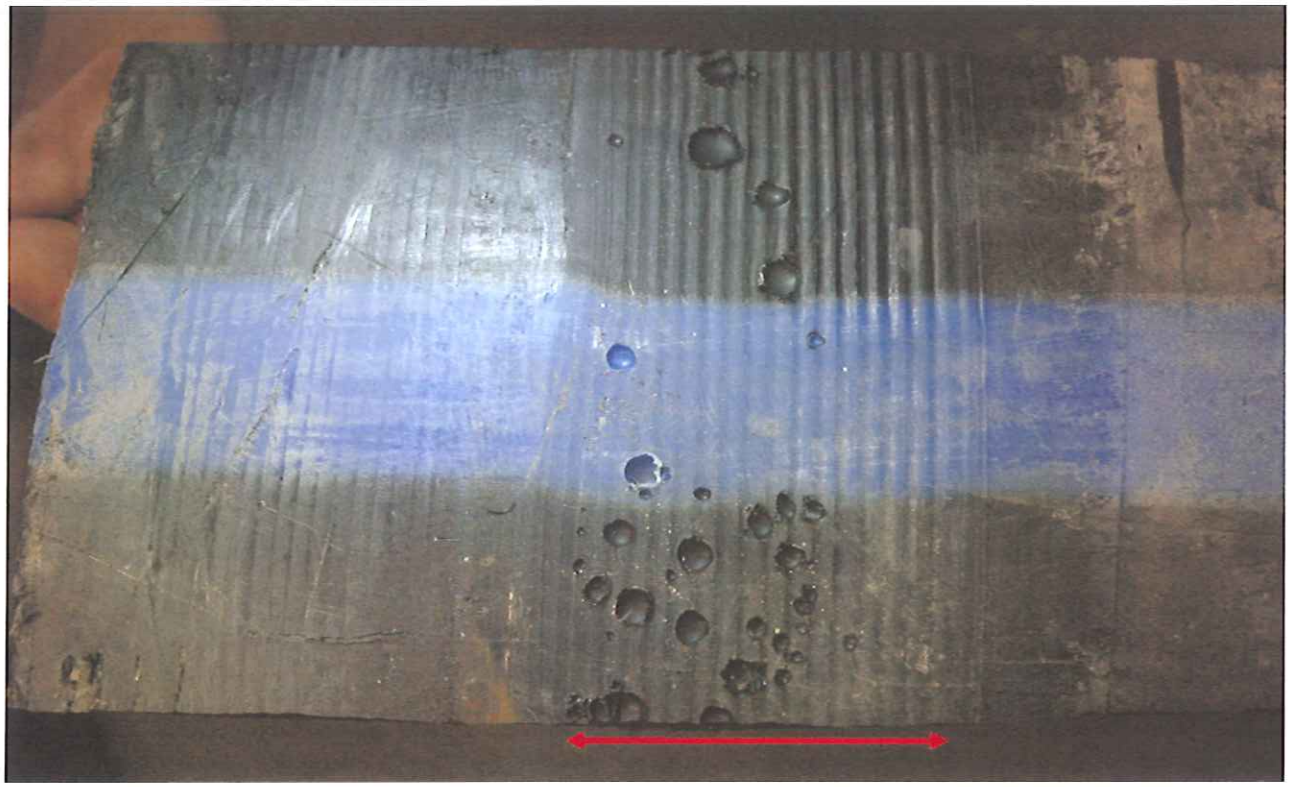
P7: Cross section at position A of previous photo P6.



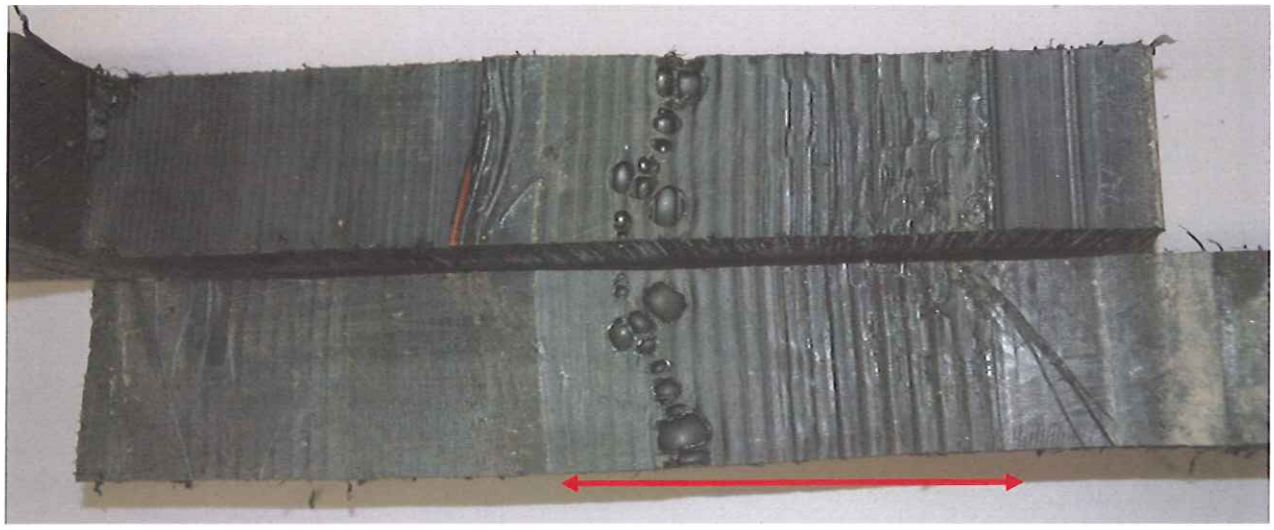
P8: Cross section of photo P6 at position B. The pipe at the right is not (well) fused.

P9: After a small effort the whole pipe section broke of the coupler DN630.

P10: Detail of the fusion surface (side of the coupler) of DN630

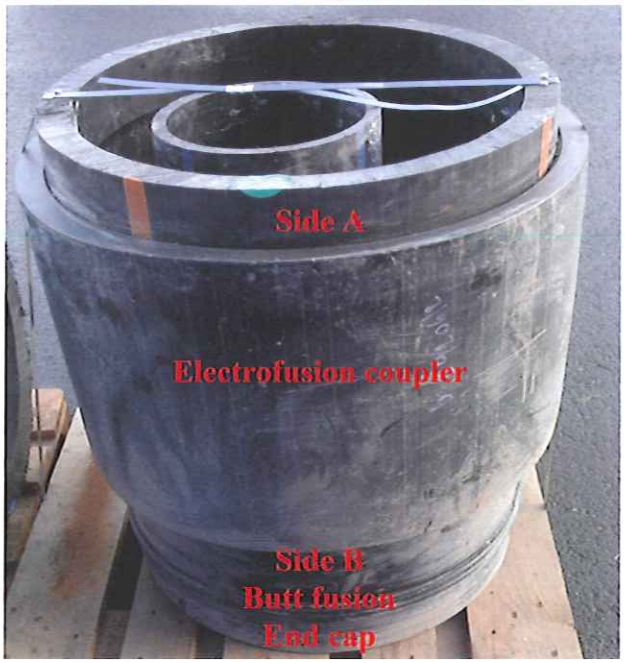


P11: Detail of the fusion surface (side of the pipe) of DN630. The surface is brittle in the fusion zone. A lot of bubbles (from cleaning agent?) are visible in the fusion zone.

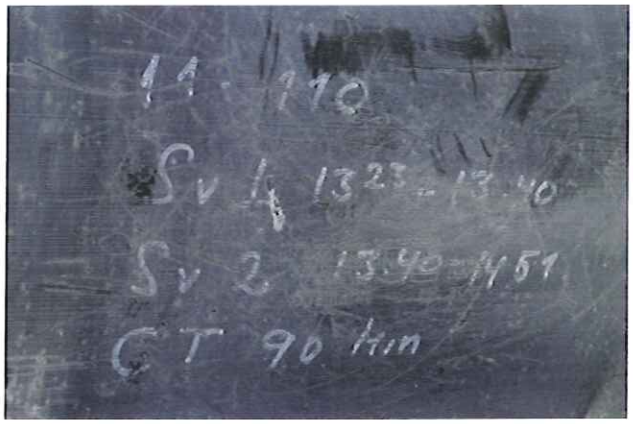


P12: Detail of the fusion surface (side of the pipe) of DN630. The surface is brittle in the fusion zone. A lot of bubbles are visible in the fusion zone.

P13: Test assembly DN560 mm

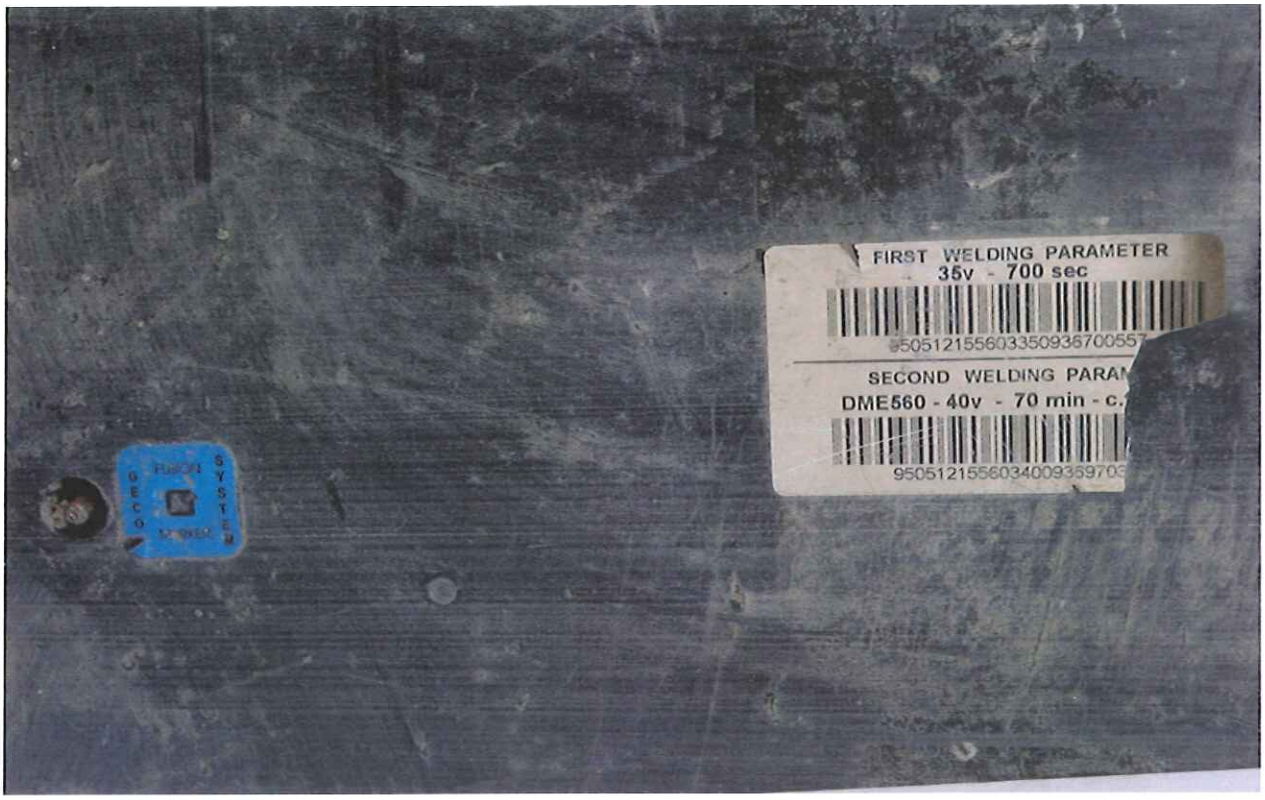


P14: Test assembly DN560 mm
(rear view of previous photo)



P15: Marking on test assembly DN560 mm

P16: An end cap DN560 was fused to the assembly with a butt fusion.



P17: Test assembly DN560 mm, detail at the fusion marker

P18: Test assembly DN560 mm, detail of sticker on the end cap.

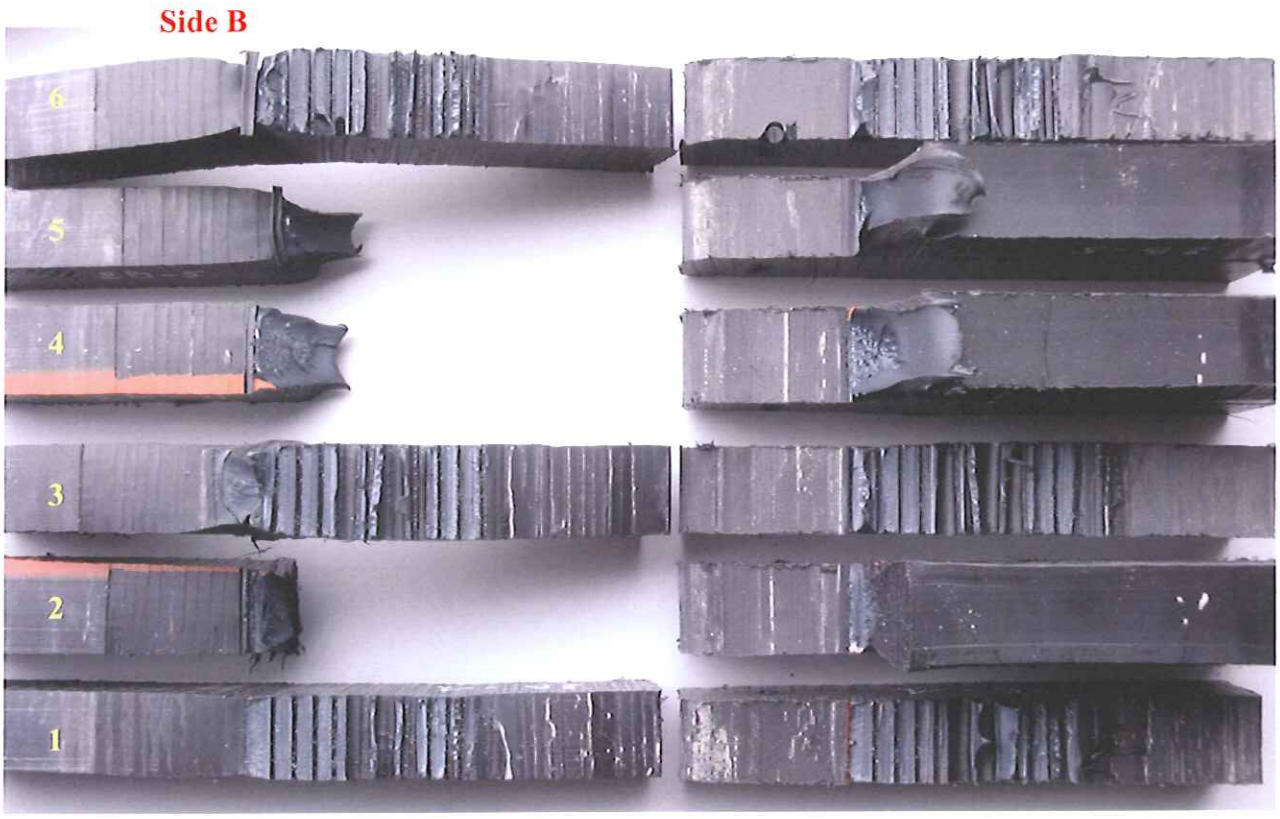
P19: Test assembly DN250 mm

P20: Test assembly DN250 mm, detail of the marking

P21 : test pieces after decohesion test on DN630 – side A

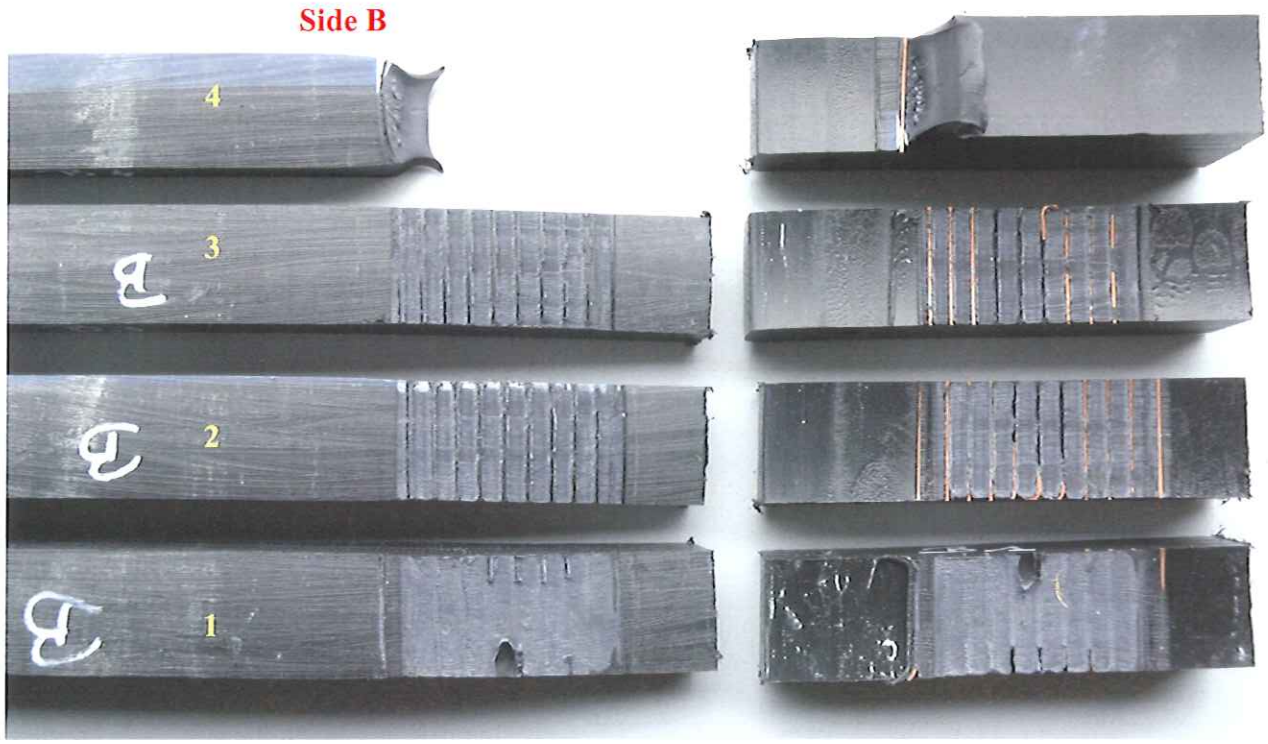
P22 : test pieces after decohesion test on DN630 – side B

P23 : test pieces after decohesion test on DN560 – side A



P24 : test pieces after decohesion test on DN560 – side B

P25 : test pieces after decohesion test on DN250 – side A



P26 : test pieces after decohesion test on DN250 – side B