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A Higher Level of Reliability

May 16, 2022

File Number: A22605-16877 – Revision 1
EGBC Permit Number: 1001973

TECHNICAL SAFETY BC
600 - 2889 EAST 12TH AVENUE
VANCOUVER, BC
V5M 4T5

Attention: [redacted]

Re: Fernie Natural Gas Explosion; Fractured Polyethylene Pipe Evaluation

1.0 INTRODUCTION

A natural gas explosion occurred at a residential property [redacted] Fernie, B.C, on February 9, 2022. The house was demolished in the explosion and subsequent fire.

It was determined that the 16mm polyethylene line suppling natural gas to the residence had fractured, allowing gas to enter the property. The pipe apparently fractured when the supply line was lifted by a piece of machinery. The 16 mm gas supply line was spliced at two locations to a ¾" steel main through couplers designed specifically for splicing steel mains to plastic supply lines. A polyethylene 90 ° elbow was placed in the line and the fracture occurred at the elbow exit on the house side of the elbow. A sketch showing the location of the fractured tube and the apparent location where lifting force was applied is shown in Figure 1.

The gas line assembly, including the couplers, the steel main, the polyethylene supply line with a polyethylene 90 ° elbow, and the two fractured ends of the 16 mm supply line, was submitted to Acuren for evaluation and analysis.

The pipe components were initially examined at the Acuren Facility on April 1, 2022 [redacted]

2.0 VISUAL EXAMINATION

2.1 As-received Condition

The piping assembly was received in a cardboard box prior to the examination. The as- received condition of the piping is shown in Figures 2 and 3. The pipe surfaces are covered with native soil remaining with the piping when the assembly was removed from the ground. The 16mm supply line is fractured at the house-side exit from the 90° elbow (Figure 4). A closer view of the pipe fracture surface shows that the fracture occurred with the pipe being pulled to one side (Figure 5). The free end of the fractured pipe is shown in Figure 6. Although plastic deformation and necking occurred around the fractured end, the amount of necking was relatively small. The high and low temperatures in Fernie on February 9 were +7 °C and -2 ° C respectively. The MDPE pipe material would be expected to perform in a ductile manner in this temperature range (-70 °C ductile-brittle transition temperature).

The connection of the polyethylene pipe to the street side of the steel main was covered with black tape and a loose plastic sleeve (Figure 7). A copper jumper wire is seen coming from the steel side of the joint. A small amount of soil is attached to the tape surface. The steel pipe beneath the black tape contains a depression which is presumably the mechanical crimp used to shut off gas flow during the connection process (Figure 8). The copper wire connection is present under the loose gray plastic sleeve.

A plastic coupler is present in the 16mm gas line. This coupler was used to connect a plastic pipe pigtail on the steel-plastic coupler connecting the steel meter pipe to the main run of 16mm polyethylene pipe. (Figure 9).

2.2 Cleaned Condition

Soil was cleaned from the pipe assembly with mild detergent and water. The cleaned pipe surfaces are shown in Figures 10, 11, and 12. A view of the crimped steel main, coupler, and 90° elbow is shown in Figure 13. A closer view of the 16mm supply line fracture surface at the elbow exit is shown in Figure 14. The fracture area is necked and the fracture surface contains ductile features. The fracture shows directionality with a "twisted" appearance.

The mating fracture surface on the longer length of 16 mm yellow pipe is shown in Figure 15. The pipe contains nicks and gouges away from the fracture as shown in Figures 16 and 17. No bulging or circumferential deformation was found with the 16mm plastic pipe away from the fracture. The crimp appears to have been done hot with evidence of paint scorching on the adjacent steel pipe. The crimp was coated with a pliable mastic material and covered with black tape. This was removed to show the condition of the crimp (Figure 18). No evidence of leaks was found in the mastic coating or in the crimped steel.

The steel – plastic pipe coupler near the crimp is shown in Figure 19. The coupler appears fully intact with no evidence of leaking.

The coupler from the yellow pipe to the threaded steel piece (meter side) is shown in Figure 20. This is a different style of coupler than was used near the crimp. This coupler was pulled apart to reveal a threaded steel pipe with the 16mm yellow polyethylene pipe secured inside the steel pipe and sealed with a rubber compound (Figure 21). The threaded orange cover ensures that the sealing compound remains in place. The 16mm polyethylene pipe to pipe coupler is shown cleaned in Figure 22. No deformations were found with the polyethylene coupler.

The steel pipe segment with the threaded going to the house meter is shown in Figure 23. The threads are in reasonably good condition, but the last 4 threads are bent as shown in Figures 24 and 25. This end of the pipe had high bending loads applied through lever action on the pipeline. This may have occurred during the gas explosion.

Coupler labels are shown in Figures 26 and 27 (orange cover). The label on the orange-coloured coupler is partially obscured by scuffing damage.

3.0 LEAK TEST

The section of pipe between the threaded steel end (meter end) and the 16mm yellow plastic pipe fracture was performed using compressed air. (Figures 28 and 29). A pressure of 10 psi was put on the line for a period of 10 minutes. The polyethylene coupler did not show any evidence of leaks. However, both the steel-polyethylene coupler and the steel-steel coupler showed significant leaking as demonstrated by bubble testing in Figure 30.

4.0 MEASUREMENT OF PERMANENT PLASTIC DEFORMATION IN 16MM YELLOW PIPE AT POINT OF FRACTURE

The pipe had necked down prior to fracture at the elbow exit point. Permanent deformation was measured diametrically using calibrated Vernier Calipers. Permanent elongation along the length of the pipe is indicated by diameter measurements taken all along the pipe. It appears that permanent "stretching" and "necking "of the pipe occurred over approximately 1 m.

Table 1: Diametrical Permanent Deformation in Fracture Zone

Distance From Fracture (mm)	Diameter (mm)	Comments
0	14.14	
2.5	14.70	
5	15.70	
10	15.68	
15	15.67	
20	15.76	
250	15.88	
1000	15.98	End of diameter change
1500	16.01	No diameter change
2000	16.02	
3000	16.00	

4.0 FTIR ANALYSIS OF 16MM FRACTURED YELLOW PIPE

FTIR analysis was performed on the yellow plastic pipe and 90-degree elbow fitting. Both had identical compositions meeting the chemical make-up of polyethylene (Appendix B). EDXA analysis of the two components contained small amounts of inorganic fillers in the plastic pipe and no fillers in the elbow fitting.

5.0 TENSILE AND HARDNESS TESTING OF 16MM YELLOW PIPE

A segment of the 16mm polyethylene yellow Pipe downstream from the fracture was cut from the pipe segment at a distance of 1m from the fracture and prepared for tensile testing. No permanent deformation had occurred to the pipe at this location. The average pipe dimensions are as follows:

- Outside diameter – 16.0 mm
- Inside diameter – 11.10 mm
- Average wall thickness – 2.45 mm

The pipe failed at a tensile load of 521 lb at a maximum stress of 3183 psi (21.95 MPa). The tensile test load - position curve is shown in Appendix B. The fracture appearance is very ductile and is much more elongated than that found with the field fracture as shown side by side in Figure 31. This is an important observation since the strain rate during tensile testing was very slow. The fact that the elongation in the field failure was low with the same material and approximate temperature range (-2° C - 7° C) indicates that the strain rate was very high.

The hardness of the yellow pipe was measured using a Shore D hardness tester calibrated in the range Shore D 30 – 90. The average hardness of the yellow pipe at least 1 m away from the fracture was Shore D 60. The pipe material was slightly harder near the fracture zone and averaged Shore D 62 – 65 in this cold worked area. These hardness values are in the correct range for medium density polyethylene gas pipe.

6.0 SCANNING ELECTRON MICROSCOPE (SEM) EVALUATION

A scanning electron microscope (SEM) with attached energy dispersive X-ray analysis capability was used to examine the 16 mm pipe fracture surface. The MDPE pipe contained very small amounts of inorganic fillers made up of silica and alumina. The polyethylene elbow and coupler did not contain any inorganic fillers.

The pipe fracture surface was prepared for viewing by cutting the fracture surface approximately 20 mm from the end. The piece was cleaned in alcohol before placing in the SEM chamber.

The fracture contains ductile tendrils that have a shear component that indicates that the pipe was pulled in tension with a moderate bending component at the same time (Figure 32 and 33). Higher magnification views of the fracture surface show fine ductile tendrils (Figure 34and 35).

The exact orientation of the pipe relative to its position in the ground could not be determined. However, the matching fracture features on the elbow indicate that bending occurred in a direction perpendicular to the plane of the "elbow". If the elbow followed the horizontal lay of the pipe and was parallel to the ground, it is likely that the yellow 16 mm pipe was pulled upward and toward the street to create both tensile and shear stresses on the 16 mm polyethylene pipe and attached elbow.

7.0 ELBOW CROSS SECTION EVALUATION

A cross section was prepared through the elbow containing the fractured 16 mm pipe as shown in Figures 36 – 38. The pipe is not completely fused along the length of the insert, but the upset of the pipe into the elbow is correct at the point of contact. The joint is fully fused to make a seal at the contact location. The elbow does not show any sign of manufacturing defects.

8.0 DISCUSSION OF FINDINGS

The evidence shows that the yellow 16 mm OD MDPE pipe suffered a catastrophic ductile fracture due to overload conditions introduced to the pipe. Permanent deformation in the unrestrained end of the yellow pipe indicates that the pipeline was lifted or pulled in a way that loaded the pipe both axially and in rotational shear. The shear component of the fracture features indicate that the pipe was being twisted during the failure event. For the fracture to occur with such little elongation, the pipe must have been fully restrained and/or loaded at a high strain rate at the elbow location. The lifting action allowed the pipe to rotate around the restrained elbow location while the remainder of the pipe leading to the house was relatively fixed.

The threaded end of the ¾" steel pipe was bent at the threads where it was attached to the meter. It is probable that this permanent bending occurred as a result of the house explosion, since no other damage or deformation was noted on the steel segments of the line.

The two steel-polyethylene couplers were found to be leaking during air pressure testing at 10 psi. There was a 2-psi pressure drop during low flow rate testing which is significant in terms of volume of gas being lost through the couplers. It is possible that the house explosion created enough movement to loosen the couplers, or that heat from the subsequent fire caused loosening of the couplers.

[redacted]

[redacted]

ACUREN GROUP INC.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

APPENDIX A

FIGURES 1 – 38

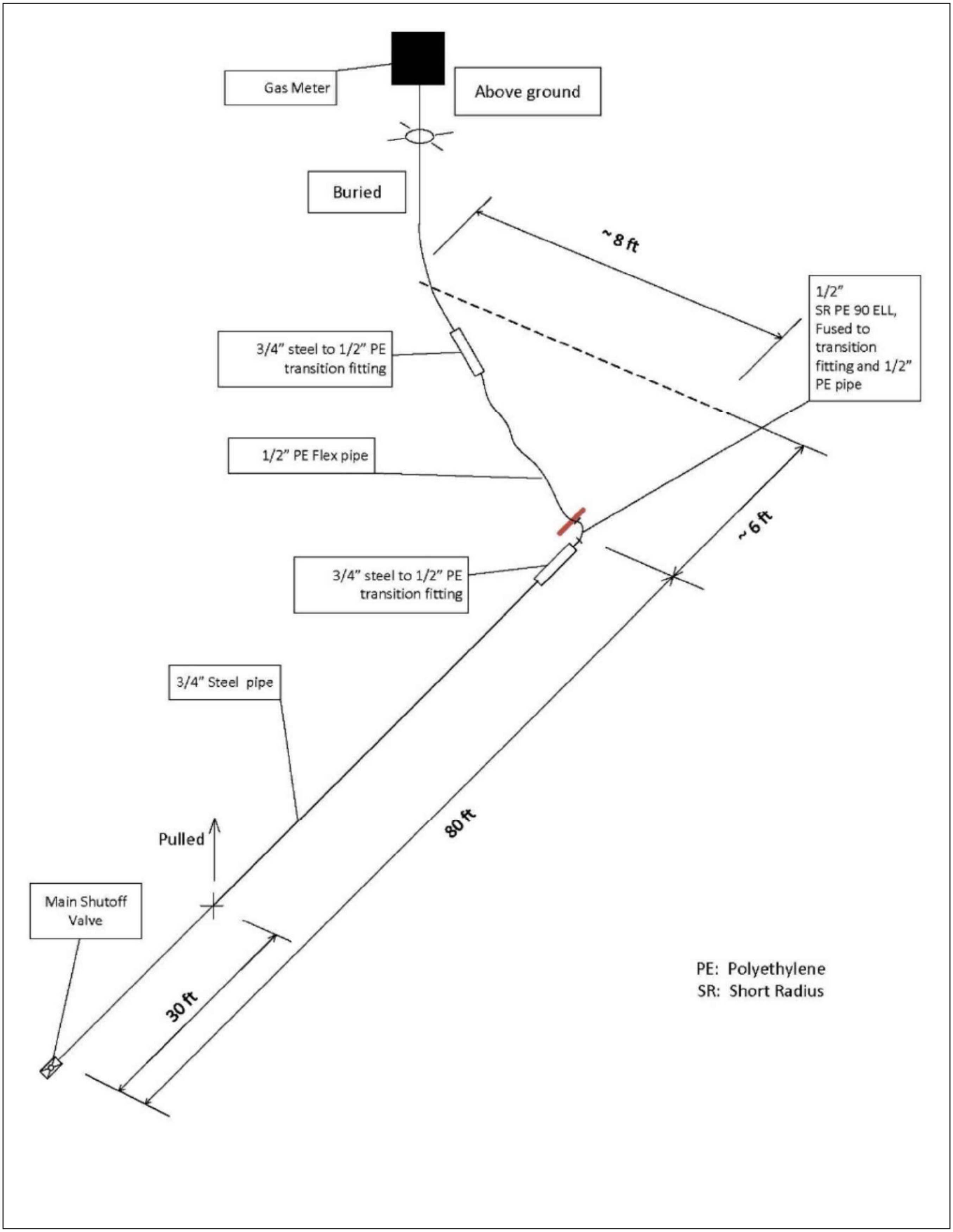


Figure 1 Sketch of gas piping found at house explosion location. Main shutoff was achieved by crimping.

Figure 2 Overall view of submitted piping system associated with natural gas explosion. Polyethylene pipe fracture took place at elbow exit point.

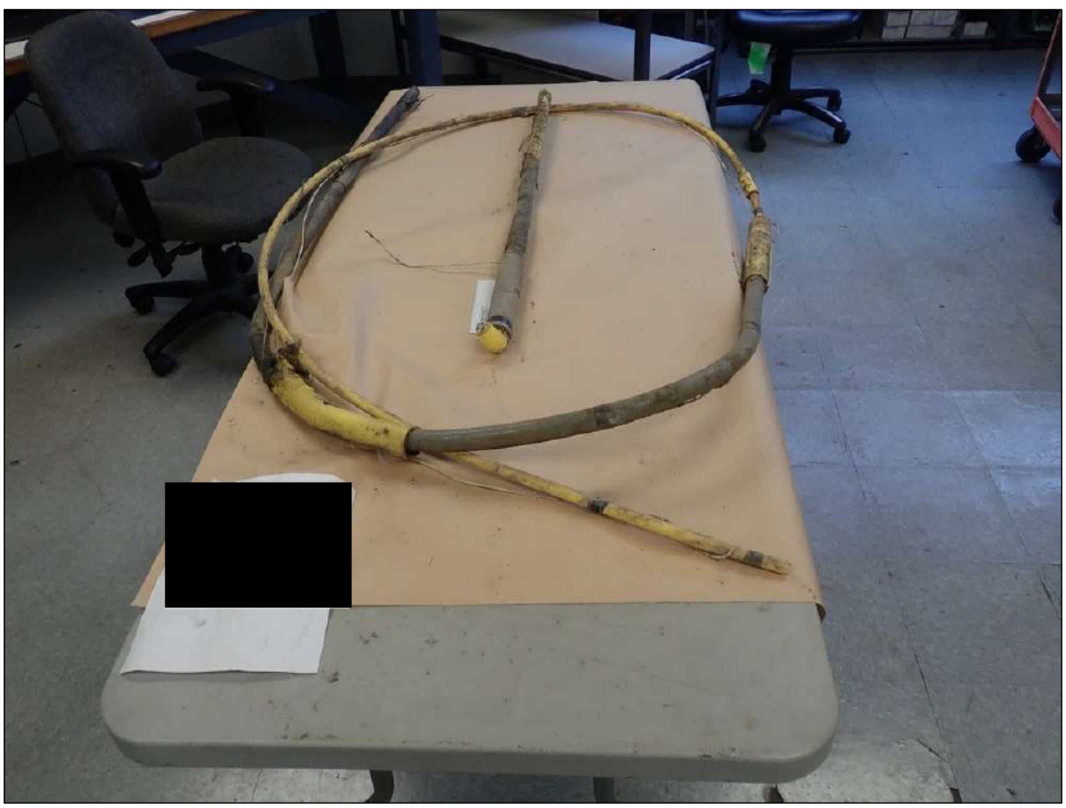


Figure 3 Second view of submitted piping system associated with natural gas explosion.

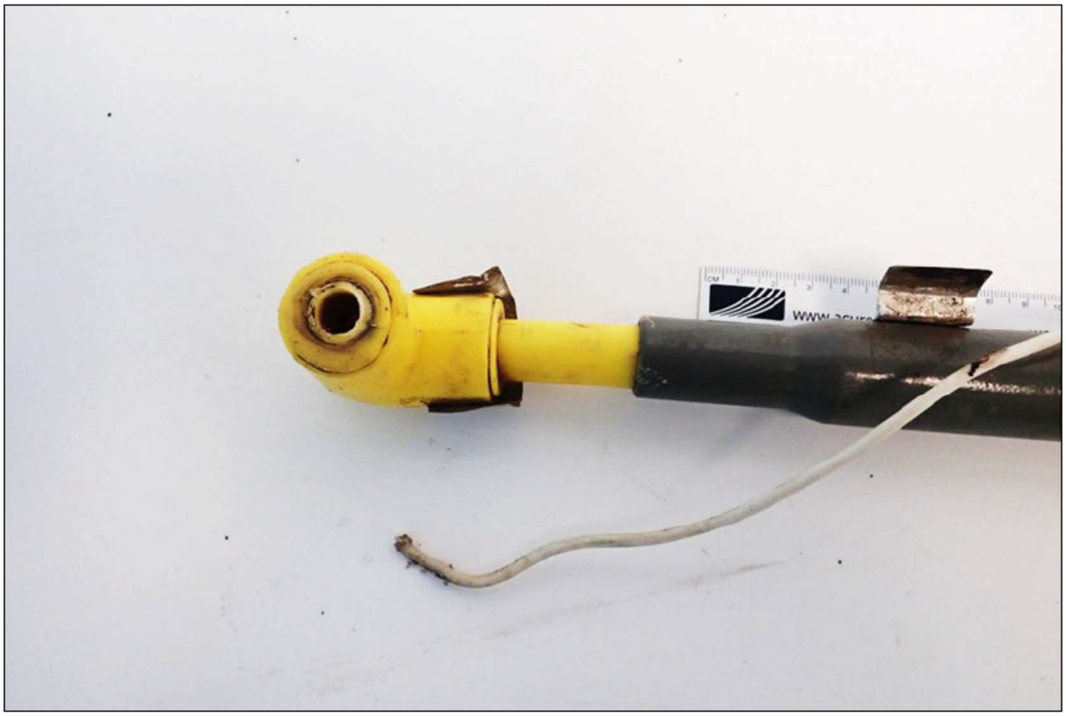


Figure 4 View of coupler on main side of elbow. Copper jumper wire has been severed.

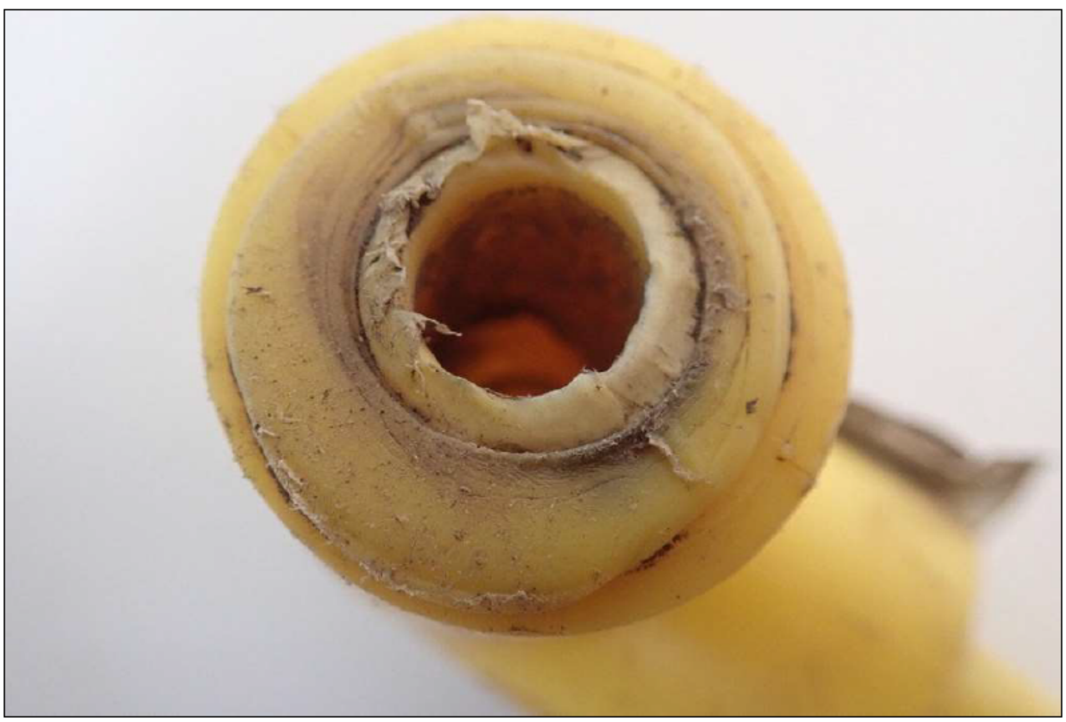


Figure 5 Close-up view of pipe fracture surface coming from elbow showing shear component to failure. Elongation was relatively small and indicative of rapid strain rate.

Figure 6 Fractured end of yellow 16 mm polyethylene pipe showing relatively light deformation and necking at fracture point.

Figure 7 Piping segment from street side of pipe run showing crimp location under tape and grey cover over copper connection.

Figure 8 Taped crimp location.

Figure 9 Polyethylene to polyethylene coupler adjacent to steel-polyethylene coupler.

Figure 10 Cleaned yellow poly cover form steel pipe run. Cover is burned from subsequent fire.

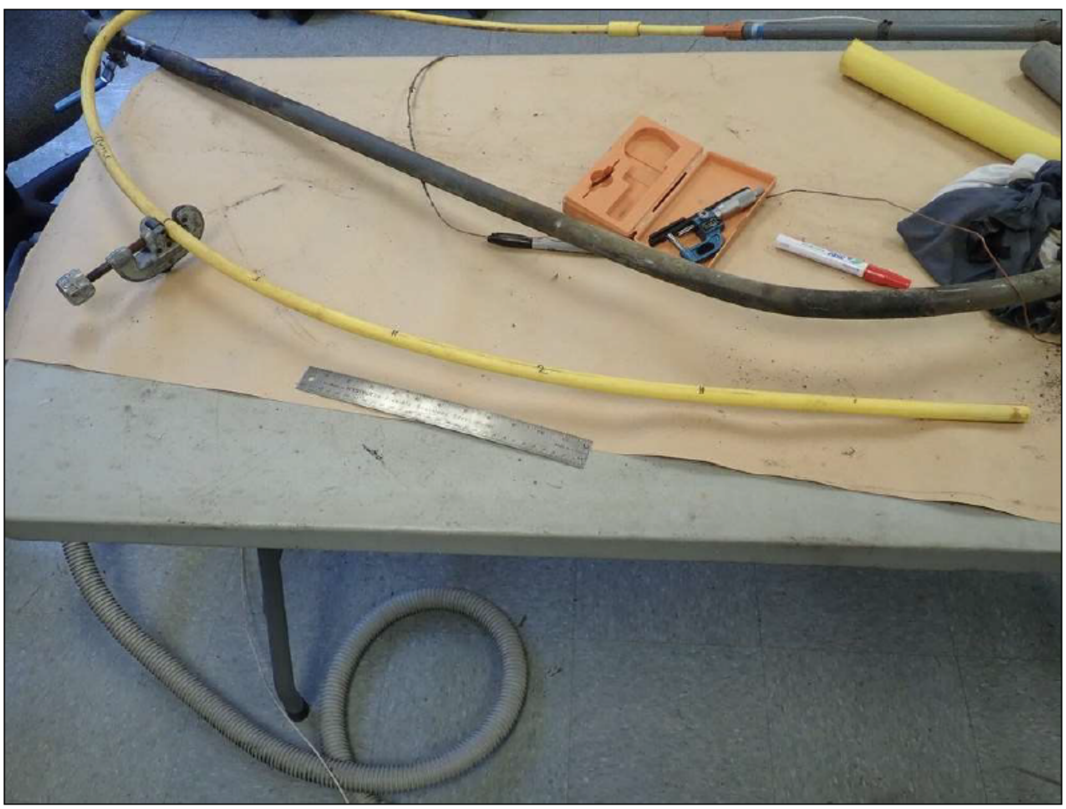


Figure 11 Cleaned 16mm polyethylene run showing location of diametrical measurements.

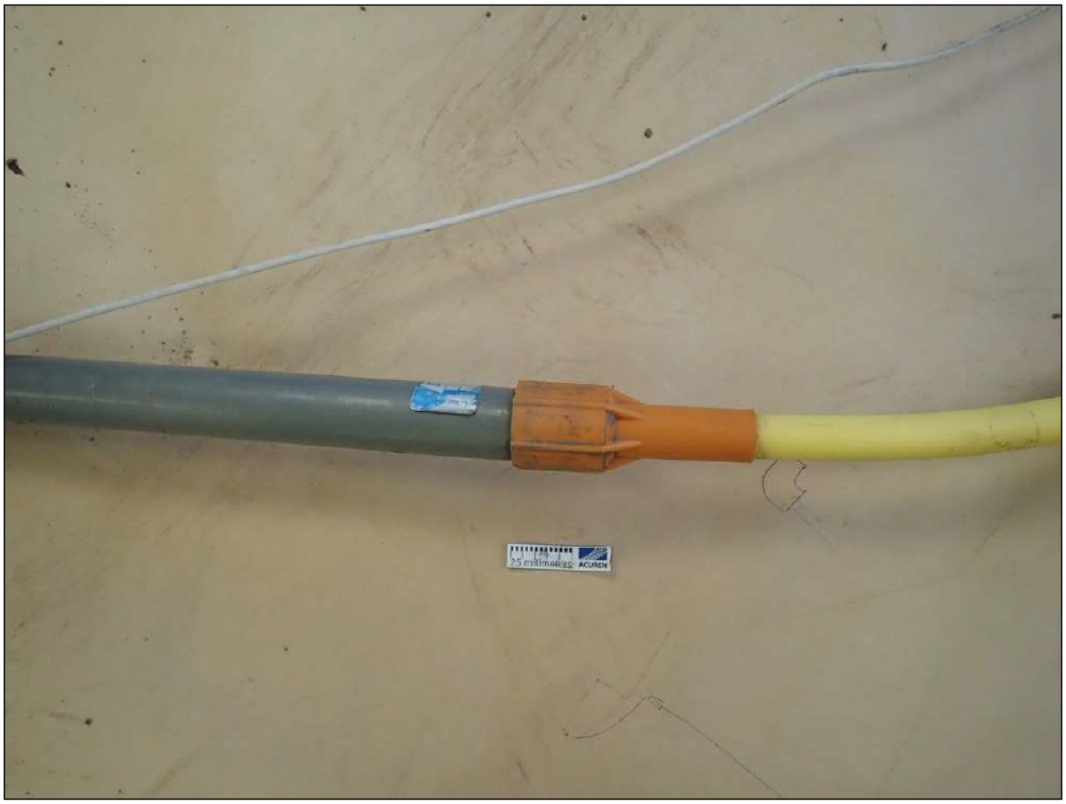


Figure 12 Overall view of steel pipe to polyethylene coupler.

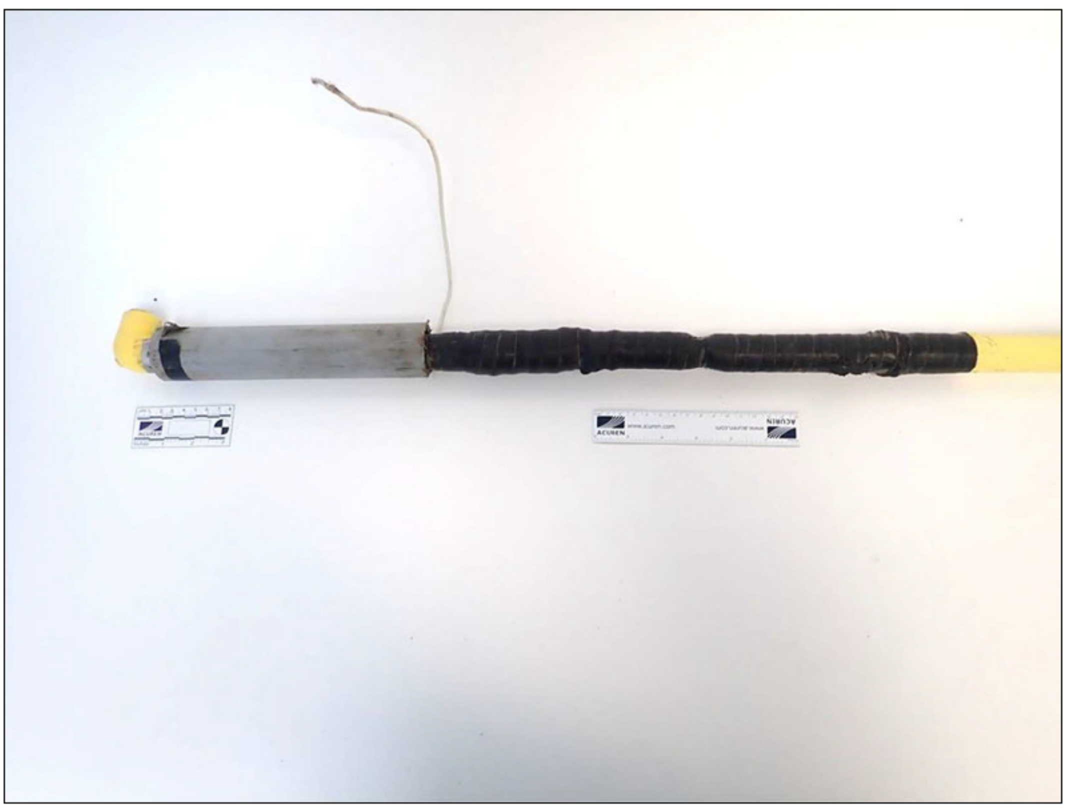


Figure 13 Cleaned crimp area with steel main, crimp, coupler, and elbow present.

Figure 14 Closer up view of cleaned pipe fracture still attached to elbow. Note shear component of failure.

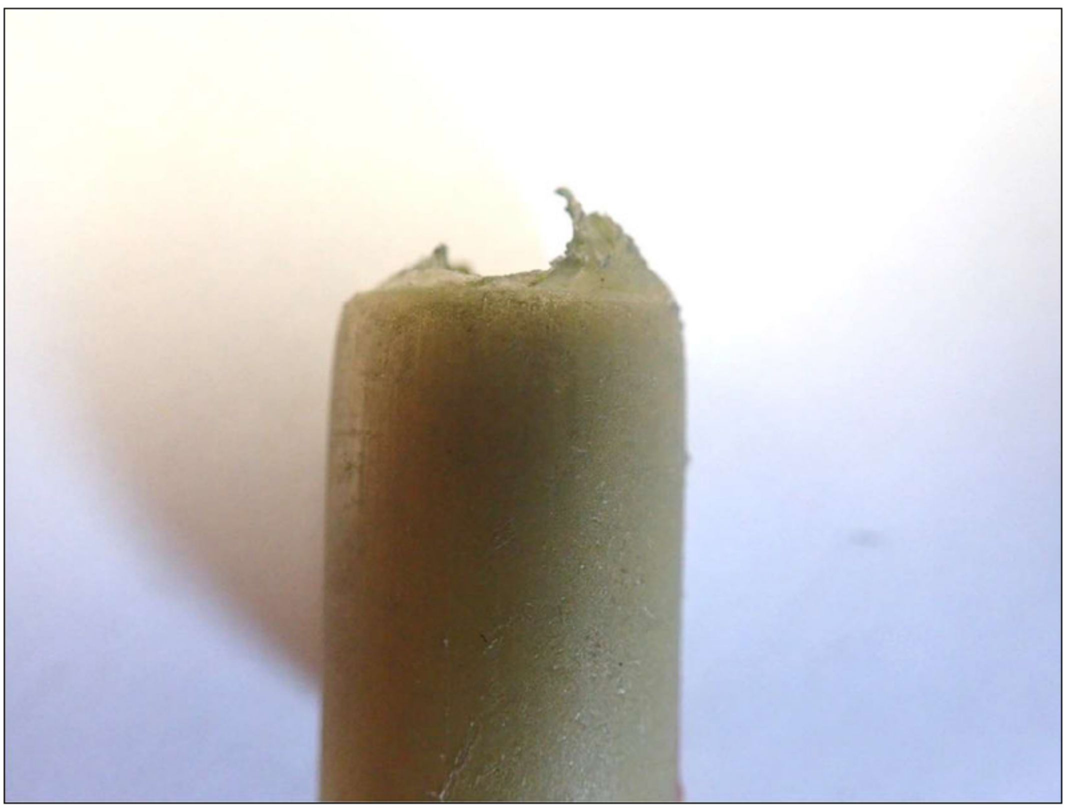


Figure 15 Side view of polyethylene pipe fracture showing small amount of necking.

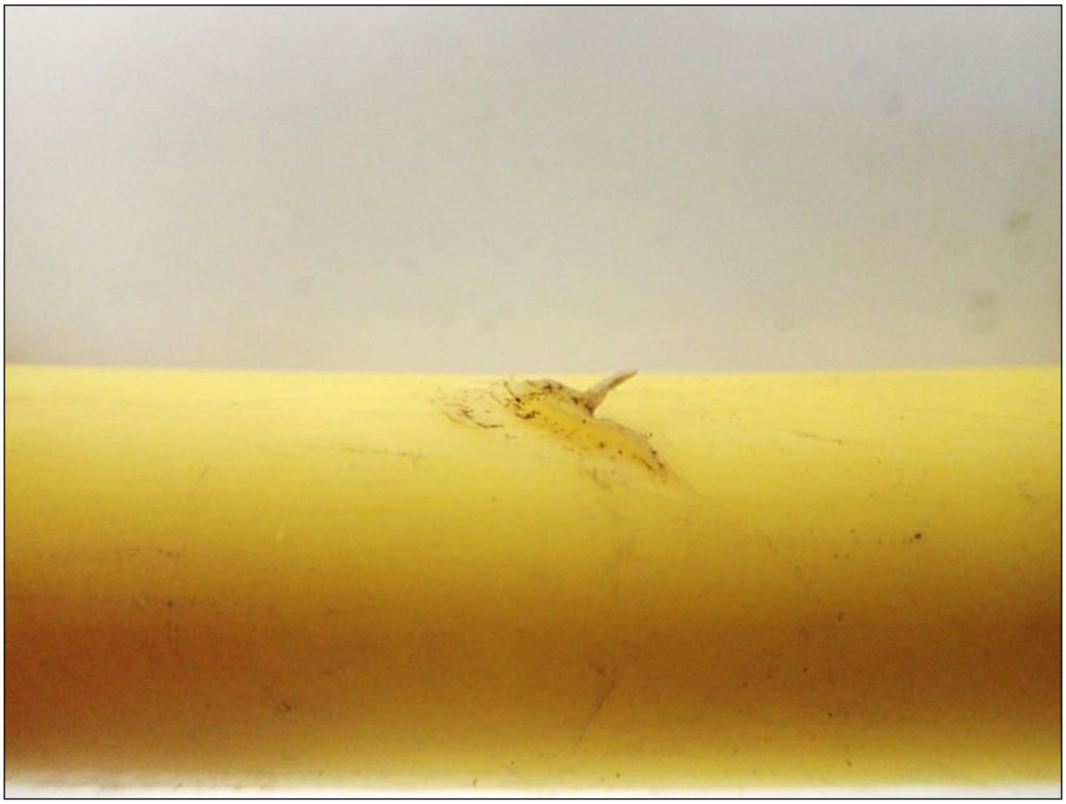


Figure 16 Nicks in pipe away from fracture.

Figure 17 Gouge in pipe away from fracture.

Figure 18 Close-up view of crimp used to shut off gas during construction.

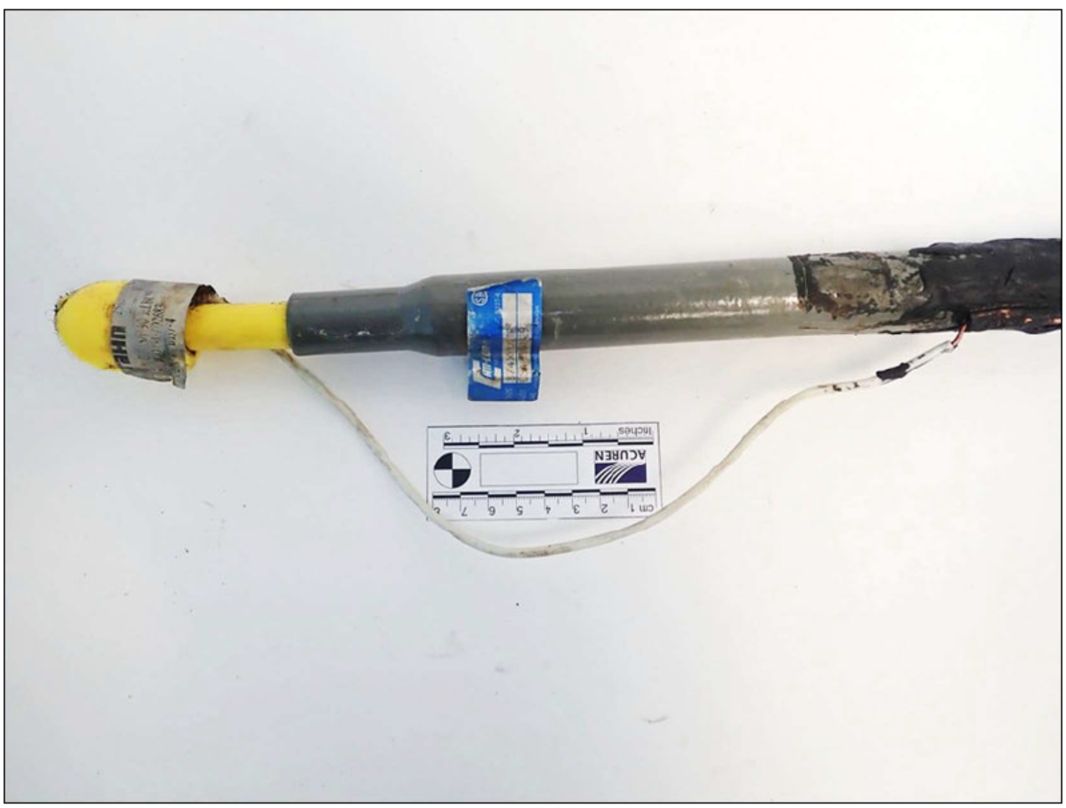


Figure 19 Cleaned coupler between short piece of polyethylene pipe and ¾" steel main.

Figure 20 Coupler from threaded steel pipe to long run of yellow 16 mm pipe.

Figure 21 Close-up view of orange cover on threaded steel to polyethylene pipe coupler. This coupler leaked during testing.

Figure 22 Cleaned polyethylene to polyethylene coupler. This coupler did not leak.

Figure 23 Threaded steel pipe going to meter. Last 4 threads are severely bent.

Figure 24 Evidence of bent threads.

Figure 25 Evidence of bent threads.

Figure 26 Label on steel – polyethylene coupler. No evidence of date is present.

Figure 27 Label on steel – polyethylene coupler. Numbers and letters are partially obscured.

Figure 28 Pressure test piping @ 10 psi.

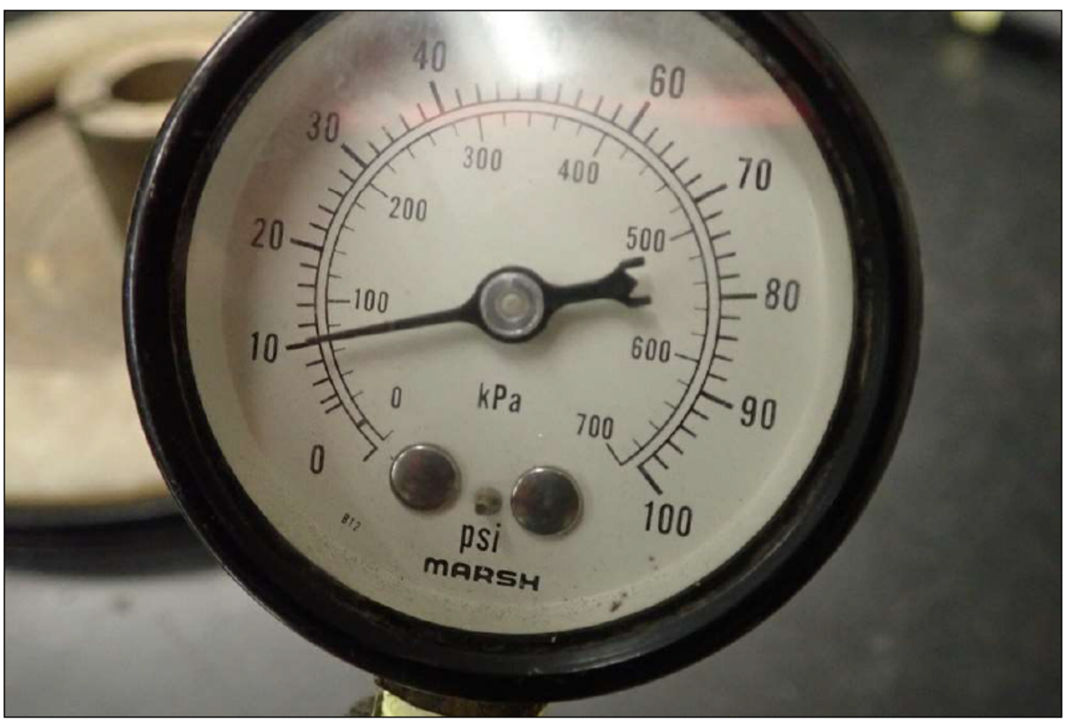


Figure 29 Pressure 10 psi held during testing.

Figure 30 Leaking found with coupling. Leaking was found on steel-steel and steel – polyethylene couplings.

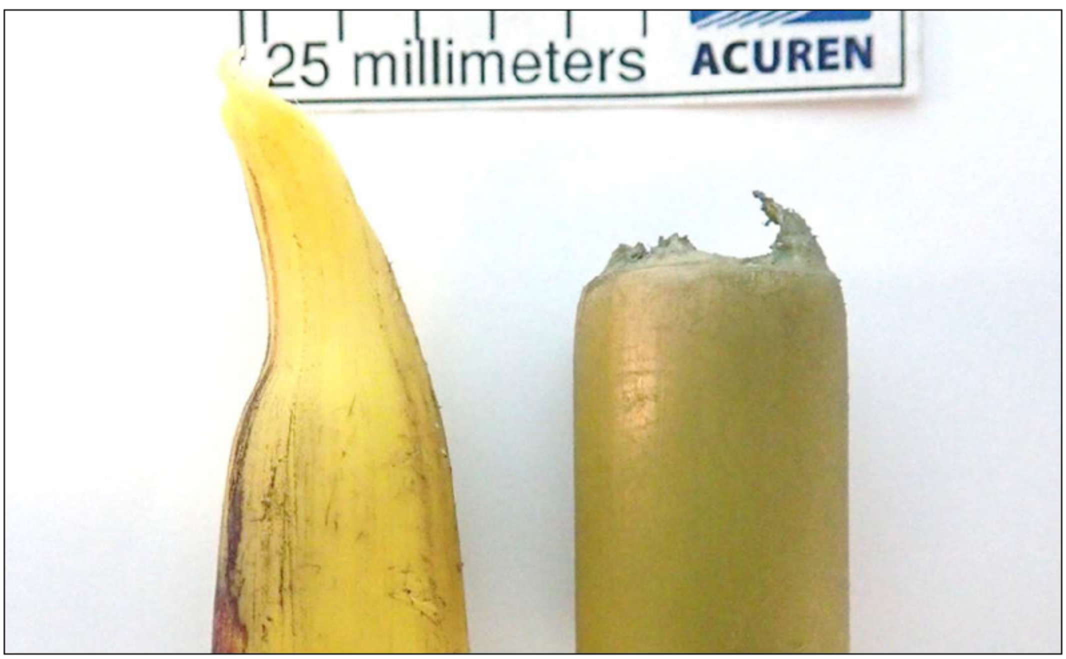


Figure 31 Difference in lab tensile fracture and field fracture at same relative temperature. Lack of ductility in filed fracture indicates high strain rate.

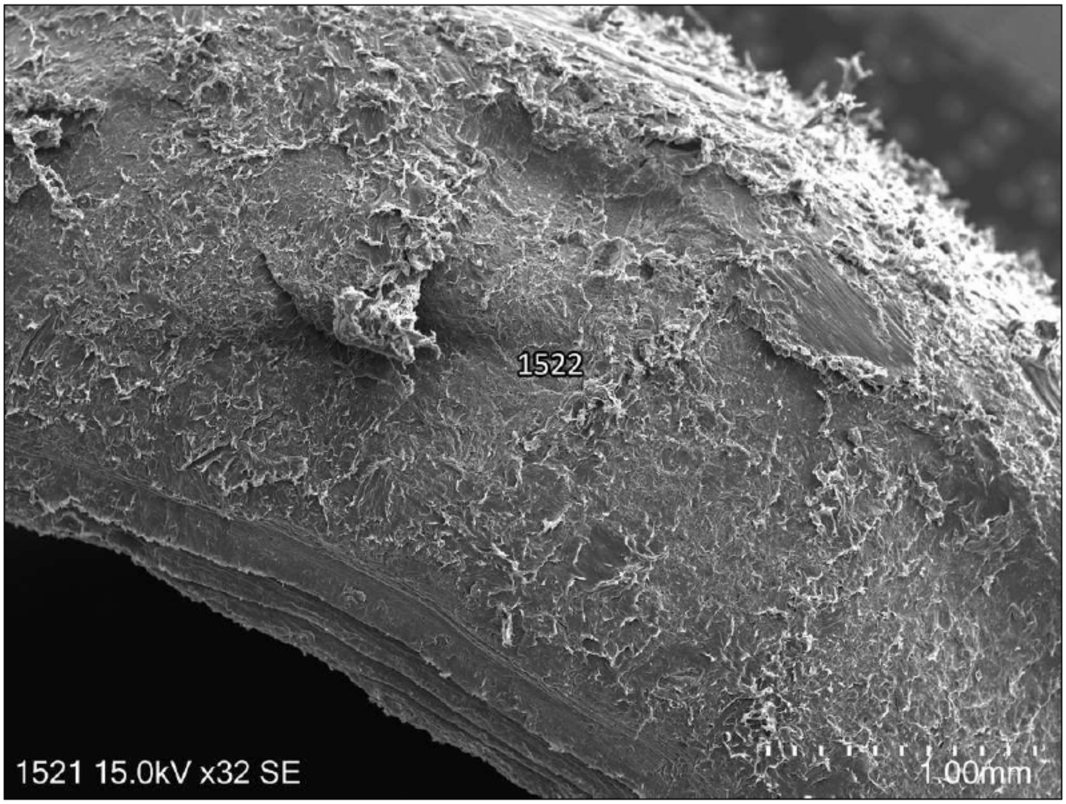


Figure 32 SEM view of 16mm pipe fracture surface on compression side of bending failure.

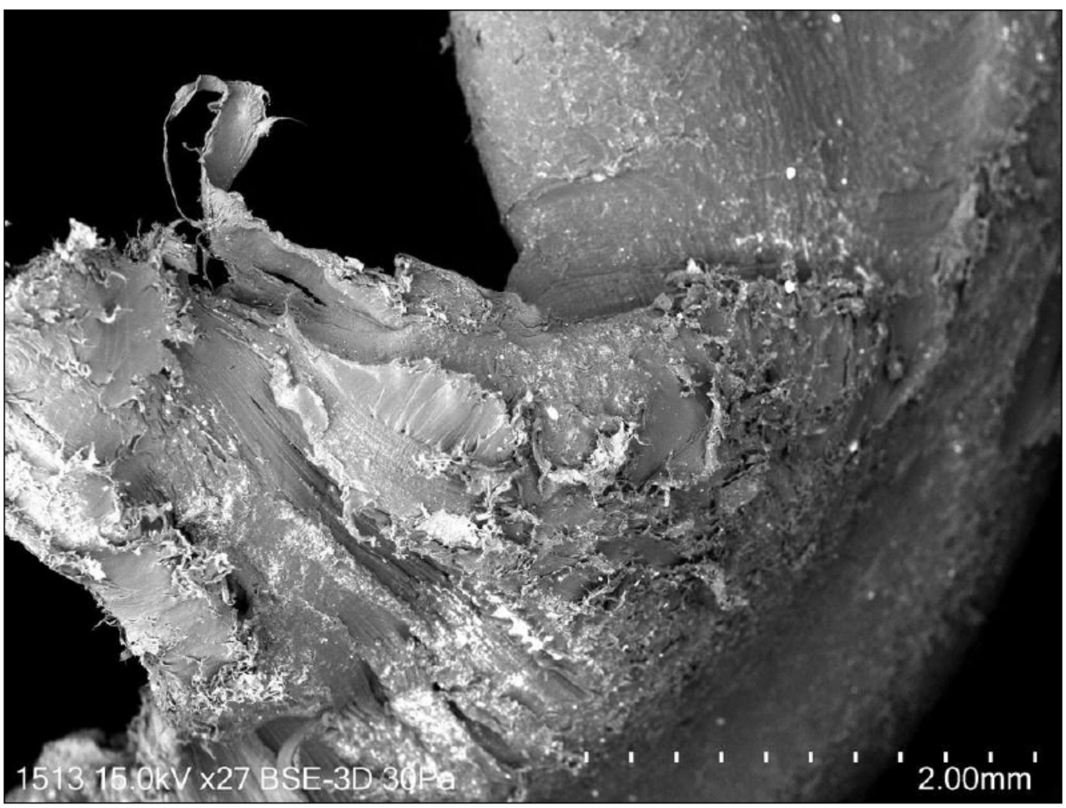


Figure 33 SEM view of 16 mm pipe fracture surface on tension side of bending failure.

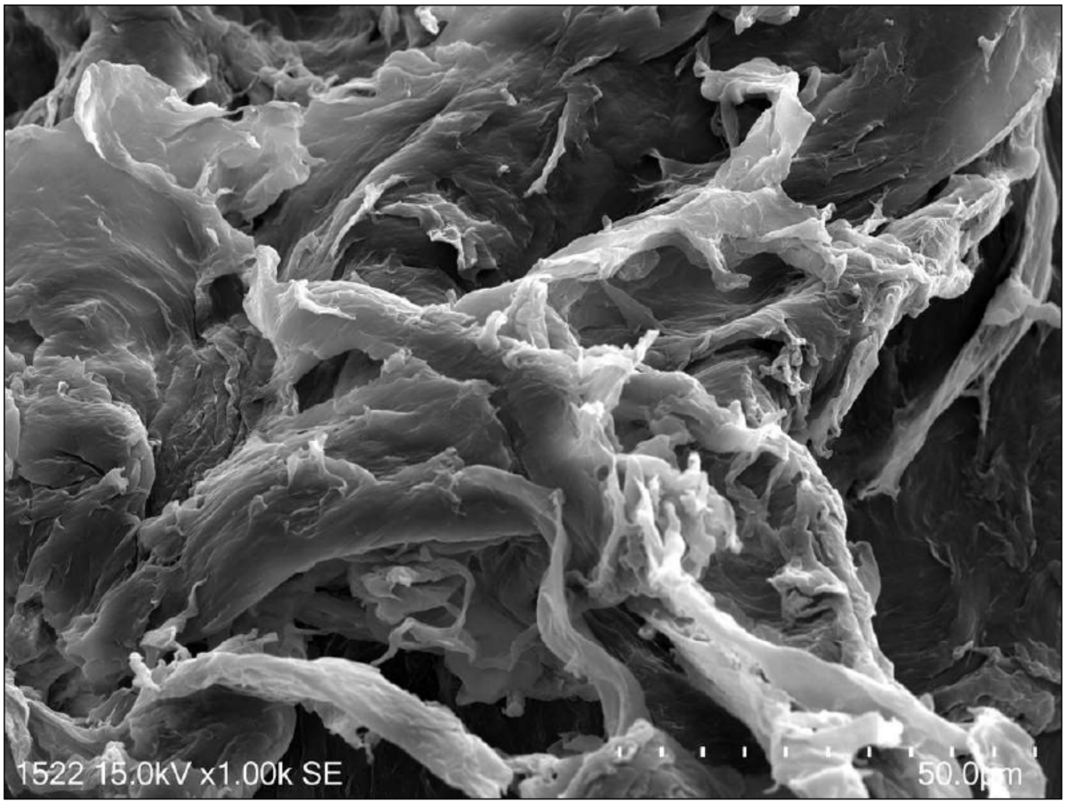


Figure 34 Ductile tendrils taken at location 1522 shown in Figure 32.

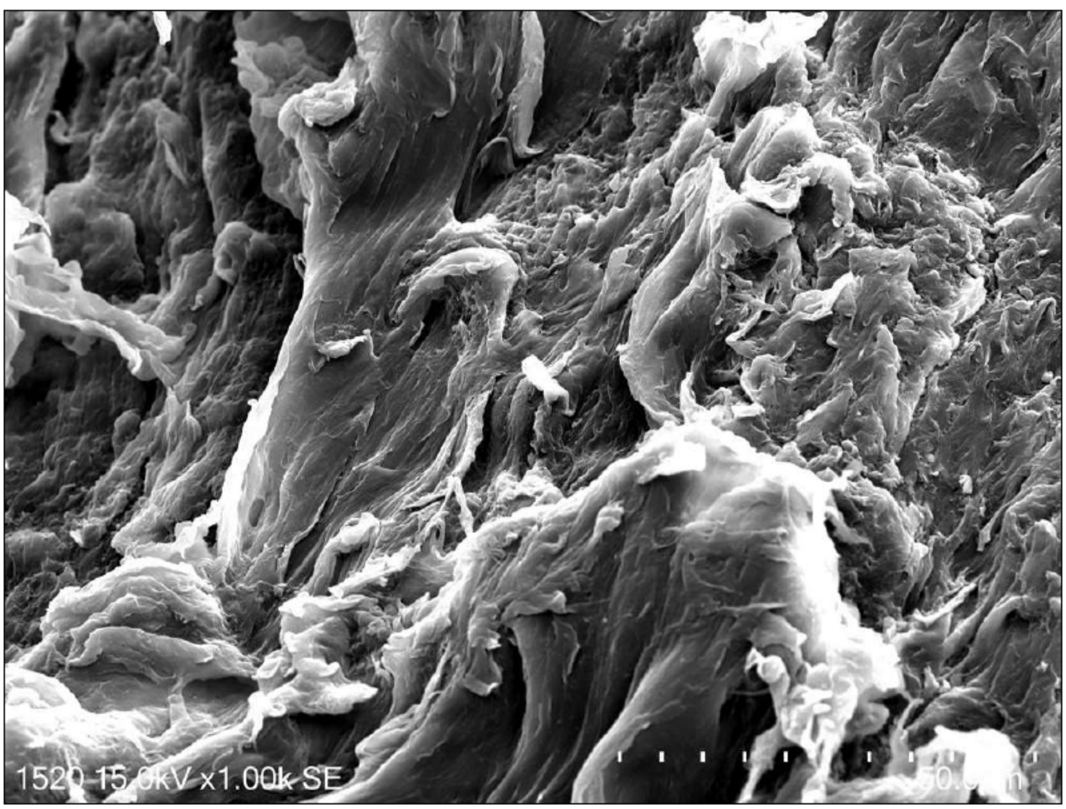


Figure 35 Ductile tendrils taken from area shown in Figure 33.

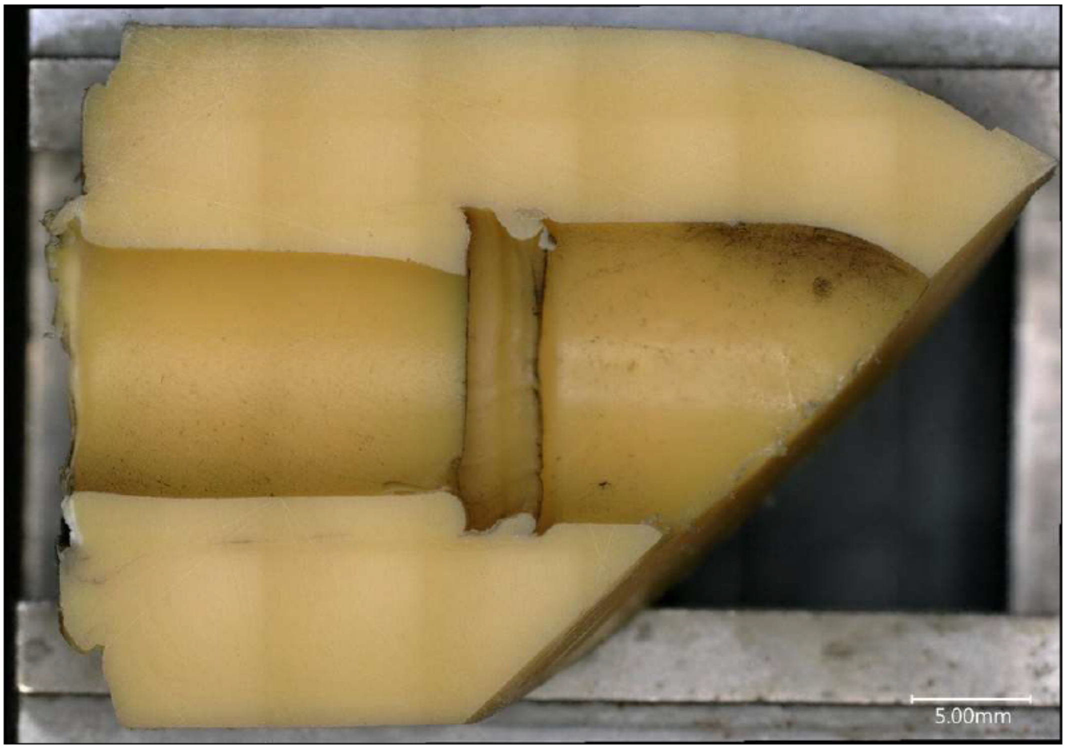


Figure 36 Cross section taken through 90 ° elbow. Fusion is complete at joint.

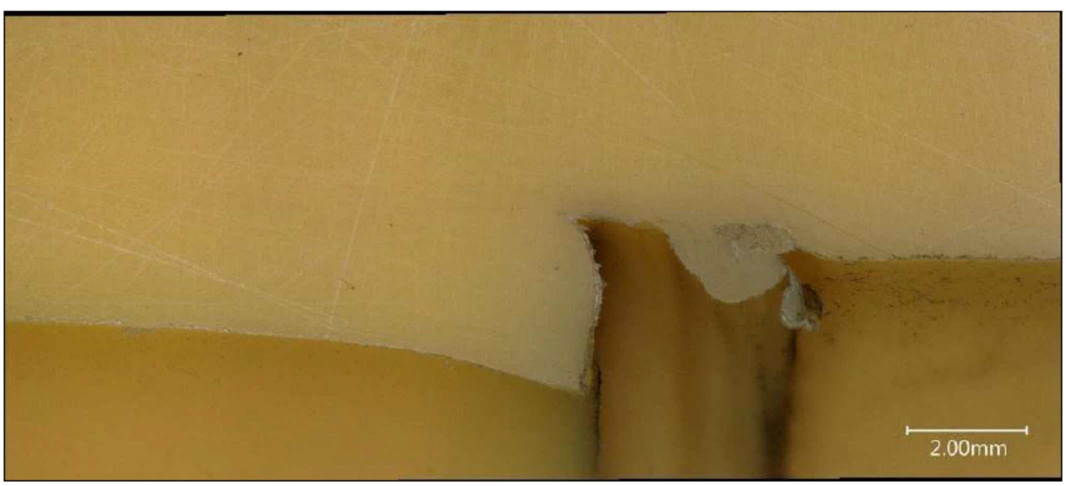


Figure 37 Cross section through 90 ° elbow showing upset and fusion at joint.

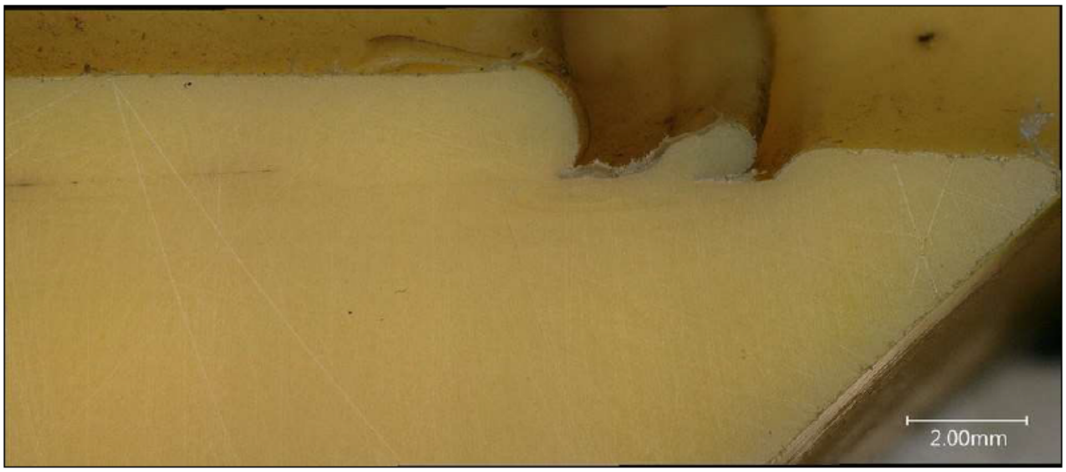
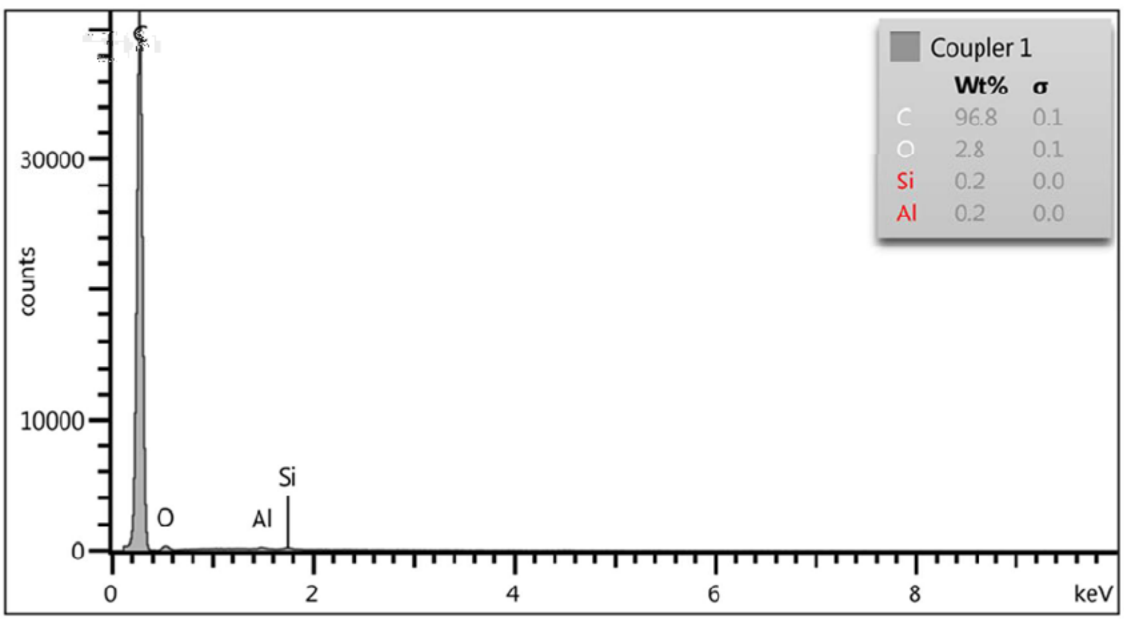
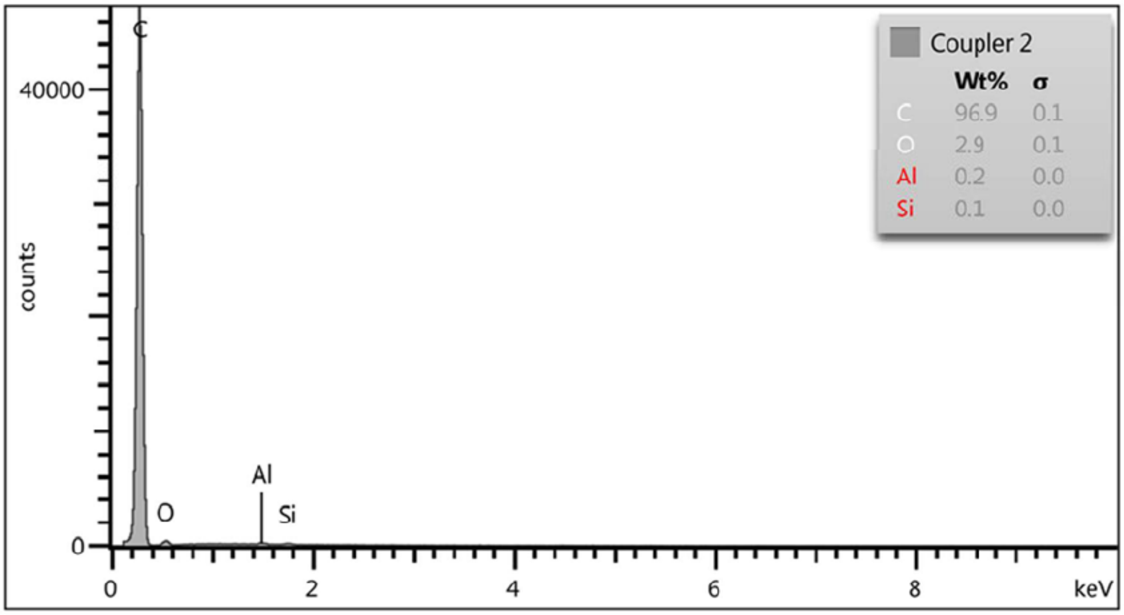


Figure 38 Opposite side of section shown in Figure 37 showing upset and proper fusion.

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Wt% σ
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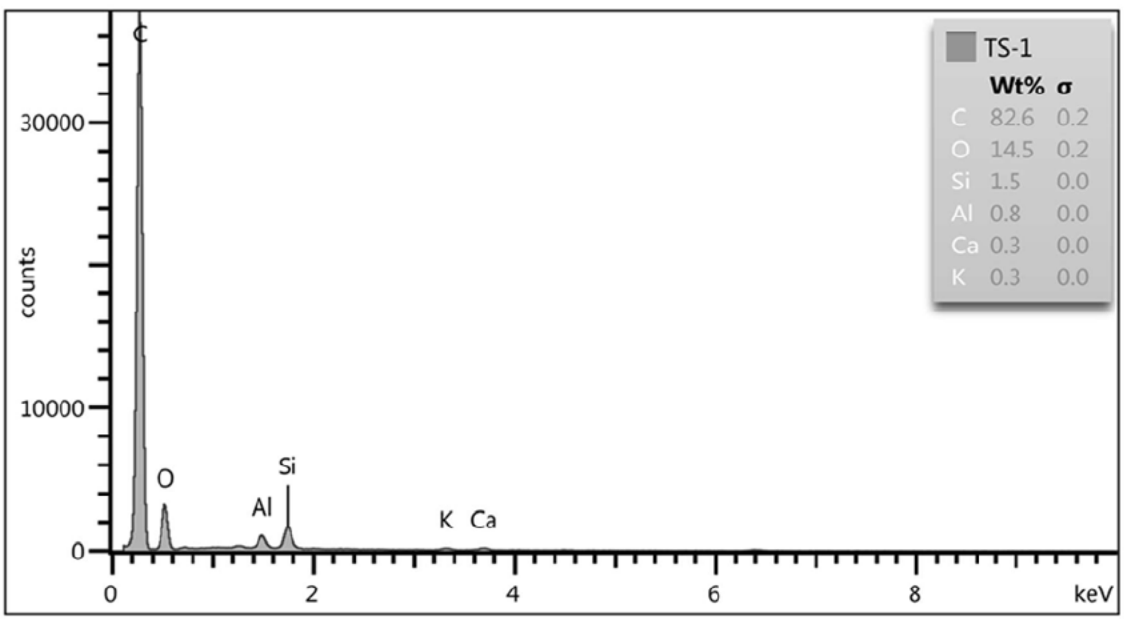
O 2.9 0.1
Al 0.2 0.0
Si 0.1 0.0
counts
40000
0
C
O
Al
Si
0
2
4
6
8
keV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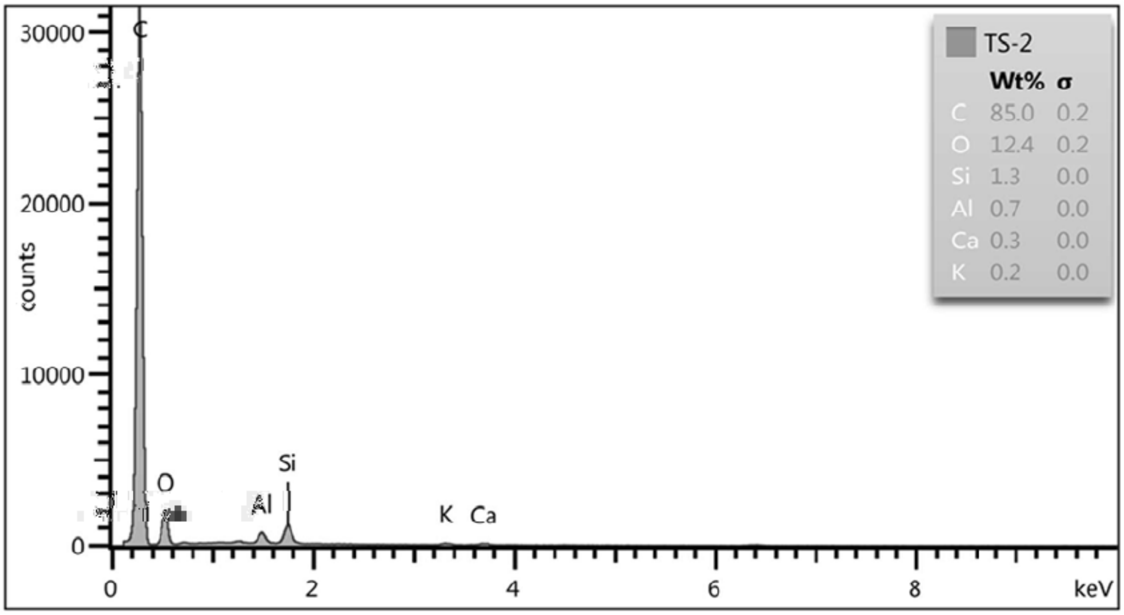
Wt% σ
C 82.6 0.2
O 14.5 0.2
Si 1.5 0.0
Al 0.8 0.0
Ca 0.3 0.0
K 0.3 0.0
counts
30000
10000
0
C
O
Al
Si
K Ca
0
2
4
6
8
keV



TS-2
Wt% σ
C 85.0 0.2
O 12.4 0.2
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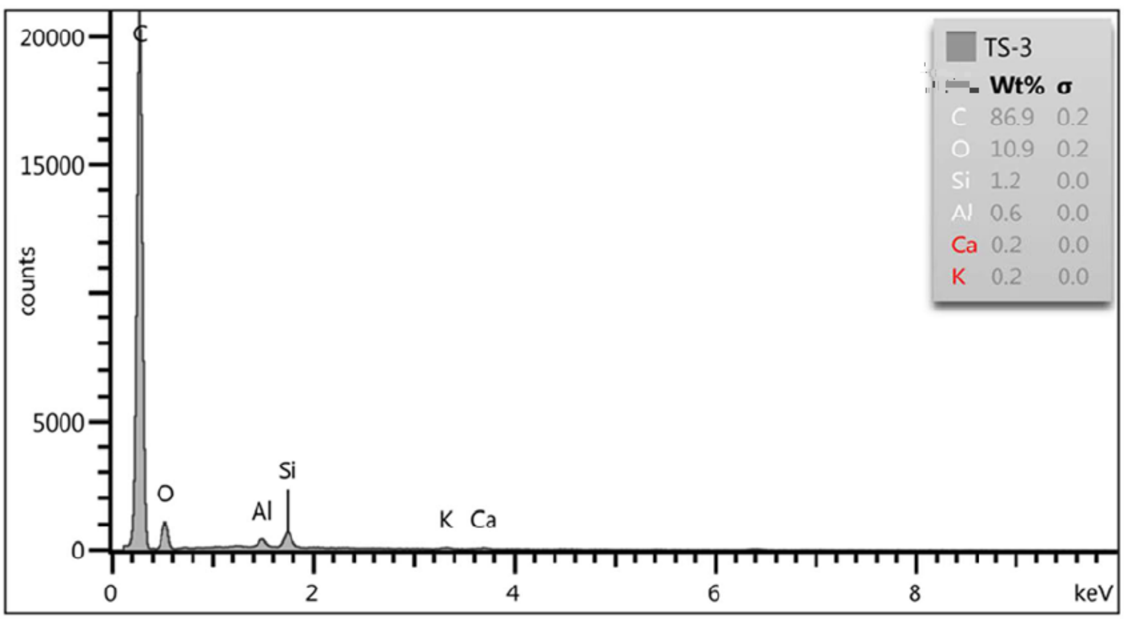
Al 0.7 0.0
Ca 0.3 0.0
K 0.2 0.0
counts
keV



TS-3
Wt% σ
C 86.9 0.2
O 10.9 0.2
Si 1.2 0.0
Al 0.6 0.0
Ca 0.2 0.0
K 0.2 0.0
counts
keV

ACUREN

APPENDIX B

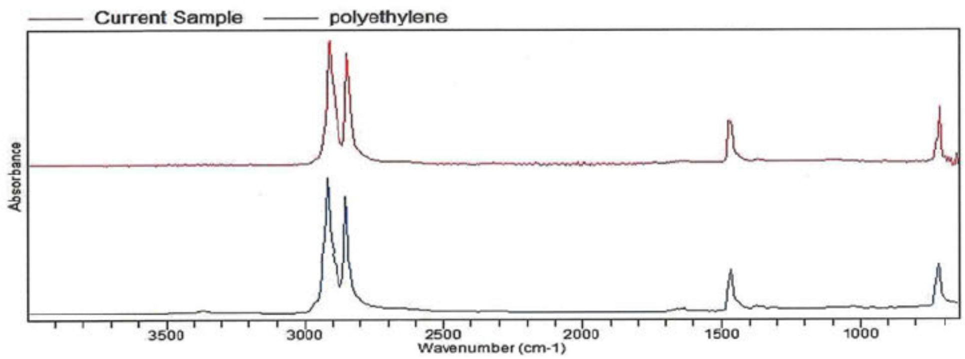
FTIR ANALYSIS OF PIPE AND COUPLER

Agilent Technologies

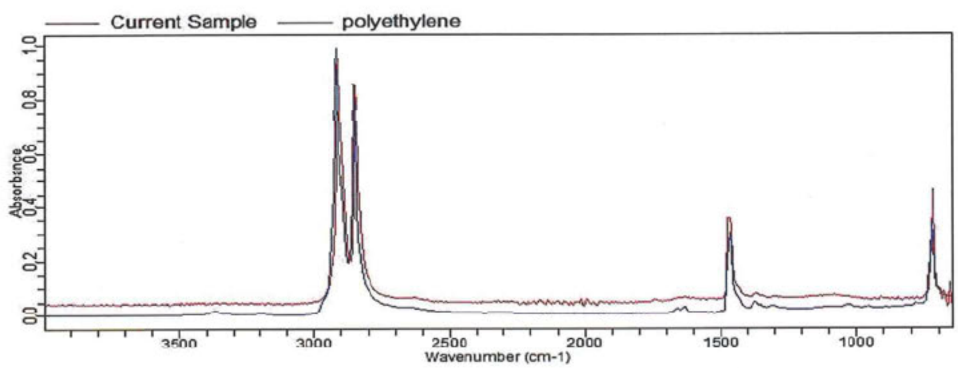
Sample ID:605-16877 TS
Sample Scans:8
Background Scans:8
Resolution:4
System Status:Good

Method Name:rjw
User[redacted]
Date/Time:2022-04-13T15:33:44.663-07:00
Range:4000 - 650
Apodization:Happ-Genzel

[redacted]



Zoomed Spectral Overlay



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page 1 of 2

Agilent Technologies

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Sample Scans:8
Background Scans:8
Resolution:4
System Status:Good

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Date/Time:2022-04-13T15:35:37.574-07:00
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Apodization:Happ-Genzel

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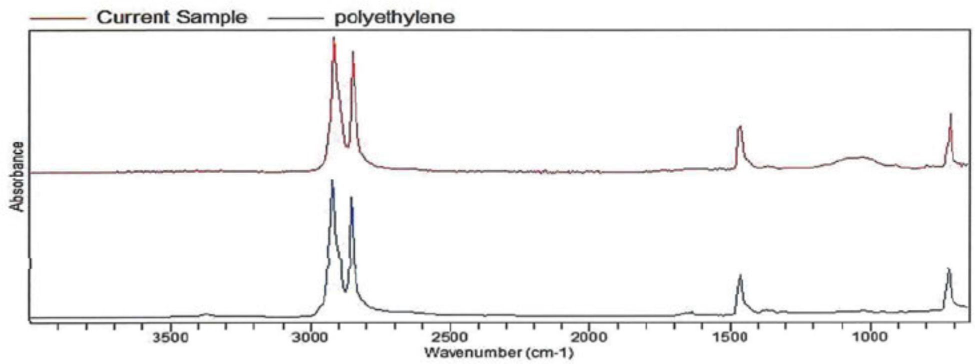
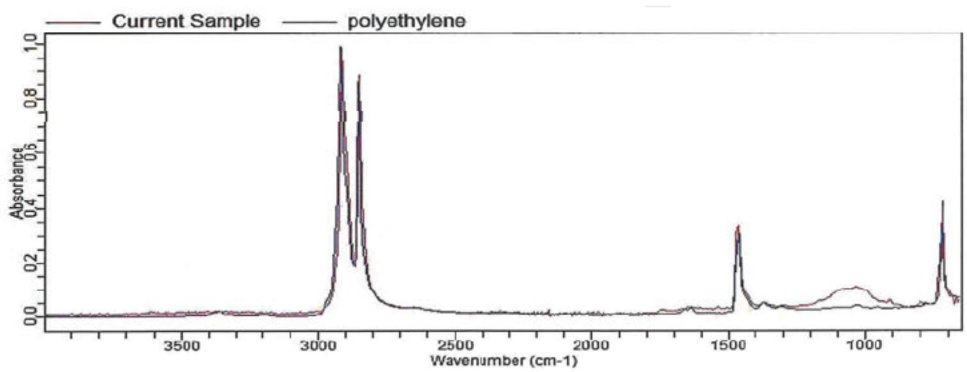


Zoomed Spectral Overlay



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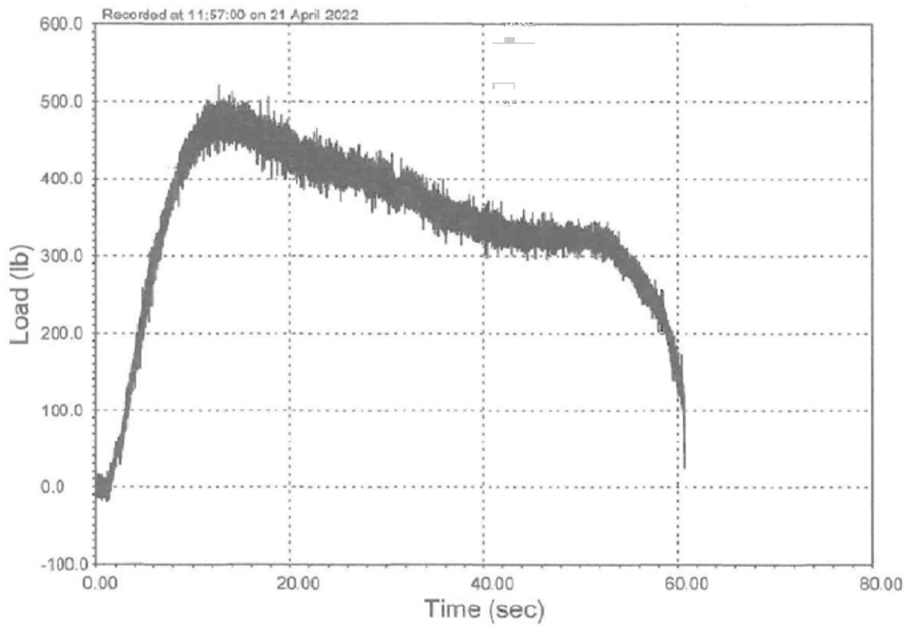
page 1 of 2

Tensile Test - Technical Safety



Specimen identifier:	1
Date:	April 21, 2022
Operator:	[redacted]
Client:	Technical Safety
Job Number:	60516877
Dimension Check:	Okay
Geometry:	Tube
Outer Diameter:	15.95000 mm
Thickness:	2.50000 mm
Area:	105.63605 sq mm

Analysis Results

Maximum Load	
Load	521 lb

A