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Guidelines/Best Practices for Scraping PE Pipe and Fittings

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Table of Contents

Legal Notice.....	2
Table of Contents.....	3
Table of Figures.....	4
List of Tables.....	8
List of Acronyms.....	8
Executive Summary.....	9
Introduction.....	12
Background on Scraping Depth.....	14
Testing.....	16
Scrape Depth Testing.....	16
Frialen Peeler, 2" IPS.....	17
Frialen Peeler, 4" IPS.....	21
Half-Moon Scraper, 2" IPS.....	25
OEM Peeler, 2" IPS.....	29
OEM Peeler, 4" IPS.....	33
Friatec Hand Scraper.....	37
Pencil Scraper, ½" CTS.....	40
Summit Rotary Scraper, 4" IPS.....	44
Subjective Scraper Comparison.....	49
Contamination Removal Testing.....	50
Frialen Peeler, 2" IPS.....	51
Frialen Peeler, 4" IPS.....	56
Half-Moon Scraper, 2" IPS.....	62
OEM Peeler, 2" IPS.....	68
OEM Peeler, 4" IPS.....	74
Friatec Hand Scraper.....	80
Summit Rotary Scraper, 4" IPS.....	86
Discussion and Conclusions.....	92
Suggested Scraping Procedure Guideline.....	95
Related OTD Projects and Potential Future Work.....	98
Works Cited.....	99
Appendix A – Tested Scrapers.....	100
2" IPS OEM Peeler.....	100

2" IPS Frialen Peeler.....	101
2" IPS Half-Moon Scraper	102
4" IPS OEM Peeler	103
4" IPS Frialen Peeler.....	104
4" IPS Summit Rotary Scraper (rotary-type scraper)	105
1/2" CTS Pencil Scraper	106
Friatec Hand Scraper	107
Appendix B – Scraping Procedures (for testing).....	108

Table of Figures

Figure 1. Tested scrapers	11
Figure 2. Overview of electrofusion process, with highlights of OTD project scope	13
Figure 3. Degradation depth vs. UV exposure time, as measured by microscopy and FTIR carbonyl index methods. Taken from (Choi, 1992), Figure 5.9.	14
Figure 4. Overall scrape depth results, showing minimum, average, and maximum depths (0.002" line is provided strictly as a plot scale reference)	16
Figure 5. Typical scrape by 2" IPS Frialen Peeler	17
Figure 6. Frialen Peeler 2" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe	17
Figure 7. Non-scraped gaps left by 2" IPS Frialen Peeler.....	18
Figure 8. 2" IPS Frialen Peeler	18
Figure 9. Frialen Peeler 2" IPS: ovality after scrape versus ovality before scrape	19
Figure 10. Scrape depth on HDPE pipe versus MDPE pipe, at 70°F, with 30% error bars	20
Figure 11. Typical scrape by 4" IPS Frialen Peeler	21
Figure 12. Frialen Peeler 4" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe	22
Figure 13. Frialen Peeler 4" IPS: Ovality after scrape versus ovality before scrape.....	23
Figure 14. Frialen Peeler 4" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F	24
Figure 15. Typical scrape by 2" IPS Half-Moon Scraper (after several passes).....	25
Figure 16. Typical scrape by 2" IPS Half-Moon Scraper (after several passes), closer view of serrated surface	25
Figure 17. Half-Moon Scraper, 2" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe	26
Figure 18. Half-Moon Scraper, 2" IPS: Ovality after scrape versus ovality before scrape	27
Figure 19. Half-Moon Scraper, 2" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F	28

Figure 20. Typical scrape by 2" IPS OEM Peeler	29
Figure 21. OEM Peeler 2" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe	30
Figure 22. OEM Peeler 2" IPS: Ovality after scrape versus ovality before scrape	31
Figure 23. OEM Peeler 2" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F	32
Figure 24. Typical scrape by 4" IPS OEM Peeler	33
Figure 25. OEM Peeler 4" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe	34
Figure 26. OEM Peeler 4" IPS: Ovality after scrape versus ovality before scrape	35
Figure 27. OEM Peeler 4" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F	36
Figure 28. Typical scrape by Friatec Hand Scraper	37
Figure 29. Friatec Hand Scraper, 4" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe	38
Figure 30. Friatec Hand Scraper, 4" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F	39
Figure 31. Typical scrape by ½" CTS Pencil Scraper	40
Figure 32. Pencil Scraper, ½" CTS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe	41
Figure 33. Pencil Scraper, ½" CTS: Ovality after scrape versus ovality before scrape	42
Figure 34. Pencil Scraper, ½" CTS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F	43
Figure 35. Typical scrape by 4" IPS Summit Rotary Scraper	44
Figure 36. Inconsistent scrape depth by 4" IPS Summit Rotary Scraper	45
Figure 37. Summit Rotary Scraper, 4" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe	46
Figure 38. Summit Rotary Scraper, 4" IPS: Ovality after scrape versus ovality before scrape	47
Figure 39. Summit Rotary Scraper, 4" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F	48
Figure 40. Success rates of complete removal of bentonite powder	50
Figure 41. Decohesion test result, 2" IPS Frialen Peeler on MDPE pipe at -10°F	51
Figure 42. FTIR spectra from decohesion test result, 2" IPS Frialen Peeler on MDPE pipe at	51
Figure 43. Decohesion test result, 2" IPS Frialen Peeler on HDPE pipe at -10°F	52
Figure 44. FTIR spectra from decohesion test result, 2" IPS Frialen Peeler on HDPE pipe at	52
Figure 45. Decohesion test result, 2" IPS Frialen Peeler on MDPE pipe at 70°F	53
Figure 46. Decohesion test result, 2" IPS Frialen Peeler on HDPE pipe at 70°F	54
Figure 47. FTIR spectra from decohesion test result, 2" IPS Frialen Peeler on HDPE pipe at	54
Figure 48. Decohesion test result, 2" IPS Frialen Peeler on MDPE pipe at 120°F	55
Figure 49. Decohesion test result, 2" IPS Frialen Peeler on HDPE pipe at 120°F	55

Figure 50. Decohesion test result, 4" IPS Frialen Peeler on MDPE pipe at -10°F.....56

Figure 51. Decohesion test result, 4" IPS Frialen Peeler on HDPE pipe at -10°F57

Figure 52. Decohesion test result, 4" IPS Frialen Peeler on MDPE pipe at 70°F58

Figure 53. Decohesion test result, 4" IPS Frialen Peeler on HDPE pipe at 70°F59

Figure 54. Decohesion test result, 4" IPS Frialen Peeler on MDPE pipe at 120°F60

Figure 55. FTIR spectra from decohesion test result, 4" IPS Frialen Peeler on MDPE pipe at...60

Figure 56. Decohesion test result, 4" IPS Frialen Peeler on HDPE pipe at 120°F61

Figure 57. FTIR spectra from decohesion test result, 4" IPS Frialen Peeler on HDPE pipe at 120°F61

Figure 58. Decohesion test result, 2" IPS Half-Moon Scraper on MDPE pipe at -10°F62

Figure 59. FTIR spectra from decohesion test result, 2" IPS Half-Moon Scraper on MDPE pipe at.....62

Figure 60. Decohesion test result, 2" IPS Half-Moon Scraper on HDPE pipe at -10°F63

Figure 61. Decohesion test result, 2" IPS Half-Moon Scraper on MDPE pipe at 70°F64

Figure 62. FTIR spectra from decohesion test result, 2" IPS Half-Moon Scraper on MDPE pipe at.....64

Figure 63. Decohesion test result, 2" IPS Half-Moon Scraper on HDPE pipe at 70°F.....65

Figure 64. Decohesion test result, 2" IPS Half-Moon Scraper on MDPE pipe at 120°F66

Figure 65. FTIR spectra from decohesion test result, 2" IPS Half-Moon Scraper on MDPE pipe at.....66

Figure 66. Decohesion test result, 2" IPS Half-Moon Scraper on HDPE pipe at 120°F.....67

Figure 67. FTIR spectra from decohesion test result, 2" IPS Half-Moon Scraper on HDPE pipe at 120°F67

Figure 68. Decohesion test result, 2" IPS OEM Peeler on MDPE pipe at -10°F68

Figure 69. FTIR spectra from decohesion test result, 2" IPS OEM Peeler on MDPE pipe at68

Figure 70. Decohesion test result, 2" IPS OEM Peeler on HDPE pipe at -10°F69

Figure 71. Decohesion test result, 2" IPS OEM Peeler on MDPE pipe at 70°F70

Figure 72. FTIR spectra from decohesion test result, 2" IPS OEM Peeler on MDPE pipe at70

Figure 73. Decohesion test result, 2" IPS OEM Peeler on HDPE pipe at 70°F71

Figure 74. Decohesion test result, 2" IPS OEM Peeler scrape on MDPE pipe at 120°F72

Figure 75. FTIR spectra from decohesion test result, 2" IPS OEM Peeler on MDPE pipe at72

Figure 76. Decohesion test result, 2" IPS OEM Peeler on HDPE pipe at 120°F73

Figure 77. FTIR spectra from decohesion test result, 2" IPS OEM Peeler on HDPE pipe at.....73

Figure 78. Decohesion test result, 4" IPS OEM Peeler on MDPE pipe at -10°F74

Figure 79. FTIR spectra from decohesion test result, 4" IPS OEM Peeler on MDPE pipe at74

Figure 80. Decohesion test result, 4" IPS OEM Peeler on HDPE pipe at -10°F75

Figure 81. Decohesion test result, 4" IPS OEM Peeler on MDPE pipe at 70°F.....	76
Figure 82. Decohesion test result, 4" IPS OEM Peeler on HDPE pipe at 70°F	77
Figure 83. Decohesion test result, 4" IPS OEM Peeler on MDPE pipe at 120°F.....	78
Figure 84. FTIR spectra from decohesion test result, 4" IPS OEM Peeler on MDPE pipe at	78
Figure 85. Decohesion test result, 4" IPS OEM Peeler on HDPE pipe at 120°F	79
Figure 86. Decohesion test result, Friatec hand scraper on 4" IPS MDPE pipe at -10°F	80
Figure 87. Decohesion test result, Friatec hand scraper on 4" IPS HDPE pipe at -10°F.....	81
Figure 88. Decohesion test result, Friatec hand scraper on 4" IPS MDPE pipe at 70°F	82
Figure 89. Decohesion test result, Friatec hand scraper on 4" IPS HDPE pipe at 70°F	83
Figure 90. Decohesion test result, Friatec hand scraper on 4" IPS MDPE pipe at 120°F.....	84
Figure 91. Decohesion test result, Friatec hand scraper on 4" IPS HDPE pipe at 120°F.....	85
Figure 92. Decohesion test result, 4" IPS Summit rotary scraper on MDPE pipe at -10°F.....	86
Figure 93. Decohesion test result, 4" IPS Summit rotary scraper on HDPE pipe at -10°F	87
Figure 94. Decohesion test result, 4" IPS Summit rotary scraper on MDPE pipe at 70°F	88
Figure 95. Decohesion test result, 4" IPS Summit rotary scraper on HDPE pipe at 70°F	89
Figure 96. Decohesion test result, 4" IPS Summit rotary scraper on MDPE pipe at 120°F	90
Figure 97. Decohesion test result, 4" IPS Summit rotary scraper on HDPE pipe at 120°F.....	91
Figure 98. FTIR spectra from decohesion test result, 4" IPS Summit rotary scraper on HDPE pipe at 120°F	91
Figure 99. Top-level generic scraping procedure incorporating best-practices	96
Figure 100. Schematic of cleaned areas for a saddle fitting	97
Figure 101. Schematic of cleaned areas for a coupling fitting.....	97
Figure 102: 2" IPS OEM Peeler.....	100
Figure 103: 2" IPS Frialen Peeler	101
Figure 104: 2" IPS Half-Moon Scraper	102
Figure 105: 4" IPS OEM Peeler.....	103
Figure 106: 4" IPS Frialen Peeler.....	104
Figure 107: 4" IPS Summit Rotary Scraper	105
Figure 108: ½" CTS Pencil Scraper	106
Figure 109: Friatec Hand Scraper	107
Figure 110: 2" IPS pipe clamps in pipe stands close together with pipe marked	110
Figure 111: 4" IPS pipe clamps in pipe stands close together with pipe marked	110
Figure 112: 2" IPS pipe with ~5% induced ovality at 70°F, before scrape – no contamination.	111
Figure 113: 2" IPS pipe with ~5% induced ovality at 70°F, before scrape – with bentonite powder contamination.....	111

Figure 114: 2" IPS pipe with no induced ovality at 120°F, after scrape by OEM Scraper – with shavings around pipe..... 112

Figure 115: 2" IPS pipe with no induced ovality at 120°F, after scrape by OEM Scraper – after removal of shavings 112

List of Tables

Table 1. Recommended Scrape Depths..... 9

Table 2. Subjective User Ratings of Scraper Ease of Use.....49

List of Acronyms

CTS	Copper Tube Size
DoE	Design of Experiment
EF	Electrofusion
FTIR	Fourier Transform Infrared
GTI	Gas Technology Institute
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
ID	Inner Diameter
IPS	Iron Pipe Size
ISO	International Organization for Standardization
MDPE	Medium Density Polyethylene
OD	Outer Diameter
OTD	Operations Technology Development
PE	Polyethylene
QC	Quality Control
SCG	Slow Crack Growth
SEM	Scanning Electron Microscope
UV	Ultraviolet

Executive Summary

The objective of this project was to develop up-to-date guidelines and best-practices with respect to PE pipe scraping to improve overall fusion quality. The scope of work was comprised of testing the scraping performance of eight commonly used scrapers (**Figure 1**) at three different temperatures, and evaluating the ability of the scrapers to remove the maximum oxidation layer and contaminants such as bentonite powder, a common contaminant found in HDD installations and representative of other soil (silicate) contaminants.

Questions regarding minimum and maximum scraping depths are specifically addressed in the Background on Scraping Depth section.

Based on maximum oxidation depth found in prior works, the following minimum scraping depths can be specified:

- 0.0063 inches (0.0126 inches of pipe diameter) for pipes yellow MDPE pipes.
- 0.004 inches (0.008 inches of pipe diameter) for black HDPE pipes.

Maximum scraping depth as pertaining to electrofusion fittings depends on the fitting design and must be assessed on a per fitting basis, but must never exceed 10 percent of the pipe wall thickness. Heat-fusion saddles are much less sensitive to gaps caused by excessive scraping as they are forced onto the pipe during heat soaking and joining.

Table 1 summarizes this report's recommended scrape depths.

Table 1. Recommended Scrape Depths

	Yellow MDPE Pipe	Black HDPE Pipe
Minimum Scrape Depth	0.0063 inches (0.0126 inches of pipe OD)	0.004 inches (0.008 inches of pipe OD)
Maximum Scrape Depth for EF fittings	Dependent on EF fitting	
Absolute Maximum Scrape Depth	10% of pipe wall thickness	

The results of the scrape depth testing showed that all scrapers can achieve a sufficient scrape depth, however, rotary type scrapers provide better scraping quality compared to handheld scrapers, in both scraping depth and coverage. Additionally, in most cases rotary scrapers require only one scraping pass to achieve sufficient scrape depth and coverage (as long as they are manufactured to meet the min. scrape depth), while handheld scrapers require several passes to do the same. Although rotary scrapers typically function consistently between scrapes, they are prone to misalignment that can lead to intermittent scraping, therefore, operators should be properly trained in the use and maintenance of such tools.

Oval pipe (up to ~5%) did not appear to adversely affect scraping depth. The test results showed that spring-loaded scrapers generally follow the outer diameter of the pipe and therefore, appreciable re-rounding by scraping may or may not occur. The pencil scraper did consistently re-round the pipe due to its fixed blade and cavity. The influence of pipe ovality on electrofusion quality is directly related to the gap sensitivity of the fitting and the fitting's dimensional tolerances – therefore, sensitivity to ovality must be evaluated on a per fitting basis.

Contamination removal testing showed that scraping alone does contribute to the removal of surface contaminants, however, this contribution is variable and not sufficient by itself. The surprising result of the contamination removal testing was that only the handheld “paint-scraper” type scraper removed 100% of the bentonite powder in all test runs. Other scrapers had some runs where all contamination was removed and other runs where contamination remained or resettled in the fusion zone.

The findings of the testing conducted in this project, together with GTI’s experience in failure analysis of fusion joint failures, led to a suggested pipe cleaning procedure where the pipe is thoroughly washed and cleaned prior to scraping (washing and cleaning should go beyond the area to be scraped) and then minimizing the opportunities for contaminating the scraped area of the pipe. The minimum and maximum scrape depths should also be followed to ensure oxidation in the pipe wall is removed. The details of this procedure and other recommendations are given in the **Discussion and Conclusions** section of this report.

Overall, the various test results lend support to the observation that to achieve successful PE fusions, best practices should be adopted, which includes maintaining minimum and maximum scrape depths, in conjunction with **thorough operator training with specific attention to prevention of contamination** of the fusion areas of the pipe and fitting.

General notes on PE fusion and contamination

PE fusion is a stochastic process where two molten interfaces are brought into contact such that upon cooling and solidification the interfaces co-crystallize to form a ductile welded area. This fusion process is normally robust within a relatively wide range of its critical process parameters: temperature and interfacial pressure. However, the presence of certain contaminants, such as silicates, oils, and surfactants, are highly detrimental to PE’s co-crystallization process.

Fusions that fail due to contamination exhibit smooth, non-ductile separation of the fitting-pipe fusion interface, either in part or in whole. It is important to note, however, that even such areas of non-ductile bonding still have some degree of bonding which can often lead to joints that pass pressure tests (e.g., 150% MAOP) and in some cases even hold operating pressure for years, but such joints are highly sensitive to impact loads and, in cases of saddles, also to forces that would cause the joint to “peel” off the pipe.

Because contamination failures are typically difficult to identify in the field, it is of utmost importance that the fusion preparation processes reflect this awareness and that operators adhere to the precautions and best-practices that help minimize fusion contamination.



Figure 1. Tested scrapers

Introduction

How to enhance and optimize fusions has been a topic of interest since the infant stages of PE use in the natural gas industry. Procedures and subsequent training has been enhanced over the years, however, failures still occur even though the procedures and training are followed.

Failure investigations and various studies performed over the decades have addressed multiple issues and installation practices have evolved as a result. More recent work in the areas of electrofusion (EF) fittings include OTD Project (2.8.c) *Electrofusion Coupling Guidelines* which identified key variables affecting EFs including heat times, ambient fusion conditions, scrape depth and the gap closing ability. Additionally, OTD Project (2.7.b) *Qualification of Saddle and Electrofusion Joint Designs and Test Methods to Validate Safe Long-Term Performance* indicated detectable differences in heat fusion performance between scraped and abraded pipe surfaces. Failure analyses observations have shown wide variation in scrape appearance and consistency that were major contributors if not the cause of fusion bond failure. The effectiveness and repeatability of the scrape has a correlating impact on the ability to produce consistent long lasting fusions and are influenced by current practices, depth of scrape, scraper tool designs and effectiveness, pipe ovality, pipe curvature, as well other process supporting equipment/hardware and installation conditions.

Field issues related to scraping and PE fusion performance have created a need for better guidelines to assist utilities and their field operators/contractors. GTI has recognized that in order to fundamentally address joint integrity issues, a comprehensive approach must be taken where the influence of all processes and materials used in creating a joint are acknowledged and understood. To achieve this goal, GTI has begun to develop a process map relating the various elements involved in creating a joint. **Figure 2** shows a portion of this map related to electrofusion joints, which are the primary joint type related to the focus of this project: pipe scraping (highlighted in green in **Figure 2**).

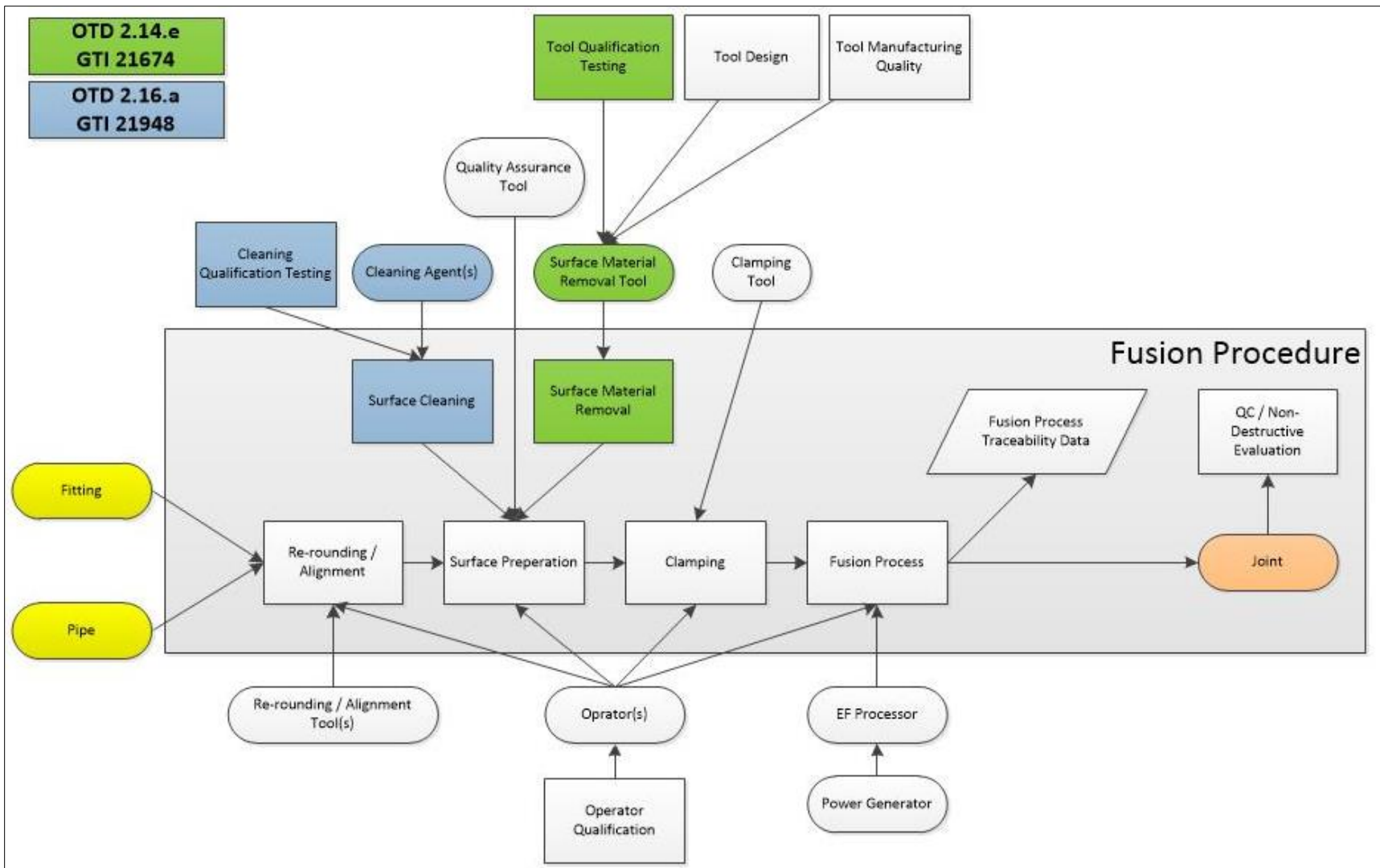


Figure 2. Overview of electrofusion process, with highlights of OTD project scope

Background on Scraping Depth

Three major questions about scraping are often asked by operators:

1. What is the minimum scraping depth?
2. What is the maximum scraping depth?
3. What is the effect of scraping depth on EF joint quality?

The reason for the first question is that minimum scraping depth specifications, typically specified by pipe and fitting manufacturers, are not always consistent. These inconsistencies are possibly due to manufacturers basing their specification on different sets of oxidation test data, however, it is important to note that the fundamental reason for scraping is to remove oxidized PE.

Some degree of PE surface oxidation normally occurs during pipe extrusion when it is initially exposed to air while still hot from the extrusion die. Exposure to UV radiation from sunlight during storage and transport will also cause surface oxidation. The presence of oxidized PE is undesirable for two reasons:

1. Oxidized PE inhibits fusion,
2. Oxidized PE is less ductile and, therefore, can accelerate the initiation of slow crack growth (SCG).

Past work by (Choi, 1992) on PE2306 MDPE (Aldyl-A) has shown that the depth of oxidation by UV light exposure is restricted to a thin layer, regardless of exposure time. **Figure 3**, taken from (Choi, 1992), shows that oxidation depth reached a maximum of 160 μm (0.0063 in) at 150 hours of UV light exposure time and remained approximately constant after 250 hours of exposure.

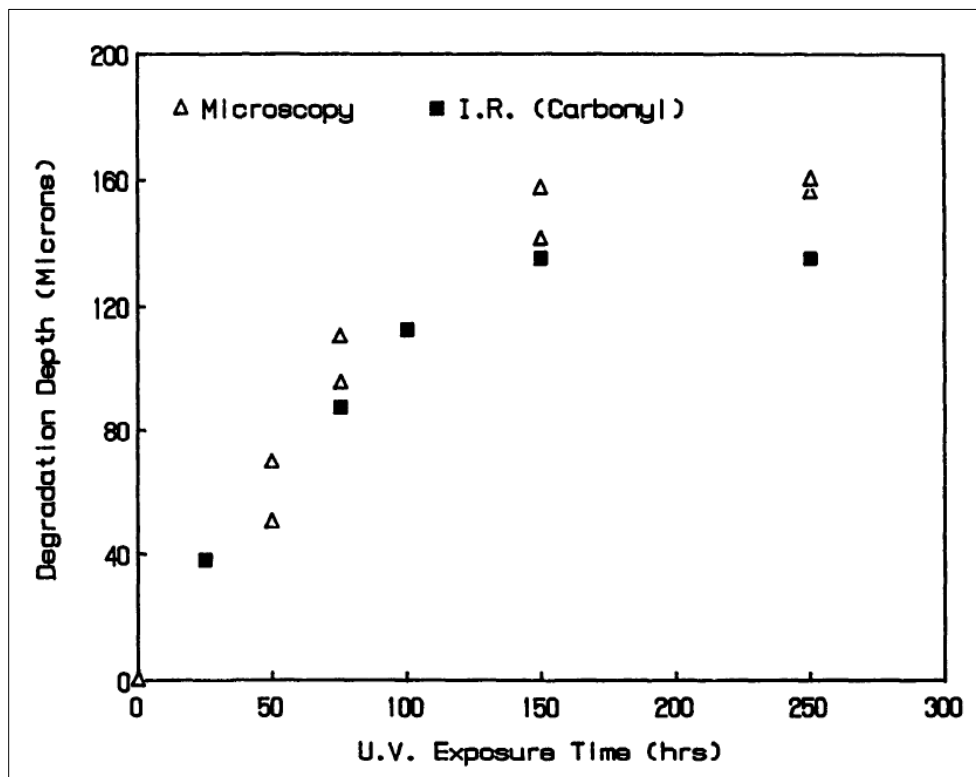


Figure 3. Degradation depth vs. UV exposure time, as measured by microscopy and FTIR carbonyl index methods. Taken from (Choi, 1992), Figure 5.9.

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Work done at Gaz de France (Nussbaum, Dufour, & Gueugnaut, 1991) reported that in polyethylene with carbon black oxidation depth does not exceed 100 μm (0.0039 in). Carbon black is known to be very effective in absorbing UV energy and converting it into heat.

Based on these past works, a minimum scraping depth of 0.0063 inches (0.0126 inches of pipe diameter) for all PE pipes could be recommended as the most conservative specification. For pipes with carbon black a minimum scraping depth of 0.004 inches (0.008 inches of pipe diameter) can be given.

The maximum allowable scraping depth is 10% of the pipe wall thickness¹, however, the practical maximum scraping depth in terms of fusion performance is defined by fitting gap sensitivity. Fitting gap sensitivity, as discussed in this report, is applied in the context of electrofusion² couplings and electrofusion saddles. To answer the second and third questions above, the gap sensitivity of a given fitting model needs to be quantified.

An electrofusion fitting’s gap sensitivity (sometimes referred to as gap-closing capability) is dependent on the following:

- Coil design,
- Energy input tolerances (combination of coil resistance tolerance and fusion box output tolerance), and
- Temperature of the fitting and pipe immediately prior to fusion.

The maximum gap a fitting can close should be specified as a function of installation temperature, over the range of installation temperatures the fitting is designed for. Such a function needs to be determined on a per-fitting-model basis by conducting a design-of-experiment (DoE) that considers the full range of installation temperatures, energy input tolerances, and expected gaps (combination of pipe, fitting, and scrape depth tolerances).

Based on the recognition above, a maximum scraping depth specification depends primarily on the electrofusion fitting being used and secondarily on the maximum allowable pipe wall thickness loss.

	Yellow MDPE Pipe	Black HDPE Pipe
Minimum Scrape Depth	0.0063 inches (0.0126 inches of pipe OD)	0.004 inches (0.008 inches of pipe OD)
Maximum Scrape Depth for EF fittings	Dependent on EF fitting	
Absolute Maximum Scrape Depth	10% of pipe wall thickness	

1 The industry accepted maximum allowable wall thickness loss is 10%.

2 In the case of conventional heat fusion saddles, there is much less gap sensitivity since the fitting is forced onto the pipe – in this case the maximum allowable scrape depth would be limited by a specification of maximum allowable pipe wall thickness reduction, and consideration of the pipe melt depth achieved by the heating iron temperature, heat soak time, and gas pressure in the pipe.

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Testing

The focus of this project was to test the performance of various commonly used scrapers in terms of scrape depth and removal of contamination (bentonite powder). Two test matrices were developed using a DoE method.

Scrape Depth Testing

Eight scrapers (shown in **Figure 1** and **Appendix A – Tested Scrapers**) were tested with the following variables:

- Ambient temperature (-10°F, 70°F, 120°F),
- Ovality (up to ~5%, except for the Pencil scraper),
- Pipe material (MDPE, HDPE).

Three scraping runs were performed at each condition, where each run was performed by a different operator. **Figure 4** shows the overall scrape depth results of all tested scrapers, including all temperatures and pipe materials. The following pages show a breakdown of the results per scraper. The scraping procedure used for testing is detailed in **Appendix B – Scraping Procedures (for testing)**.

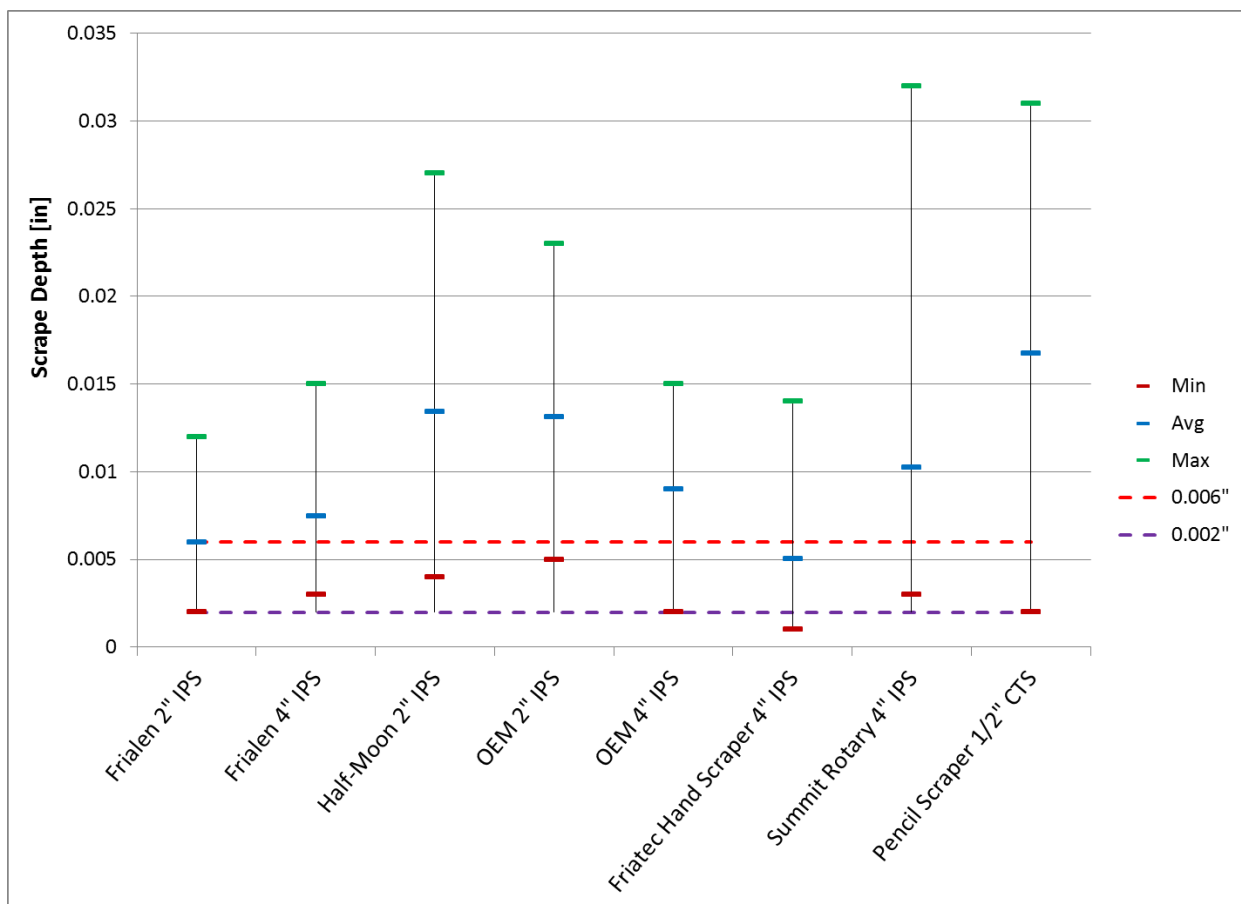


Figure 4. Overall scrape depth results, showing minimum, average, and maximum depths (0.002" line is provided strictly as a plot scale reference)

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Frialen Peeler, 2" IPS

A typical scrape by a 2" IPS Frialen Peeler is shown in **Figure 5** and the scrape depth results are shown in **Figure 6**. Single-pass scrape depth was sometimes as low as 0.002 inches, which suggests that more than one scraping pass may be needed in field conditions. It was also noted that the scraper takes deeper cuts as it progresses along the pipe.



Figure 5. Typical scrape by 2" IPS Frialen Peeler

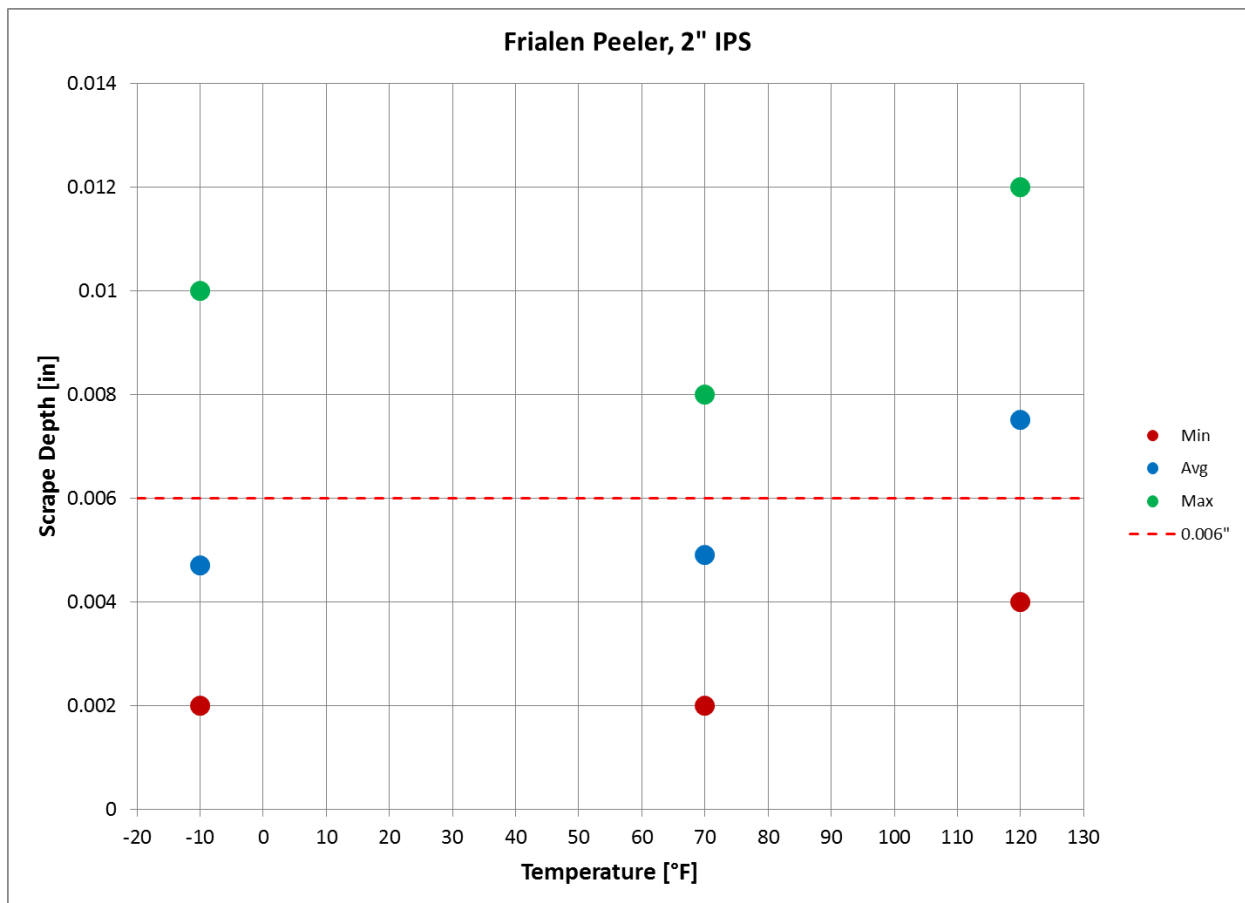


Figure 6. Frialen Peeler 2" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe

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In some cases the scraper left non-scraped gaps, as can be seen in **Figure 7**. These gaps were left due to misalignment of the wheels that determine the pitch of the helical scraping path (see **Figure 8**). Users should be aware of this adjustability if gaps in the scrape are encountered.



Figure 7. Non-scraped gaps left by 2" IPS Frialen Peeler

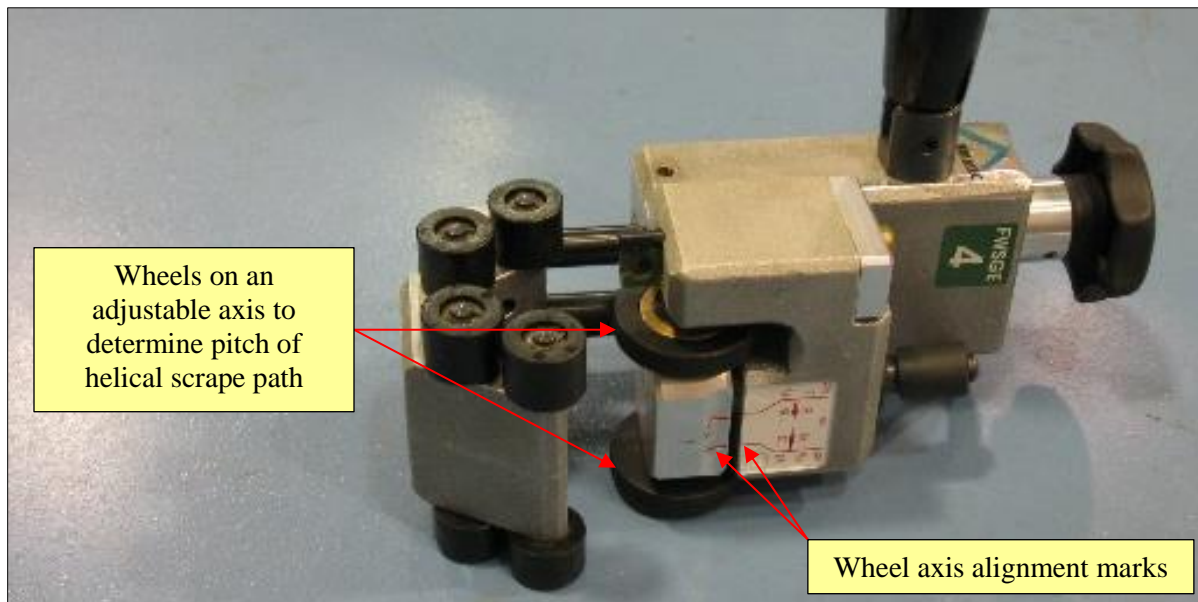


Figure 8. 2" IPS Frialen Peeler

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Figure 9 shows pipe ovality before and after scraping. As can be seen in the figure, scraping did re-round the pipe to various degrees.

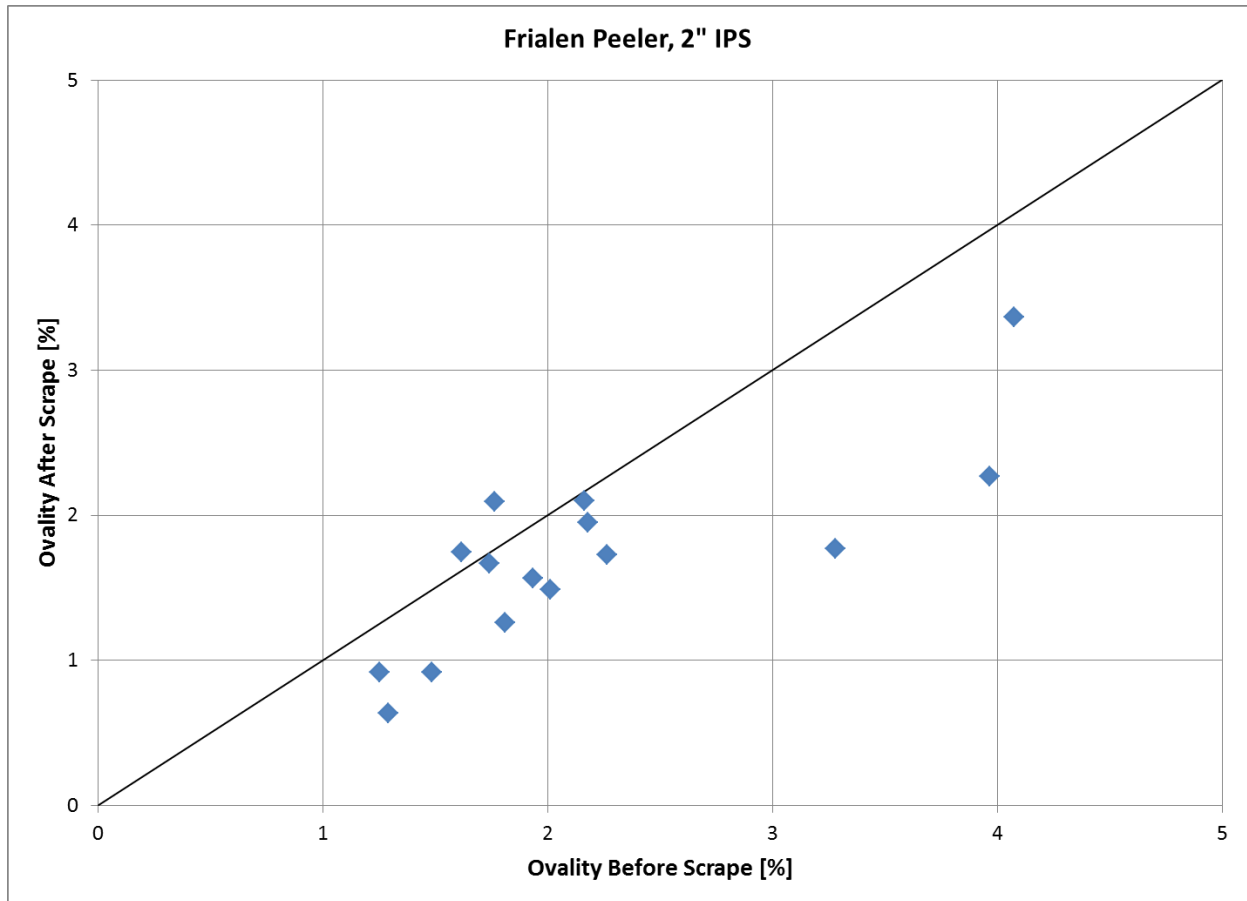


Figure 9. Frialen Peeler 2\" IPS: ovality after scrape versus ovality before scrape

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Figure 10 shows the scrape depth difference between HDPE and MDPE at 70°F. Scrape depth was approximately 25-50% higher on HDPE. This difference is most likely due to the lower compliance³ of HDPE versus MDPE and the spring-loaded blade.

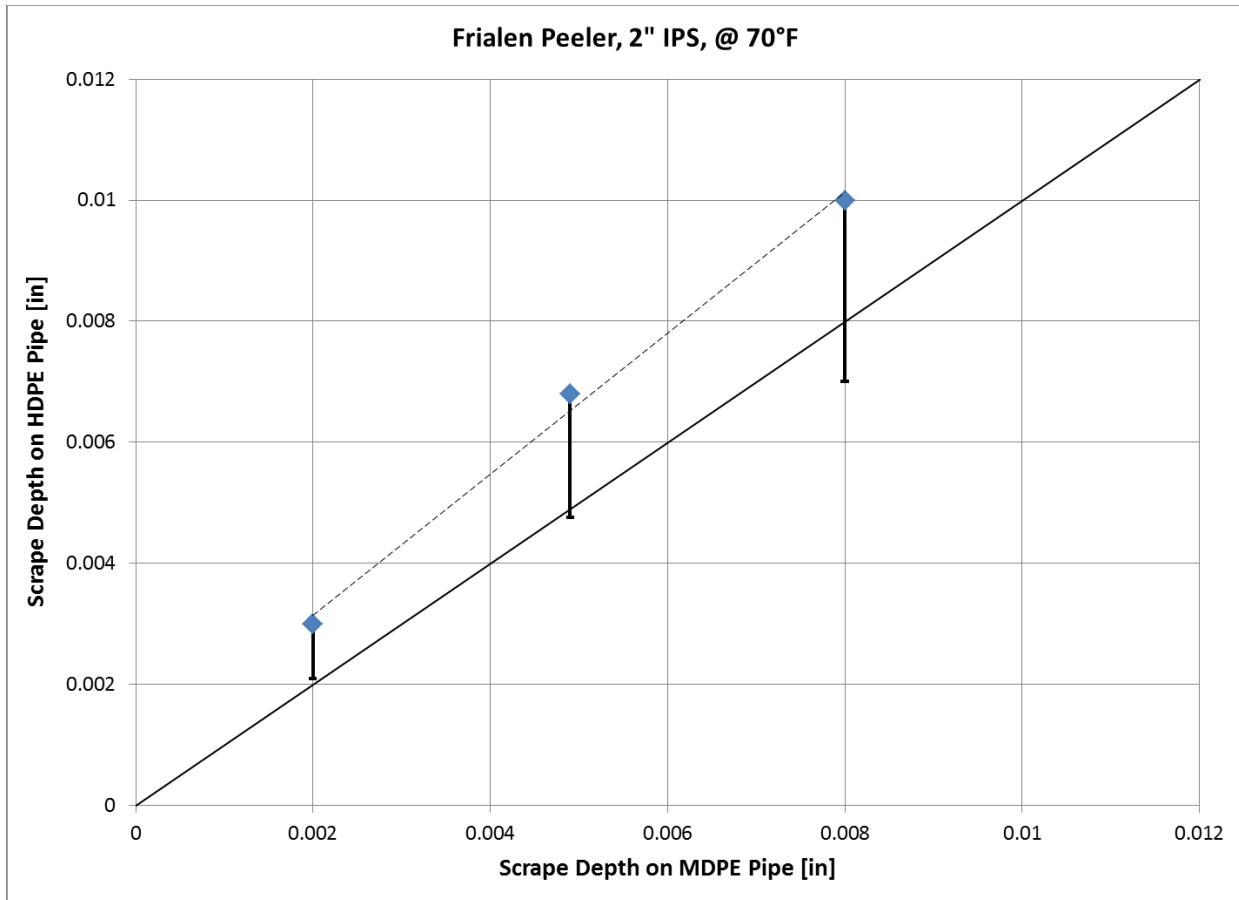


Figure 10. Scrape depth on HDPE pipe versus MDPE pipe, at 70°F, with 30% error bars

3 Compliance is the reciprocal of stiffness (i.e., a softer material is more compliant, a harder material is less compliant).

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Frialen Peeler, 4" IPS

A typical scrape by a 4" IPS Frialen Peeler is shown in **Figure 11** and the scrape depth results are shown in **Figure 12**. Single-pass scrape depth was mostly above 0.006 inches, and sometimes as low as 0.003 inches. These results suggest that more than one scraping pass would not be expected, but may still be necessary in some circumstances.



Figure 11. Typical scrape by 4" IPS Frialen Peeler

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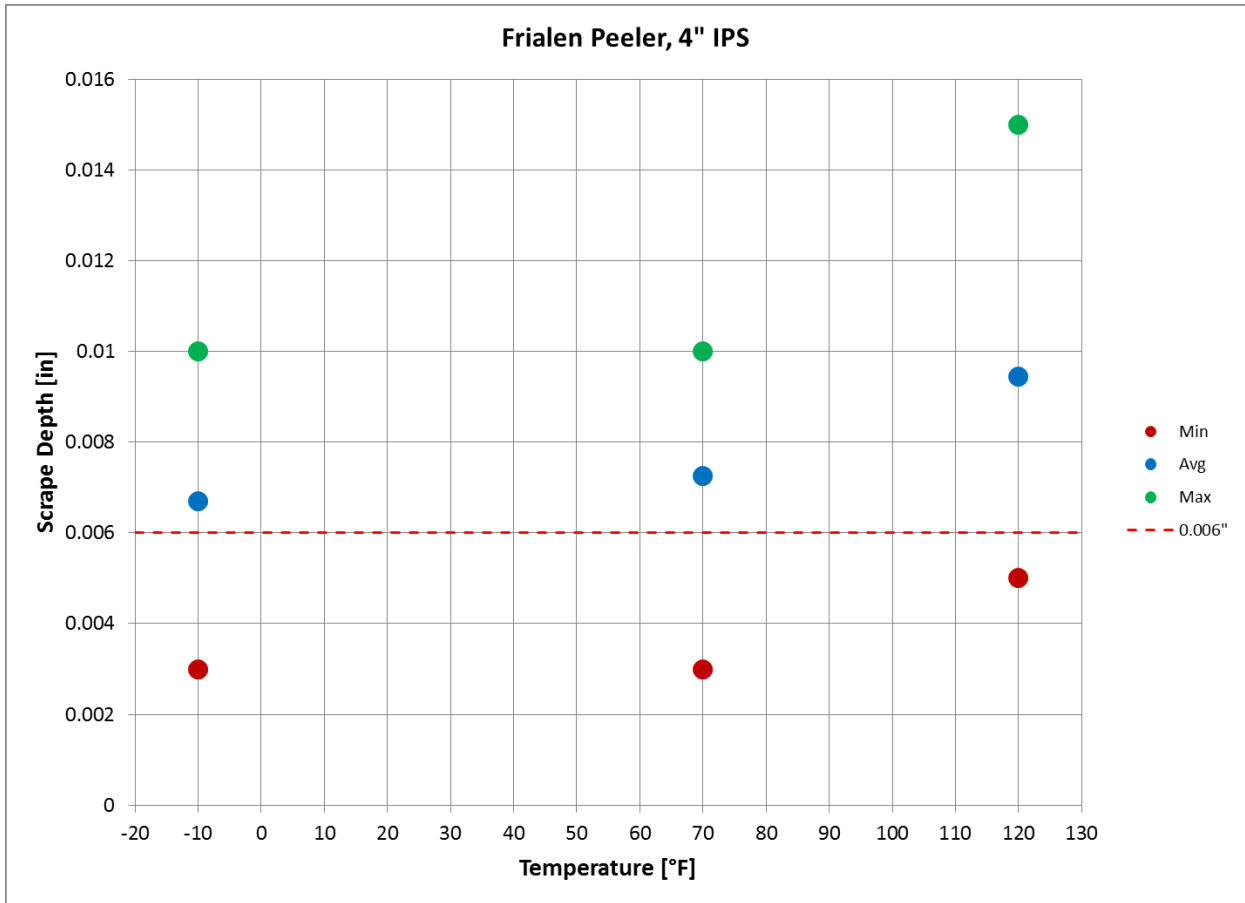


Figure 12. Frialen Peeler 4" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe

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Figure 13 shows pipe ovality before and after scraping. As can be seen in the figure, scraping did not effectively re-round the pipe, indicating that the spring loaded peeling blade kept track of the contour of the pipe.

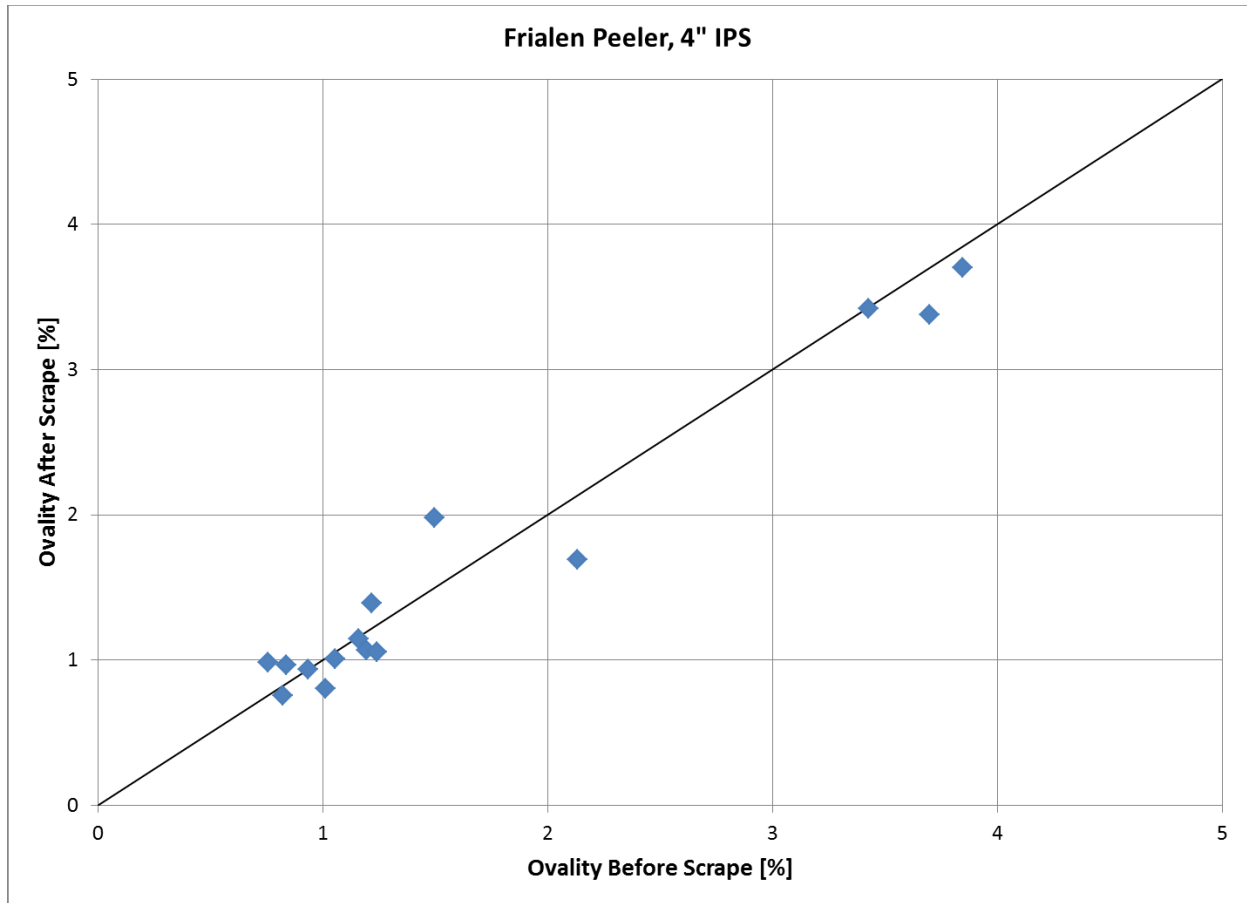


Figure 13. Frialen Peeler 4\" IPS: Ovality after scrape versus ovality before scrape

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Figure 14 shows the scrape depth difference between HDPE and MDPE at 70°F. Scrape depth was almost identical on each pipe material.

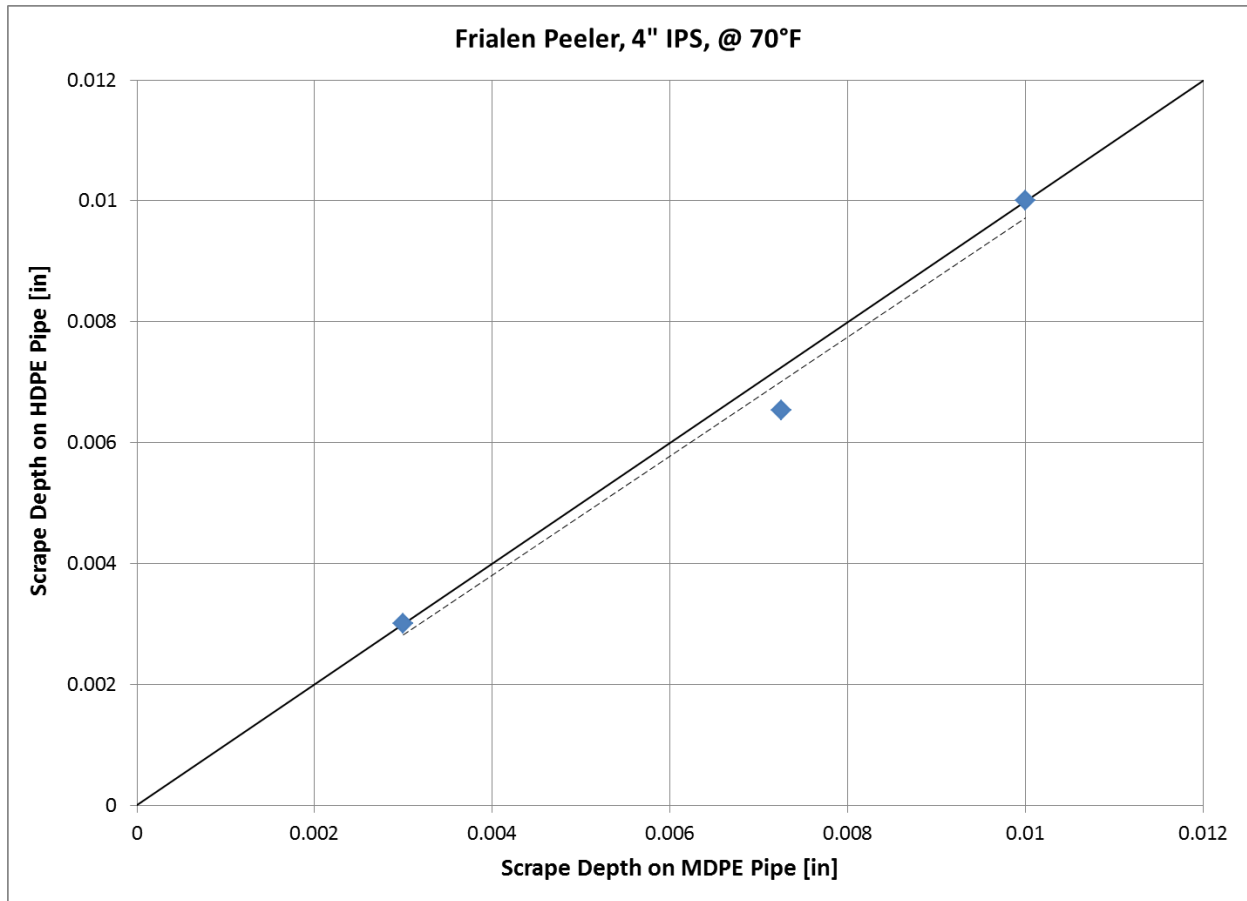


Figure 14. Frialen Peeler 4\" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F

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Half-Moon Scraper, 2" IPS

A typical scrape by a 2" IPS Half-Moon scraper is shown in **Figure 15** and the scrape depth results are shown in **Figure 17**. Due to its serrated edge and handheld nature, this scraper typically requires several passes over the fusion zone to completely remove the outer layer of the pipe. Final scrape depth was mostly above 0.006 inches, and sometimes as low as 0.004 inches. It was noted that the scraping depth along the pipe may not be consistent because of the handheld nature of the tool.



Figure 15. Typical scrape by 2" IPS Half-Moon Scraper (after several passes)



Figure 16. Typical scrape by 2" IPS Half-Moon Scraper (after several passes), closer view of serrated surface

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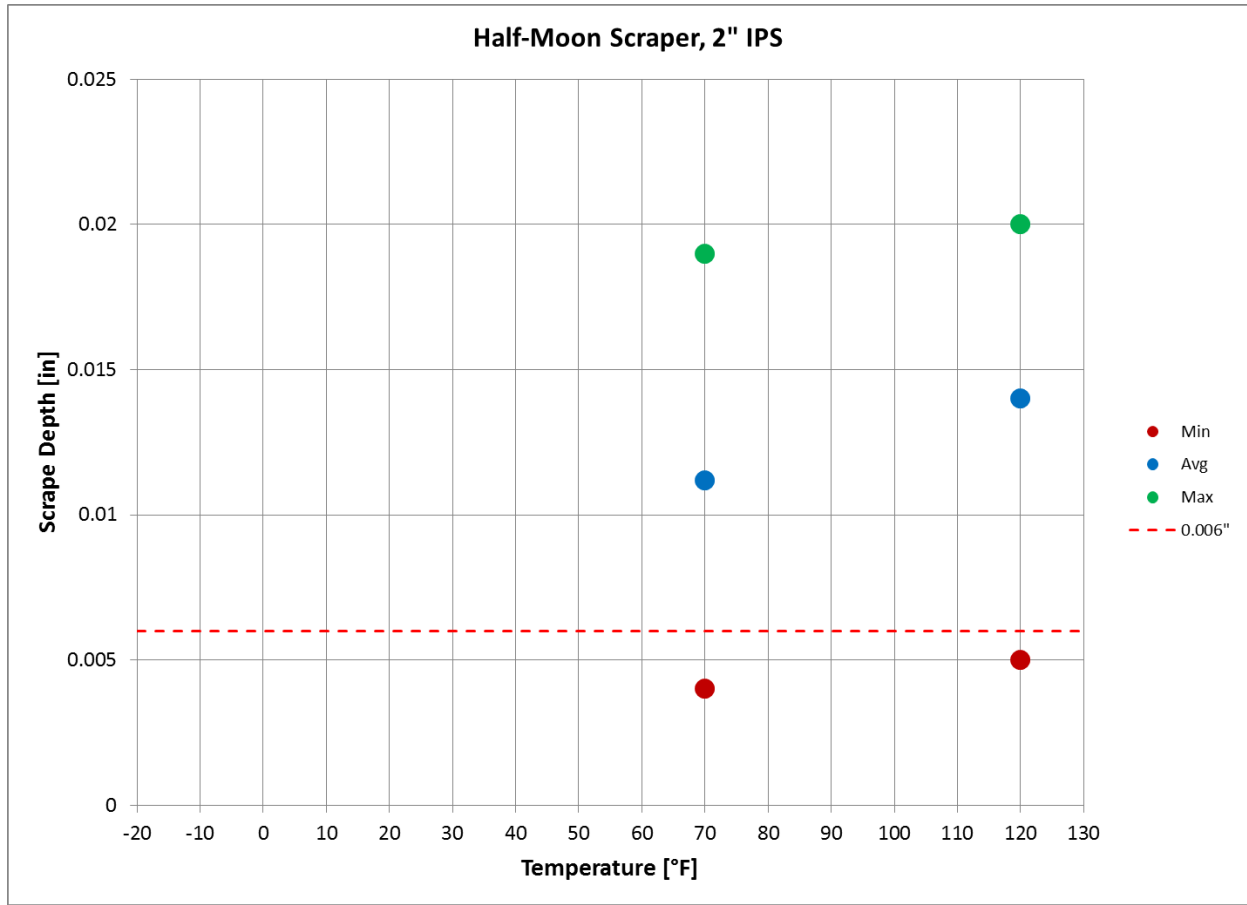


Figure 17. Half-Moon Scraper, 2" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe

Figure 17 does not show scrape depth results for -10°F because the Half-Moon scraper was unable to remove any appreciable material at this low temperature.

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Figure 18 shows pipe ovality before and after scraping. As can be seen in the figure, in most cases the Half-Moon scraper re-rounded the pipe.

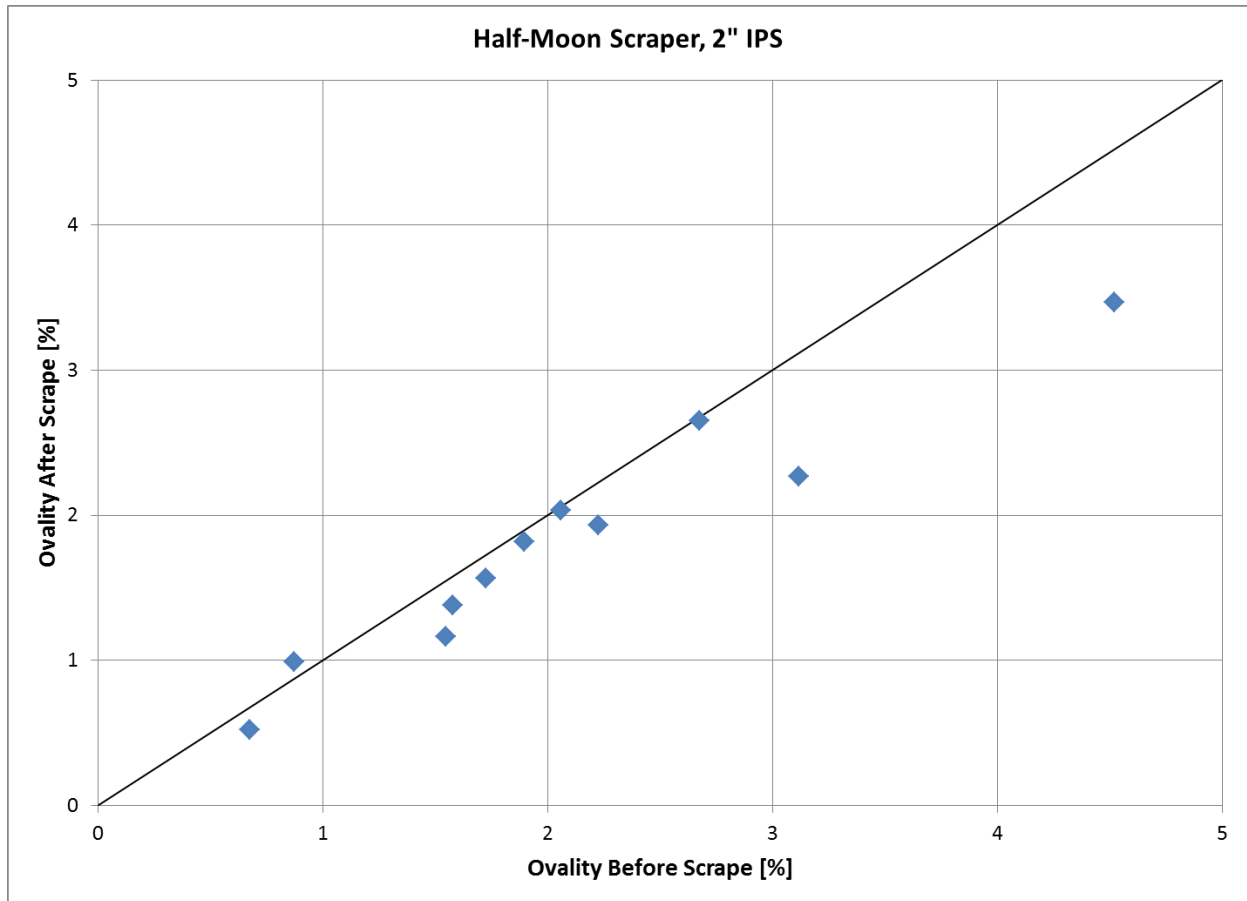


Figure 18. Half-Moon Scraper, 2\" IPS: Ovality after scrape versus ovality before scrape

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Figure 19 shows the scrape depth difference between HDPE and MDPE at 70°F. Scrape depth was higher on HDPE pipe.

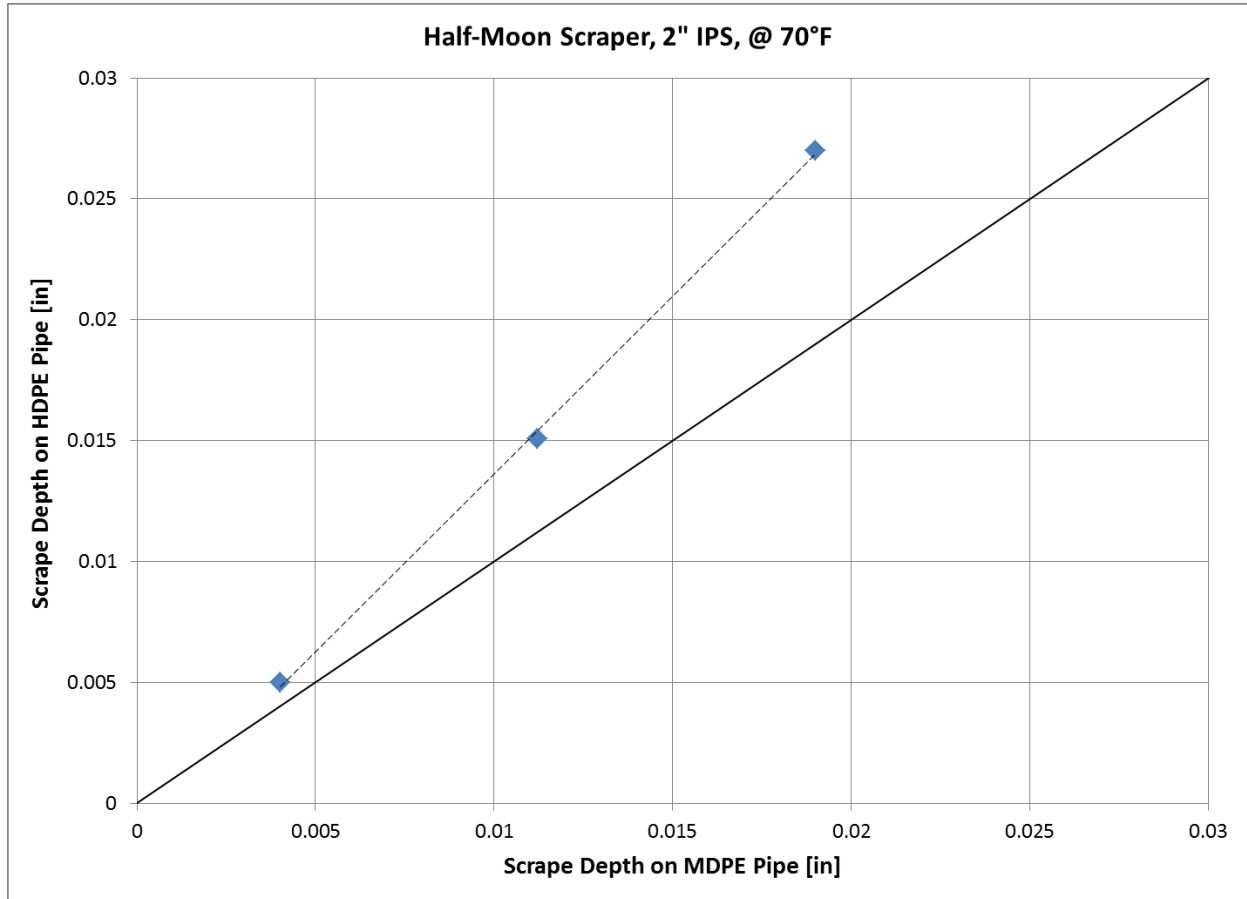


Figure 19. Half-Moon Scraper, 2\" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F

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OEM Peeler, 2" IPS

A typical scrape by a 2" IPS OEM Peeler is shown in **Figure 20** and the scrape depth results are shown in **Figure 21**. Single-pass scrape depth was mostly above 0.006 inches, the lowest measured depth was 0.005 inches. These results suggest that only one scraping pass would be expected in most cases.

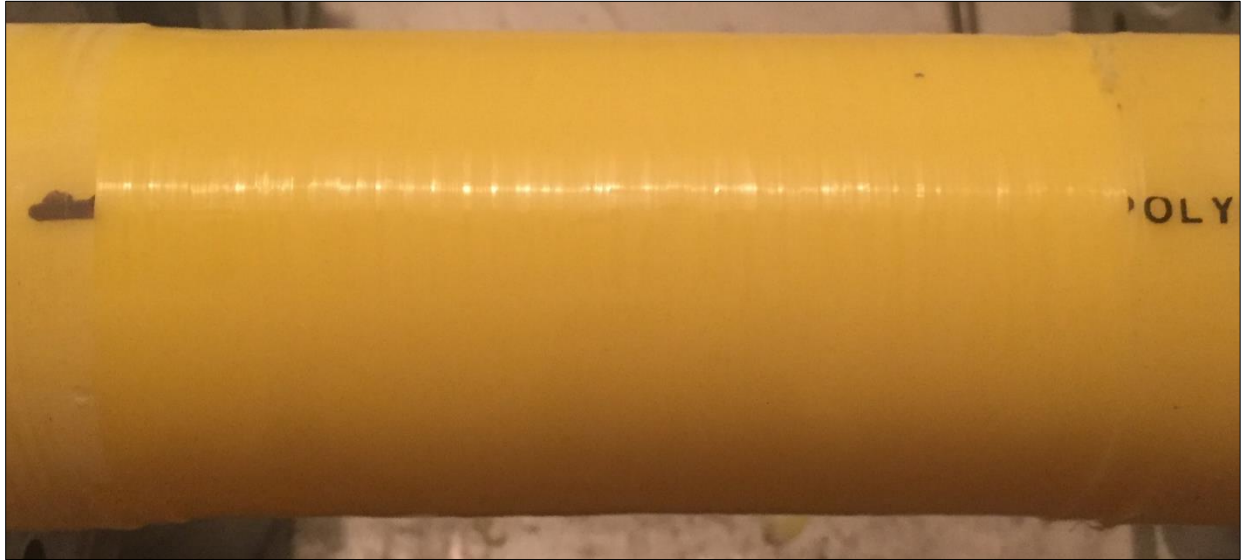


Figure 20. Typical scrape by 2" IPS OEM Peeler

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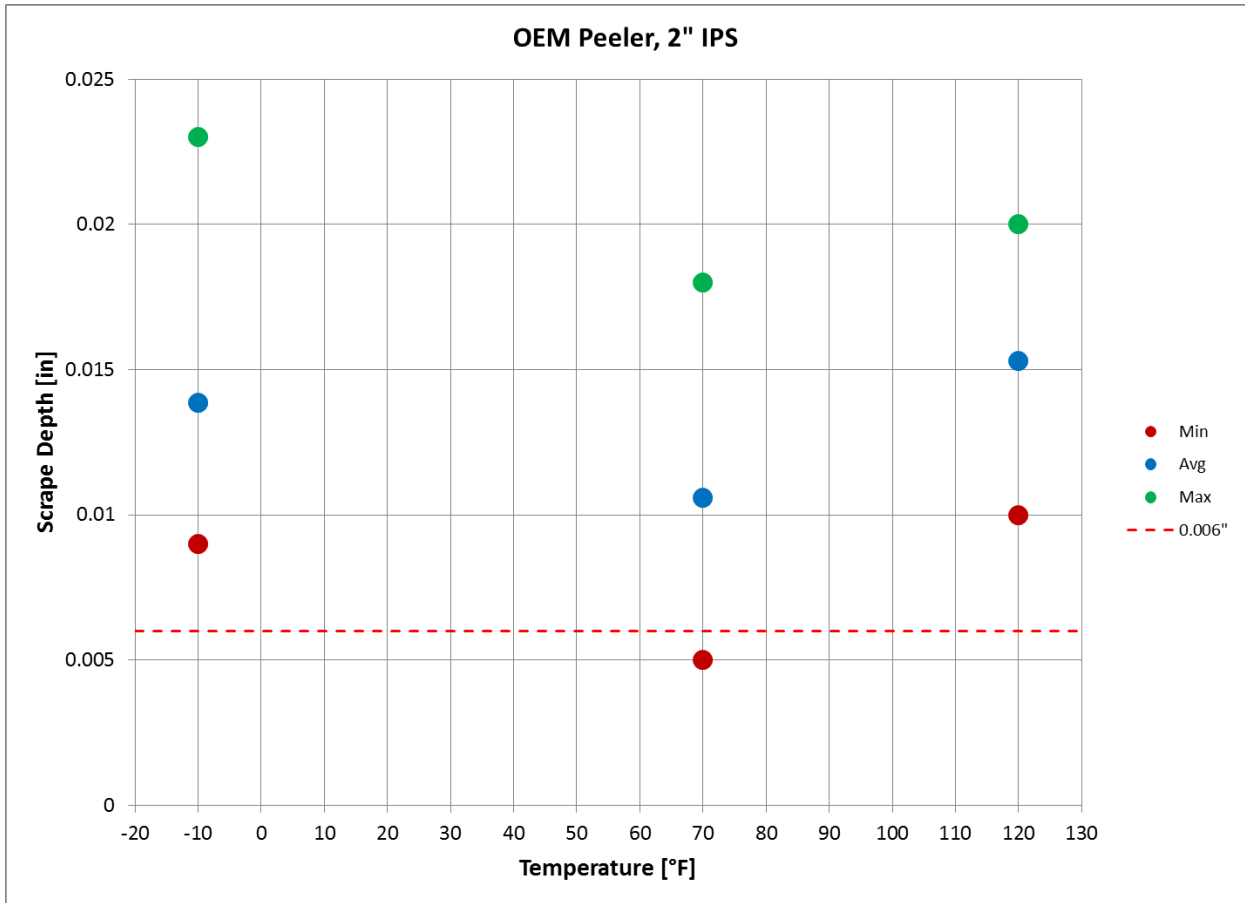


Figure 21. OEM Peeler 2" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe

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Figure 22 shows pipe ovality before and after scraping. As can be seen in the figure, in most cases the 2" IPS OEM Peeler re-rounded the pipe.

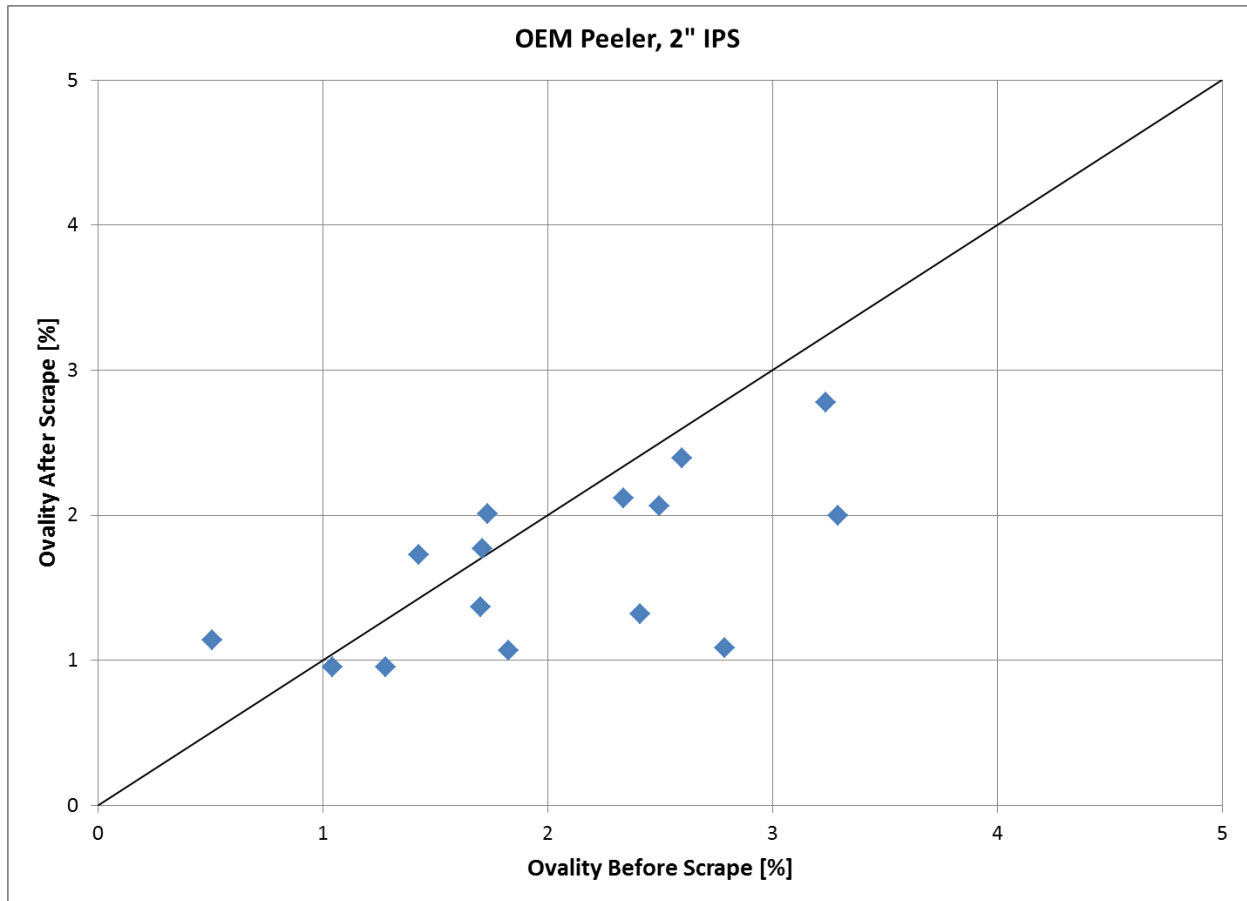


Figure 22. OEM Peeler 2" IPS: Ovality after scrape versus ovality before scrape

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Figure 23 shows the scrape depth difference between HDPE and MDPE at 70°F. Scrape depth was higher on HDPE pipe. This difference is most likely due to the lower compliance of HDPE versus MDPE and the spring-loaded blade.

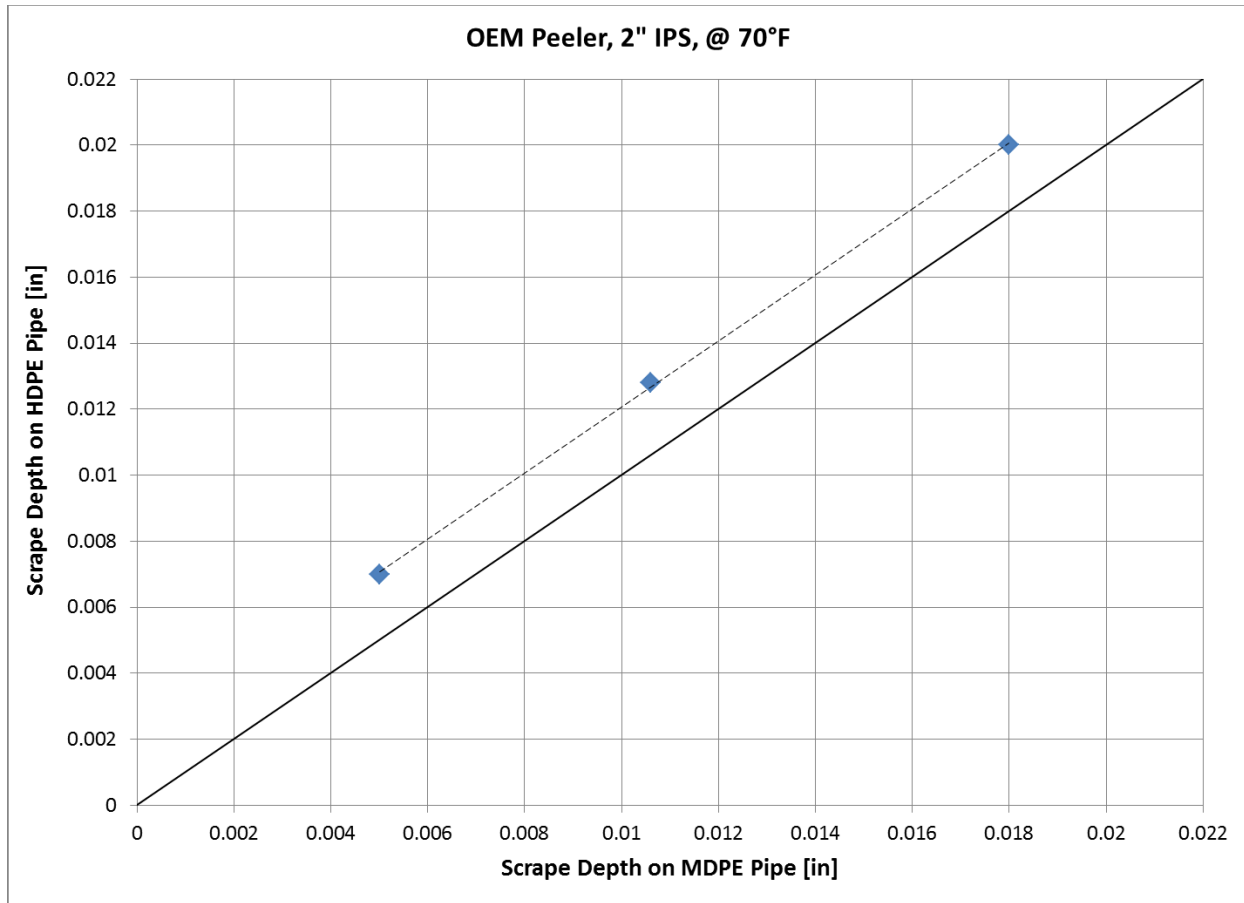


Figure 23. OEM Peeler 2\" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F

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OEM Peeler, 4" IPS

A typical scrape by a 4" IPS OEM Peeler is shown in **Figure 24** and the scrape depth results are shown in **Figure 25**. Single-pass scrape depth was mostly above 0.006 inches, the lowest measured depth was 0.002 inches. These results suggest that only one scraping pass would be expected in most cases.

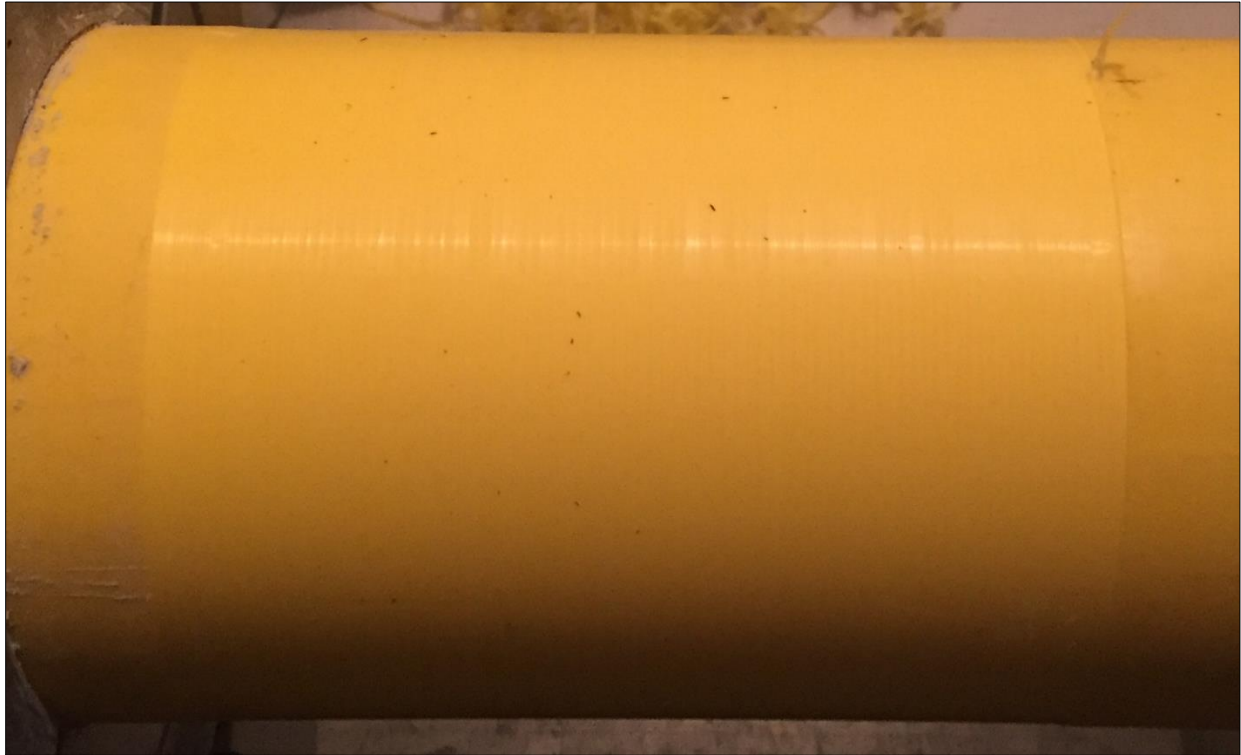


Figure 24. Typical scrape by 4" IPS OEM Peeler

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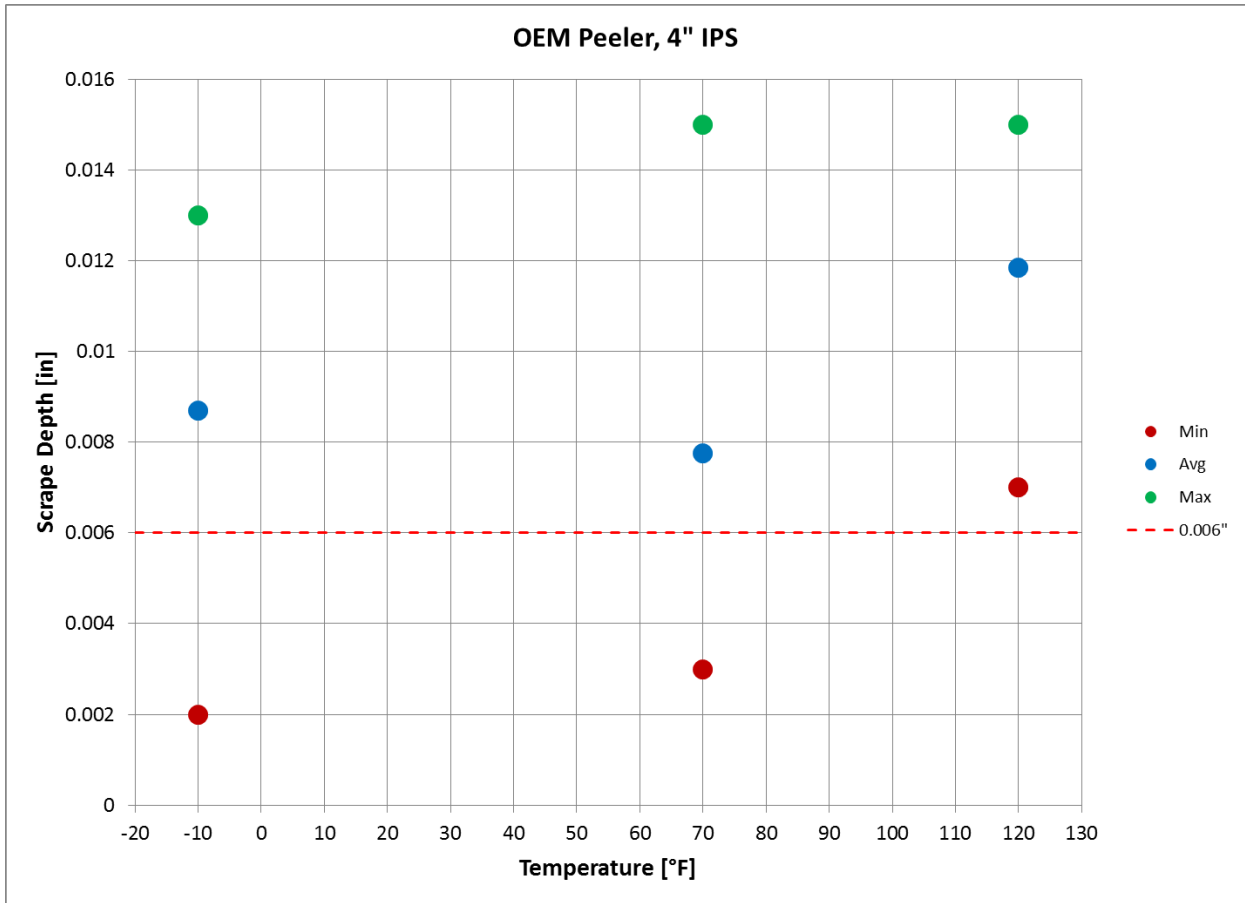


Figure 25. OEM Peeler 4" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe

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Figure 26 shows pipe ovality before and after scraping. As can be seen in the figure, the 4" IPS OEM Peeler maintained the original ovality of the pipe in most cases, but also reduced and increased ovality in some cases.

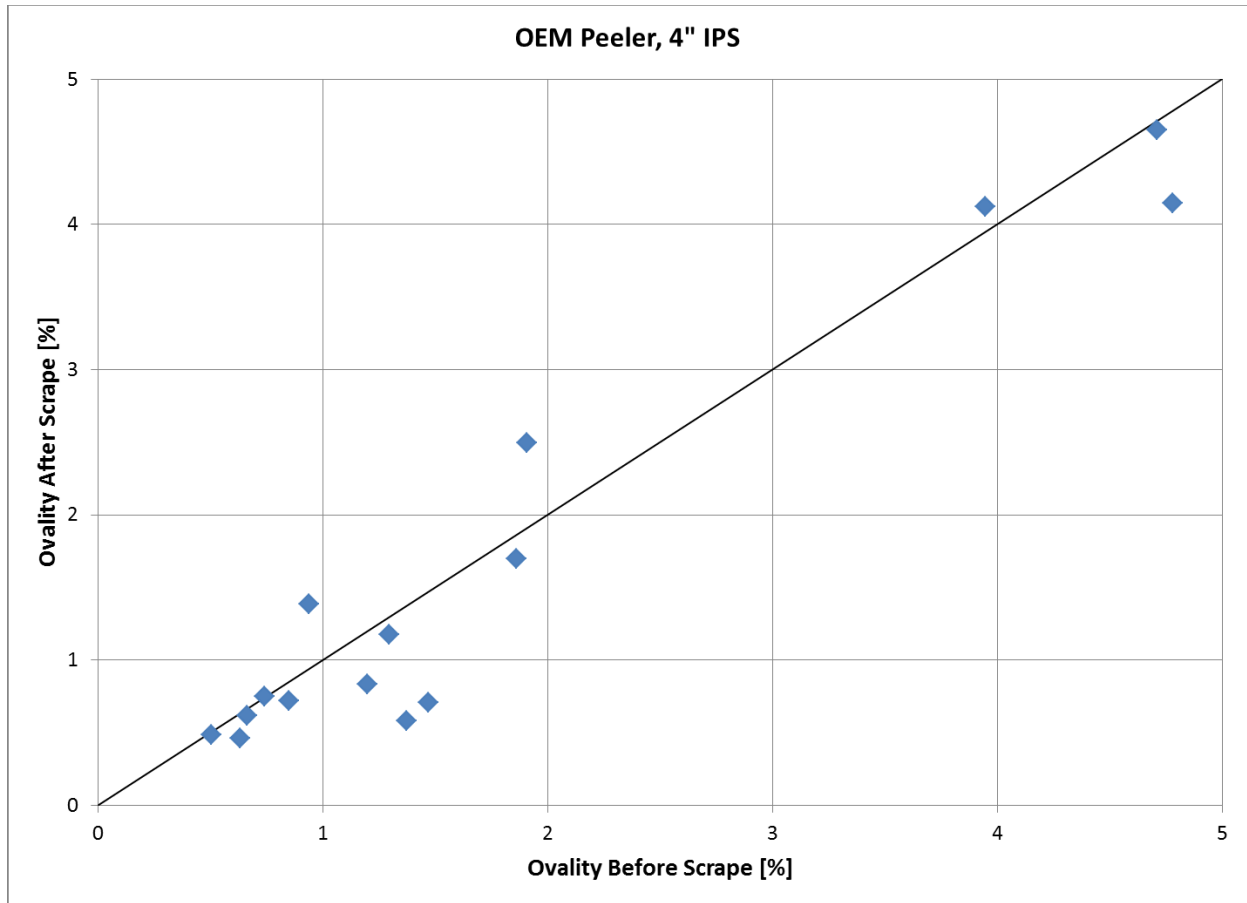


Figure 26. OEM Peeler 4" IPS: Ovality after scrape versus ovality before scrape

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Figure 27 shows the scrape depth difference between HDPE and MDPE at 70°F. Average scrape depth was similar on both materials. The minimum depth was higher on HDPE pipe, and the maximum depth was higher on MDPE pipe.

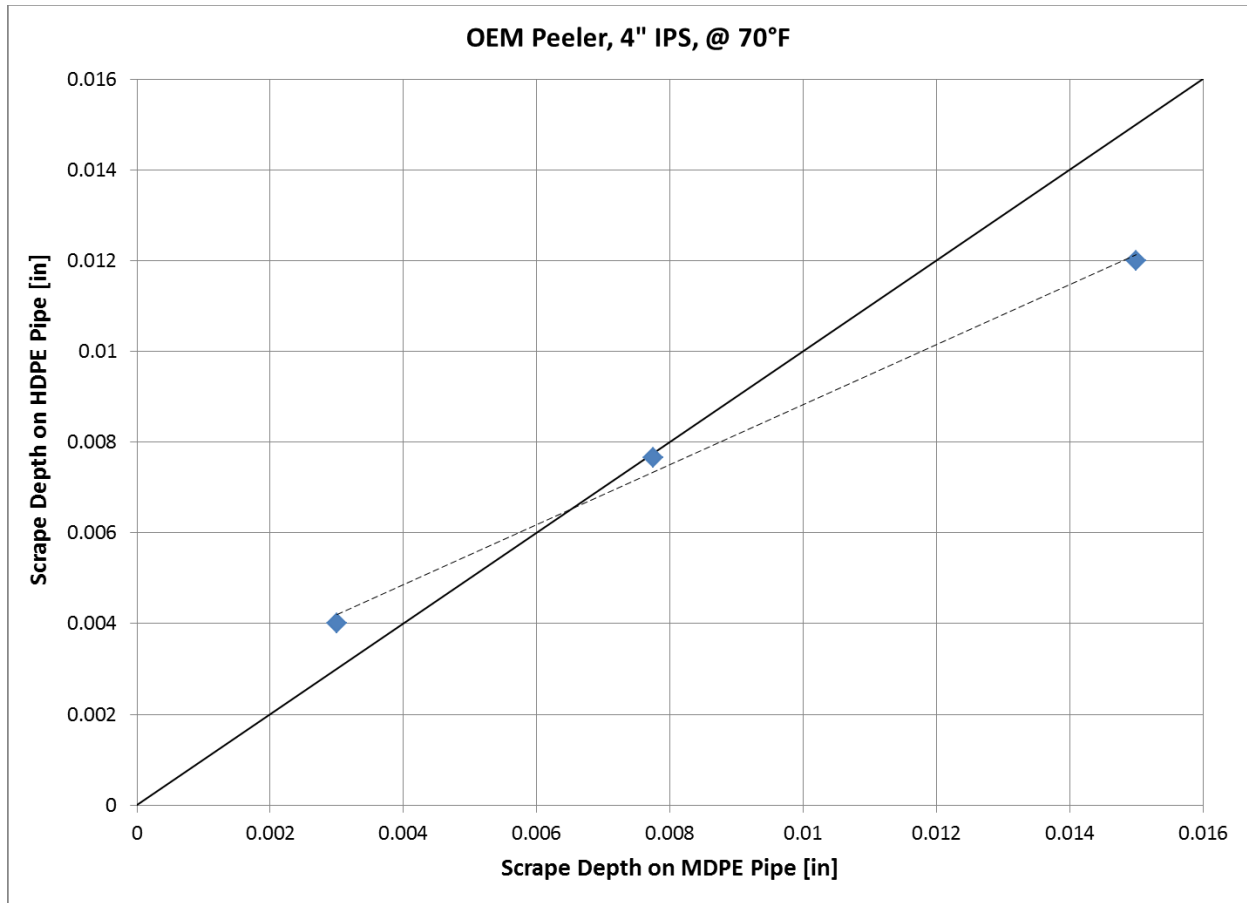


Figure 27. OEM Peeler 4" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F

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Friatec Hand Scraper

A typical scrape by a Friatec hand scraper is shown in **Figure 28** and the scrape depth results are shown in **Figure 29**. Single-pass scrape depth was mostly below 0.006 inches, the lowest measured depth was 0.001 inches. These results suggest that when using a “paint scraper” type tool, particular care should be taken to thoroughly scrape the entire fusion zone area to a sufficient depth.

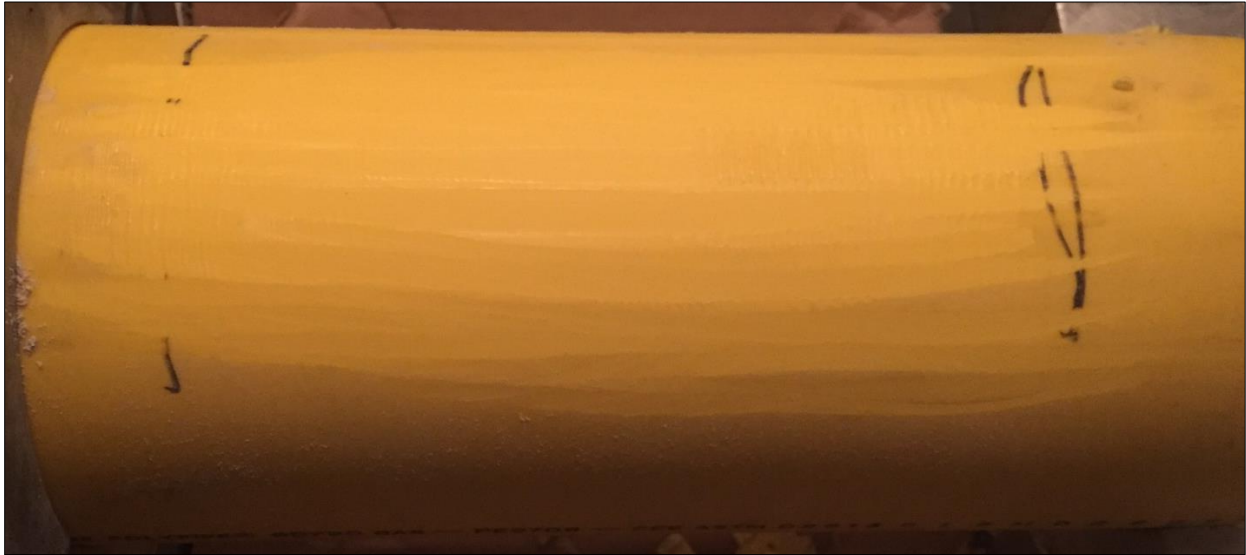


Figure 28. Typical scrape by Friatec Hand Scraper

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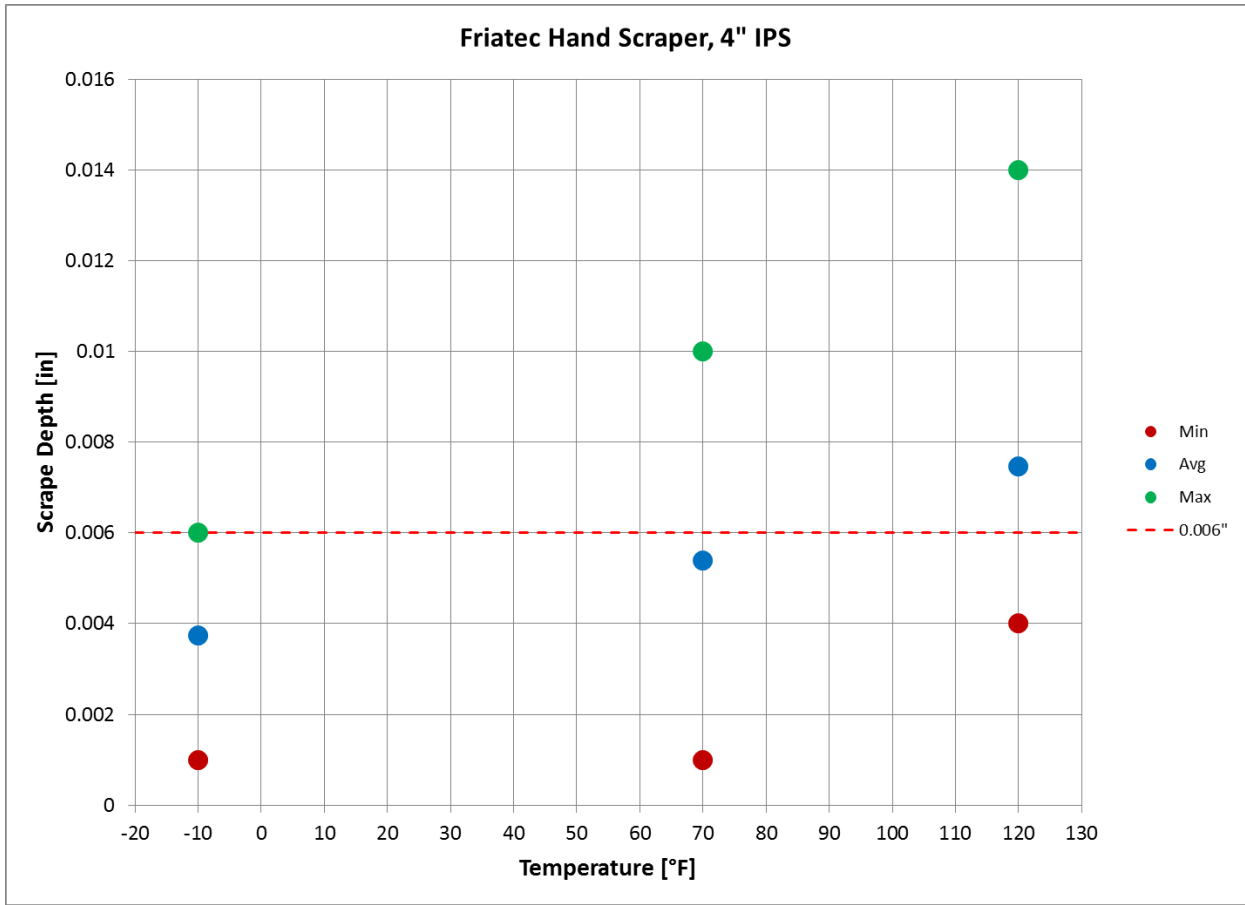


Figure 29. Friatec Hand Scraper, 4" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe

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Figure 30 shows the scrape depth difference between HDPE and MDPE at 70°F. The minimum depth was the same on HDPE pipe, while the average and maximum depths were higher on MDPE pipe.

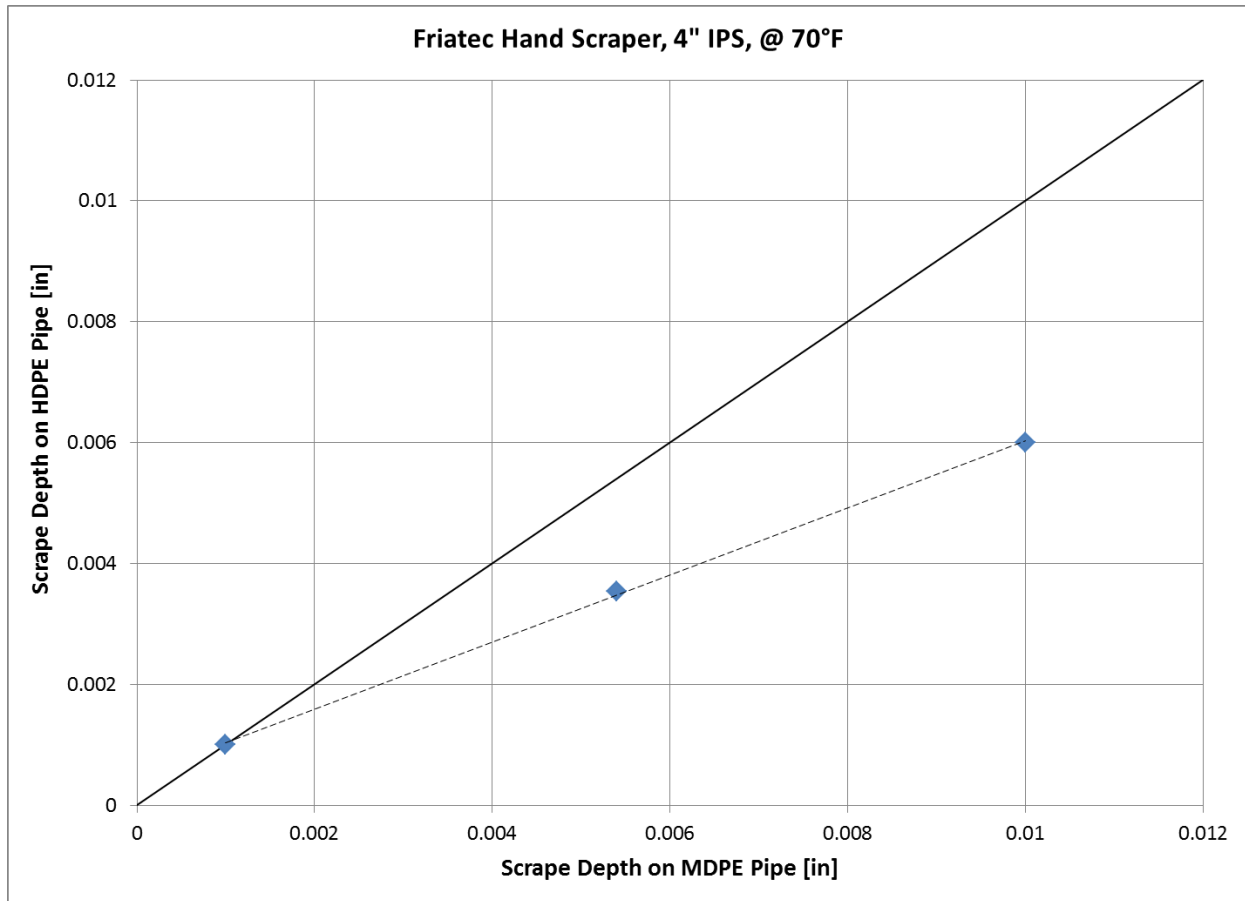


Figure 30. Friatec Hand Scraper, 4" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F

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Pencil Scraper, ½" CTS

A typical scrape by a Central Plastics Mini Scraper is shown in **Figure 31** and the scrape depth results are shown in **Figure 32**. Scrape depth was mostly above 0.006 inches, the lowest measured depth was 0.005 inches. These results suggest that the Central Plastics Mini Scraper should consistently remove oxidized material on the pipe surface.



Figure 31. Typical scrape by ½" CTS Pencil Scraper

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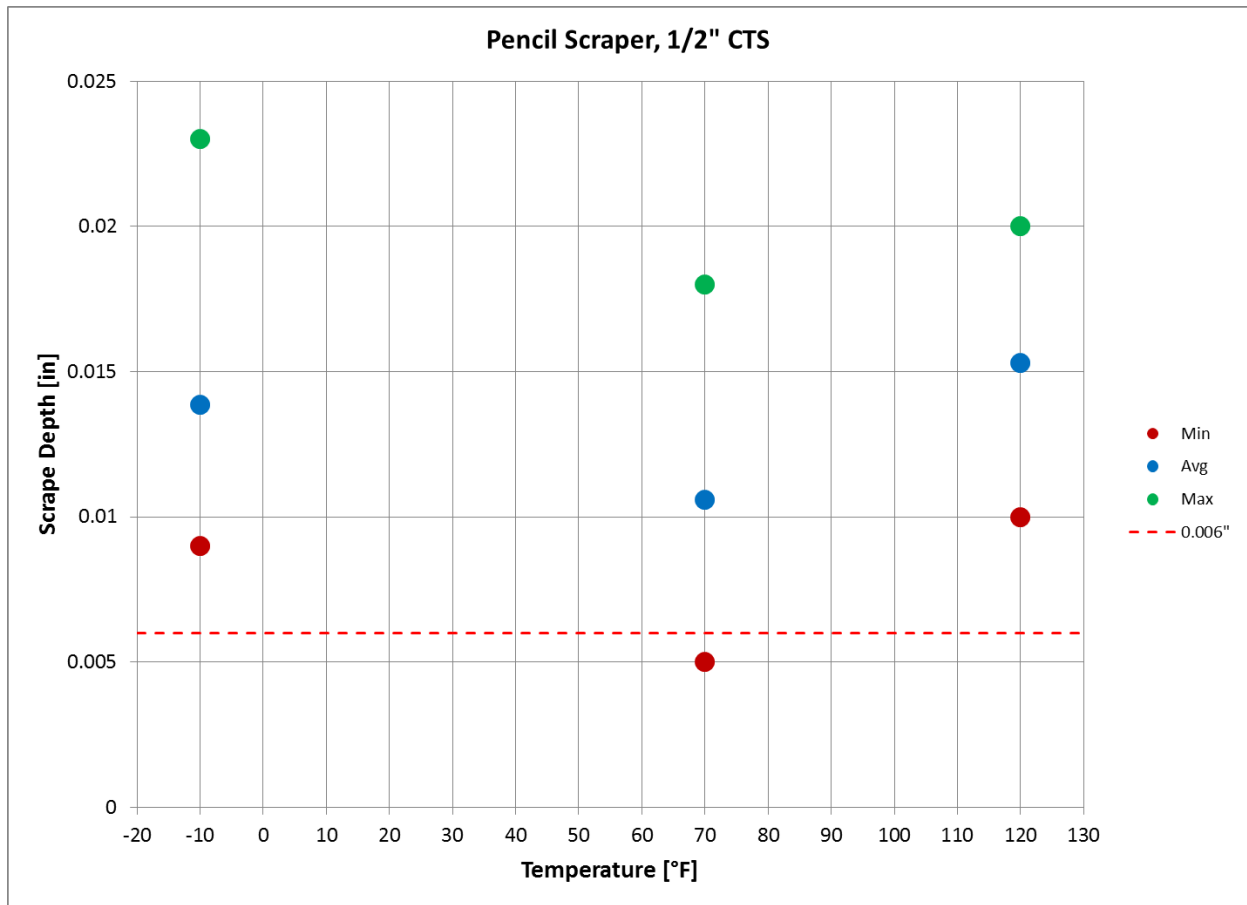


Figure 32. Pencil Scraper, 1/2" CTS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe

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Figure 33 shows pipe ovality before and after scraping. As can be seen in the figure, the 1/2" CTS Pencil Scraper consistently re-rounds the pipe. This can be attributed to the scraper's non-spring-loaded blade and fixed cavity diameter.

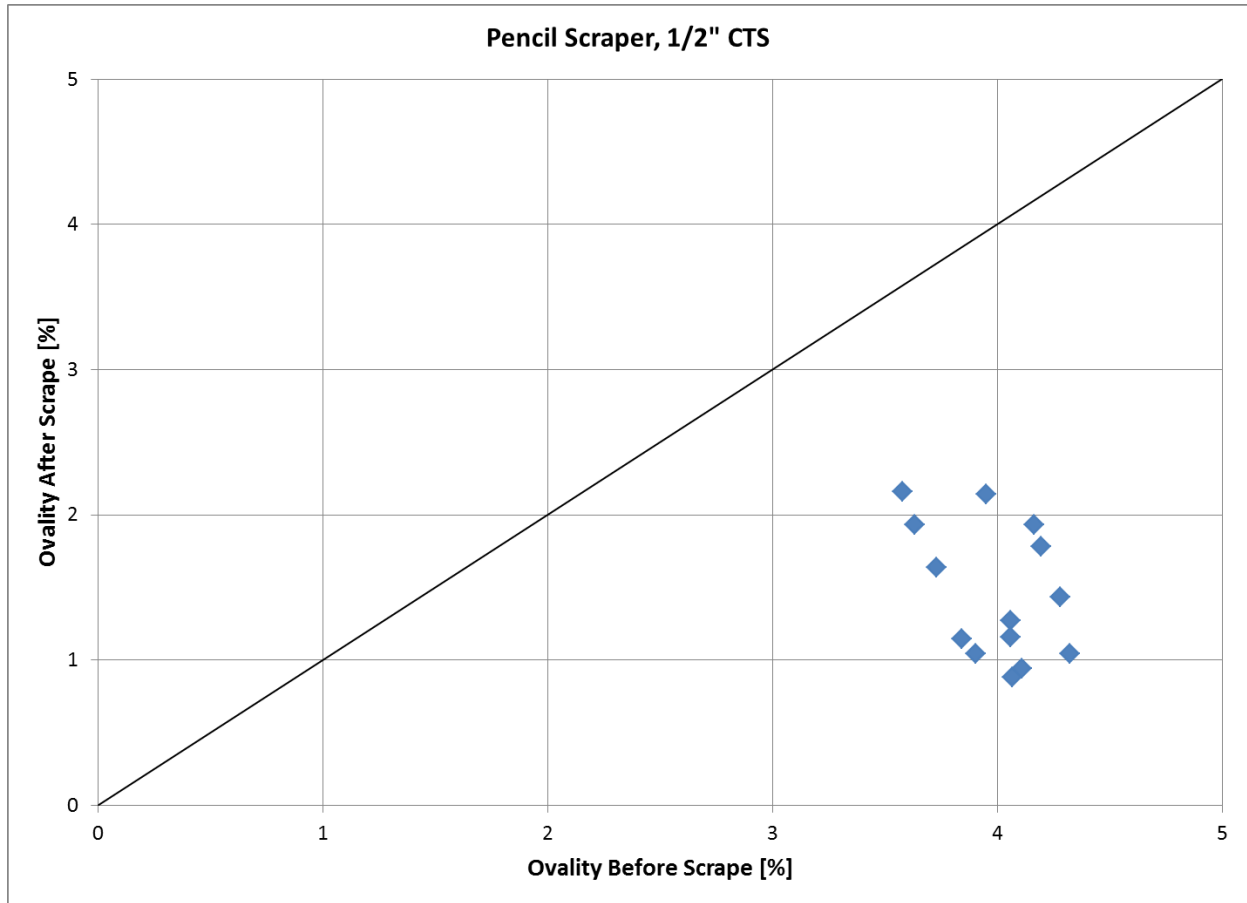


Figure 33. Pencil Scraper, 1/2" CTS: Ovality after scrape versus ovality before scrape

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Figure 34 shows the scrape depth difference between HDPE and MDPE at 70°F. Scrape depth was consistently higher on MDPE versus HDPE. This result suggests that because the pencil scraper does not have a spring-loaded blade, the higher stiffness of HDPE leads to shallower scrapes when compared to MDPE.

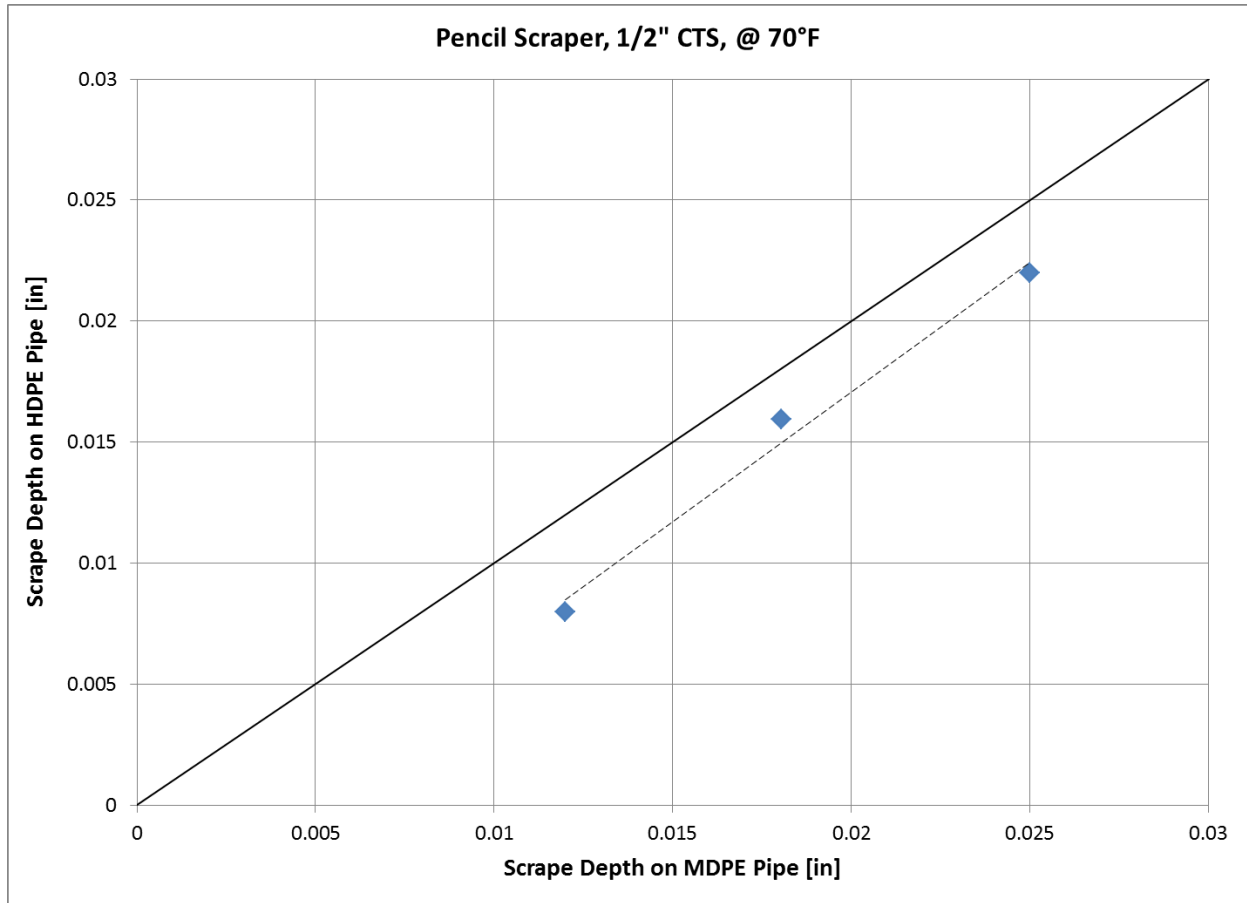


Figure 34. Pencil Scraper, 1/2\" CTS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F

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Summit Rotary Scraper, 4" IPS

Scrapes by a 4" IPS Summit Rotary Scraper are shown in **Figure 35** and **Figure 36**. Scrape depth results are shown in **Figure 37**. Single-pass scrape depth was mostly above 0.006 inches, the lowest measured depth was 0.003 inches. These results suggest that only one scraping pass would be expected in most cases, however, issues with scraping consistency around the circumference of the pipe were encountered during testing.



Figure 35. Typical scrape by 4" IPS Summit Rotary Scraper

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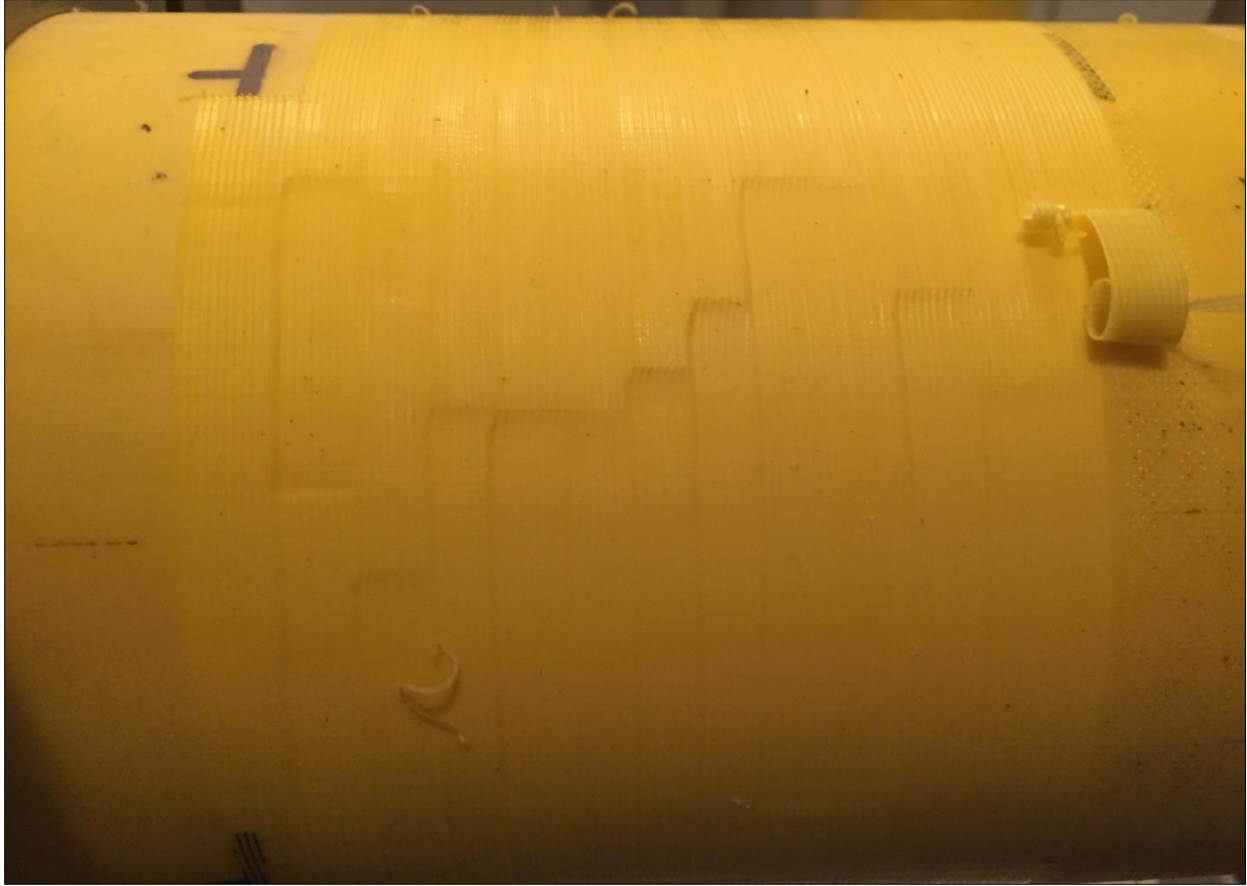


Figure 36. Inconsistent scrape depth by 4" IPS Summit Rotary Scraper

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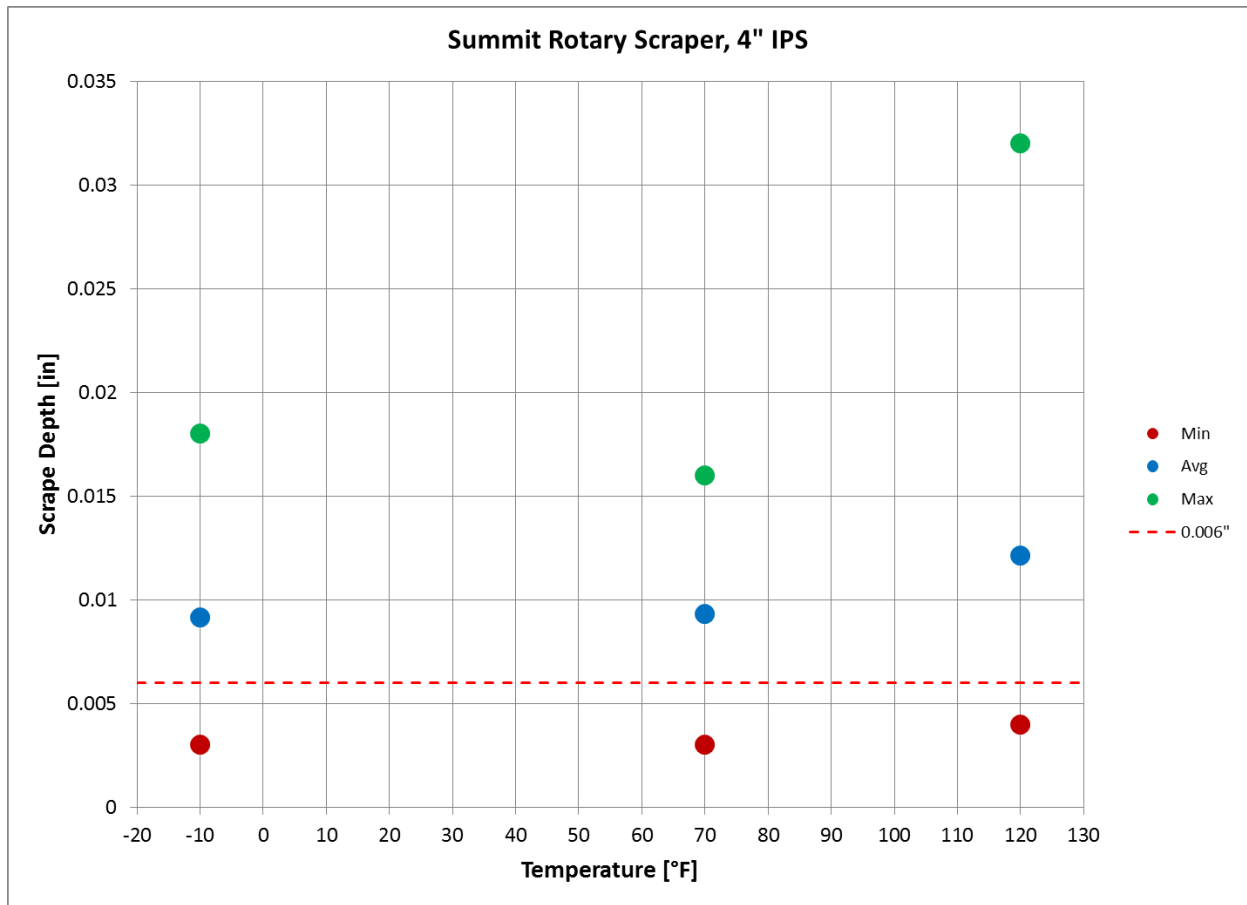


Figure 37. Summit Rotary Scraper, 4\" IPS: minimum, average, and maximum scraping depths at three temperatures, on MDPE pipe

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Figure 38 shows pipe ovality before and after scraping. As can be seen in the figure, the 4" IPS Summit Rotary Scraper typically maintains the original pipe ovality, but may increase or reduce ovality in some cases.

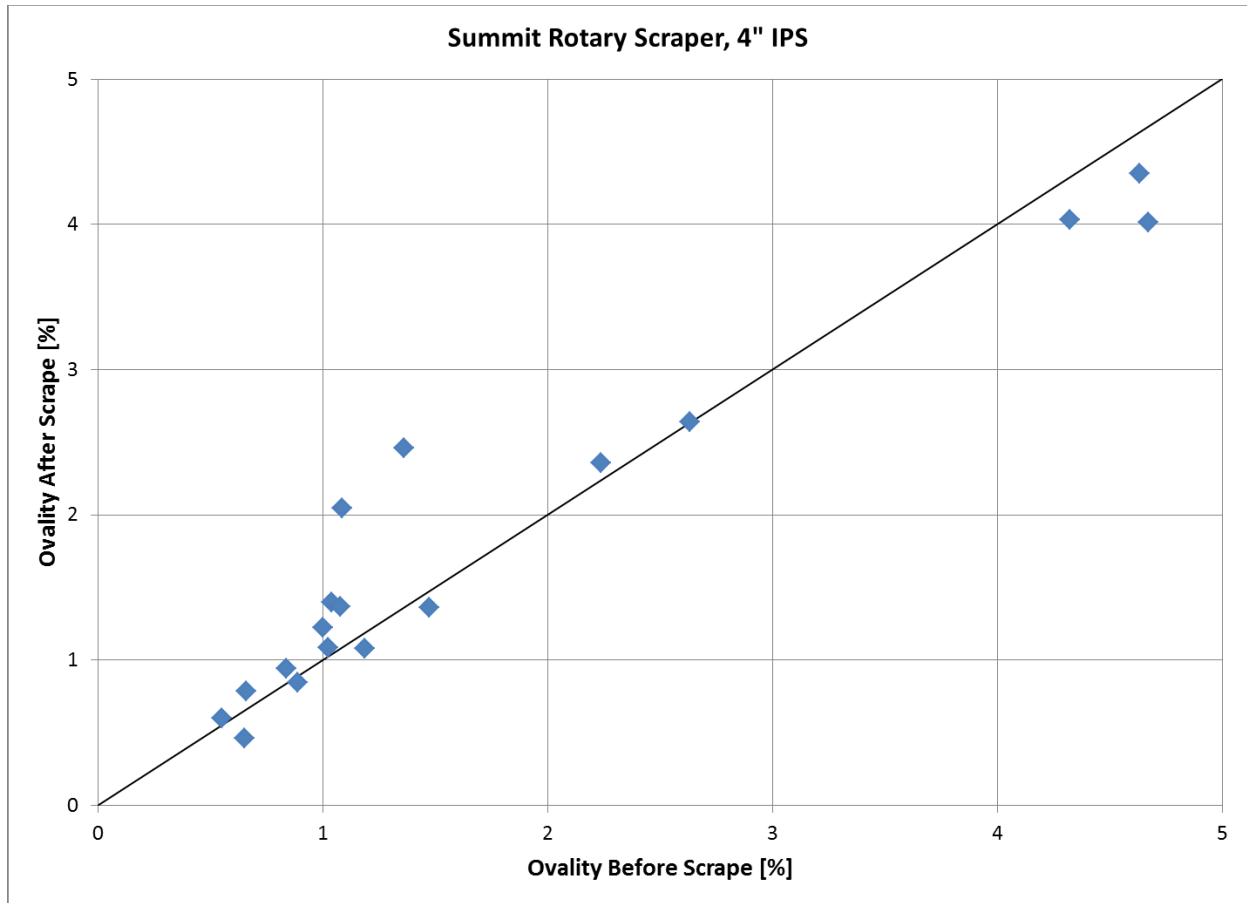


Figure 38. Summit Rotary Scraper, 4" IPS: Ovality after scrape versus ovality before scrape

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Figure 39 shows the scrape depth difference between HDPE and MDPE at 70°F. Minimum and average scrape depths were higher on HDPE and maximum depth was higher on MDPE. The slope of the regression line through the points probably highlights the scrape inconsistency issues.

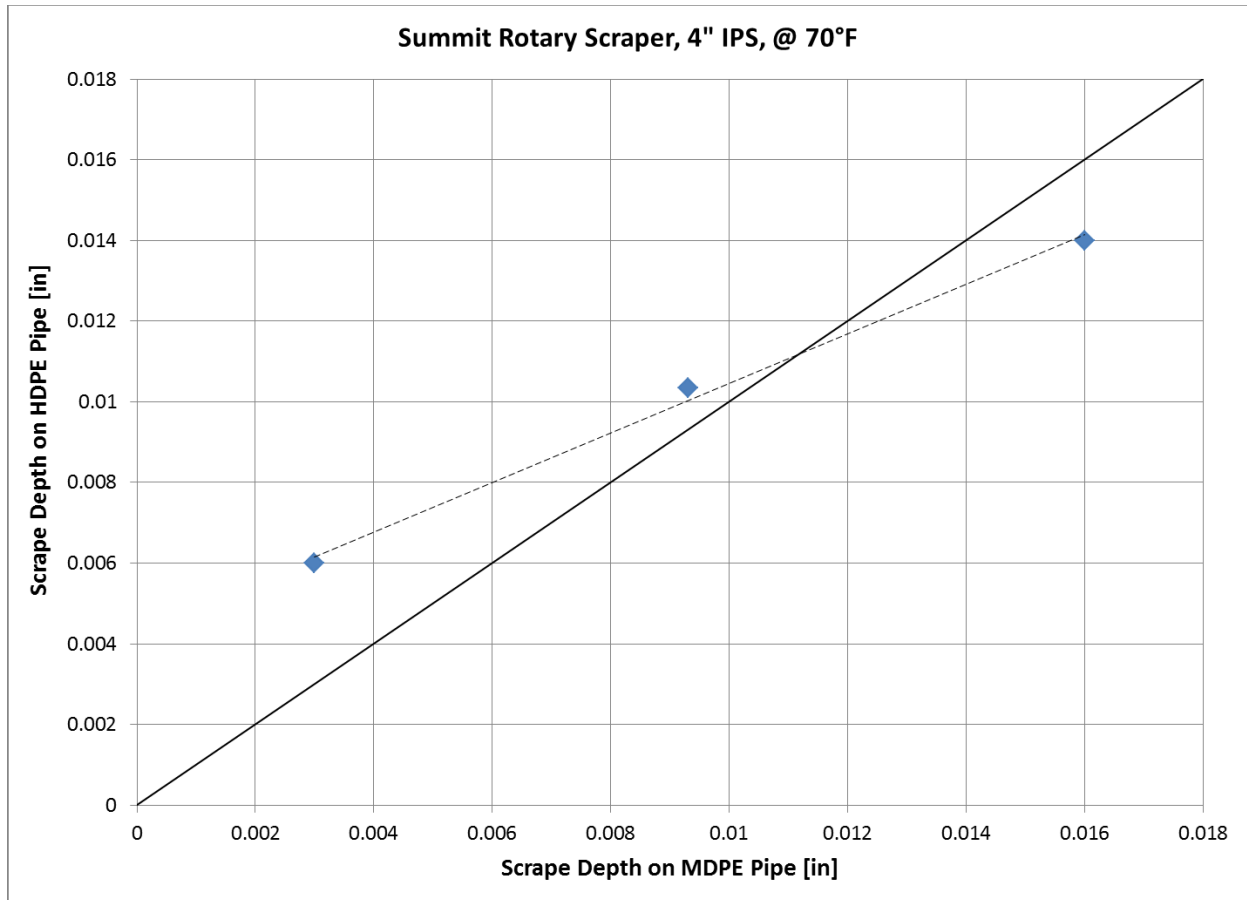


Figure 39. Summit Rotary Scraper, 4" IPS: Scrape depth on HDPE pipe versus MDPE pipe, at 70°F

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Subjective Scraper Comparison

Table 2 shows subjective ratings of ease of use of each of the tested scrapers, based on the experience of the GTI personnel who tested the scrapers for this report. The ratings are relative between the tested scrapers and are intended to give a qualitative comparison from an operator perspective.

Table 2. Subjective User Ratings of Scraper Ease of Use

Scraper	Ease of Clamping/Alignment	Ease of Scrape
2" IPS OEM Peeler	3	4
4" IPS OEM Peeler	3	4
2" IPS Frialen Peeler	3	5
4" IPS Frialen Peeler	3	4
2" IPS Half-Moon Scraper	1	1
4" IPS Summit Rotary Scraper	4	2
1/2" CTS Pencil Scraper	5	5
Friatec Hand Scraper	1	4

Rating guide: 1=Worst, 5=Best

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Contamination Removal Testing

Contamination removal tests were performed in the same manner as the scrape depth tests, however, the pipe was deliberately contaminated with bentonite powder prior to scraping. Bentonite powder was selected because it is the primary mineral in drilling fluids used in horizontal directional drilling (HDD) and, being a silicate, it has a similar detrimental effect as other soils or dust.

Following the scraping procedure, electrofusion saddles were fused and then peeled off using the ISO decohesion test method. Fusions that exhibited 100% ductility were scored as “pass”, fusions with less than 100% ductility scored as “fail”. Since the objective of this test was to assess removal of contamination, fusion voids were disregarded in the scoring.

Figure 40 shows the success rate of complete removal of the bentonite contamination, per scraper. Each scraper was tested a total of six times, which included scraping at three temperatures on both MDPE and HDPE pipes.

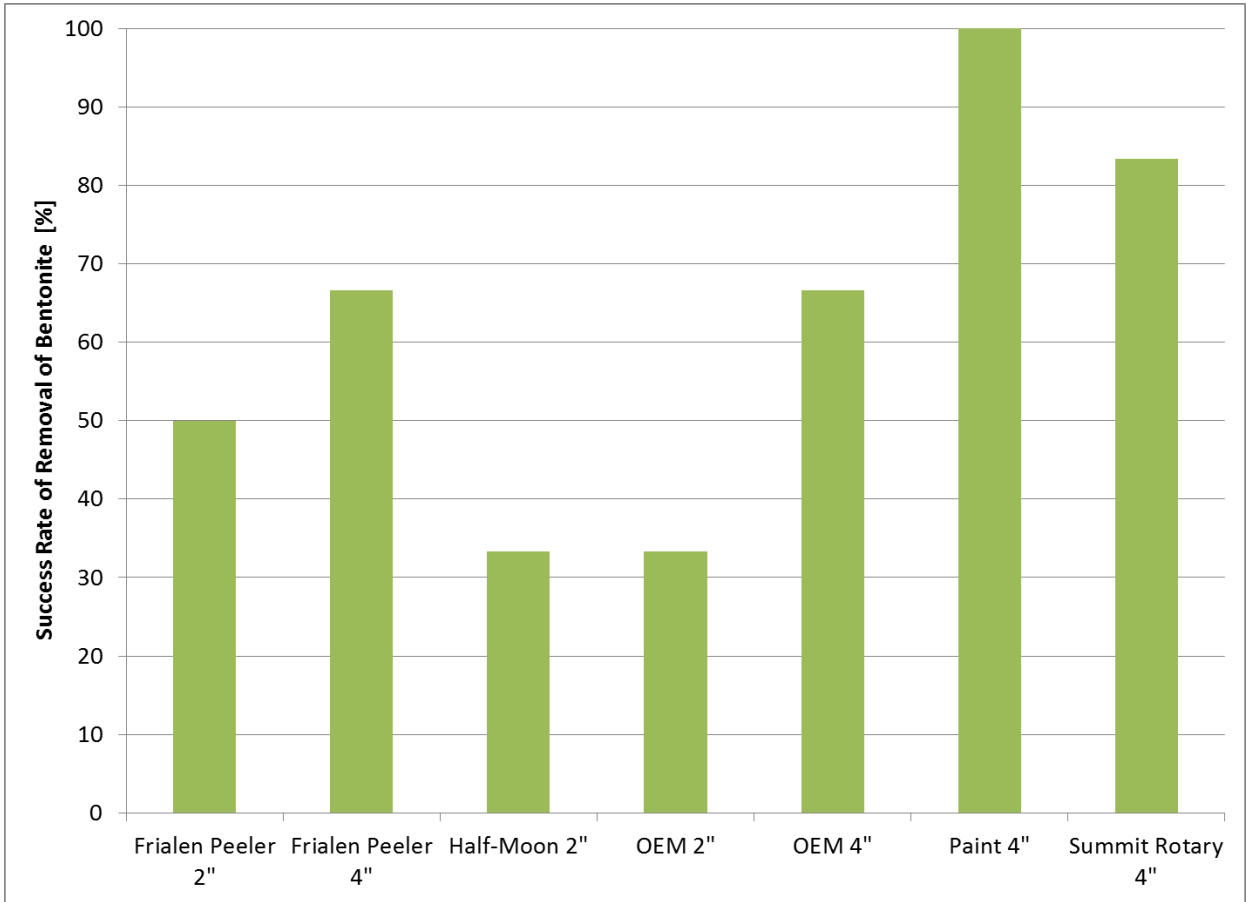


Figure 40. Success rates of complete removal of bentonite powder

The following figures show the test results of the decohesion tests and FTIR data where applicable. Circles on photographs indicate the locations where FTIR readings were taken, and are color-coded to match the corresponding FTIR spectra figure.

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Frialen Peeler, 2" IPS



Figure 41. Decohesion test result, 2" IPS Frialen Peeler on MDPE pipe at -10°F

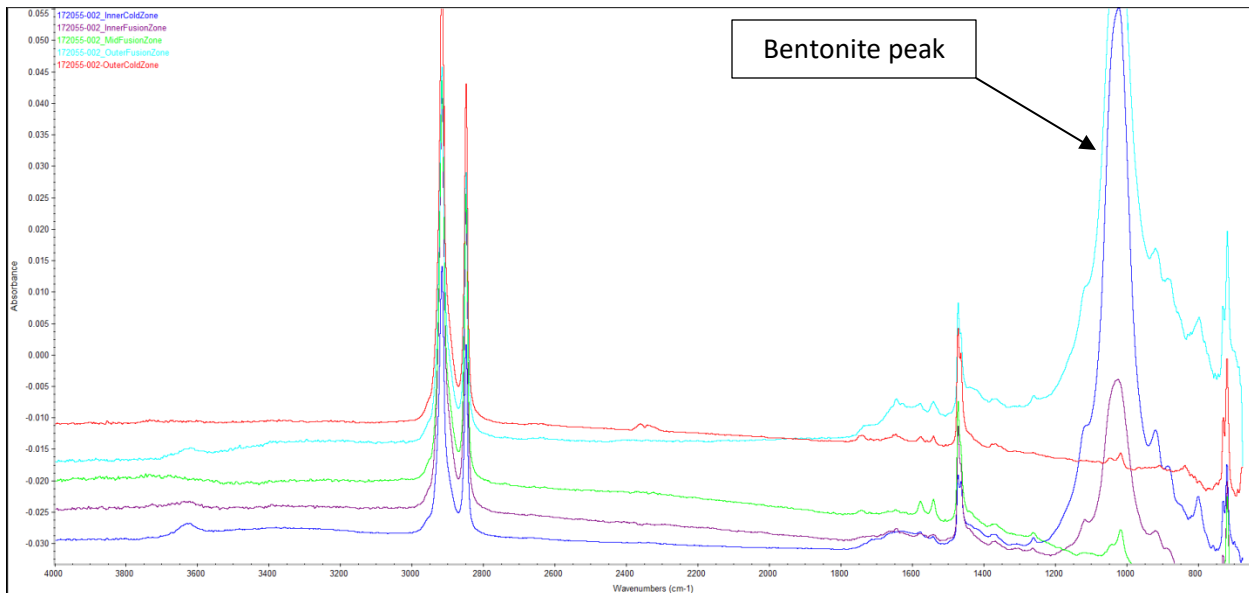


Figure 42. FTIR spectra from decohesion test result, 2" IPS Frialen Peeler on MDPE pipe at -10°F

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Figure 43. Decohesion test result, 2" IPS Frialen Peeler on HDPE pipe at -10°F

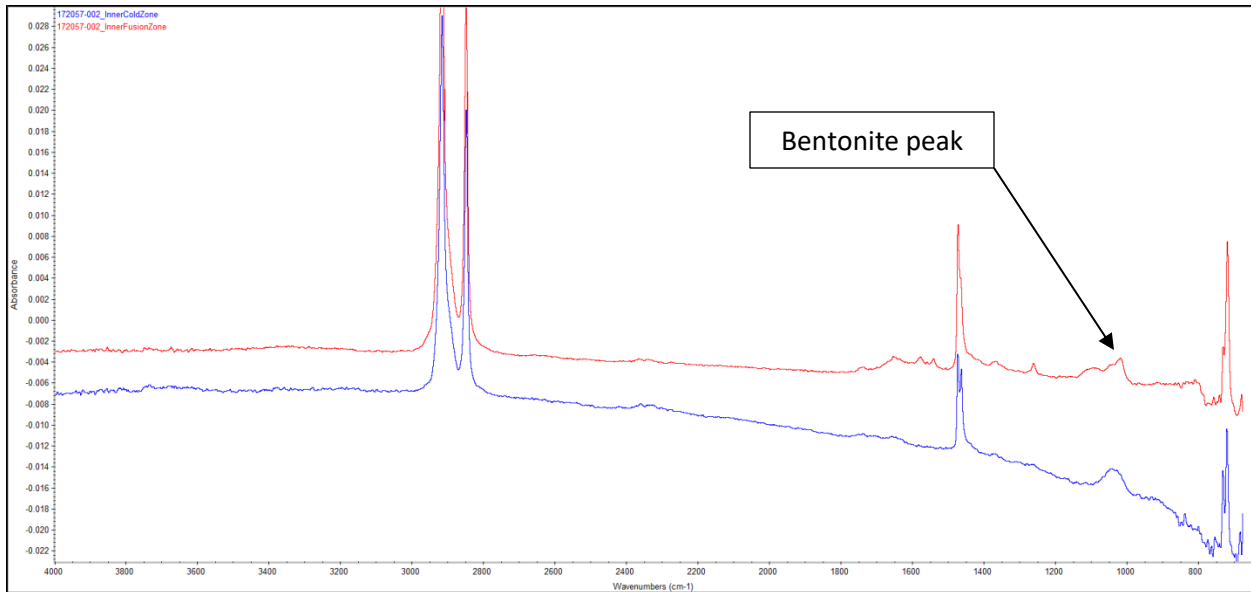


Figure 44. FTIR spectra from decohesion test result, 2" IPS Frialen Peeler on HDPE pipe at -10°F

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Figure 45. Decohesion test result, 2" IPS Frialen Peeler on MDPE pipe at 70°F

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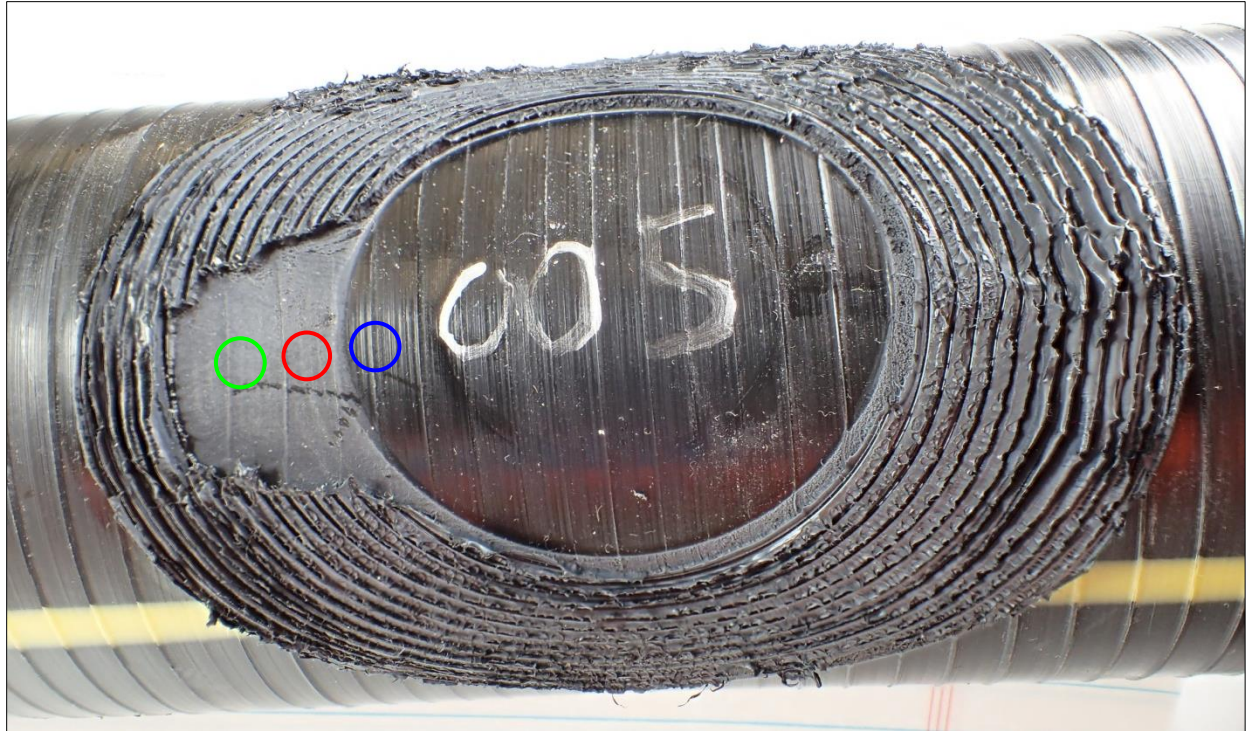


Figure 46. Decohesion test result, 2" IPS Frialen Peeler on HDPE pipe at 70°F

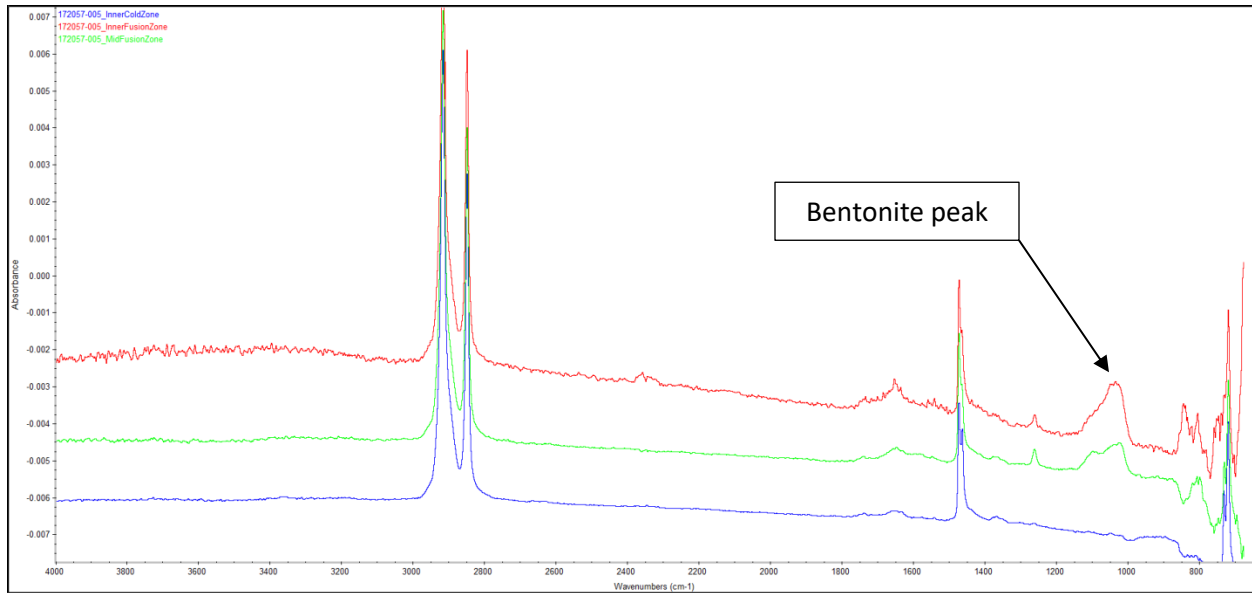


Figure 47. FTIR spectra from decohesion test result, 2" IPS Frialen Peeler on HDPE pipe at 120°F

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Figure 48. Decohesion test result, 2" IPS Frialen Peeler on MDPE pipe at 120°F



Figure 49. Decohesion test result, 2" IPS Frialen Peeler on HDPE pipe at 120°F

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Figure 50. Decohesion test result, 4" IPS Frialen Peeler on MDPE pipe at -10°F

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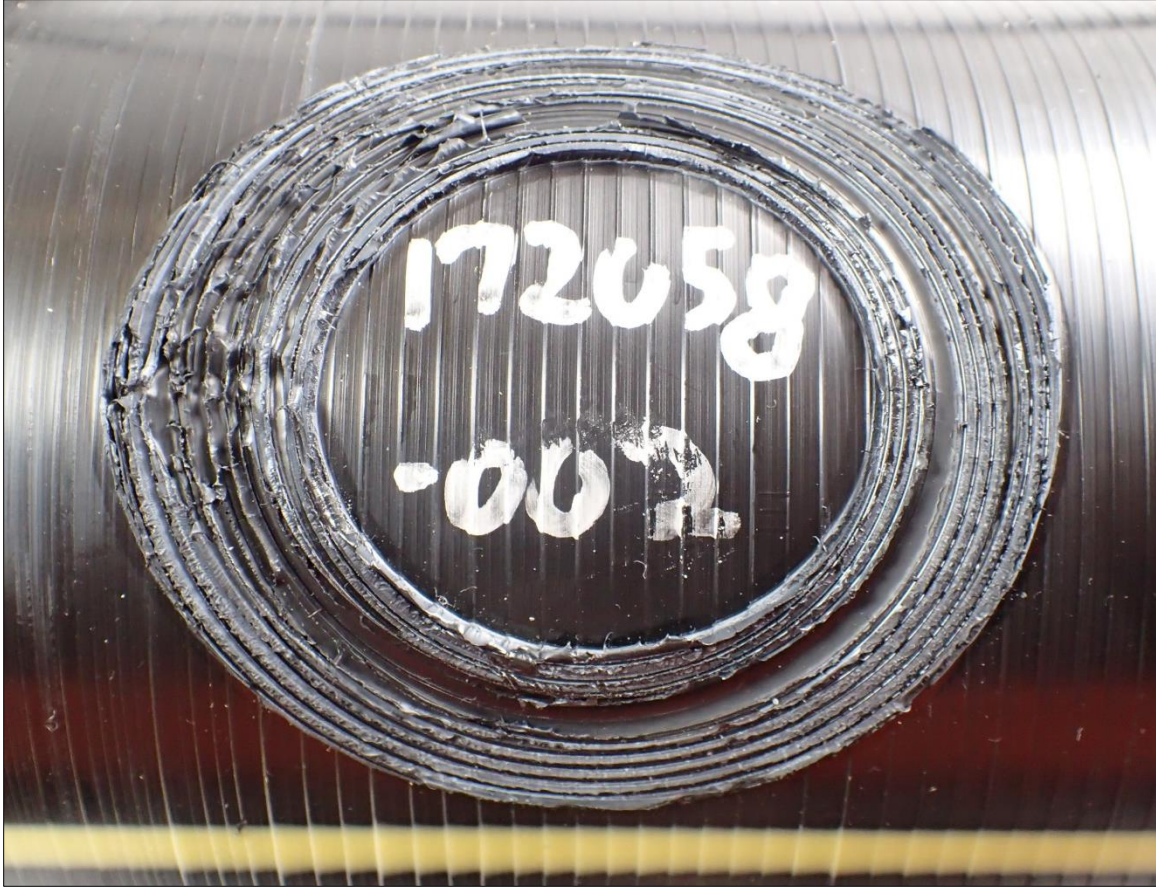


Figure 51. Decohesion test result, 4" IPS Frialen Peeler on HDPE pipe at -10°F

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Figure 52. Decohesion test result, 4" IPS Frialen Peeler on MDPE pipe at 70°F

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Figure 53. Decohesion test result, 4" IPS Frialen Peeler on HDPE pipe at 70°F

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Figure 54. Decohesion test result, 4" IPS Frialen Peeler on MDPE pipe at 120°F

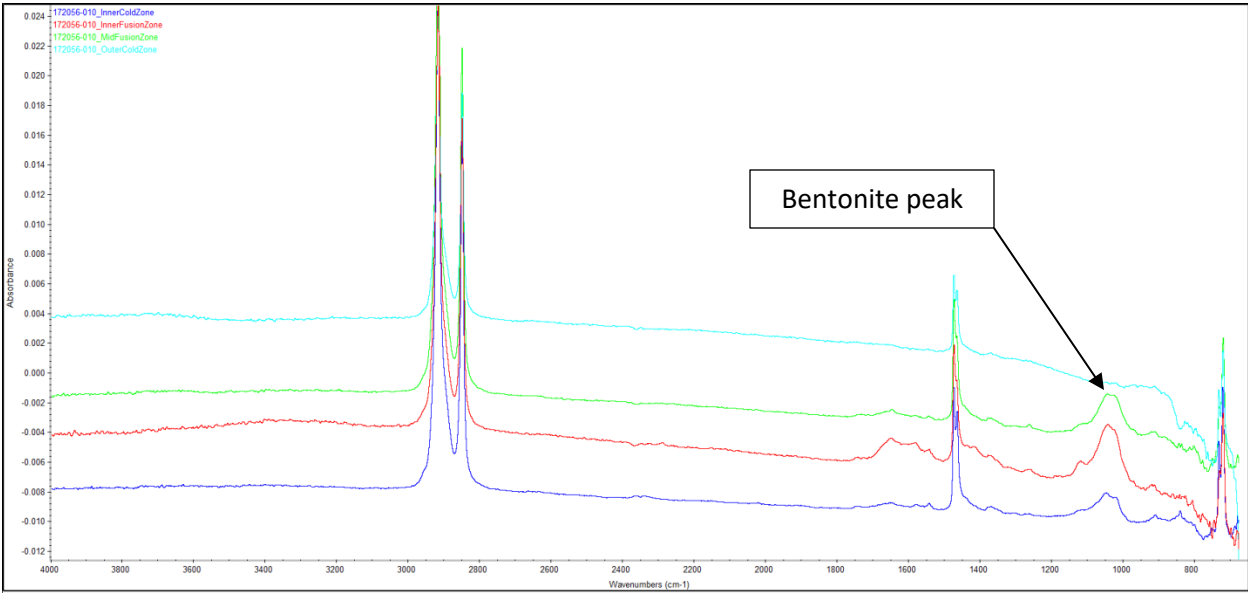


Figure 55. FTIR spectra from decohesion test result, 4" IPS Frialen Peeler on MDPE pipe at 120°F

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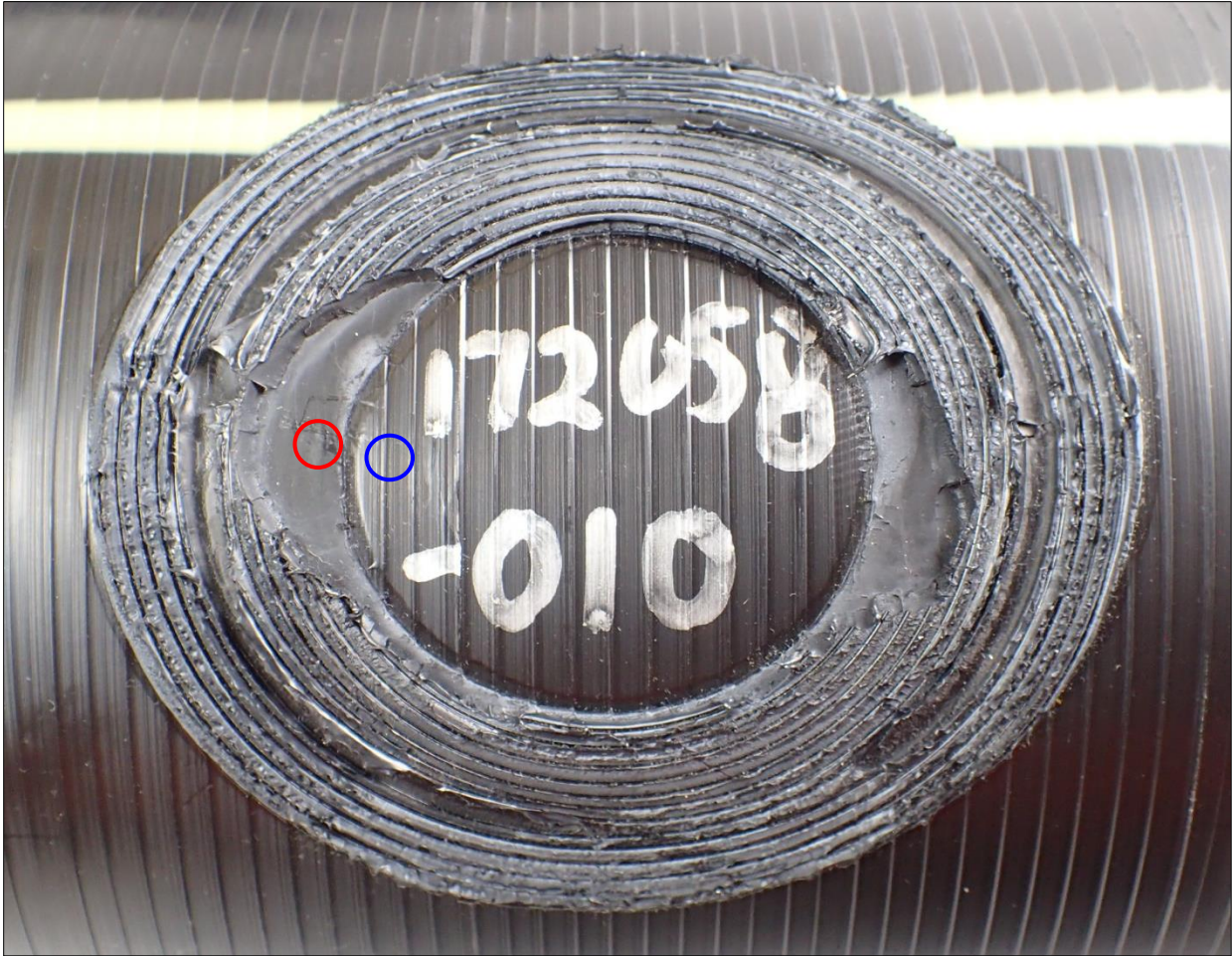


Figure 56. Decohesion test result, 4" IPS Frialen Peeler on HDPE pipe at 120°F

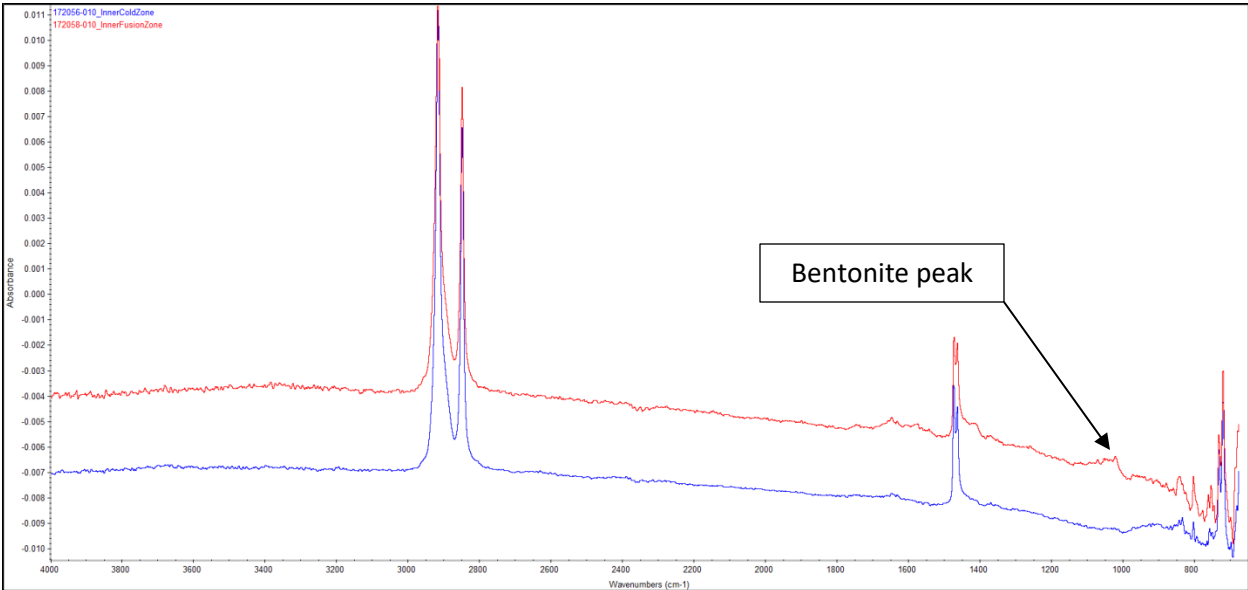


Figure 57. FTIR spectra from decohesion test result, 4" IPS Frialen Peeler on HDPE pipe at 120°F

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Half-Moon Scraper, 2" IPS



Figure 58. Decoherion test result, 2" IPS Half-Moon Scraper on MDPE pipe at -10°F

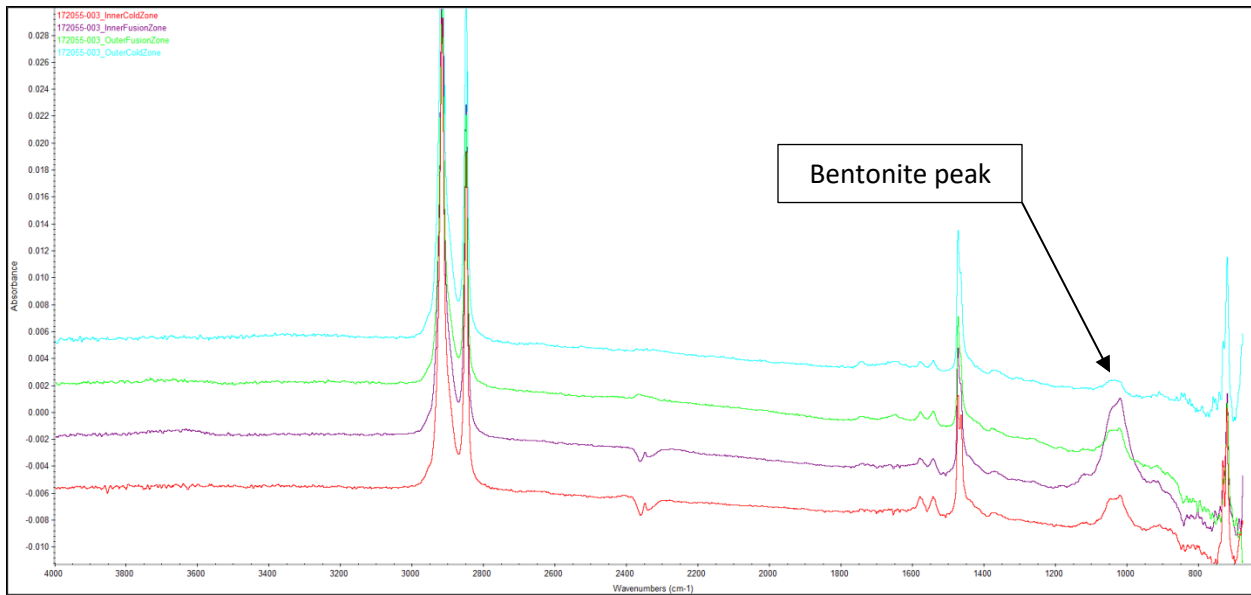


Figure 59. FTIR spectra from decoherion test result, 2" IPS Half-Moon Scraper on MDPE pipe at -10°F

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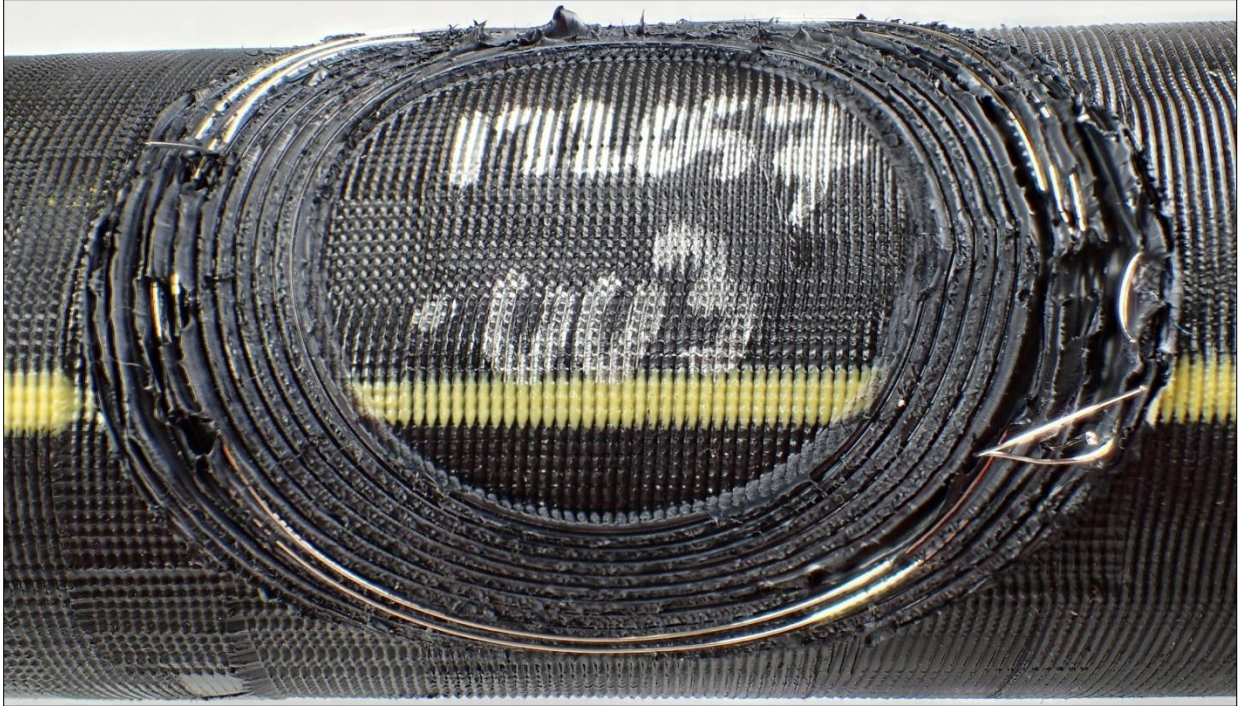


Figure 60. Decohesion test result, 2" IPS Half-Moon Scraper on HDPE pipe at -10°F

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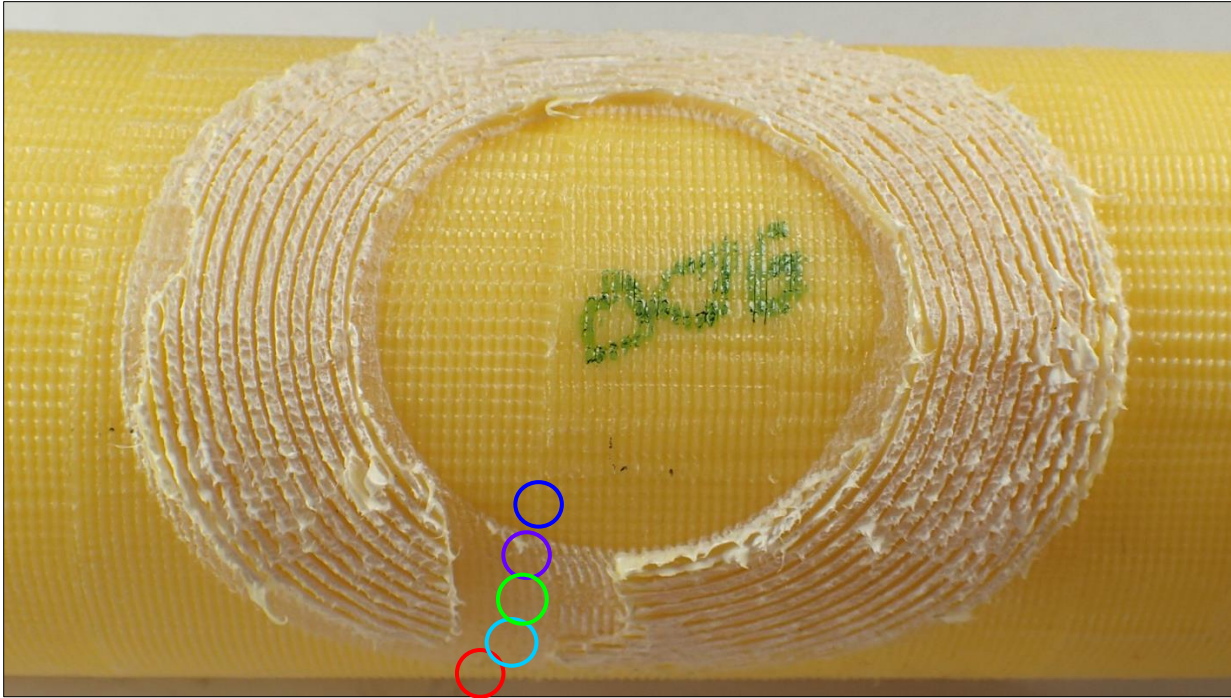


Figure 61. Decohesion test result, 2" IPS Half-Moon Scraper on MDPE pipe at 70°F

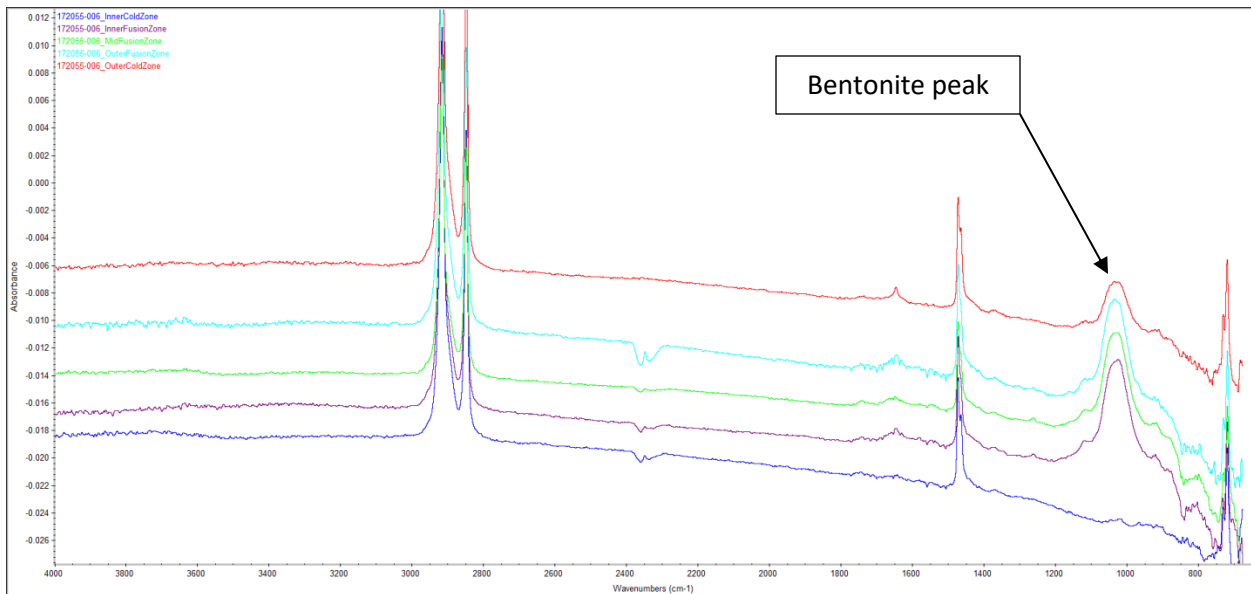


Figure 62. FTIR spectra from decohesion test result, 2" IPS Half-Moon Scraper on MDPE pipe at 70°F

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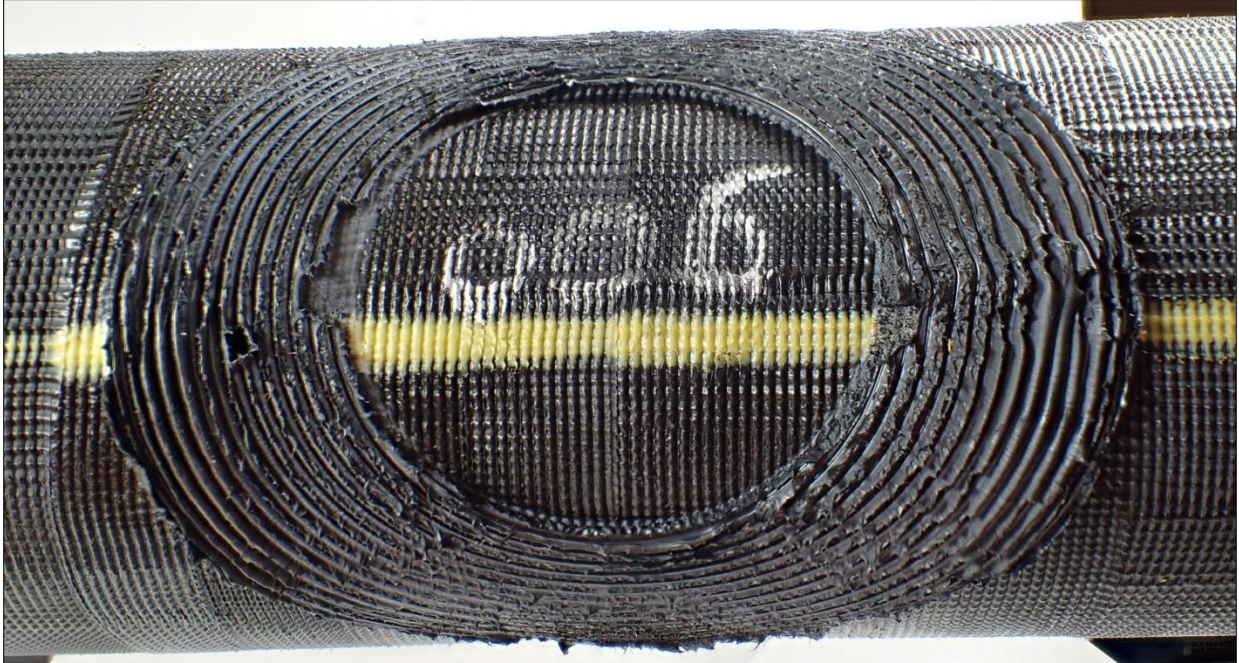


Figure 63. Decohesion test result, 2" IPS Half-Moon Scraper on HDPE pipe at 70°F

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Figure 64. Decohesion test result, 2" IPS Half-Moon Scraper on MDPE pipe at 120°F

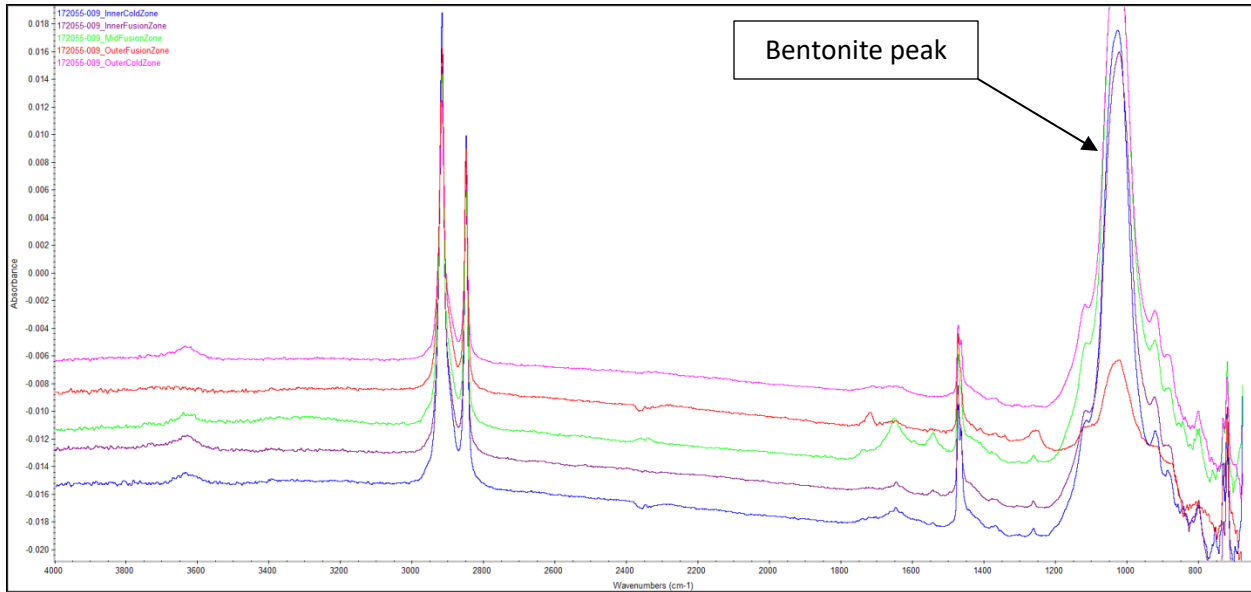


Figure 65. FTIR spectra from decohesion test result, 2" IPS Half-Moon Scraper on MDPE pipe at 120°F

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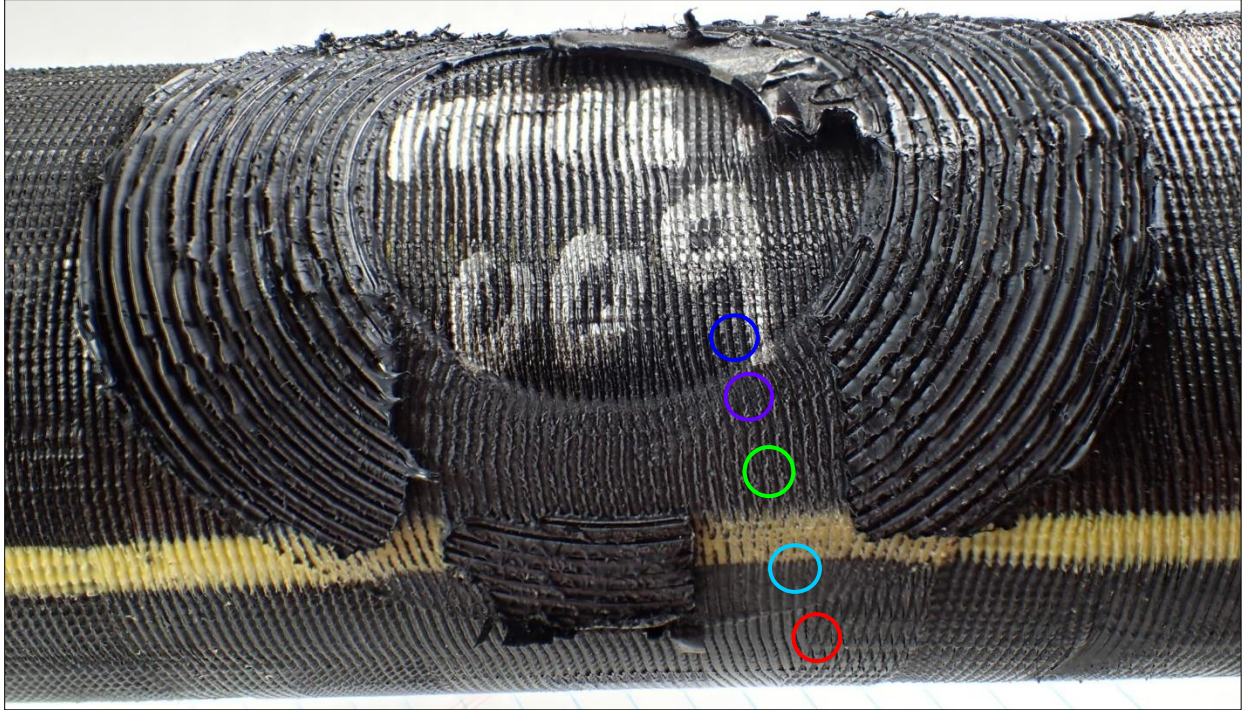


Figure 66. Decohesion test result, 2" IPS Half-Moon Scraper on HDPE pipe at 120°F

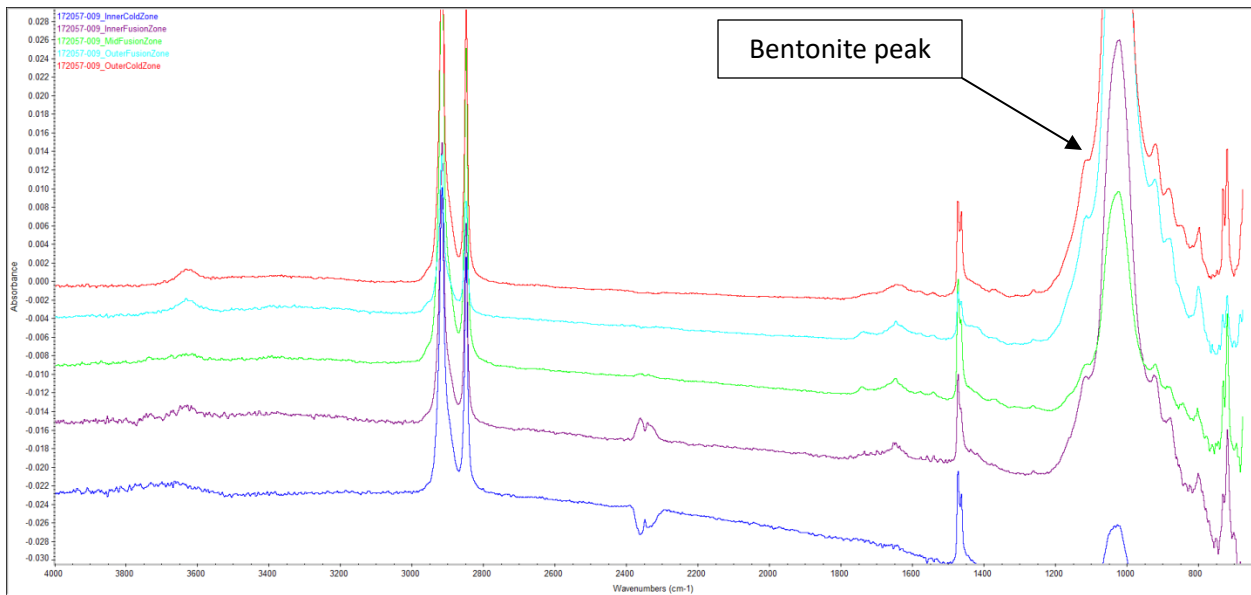


Figure 67. FTIR spectra from decohesion test result, 2" IPS Half-Moon Scraper on HDPE pipe at 120°F

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OEM Peeler, 2" IPS

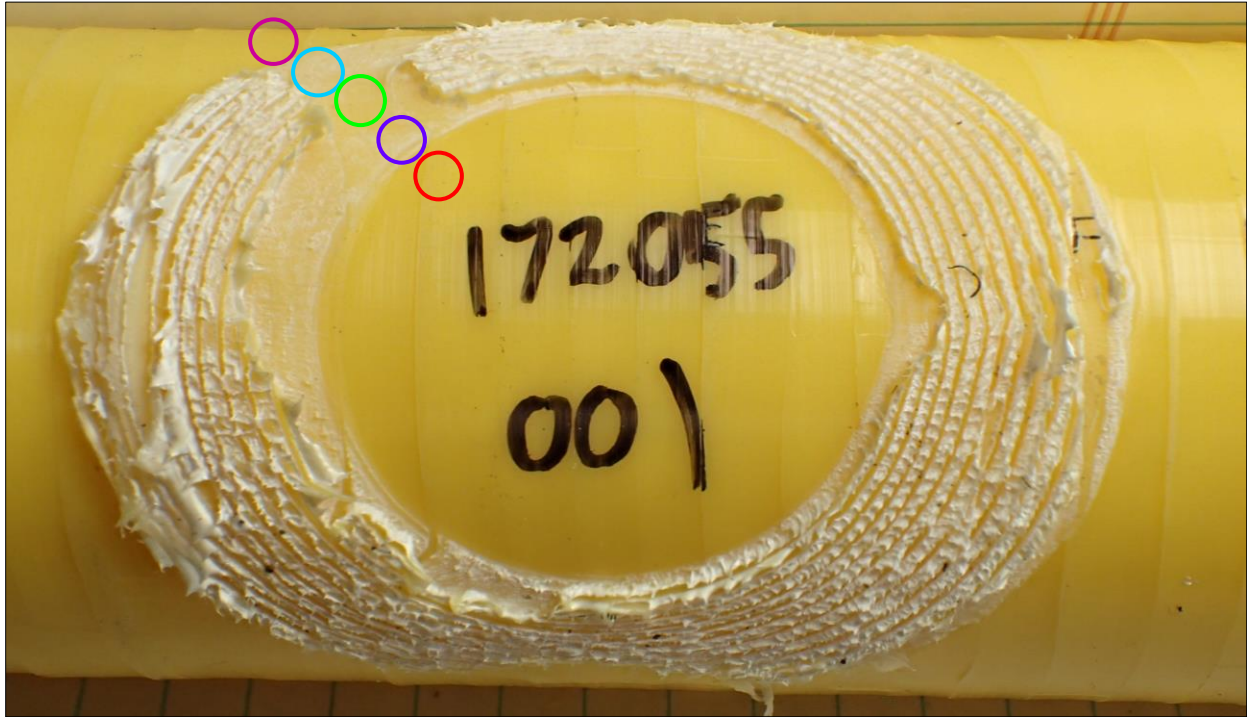


Figure 68. Decohesion test result, 2" IPS OEM Peeler on MDPE pipe at -10°F

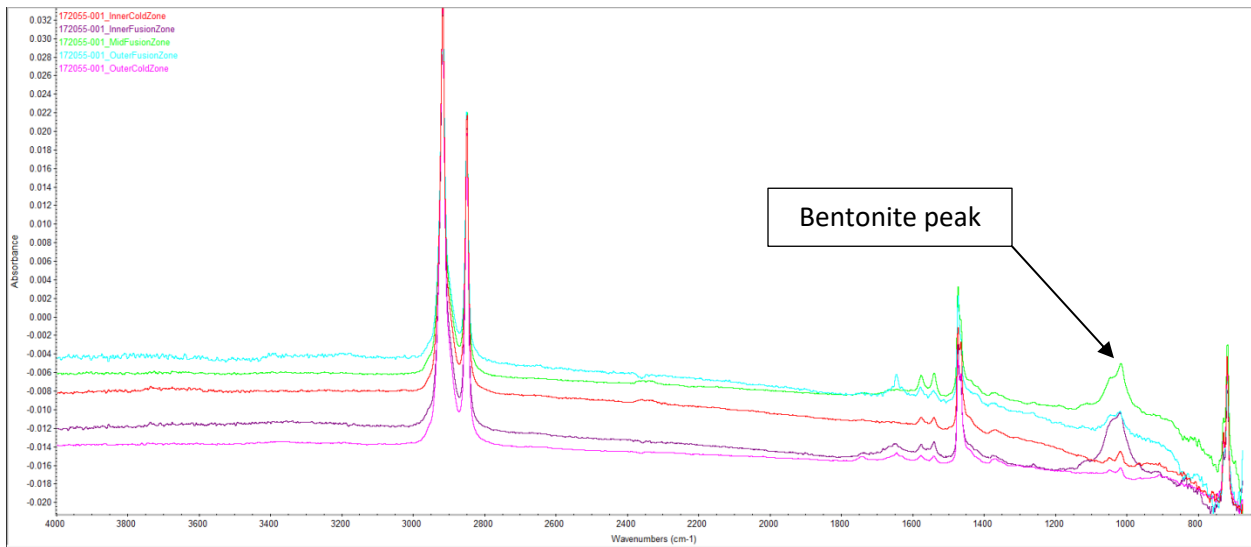


Figure 69. FTIR spectra from decohesion test result, 2" IPS OEM Peeler on MDPE pipe at -10°F

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Figure 70. Decohesion test result, 2" IPS OEM Peeler on HDPE pipe at -10°F

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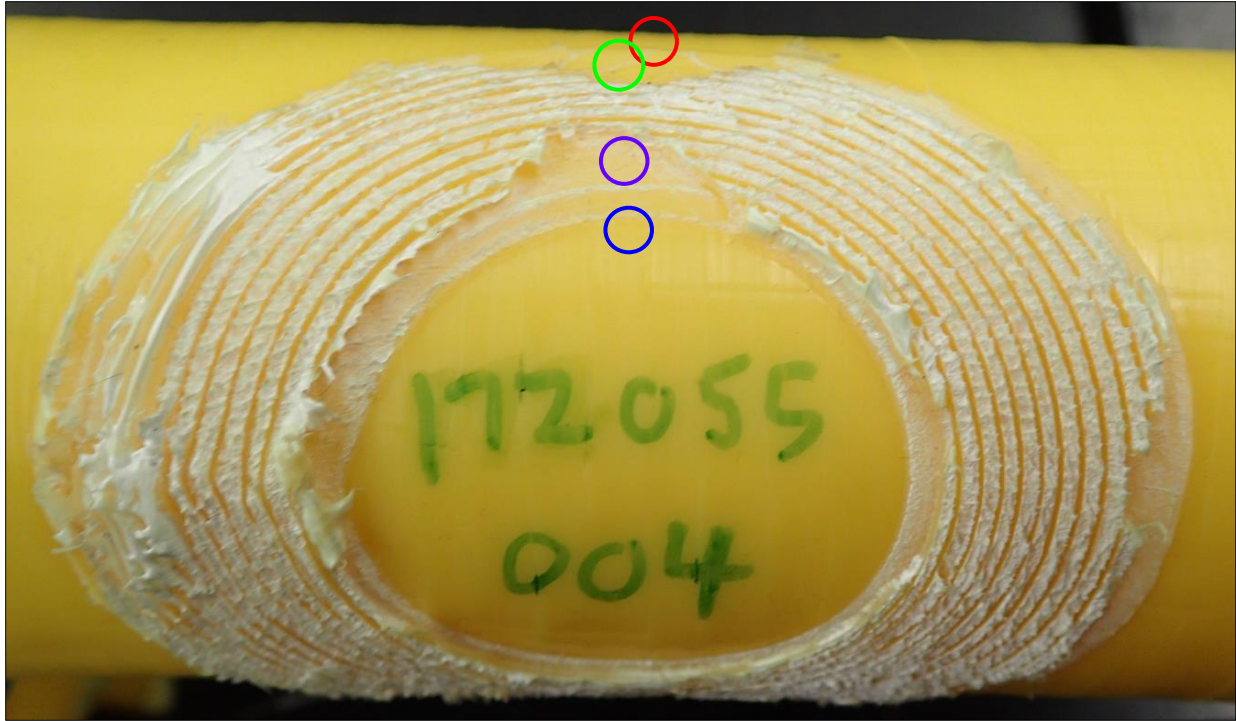


Figure 71. Decohesion test result, 2" IPS OEM Peeler on MDPE pipe at 70°F

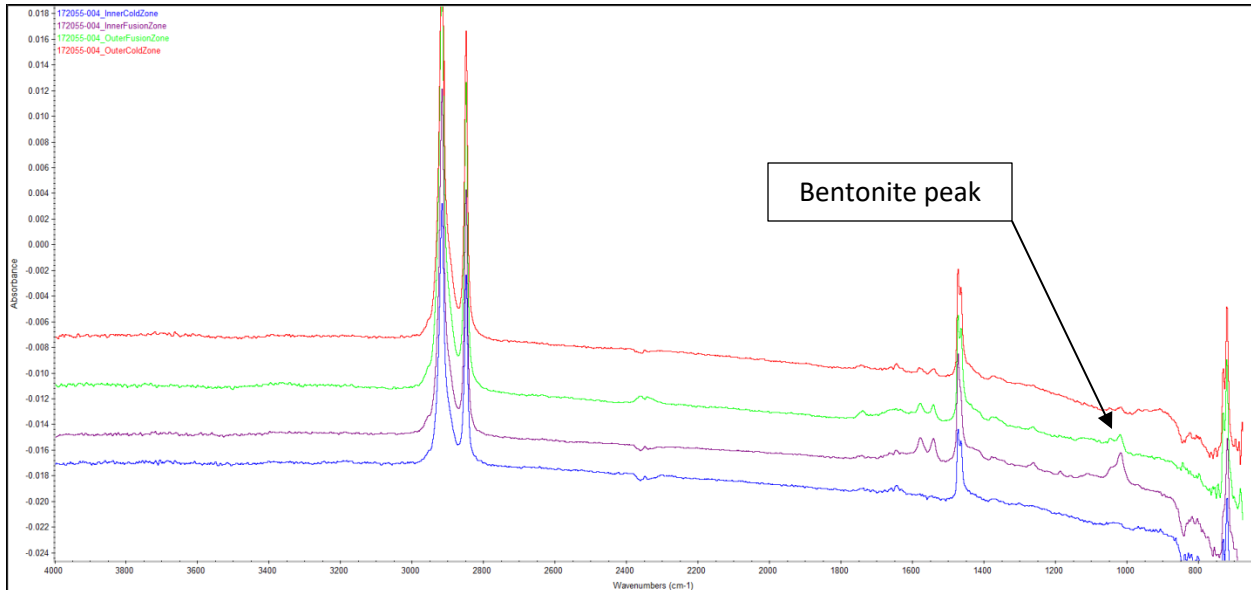


Figure 72. FTIR spectra from decohesion test result, 2" IPS OEM Peeler on MDPE pipe at 70°F

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Figure 73. Decohesion test result, 2" IPS OEM Peeler on HDPE pipe at 70°F

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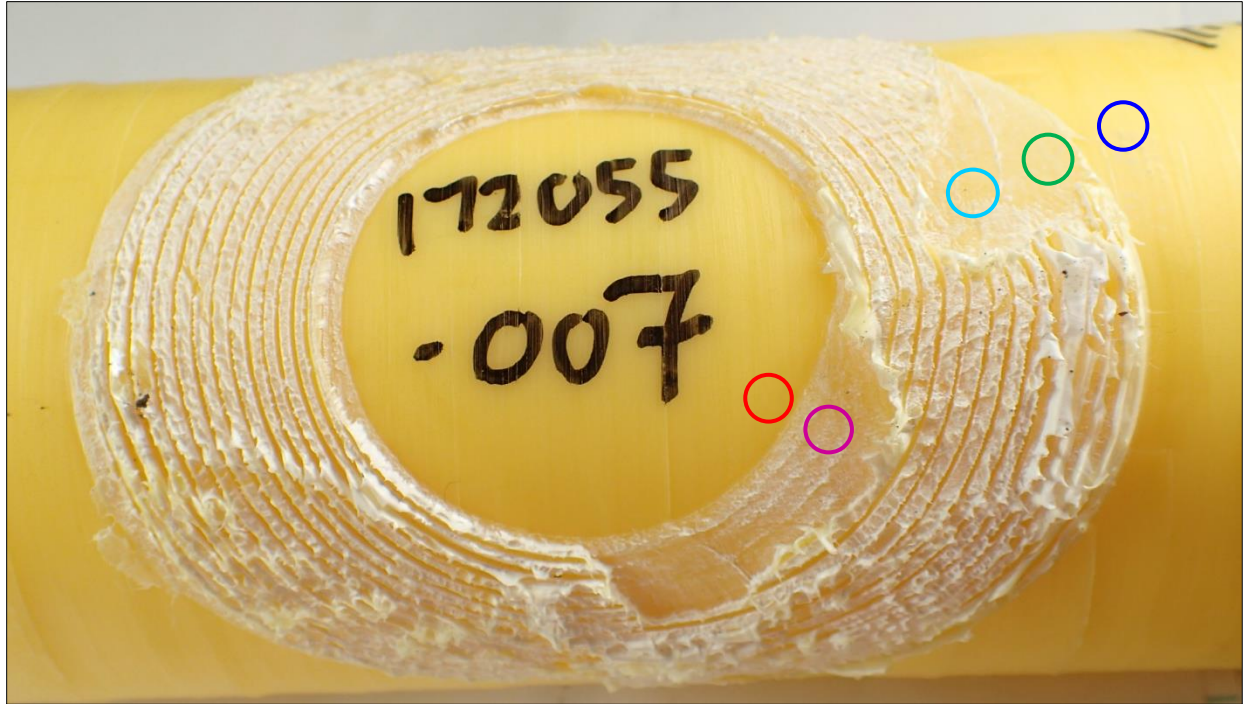


Figure 74. Decoherion test result, 2" IPS OEM Peeler scrape on MDPE pipe at 120°F

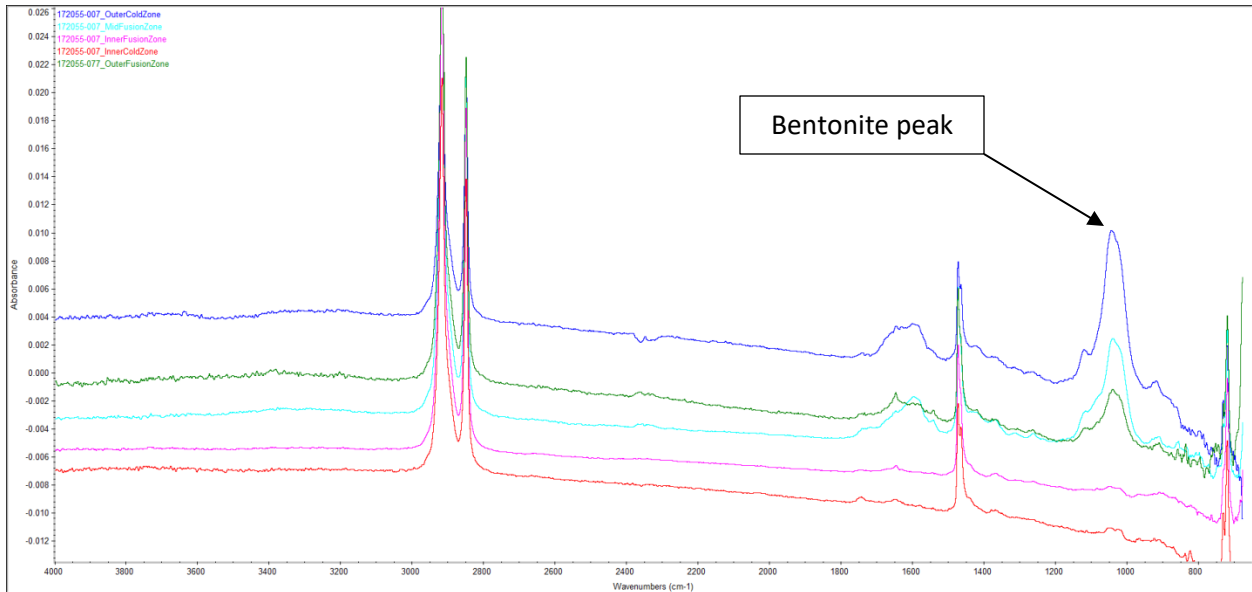


Figure 75. FTIR spectra from decoherion test result, 2" IPS OEM Peeler on MDPE pipe at 120°F

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Figure 76. Decohesion test result, 2" IPS OEM Peeler on HDPE pipe at 120°F

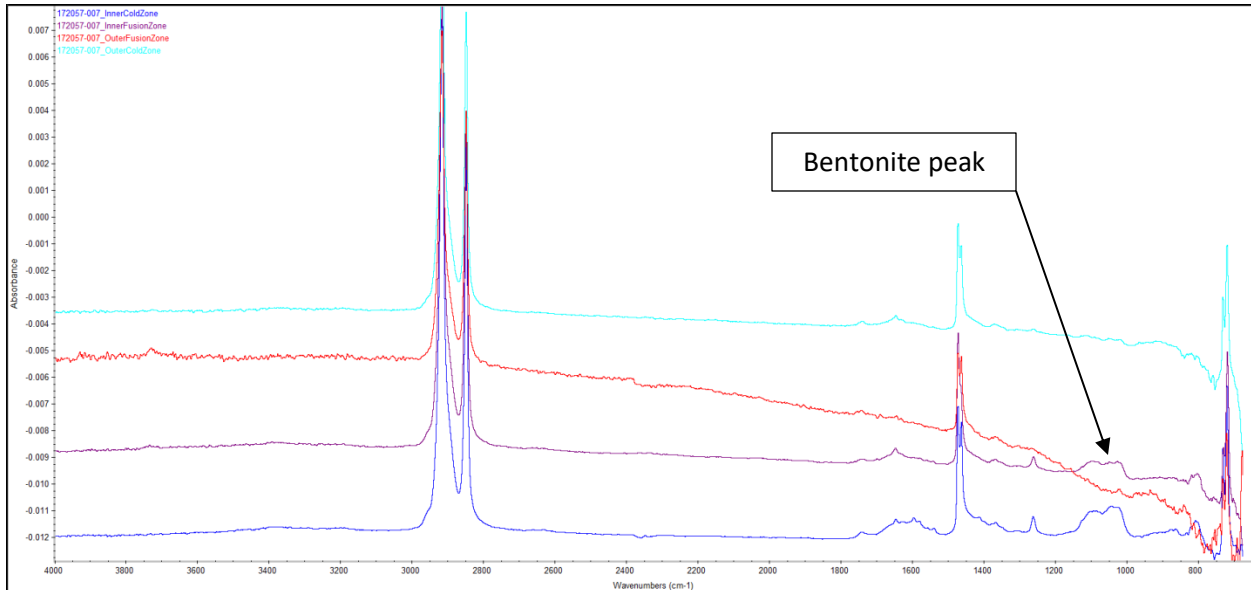


Figure 77. FTIR spectra from decohesion test result, 2" IPS OEM Peeler on HDPE pipe at 120°F

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OEM Peeler, 4" IPS

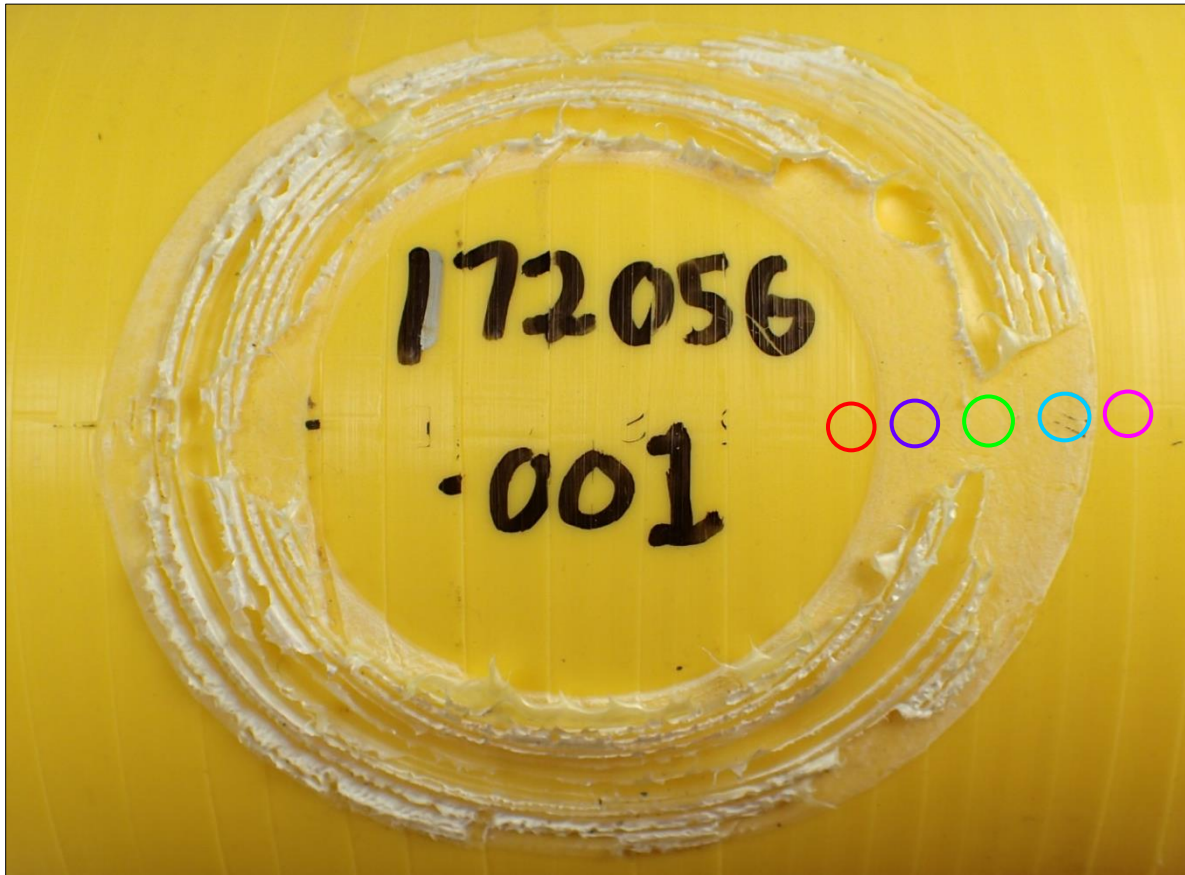


Figure 78. Decoherion test result, 4" IPS OEM Peeler on MDPE pipe at -10°F

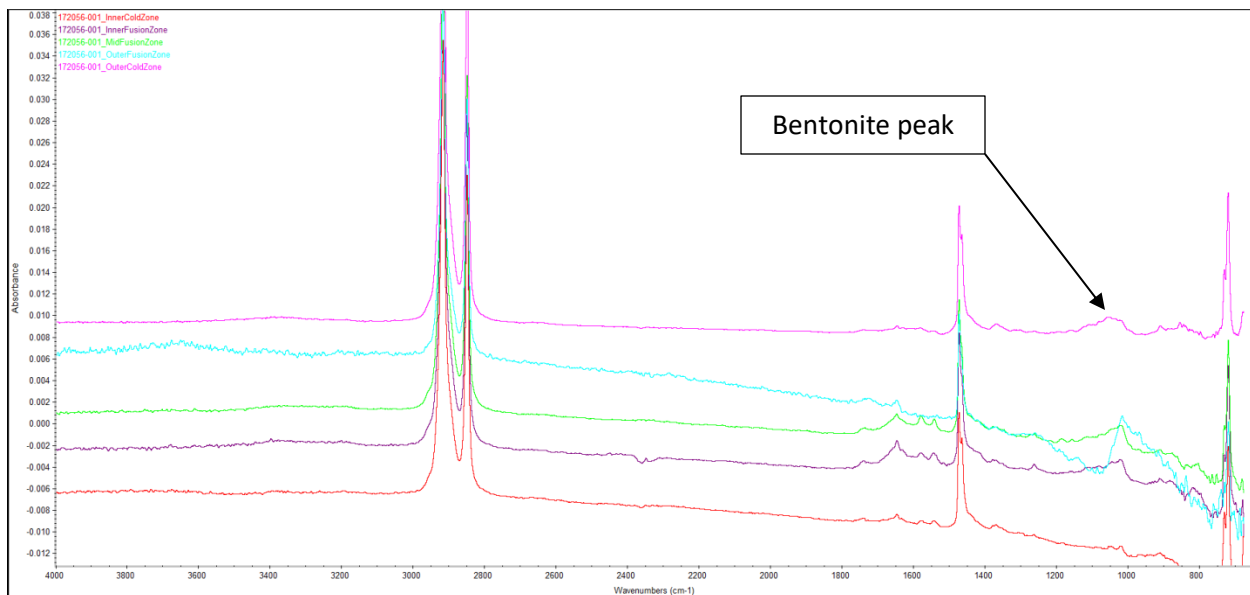


Figure 79. FTIR spectra from decoherion test result, 4" IPS OEM Peeler on MDPE pipe at -10°F

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Figure 80. Decohesion test result, 4" IPS OEM Peeler on HDPE pipe at -10°F

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Figure 81. Decohesion test result, 4" IPS OEM Peeler on MDPE pipe at 70°F

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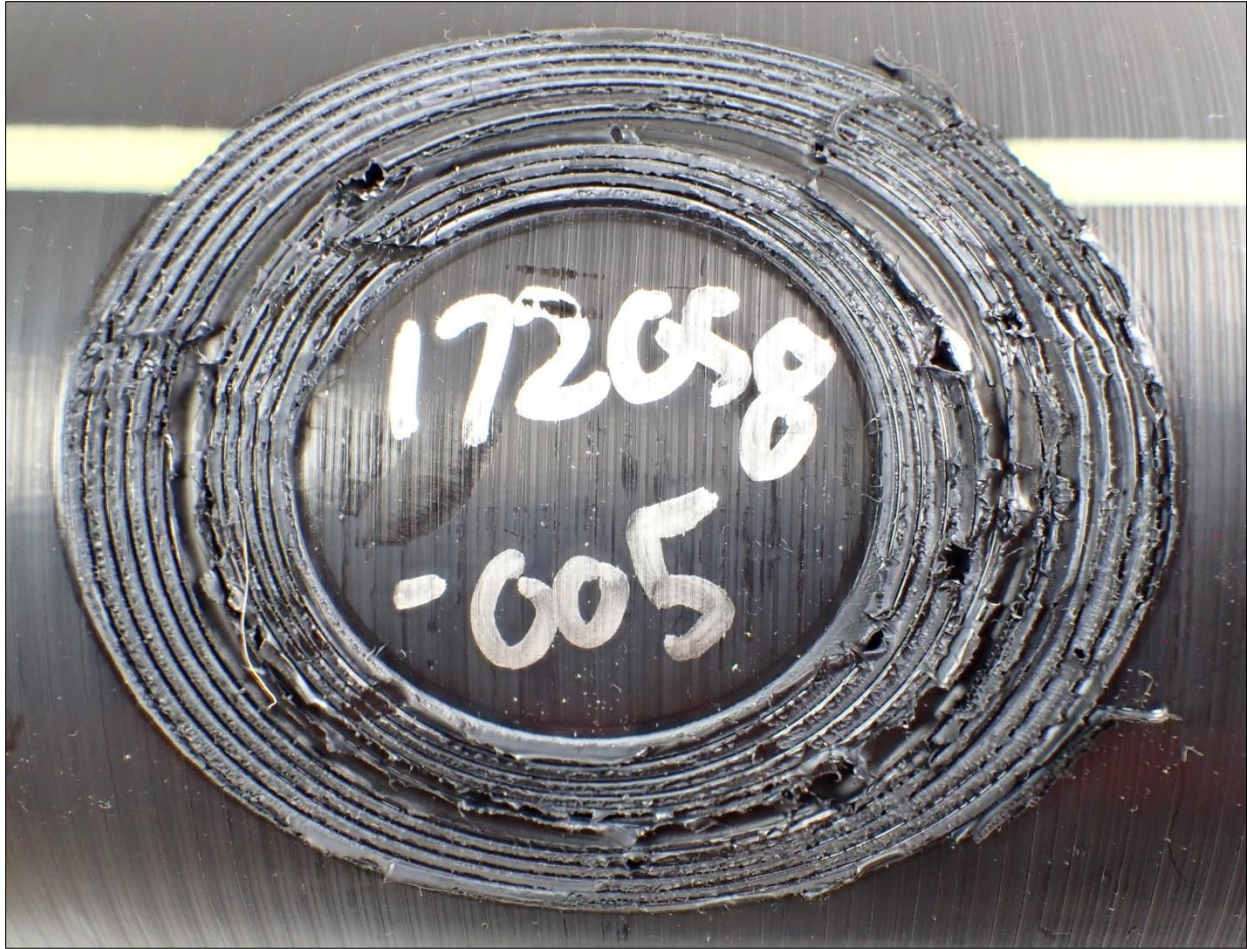


Figure 82. Decohesion test result, 4" IPS OEM Peeler on HDPE pipe at 70°F

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Figure 83. Decohesion test result, 4" IPS OEM Peeler on MDPE pipe at 120°F

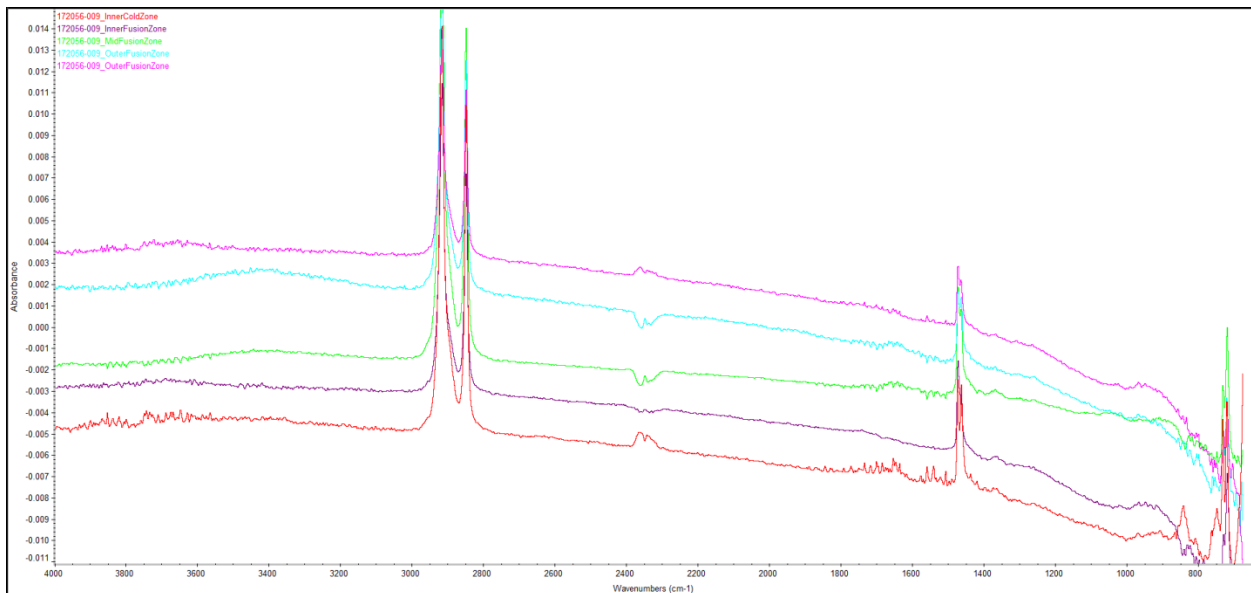


Figure 84. FTIR spectra from decohesion test result, 4" IPS OEM Peeler on MDPE pipe at 120°F

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Figure 83 and **Figure 84** illustrate a case where contamination failure can be visually identified, but FTIR readings do not show a clear contamination (in this case bentonite) peak. Such cases have been encountered in failure analyses.



Figure 85. Decohesion test result, 4" IPS OEM Peeler on HDPE pipe at 120°F

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Friatec Hand Scraper

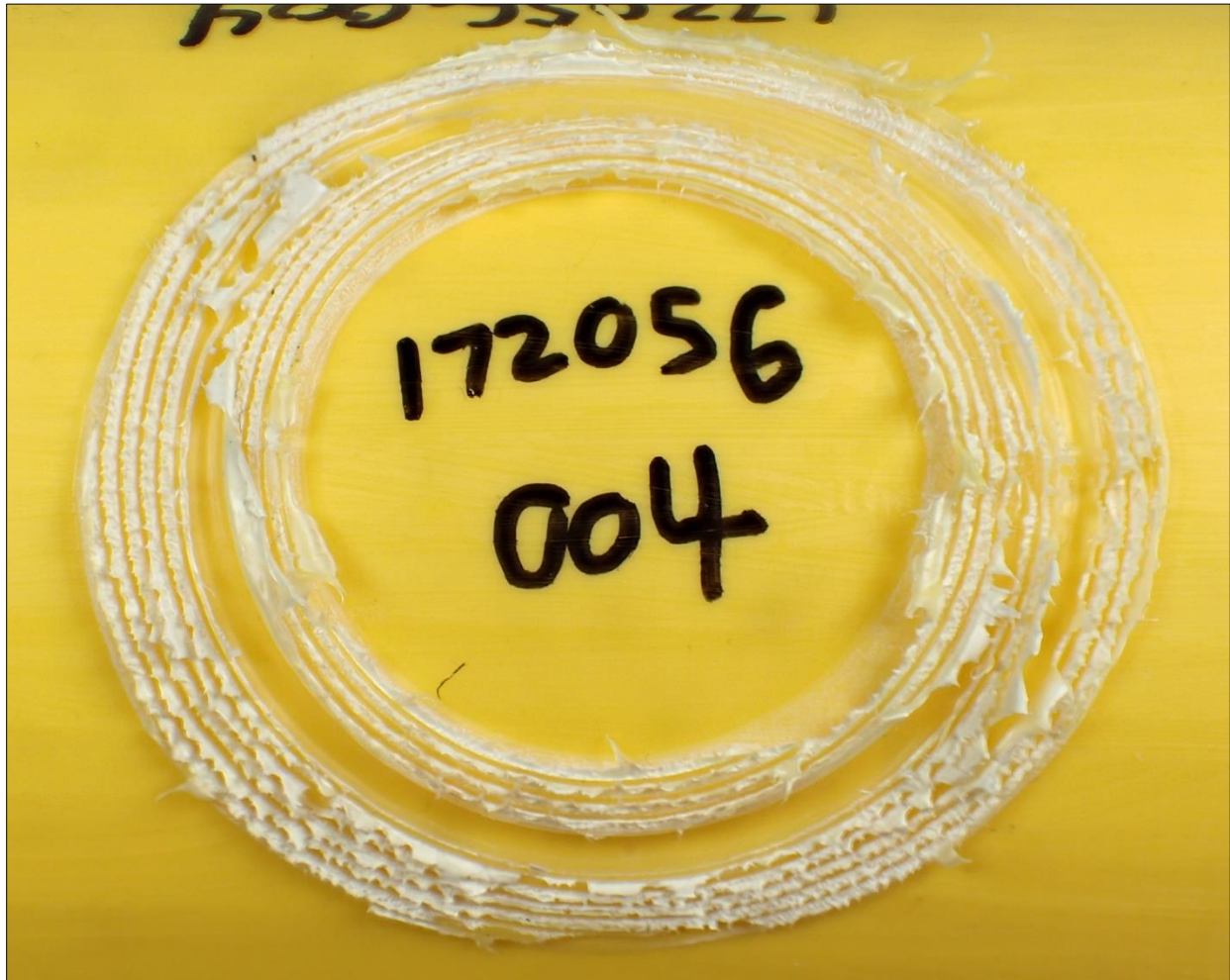


Figure 86. Decohesion test result, Friatec hand scraper on 4" IPS MDPE pipe at -10°F

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Figure 87. Decohesion test result, Friatec hand scraper on 4" IPS HDPE pipe at -10°F

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Figure 88. Decohesion test result, Friatec hand scraper on 4" IPS MDPE pipe at 70°F

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Figure 89. Decohesion test result, Friatec hand scraper on 4" IPS HDPE pipe at 70°F

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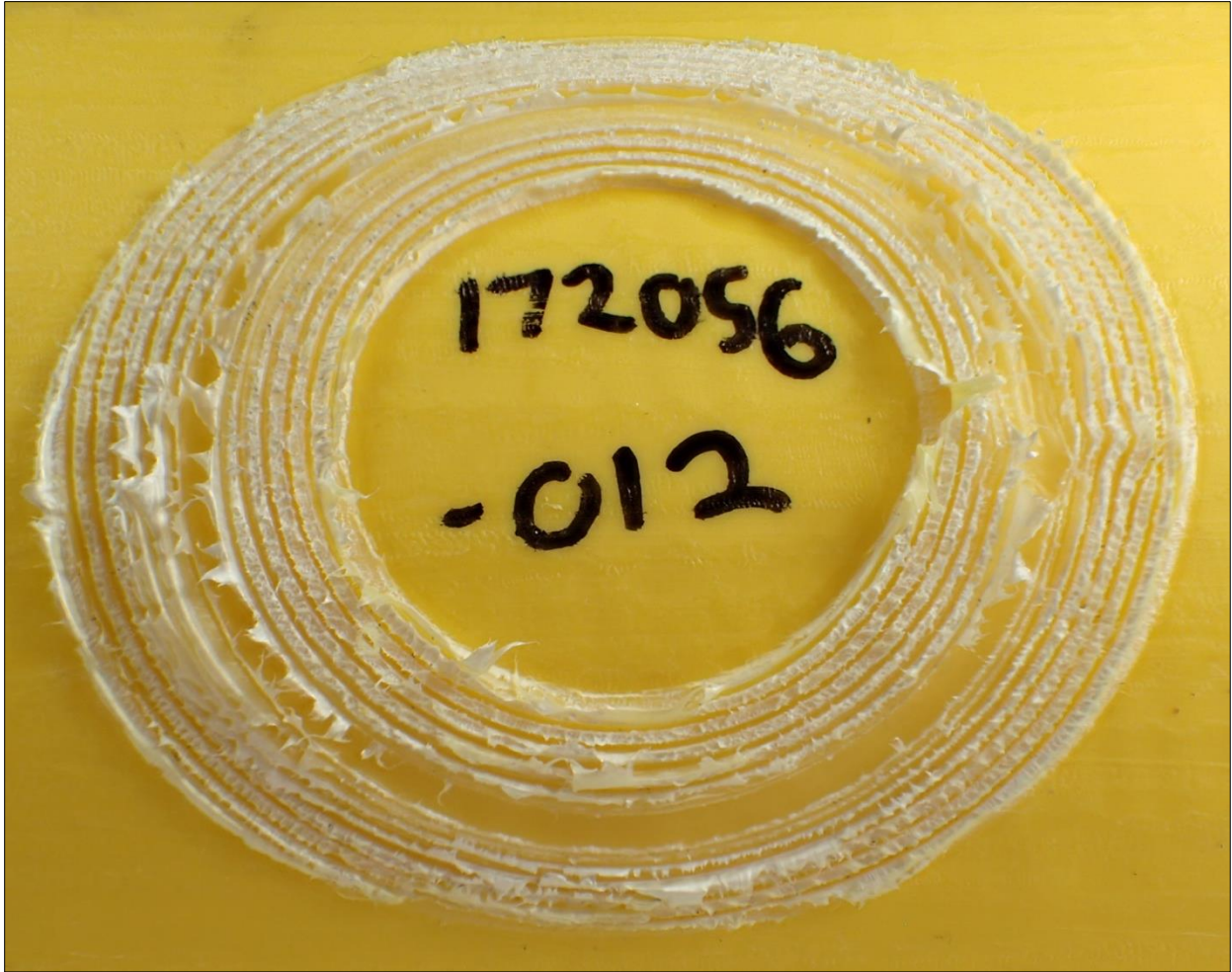


Figure 90. Decohesion test result, Friatec hand scraper on 4" IPS MDPE pipe at 120°F

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Figure 91. Decohesion test result, Friatec hand scraper on 4" IPS HDPE pipe at 120°F

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Summit Rotary Scraper, 4" IPS



Figure 92. Decohesion test result, 4" IPS Summit rotary scraper on MDPE pipe at -10°F

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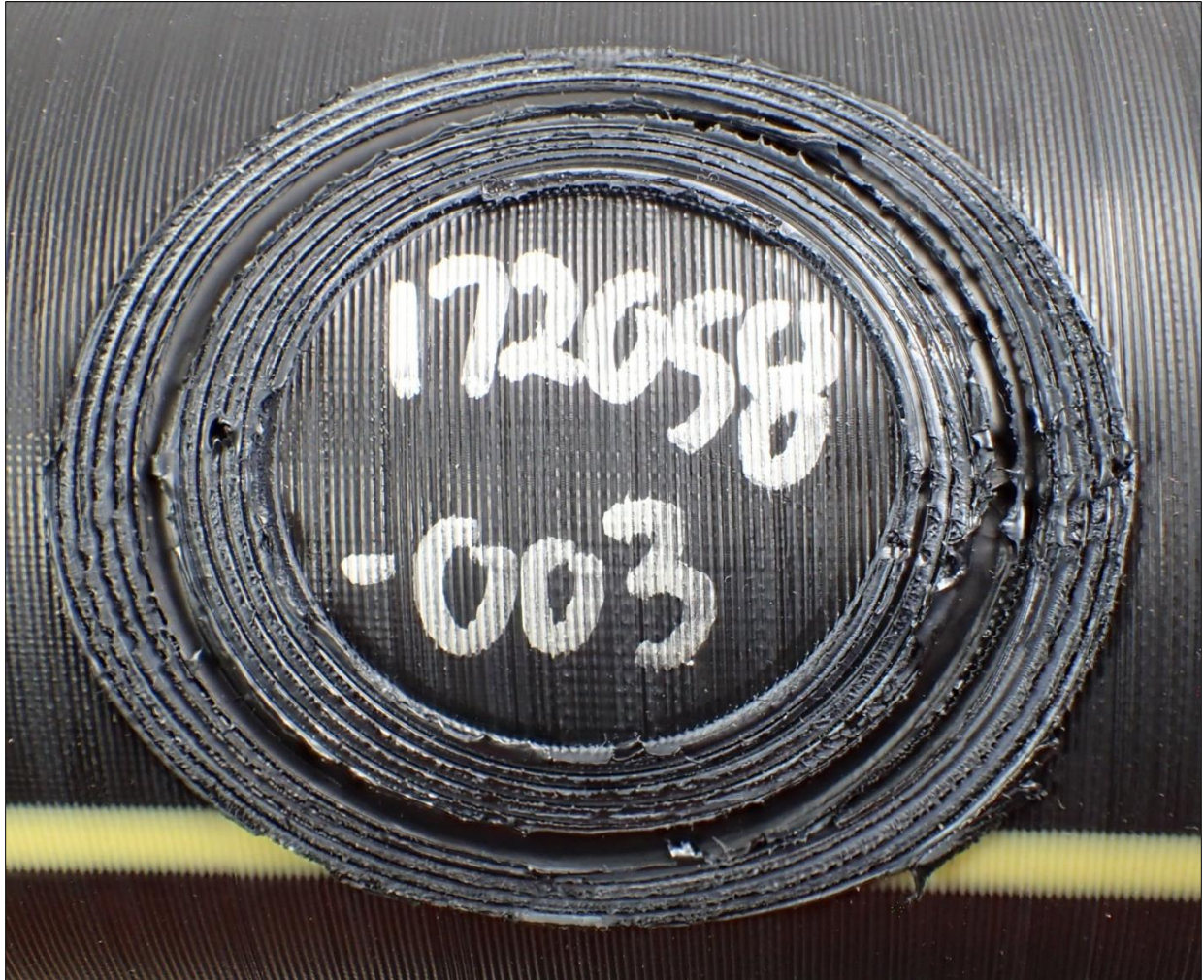


Figure 93. Decohesion test result, 4" IPS Summit rotary scraper on HDPE pipe at -10°F

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Figure 94. Decohesion test result, 4" IPS Summit rotary scraper on MDPE pipe at 70°F

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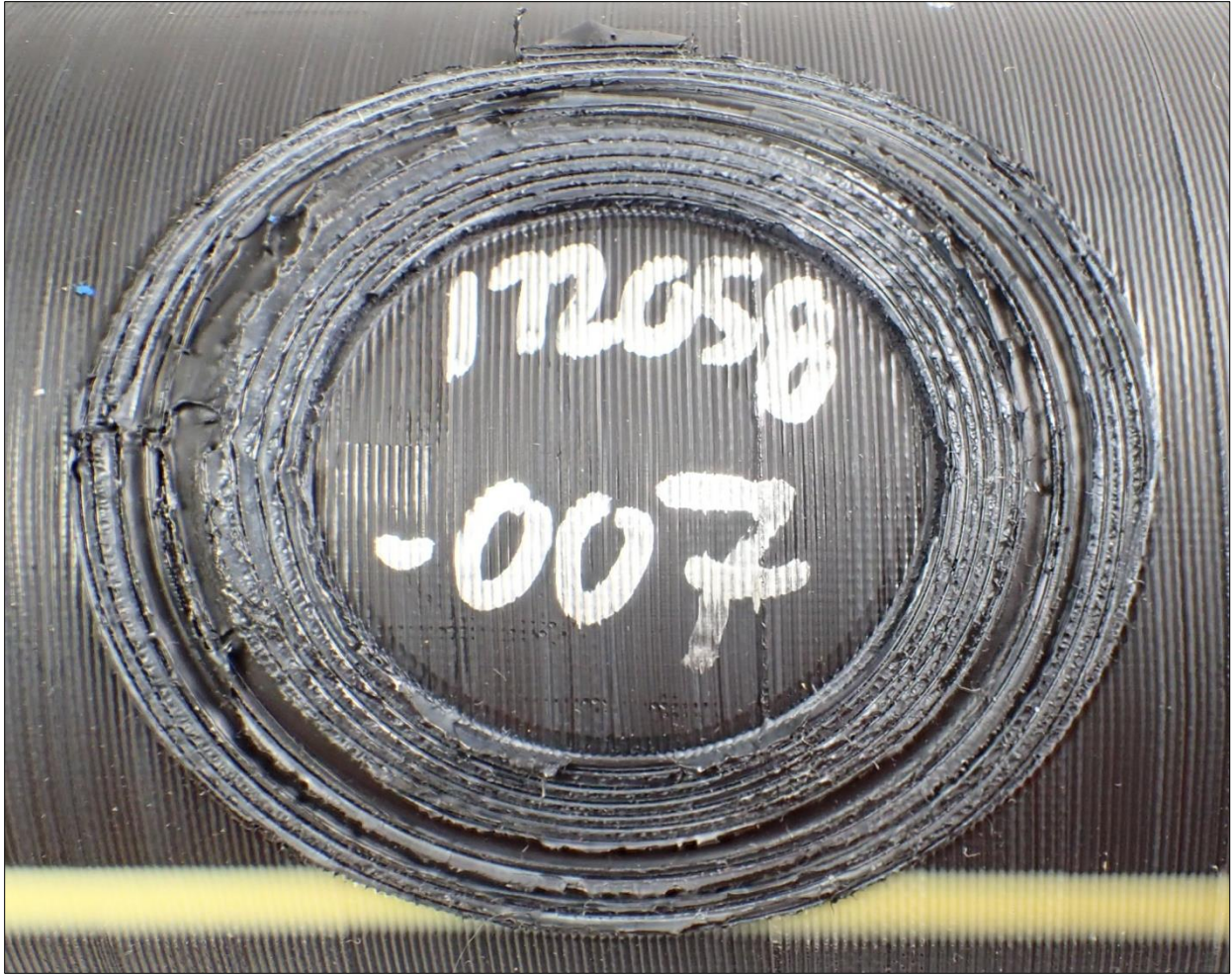


Figure 95. Decohesion test result, 4" IPS Summit rotary scraper on HDPE pipe at 70°F

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Figure 96. Decohesion test result, 4" IPS Summit rotary scraper on MDPE pipe at 120°F

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Figure 97. Decohesion test result, 4" IPS Summit rotary scraper on HDPE pipe at 120°F

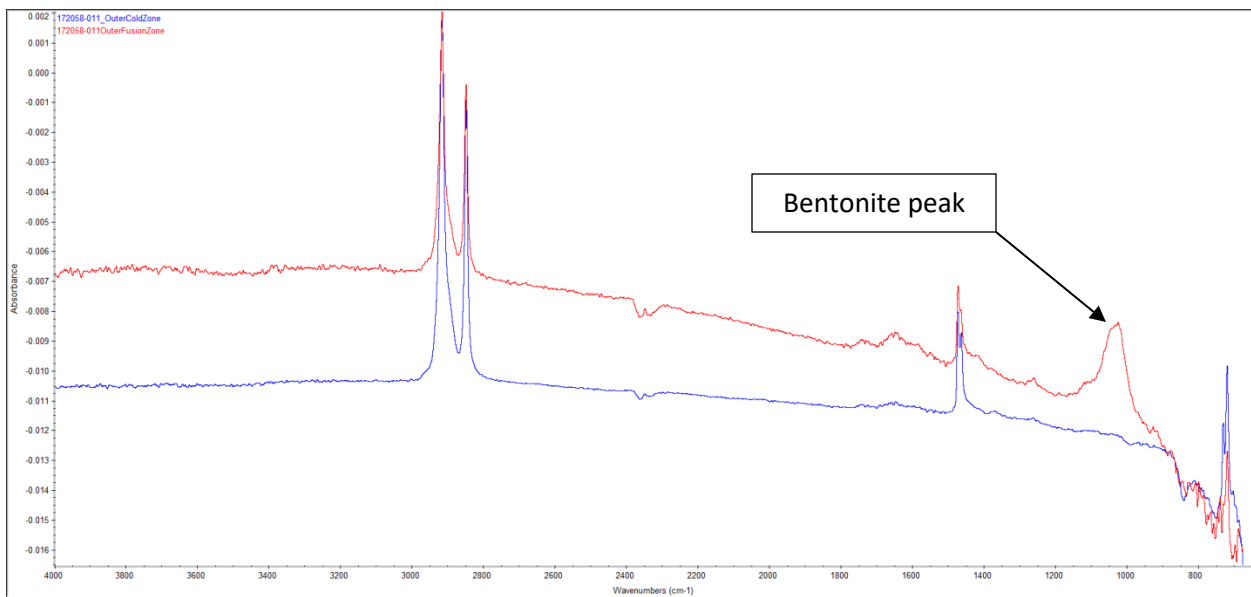


Figure 98. FTIR spectra from decohesion test result, 4" IPS Summit rotary scraper on HDPE pipe at 120°F

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Discussion and Conclusions

Based on maximum oxidation depth found in prior works, the following minimum scraping depths are recommended:

- 0.0063 inches (0.0126 inches of pipe diameter) for yellow MDPE pipes.
- 0.004 inches (0.008 inches of pipe diameter) for black HDPE pipes.

	Yellow MDPE Pipe	Black HDPE Pipe
Minimum Scrape Depth	0.0063 inches (0.0126 inches of pipe OD)	0.004 inches (0.008 inches of pipe OD)
Maximum Scrape Depth for EF fittings	Dependent on EF fitting	
Absolute Maximum Scrape Depth	10% of pipe wall thickness	

Maximum scraping depth is practically limited by electrofusion fitting design and must be quantified on a per fitting basis, but must never exceed 10 percent of the pipe wall thickness. Heat-fusion saddles are much less sensitive to gaps caused by excessive scraping as they are forced onto the pipe during heat soaking and joining.

Based on the results of the scraping tests, rotary scrapers provide the most consistent scrapes and most often achieve sufficient scrape depth in a single pass (see **Figure 4**). Handheld scrapers can achieve sufficient scrape depth, but require multiple passes and attention to full coverage of the area to be scraped, therefore, rotary scrapers are preferable to handheld scrapers.

Oval pipe (up to ~5%) did not appear to adversely affect scraping depth. The test results showed that spring-loaded scrapers generally follow the outer diameter of the pipe and therefore appreciable re-rounding by scraping may or may not occur. The Pencil Scraper did consistently re-round the pipe due to its fixed blade and cavity. The influence of pipe ovality on electrofusion quality is directly related to the gap sensitivity of the fitting and the fitting's dimensional tolerances – therefore, sensitivity to ovality must be evaluated on a per fitting basis.

Despite a sufficient scrape depth, successful and unsuccessful fusions are still possible with any of the scrapers if contamination is present and, therefore, simply operating the scrapers to remove any oxidized pipe material does not guaranty a good fusion. Testing of the scrapers' ability to remove bentonite powder contamination (see **Figure 40**) showed a surprising result where the Friatec **handheld** scraper was the only scraper that achieved a 100% success rate in removing bentonite contamination. This result is of note, as it suggests that repeated, unidirectional scraping passes can achieve full removal of a powder contaminant and, in contrast, rotary scrapers that typically drag shavings around the pipe apparently transfer loose contaminants onto the scraped surface. These findings lead to the suggestion of a preparation technique where the pipe is thoroughly washed and cleaned prior to scraping. This proposed technique is detailed later in this section.

Overall, the various test results lend support to the observation that to achieve successful PE fusions best practices should be adopted, which includes maintaining minimum and maximum scrape depths, in conjunction with thorough operator training with specific attention to prevention of contamination of the fusion areas of the pipe and fitting. The following are aspects that should be taken into account in operator training and reflected in operating procedures.

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Ensuring sufficient scrape depth

- Understand that sufficient scrape depth is dependent on the depth of oxidation on the outer diameter of the pipe (oxidation layer).
 - In the worst case, the oxidation layer should be less than 0.0063", on any PE pipe.
 - Ideally, scrapers should remove a minimum of 0.0063" in a single pass.
- Be aware of scratches deeper than the oxidation layer.
 - Additional scraping passes should be performed at such locations.
 - Be aware of excessive scrape depth, where "excessive" depends on the fitting and the temperature of the pipe and fitting.
- Understand scraper performance and operating technique.
 - With rotary scrapers, scrape depth depends on:
 - Spring loading of the blade,
 - Sharpness of the blade,
 - Temperature of the pipe.
 - With hand-held scrapers, scrape depth depends on:
 - Angle of the blade,
 - Force applied to the blade,
 - Sharpness of the blade,
 - Temperature of the pipe.
 - Understand scraper sensitivity to pipe ovality.
 - Scrapers may or may not contribute to pipe re-rounding.
- Be aware of scraping tool condition and maintenance.
 - Tool wear and tear can affect scraping depth and alignment.
 - Tools should be periodically checked for scrape depth and uniformity
- Marking the area to be scraped with a permanent marker provides a positive visual indication of material removal.

Avoiding excessive scrape depth

- Understand that "excessive" depth depends on the fitting being fused and the temperature of the pipe and fitting.
- Know the gap sensitivity of the (electrofusion) fitting being fused.
 - Gap sensitivity is temperature dependent.
- Be aware that scrapers that normally make deep scrapes can potentially over-scrape (depending on the fitting) with additional passes.
- Be aware of minimum allowable pipe wall thickness.

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Qualifying EF fitting gap sensitivity

- Qualify EF fitting gap sensitivity via testing, with consideration of the following variables:
 - Fitting and pipe temperature.
 - Energy input tolerance.
 - Maximum foreseeable gap, due to combination of:
 - Coupling ID tolerance.
 - Pipe OD tolerance.
 - Pipe ovality tolerance.
 - Maximum scrape depth.
 - Saddle-to-pipe gap after clamping.

Avoiding contamination of fusion zone

- Water wash any loose dirt and dust on the pipe prior to scraping.
 - The cleaned area should exceed the area to be scraped.
- Solvent wash the assembly area immediately prior to scraping of the pipe.
 - The solvent washed area should be within the area cleaned with water.
 - Fitting should also be solvent-cleaned immediately before assembly onto the pipe.
 - Allow solvent to fully dry before assembly.
- Minimize time between cleaning, scraping, assembling and fusing.
- Be aware that the scraping tool should be clean of contaminants before each use.
- Be aware that the scraping tool should be in proper working condition.
- Be aware that shavings from the scraping operation may wipe against a scraped surface, and thus may transfer contaminants onto it, if contaminants are present prior to scraping.
- Be aware that dirt, mud, water, and dust can resettle on the pipe during and after scraping due to one or a combination of:
 - Wind
 - Rain
 - Operator motion
 - Static charge on the pipe
- Additional solvent cleaning should be required if the scraped pipe gets contaminated.
- If the joining procedure must be delayed, apply stretch wrap to minimize contamination of the cleaned area.
- Smooth scraper blades may be preferable to serrated blades,
 - Serrated blades leave a rough surface that is harder to clean than a smooth surface.
 - Serrated blades are less consistent in terms of scrape depth and are more likely to leave portions of shallow scraping (ridges).

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General notes on PE fusion and contamination

PE fusion is a stochastic process where two molten interfaces are brought into contact such that upon cooling and solidification the interfaces co-crystallize to form a ductile welded area. This fusion process is normally robust within a relatively wide range of its critical process parameters: temperature and interfacial pressure. However, the presence of certain contaminants, such as silicates, oils, and surfactants, are highly detrimental to PE's co-crystallization process.

Fusions that fail due to contamination exhibit smooth, non-ductile separation of the fitting-pipe fusion interface, either in part or in whole. It is important to note, however, that even such areas of non-ductile bonding still have some degree of bonding which can often lead to joints that pass pressure tests (e.g., 150% MAOP) and in some cases even hold operating pressure for years, but such joints are highly sensitive to impact loads and, in cases of saddles, also to forces that would cause the joint to "peel" off the pipe.

Because contamination failures are typically difficult to identify in the field, it is of utmost importance that the fusion preparation processes reflect this awareness and that operators adhere to the precautions and best-practices that help minimize fusion contamination.

Suggested Scraping Procedure Guideline

Figure 99 shows a top-level generic scraping procedure guideline incorporating the lessons learned during this project, addressing contamination prevention in particular. The theory behind this procedure is that all contamination will be removed prior to scraping and then minimizing the chances of the scraped pipe getting contaminated. The critical contamination avoidance aspects of the proposed procedure are (in chronological order):

1. Water-wash of pipe (exceeding the area to be scraped).
2. Solvent-wash of the pipe with a specific wiping technique (exceeding area to be scraped, but within water-washed area).
3. Scraping of the pipe, immediately after solvent-wash. (within the solvent-washed area)
4. Assembly of the fitting and performing the fusion, immediately after scraping.

Figure 100 and **Figure 101** show schematics of the cleaned areas for saddle and coupling fittings, respectively.

Use of stretch wrap is suggested in this procedure for situations where a fitting cannot be fused shortly after cleaning or scraping of the pipe. In such cases, stretch wrap can help minimized or eliminate recontamination of the area already cleaned or scraped.

For quality control (QC) purposes, this procedure also suggests that a wipe that was used to clean the pipe with solvent be kept in a plastic bag as it can be tested for contaminants.

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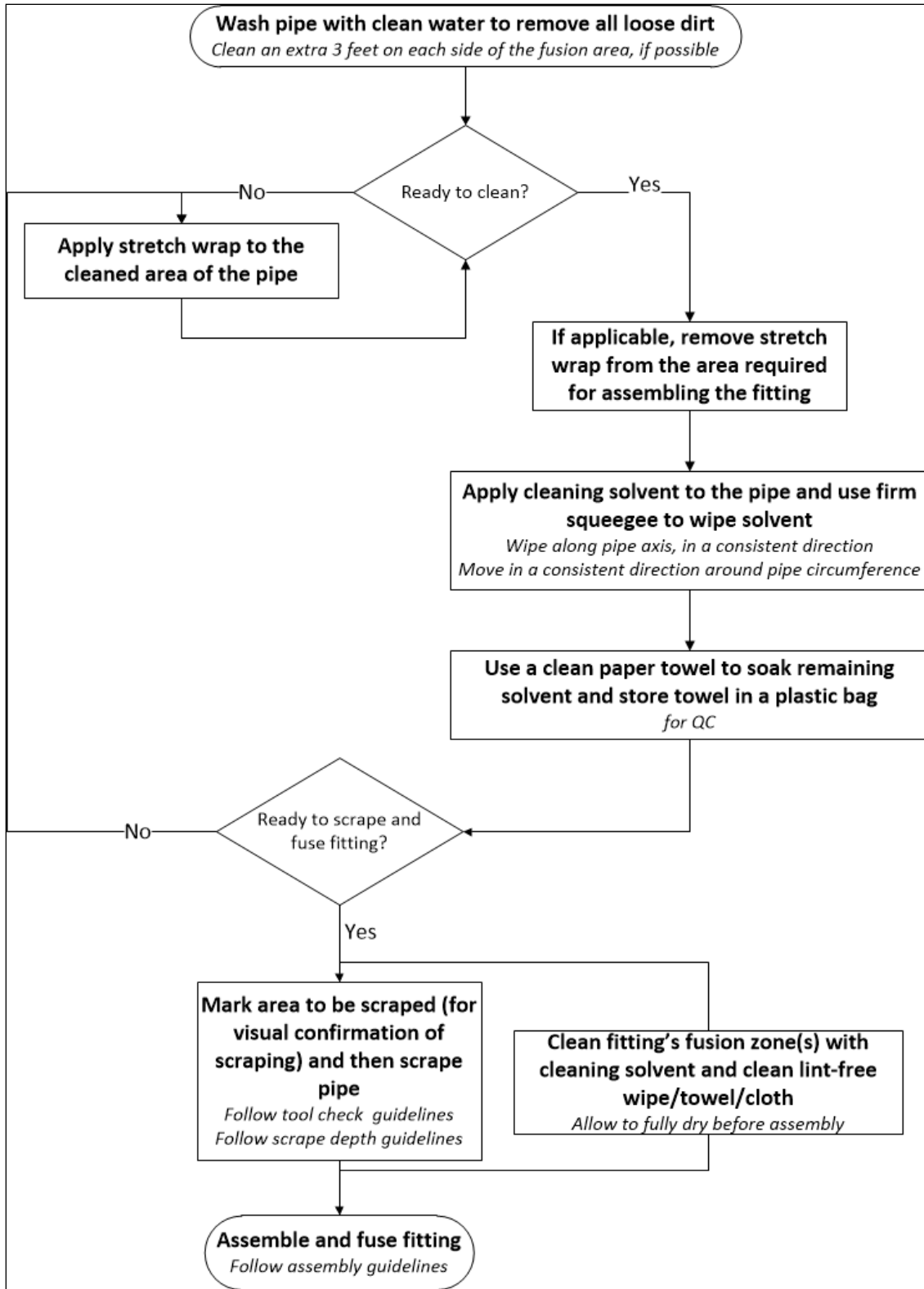


Figure 99. Top-level generic scraping procedure incorporating best-practices

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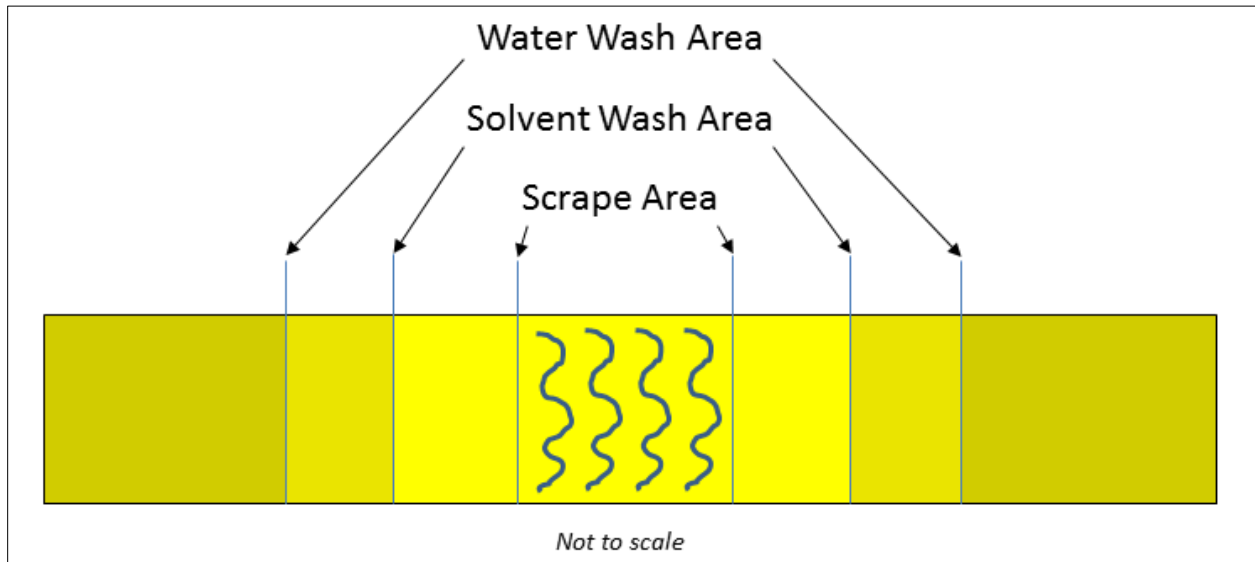


Figure 100. Schematic of cleaned areas for a saddle fitting

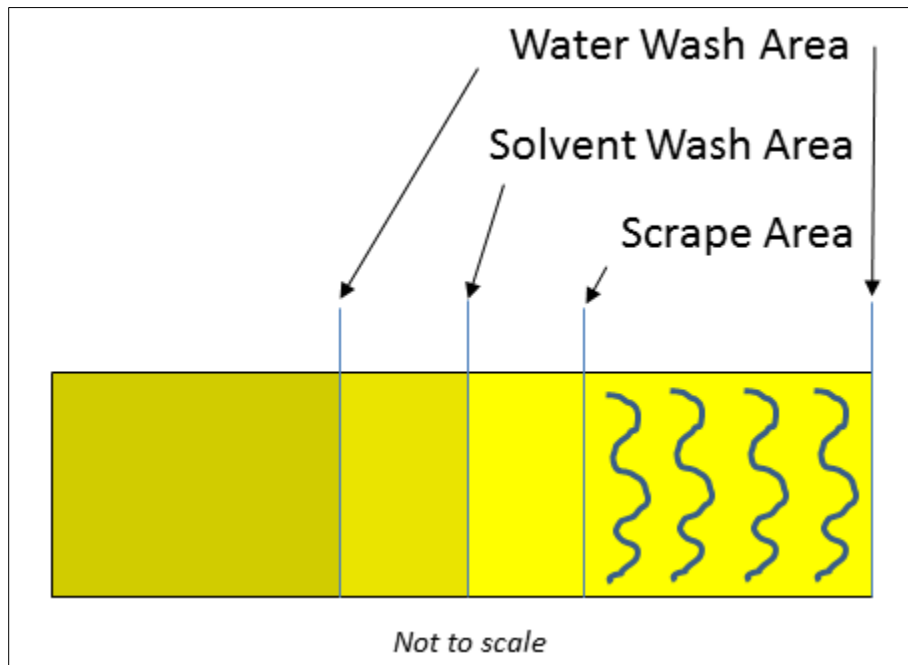


Figure 101. Schematic of cleaned areas for a coupling fitting

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Related OTD Projects and Potential Future Work

In light of the findings of this project, GTI suggests that the proposed solvent cleaning technique be tested under the OTD Project 5.16.a: *Solvent Cleaning and PE Joining Procedures*. Additionally, the commercial availability of handheld FTIR systems⁴ could be utilized under Project 5.16.a and evaluated as a field QA/QC tool that can detect contamination and oxidation before and/or after scraping. Future work could include in-field evaluation of the suggested cleaning technique and/or handheld FTIR inspection tools.

⁴ <http://www.agilent.com/en-us/products/ftir/ftir-compact-portable-systems>

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Works Cited

Choi, S. (1992). *Surface Embrittlement of Polyethylene*. Chicago, IL: Illinois Institute of Technology.

Nussbaum, M., Dufour, D., & Gueugnaut, D. (1991). *Electrofusion of Polyethylene: How and Why*. Boston, MA: Twelfth Plastic Fuel Gas Pipe Symposium.

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Appendix A – Tested Scrapers

2" IPS OEM Peeler

The 2" IPS OEM Peeler is a rotary-type scraper. The scraper will move along the pipe as it is rotated to give a helical scraping path. Scrape depth is adjustable via clamping tightness.



Figure 102: 2" IPS OEM Peeler

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2" IPS Frialen Peeler

The 2" IPS Frialen Peeler is a rotary-type scraper. The scraper will move along the pipe as it is rotated to give a helical scraping path. Scrape depth is adjustable via clamping tightness. This scraper has adjustable wheels that determine the pitch of the helical scraping path. Users should be aware of this adjustability if gaps in the scrape are encountered.

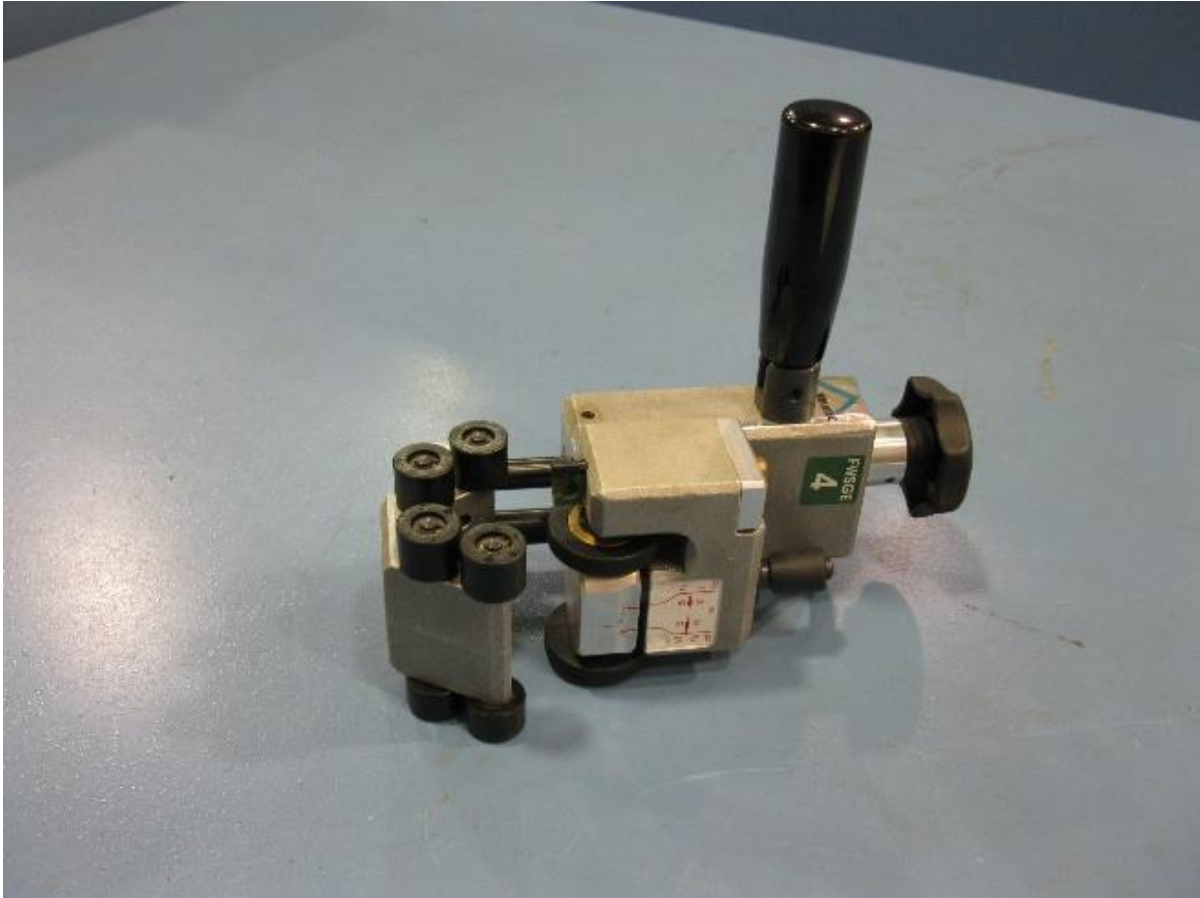


Figure 103: 2" IPS Frialen Peeler

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2" IPS Half-Moon Scraper

The 2" IPS Half-Moon Scraper is a handheld scraper that conforms to the pipe. It is operated by rotation around the pipe. The scraper must be manually moved along the pipe after each rotation. Scrape depth (per pass) is determined by the force operator applied.



Figure 104: 2" IPS Half-Moon Scraper

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4" IPS OEM Peeler

The 4" IPS OEM Peeler is a rotary-type scraper. The scraper will move along the pipe as it is rotated to give a helical scraping path. Scrape depth is adjustable via clamping tightness.

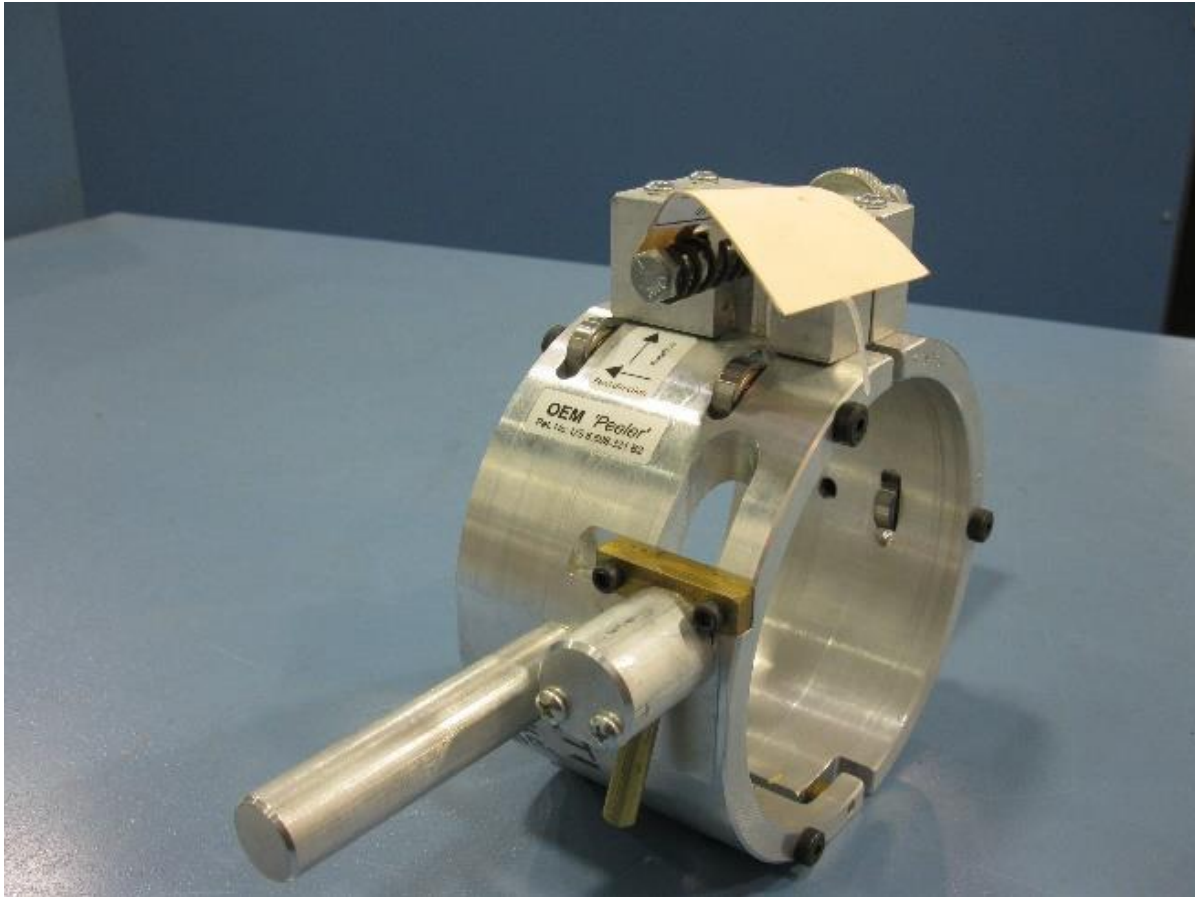


Figure 105: 4" IPS OEM Peeler

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4" IPS Frialen Peeler

The 4" IPS Frialen Peeler is a rotary-type scraper that clamps on the end of a pipe, as it is designed for coupling joint applications. The scraper remains on the end of the pipe while a geared boom that contains the blade moves along the pipe as it is rotated, which gives a helical scraping path. Scrape depth is adjustable via clamping tightness.



Figure 106: 4" IPS Frialen Peeler

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4" IPS Summit Rotary Scraper (rotary-type scraper)

The 4" IPS Summit Rotary Scraper is a rotary-type scraper. The scraper will move along the pipe as it is rotated to give a helical scraping path. Scrape depth is not readily adjustable and is determined by the preset spring loading of the clamping mechanism.



Figure 107: 4" IPS Summit Rotary Scraper

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1/2" CTS Pencil Scraper

The 1/2" CTS Pencil Scraper is a handheld scraper that is designed to have the pipe inserted into it and then rotated. The scraper will move along the pipe as it is rotated to give a helical scraping path. The blade is not spring loaded and scrape depth is preset by adjustment of the blade's protrusion in to the scrapers socket.



Figure 108: 1/2" CTS Pencil Scraper

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Friatec Hand Scraper

The Friatec Hand Scraper is a simple handheld scraper, sometimes referred to as a “paint scraper”. Scrape depth is determined by the force applied by the operator.



Figure 109: Friatec Hand Scraper

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Appendix B – Scraping Procedures (for testing)

Steps (if not inducing any pipe ovality with pipe clamps):

- 1) Ensure that the Standard Pipe Clamps are in the Pipe Stands.
- 2) Move the Pipe Stands such that they clamp the ends of a 12" section of Pipe.
- 3) Clamp the Pipe in the Standard Pipe Clamps with the Center of the Pipe being in the Center of the Pipe Stands (as seen in the image below) and take an Overhead Picture.
 - a. If testing the 2" IPS or 4" IPS Frialen Scrapers, have the Pipe stick out to the side with the one Pipe Clamp tightened on one end of the Pipe.
- 4) Using Long-Nose Calipers, measure the minimum and maximum OD of the Pipe $\frac{1}{4}$ of the way from the Left Pipe Clamp and place those values in the table under Left Edge (OD 0.1). Repeat this process for the locations $\frac{1}{2}$ and $\frac{3}{4}$ of the way down the Pipe from the Left Pipe Clamp and place those values in the table under Middle (OD 0.2) and Right Edge (OD 0.3) respectively.
- 5) Contaminate the Pipe with Bentonite Powder by taking powder on a brush and evenly coating the Pipe with the brush.
- 6) Clamp the scraper on Pipe at the far end of the scraping zone, next to one of the pipe clamps, such that it will be able to move across the scraping zone.
- 7) Execute one pass of scraping until the scraper hits the other pipe clamp.
- 8) Remove scraper and take an overhead picture.
- 9) Remove shavings and take an overhead picture.
- 10) Using long-nose calipers, measure OD of the left portion of the scraped zone and place the values for the minimum and maximum OD in the table under Left Edge (OD 1.1). Repeat for the middle and right portion of the scraped zone for the Middle (OD 1.2) and Right Edge (1.3) measurements respectively.
- 11) Using calipers, measure the thickness of 5 different portions of the shavings that are removed.
 - a. If there are 5+ shavings, each measurement should be of a different shaving.
- 12) If the average shaving thickness is less than 0.0035"-0.005" then repeat steps 6 through 11 until the total thickness of scrapes from each pass added together is 0.0035"-0.005". Stop as soon as total material removed is above that threshold.
- 13) Place the pipe and shavings into a bag and label properly.

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Steps (if inducing ~5% pipe ovality with pipe clamps):

- 1) Replace the Standard Pipe Clamps in the Pipe Stands with the 5% Pipe Clamps.
- 2) Move the Pipe Stands as close together as possible while still being able to tighten the Pipe Clamps.
- 3) Clamp the Pipe in the 5% Pipe Clamps with the Center of the Pipe being in the Center of the Pipe Stands (as seen in the image below).
 - a. If testing the 2" IPS or 4" IPS Frialen Scrapers, have the Pipe Clamps tightened on one end of the Pipe.
- 4) Mark the outside of the Pipe Clamps with a Sharpie, this will signify the Scraping Zone. In addition, mark the top of the Pipe.
- 5) Leave the Pipe for 24 hours so that the Pipe Clamps can induce the 5% ovality to the Pipe.
- 6) After 24 hours of conditioning, unclamp the Pipe and move the Pipe Stands so that they grip the ends of the Pipe
 - a. If testing the 2" IPS or 4" IPS Frialen Scrapers, the Pipe Stands do not have to move.
 - b. Take an overhead Picture either before or after the Pipe Stands are moved
- 7) Clamp the Pipe in the 5% Pipe Clamps making sure that the Top of the Induced Pipe lines up with the Top of the Pipe Clamps and that the Scraping Area can be fully scraped.
- 8) Using Long-Nose Calipers, measure the minimum and maximum OD of the left part of the area between the left two sharpie markings and place those values in the table under Left Edge (OD 0.1). Repeat this process for the area between the two middle sharpie markings and the right part of the area between the right two sharpie markings and place those values in the table under Middle (OD 0.2) and Right Edge (OD 0.3) respectively.
- 9) Contaminate the Pipe with Bentonite Powder by taking powder on a brush and evenly coating the Pipe with the brush.
- 10) Clamp the scraper on Pipe at the far end of the scraping zone, next to one of the pipe clamps, such that it will be able to move across the scraping zone.
- 11) Execute one pass of scraping until the scraper hits the other pipe clamp.
- 12) Remove scraper and take an overhead picture.
- 13) Remove shavings and take an overhead picture.
- 14) Using Long-Nose Calipers, measure OD of the left portion of the scraped zone and place the values for the minimum and maximum OD in the table under Left Edge (OD 1.1). Repeat for the middle and right portion of the scraped zone for the Middle (OD 1.2) and Right Edge (1.3) measurements respectively.
- 15) Using Calipers, measure the thickness of 5 different portions of the shavings that are removed.
 - a. If there are 5+ shavings, each measurement should be of a different shaving.
- 16) If the average shaving thickness is less than 0.0035"-0.005" then repeat steps 10 through 14 until the total thickness of scrapes from each pass added together is 0.0035"-0.005". Stop as soon as total material removed is above that threshold.
- 17) Place the pipe and shavings into a bag and label properly.

Notes:

- For the Pencil Scraper, remove material until it freely moves in pencil scraper
- For serrated blades (Summit) measure the bulk thickness

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The following figures are provided for reference.



Figure 110: 2" IPS pipe clamps in pipe stands close together with pipe marked



Figure 111: 4" IPS pipe clamps in pipe stands close together with pipe marked

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Figure 112: 2" IPS pipe with ~5% induced ovality at 70°F, before scrape – no contamination



Figure 113: 2" IPS pipe with ~5% induced ovality at 70°F, before scrape – with bentonite powder contamination

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Figure 114: 2" IPS pipe with no induced ovality at 120°F, after scrape by OEM Scraper – with shavings around pipe



Figure 115: 2" IPS pipe with no induced ovality at 120°F, after scrape by OEM Scraper – after removal of shavings

END OF REPORT

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