Public Quarterly Report

Date of Report: 11th Quarterly Report-July, 2025
Contract Number: 693JK322RA0001
Prepared for: US Pipeline and Hazardous Materials Safety Administration
Project Title: Rapid Ultraviolet (UV) Cured Adhesive for Gas Main Cured-in-Place-Lining (CIPL)
Prepared by: Progressive Pipeline Management
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For quarterly period ending: June 30, 2025

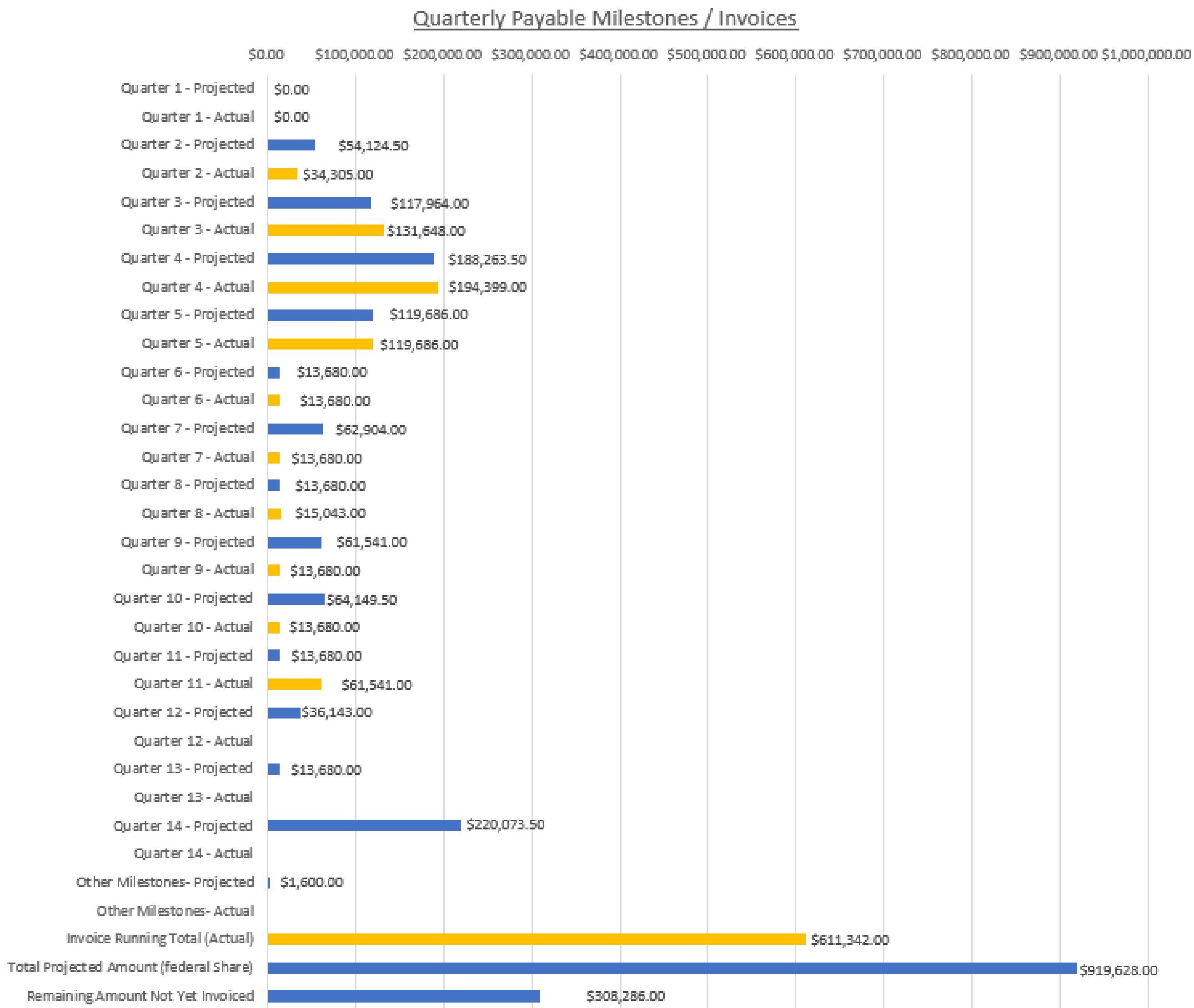
1: Items Completed During this Quarterly Period:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
39	34	Chemical Resistance [Adhesive System (Post-Installation and Cure)]	Chemical Resistance	$3,964.00	$3,964.00
40	35	Chemical Resistance (composite, post-installation and cure)	Chemical Resistance	$6,606.50	$6,606.50
42	37	Laboratory Mobilization & Test Plans	Laboratory Mobilization & Test Plans	$37,290.50	$37,290.50

2: Items Not-Completed During this Quarterly Period:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
46	39	Traffic Loading/Fatigue & Parallel Excavation	Traffic Loading/Fatigue & Parallel Excavation	$50,469.50	$50,469.50

3: Project Financial Tracking During this Quarterly Period:



4: Project Technical Status –

1. Chemical Tests (ASTM D543)

a. Chemical Test Specimens

The chemical test samples are approximately ½ inch thick (12.7 mm), 1-inch-wide (25.4 mm), and 6-inch-long (152.4 mm) coupon samples, cut from both cast iron and steel pipelines. An 8-inch-long (203.2 mm) internal pipe replacement liner is adhered to all test samples of both types. Eight cast iron samples and eight steel samples were tested for each chemical, totaling 88 coupons for each material. Each coupon was measured to find the initial length, width, thickness, and weight of the liner and host pipe before the chemical treatment. These measurements were taken using calipers with a precision of 0.0005 in (0.01 mm) and a scale with a precision of 0.01 g (2.2e-5 lbf).

b. Chemical Test Setup (ASTM D543 Procedure B)

Chemical testing was done following Procedure B of ASTM D543, using the wet patch method. Each chemical was prepared according to Table 1 of ASTM F2207, shown in **Figure 6.1**. Mercaptans were excluded from this testing. Each test composition was mixed in a beaker, using enough to completely submerge a piece of cheesecloth. The cheesecloth was soaked in the chemical composition for about five minutes before it was removed and placed flat on the bottom of a glass container. Four coupons were placed in each container on top of the cheesecloth, with the inner portion of the liner touching the cheesecloth and the outer metal side upward. This test setup is shown in **Figure 6.2**. These containers were then covered and placed under a vent hood for 7 days. The cheesecloth was periodically checked to see if it was still saturated, and more chemical composition was added to the cheesecloth when necessary.

TABLE 1 Chemical Resistivity List of Reagents

Liquids	Test Composition
Water (External and Internal)	Freshly prepared distilled water (in accordance with Practice D543)
Gasoline (External)	Gasoline-Automotive Spark-Ignition Engine Fuel per Specification D4814
Gas Condensate (Internal)	70 % volume isooctane + 30 % volume toluene
Methanol	20 % volume methanol + 80 % volume distilled water
Triethylene Glycol	10 % volume triethylene glycol + 90 % volume distilled water
Brine Solution	10 % mass NaCl solution made up with a balance of distilled water
Mineral Oil	100 % White Mineral Oil USP, specific gravity 0.830 to 0.860, Saybolt at 100°F: 125 to 135 s, in accordance with Practice D543
Isopropanol	10 % volume isopropanol + 90 % volume distilled water
Sulfuric Acid	5 % weight (of total solution) H_2SO_4 in distilled water
Surfactants	5 % mass (of solution weight) dehydrated pure white soap flakes (dried 1 h at 105°C) dissolved in distilled water, in accordance with Practice D543
Mercaptans	2 % volume tertiary butyl mercaptan + 98 % volume mineral oil, white, USP

Figure 6.1:

A list of the chemical reagents tested and their makeup, from ASTM F2207

Figure 6.2: Chemical test setup, four coupons in a glass container on top of cheese cloth soaked in a chemical bath

c. Chemical Test Results

Less than 5% change in value was recorded for all measurements except thickness. The thickness of the steel coupon liner increased significantly when exposed to Distilled Water, Gasoline, Methanol, Brine, Isopropanol, and

Soap. The thickness of the cast iron coupon liner increased significantly when exposed to Distilled Water, Gas Condensate, Methanol, Brine, and Soap. The thickness of the cast iron liner decreased significantly when exposed to Isopropanol. Considering the initial liner thickness – approximately 0.07 in (1.78 mm) - a change of even 0.01 in (0.25 mm) could result in a high percentage change relative to the original value, so these observed changes may be partially due to measuring error. However, it is important to note that for some chemical exposures, the change in liner thickness was insignificant.

Table 6.1: Chemical testing results, showing percent increase in dimensions of the liner and coupon weight for every chemical test type.

Coupon Treatment	Steel Avg % Length Increase	Steel Avg % Width Increase	Steel Avg % Thickness Increase	Steel Avg % Weight Increase	Cast Iron Avg % Length Increase	Cast Iron Avg % Width Increase	Cast Iron Avg % Thickness Increase	Cast Iron Avg % Weight Increase
Distilled Water	0.05	0.14	10.45	-0.002	0.20	-1.94	11.51	0.06
Gasoline	0.87	-0.40	13.84	0.10	0.84	0.94	0.59	-0.65
Gas Condensate	0.79	-0.82	0.38	0.04	0.16	-1.42	7.36	0.01
Methanol	0.77	1.60	9.37	1.51	0.21	-0.82	8.10	0.11
Triethylene Glycol	0.39	-0.86	-0.93	-0.03	0.16	0.53	-0.04	1.85
Brine	0.33	1.44	8.19	1.44	0.12	1.43	38.97	-0.05
Mineral Oil	0.86	4.38	-1.04	0.20	0.67	-0.32	0.92	0.14
Isopropanol	0.47	-2.26	13.22	-0.03	-0.02	0.26	-10.12	0.22
Sulfuric Acid	0.25	-2.27	-1.74	0.003	0.79	-0.38	-0.80	1.54
Soap	0.02	0.18	34.05	1.04	0.32	-2.31	27.12	0.05

(b) Peel Tests (ASTM D3167-10)

a. Peel Test Specimens

The peel test samples are approximately ½-inch thick (12.7 mm), 1-inch-wide (25.4 mm), and 6-inch-long (152.4 mm) coupon samples, cut from both cast iron and steel pipelines. An 8-inch-long (203.2 mm) internal pipe replacement liner is adhered to all test samples of both types. Each coupon was measured to determine the length and width of the area of metal adhered to the liner. These measurements were taken using calipers with a precision of 0.0005in (0.01 mm). The chemically tested coupons discussed in this section are the same as those detailed in Section 6. The objective of the peel test is to determine the strength required to break the bond between the liner and host pipe through peeling the liner from the host pipe coupon.

b. Peel Test Setup (ASTM D3167)

The majority of the peel tests were performed on an Instron Universal Test Machine, model 5869, with load cells capable of measuring up to 1124.04 lbf (5 kN) or 11240.4 lbf (50 kN). A minority of the tests were completed on an MTS Exceed Electromechanical Test System, model E43-504, with a load cell capable of measuring up to 1124.04 lbf (5 kN) or 11,240.45 lbf (50 kN). **Table 7.1** shows the test equipment used for each of the tests analyzed. A peel fixture was ordered to match the specification in the standard. However, the coupons were larger than the standard specified. As such, the design of the peel fixture was modified such that the coupons could fit inside of it for testing.

The peel fixture was modified so that the rollers would have more distance between them, and the triangle plates would be farther apart. **Figure 7.1** shows the new design of the triangle plates. The centers of the holes pictured in the drawing are also the centers of the rollers. The distance between the two horizontal holes on the bottom was increased from 1.20 inches (30.5 mm) to 1.85 inches (47.0 mm). The distance between the two vertical holes on the right side was increased from 1.3 inches (33.0 mm) to 2 inches (50.8 mm). These two distances were increased by a factor of about 1.54 to keep the peel angle the same before and after modification. Further modifications included: increasing the distance between the two plates to 1.8625 in (47.3 mm) and lengthening the pins to 2.602 in (66.1 mm). The original rollers were kept in the design of the new peel fixture, and washers were used as spacers to keep the rollers centered on the larger pins.

Table 7.2: The testing equipment used for each peel test.

Chemical Treatment	CI Coupon 1	CI Coupon 2	Steel Coupon 1	Steel Coupon 2
Control	Instron, 5kN	Instron, 5kN	Instron, 5kN	Instron, 5kN
Distilled Water	MTS, 50kN	Instron, 5kN	Instron, 50kN	MTS, 5kN
Gasoline	Instron, 5kN*	Instron, 5kN*	Instron, 5kN*	Instron, 5kN*

Gas Condensate	Instron, 5kN	Instron, 5kN	Instron, 5kN	Instron, 5kN
Methanol	Instron, 5kN*	Instron, 5kN*	Instron, 5kN*	Instron, 5kN*
Triethylene Glycol	MTS, 50kN	Instron, 5kN*	MTS, 50kN	Instron, 50kN
Brine Solution	MTS, 50kN	MTS, 50kN	MTS, 50kN	MTS, 50kN
Mineral Oil	Instron, 5kN	Instron, 5kN	Instron, 5kN	Instron, 50kN
Isopropanol	MTS, 50kN	Instron, 5kN	Instron, 5kN*	Instron, 5kN*
Sulfuric Acid	Instron, 5kN	Instron, 5kN	Instron, 50kN	Instron, 50kN
Surfactants (Soap)	MTS, 50kN	Instron, 5kN	MTS, 5kN	MTS, 5kN

*A correction factor of 2.2591 was applied to this test due to a discrepancy in the load cell readings. This is explained further in Section 12.3 of the Appendix.

During preliminary testing the coupons would occasionally rotate to the side on the rollers, causing the coupon to rub on the new triangle side plates and causing a diagonal peel. To fix the issue, acrylic triangle plates were fabricated and placed on the inside of the steel plates as pictured in **Figure 7.3.** The acrylic spacers reduced the space between plates to 1.398 in (35.5 mm). This ensured a straight, low-friction travel of the specimen on the peel fixture.

Due to the modifications of the test fixture, each sample was pre-peeled one inch by hand to prevent it from slipping out of the peel fixture during testing. The liner was gripped using the lower Instron tension grip, and tensile load was applied at a constant speed of 6-in./min (152 mm/min). Each peel test was conducted until the liner was fully detached from the metal.

These samples were chemically prepared using the same reagents as the previous testing, detailed in Section 6. Two control samples of each material were tested to obtain baseline peel strength values. Two samples of each material were tested from each chemical treatment.

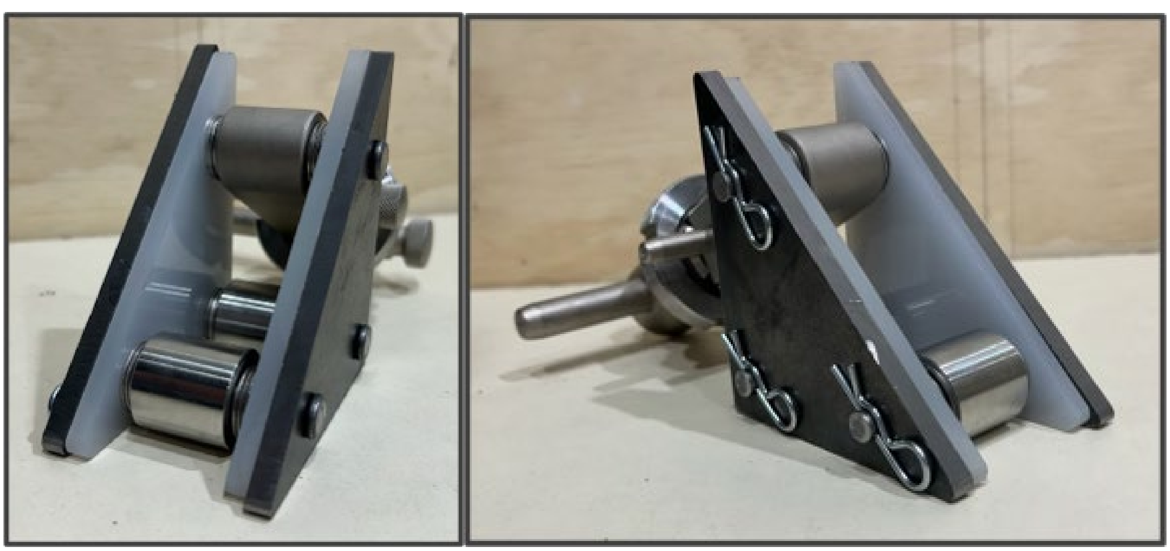
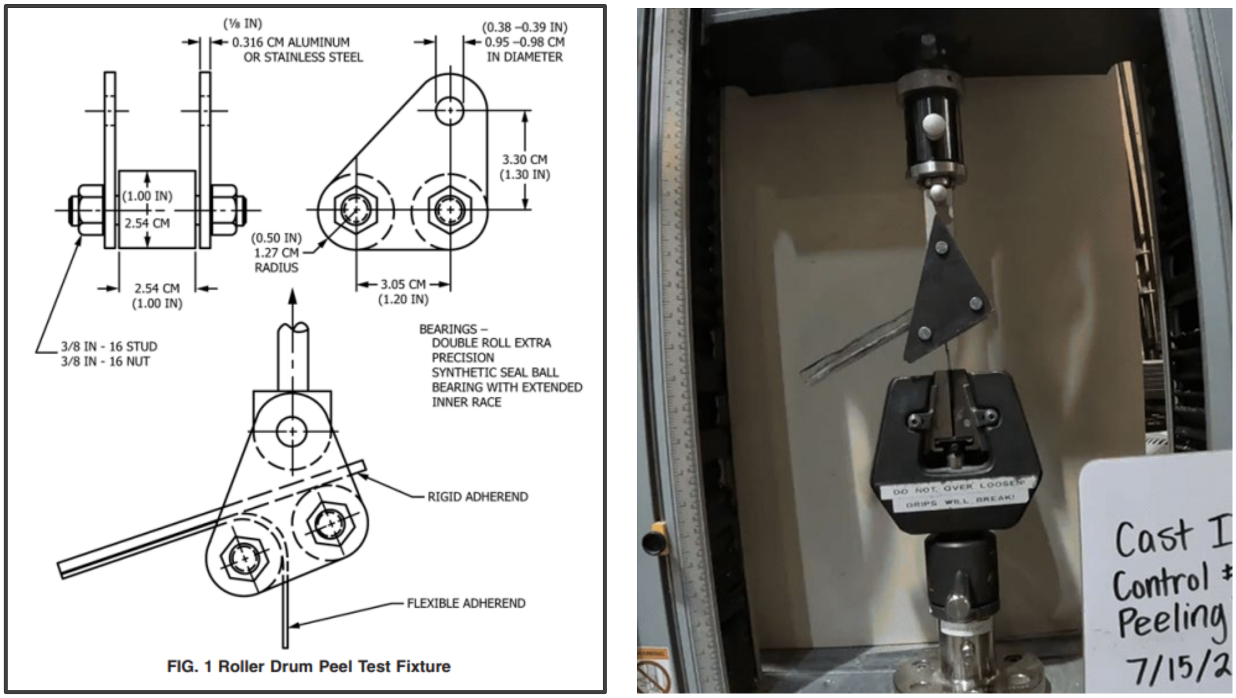


Figure 7.4: The final modified floating roller peel drum.

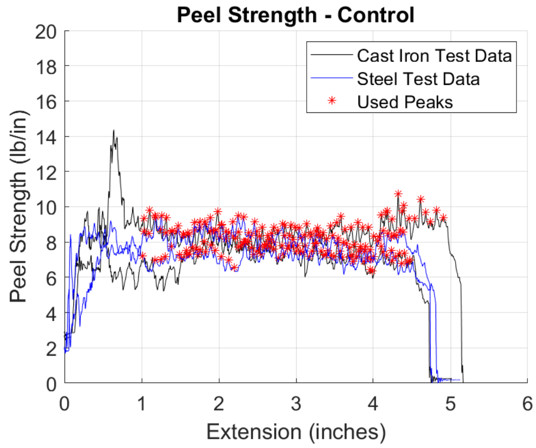


(a) (b)

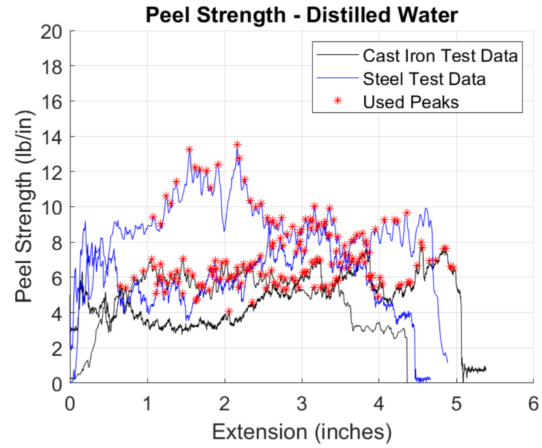
Figure 7.5: Peel test setup including: (a) The original floating roller peel drum setup and dimensions as specified by ASTM D3167 (b) The modified floating roller peel drum test setup

c. Peel Test Results

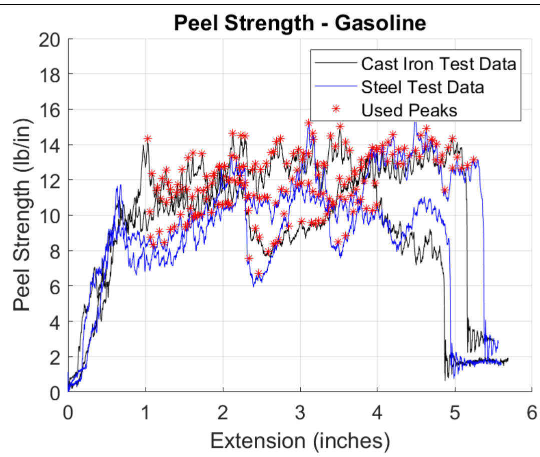
The average peel strength of the steel control tests was 8.32 lbf/in (1.46 N/mm), and the average peel strength of the cast iron control tests was 7.96 lbf/in (1.39 N/mm). The results of the peel tests are shown in **Figure 7.3**. The peel strength of each test was determined by taking an average of the significant peaks over at least 3 inches (76.2 cm) of peel, disregarding the first inch. This extension range was most heavily influenced by the amount of data collected, with tests reaching an extension of 5 inches (127 mm) often having a larger range of used data. For a minority of coupons that did not provide at least (101.6 mm) inches of extension data or for which the end behavior was not representative of the whole test, the extension range would start before the first inch was completed. In these cases, the used extension range was never started before 0.5 inches (12.7 mm) of extension. The significant peaks used in calculations were first determined by the peaks that were at least 0.05-0.1 lb/in (0.009-0.017 N/mm) higher than the two valleys surrounding it. After that, the data was inspected and edited to include or disregard any peaks that had been wrongfully added or excluded due to noise in the data. The used peaks can be seen in **Figure 7.3** as compared to the data collected from each test.



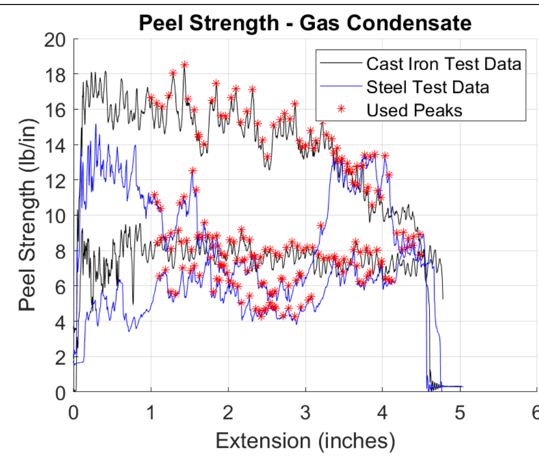
(a) Control



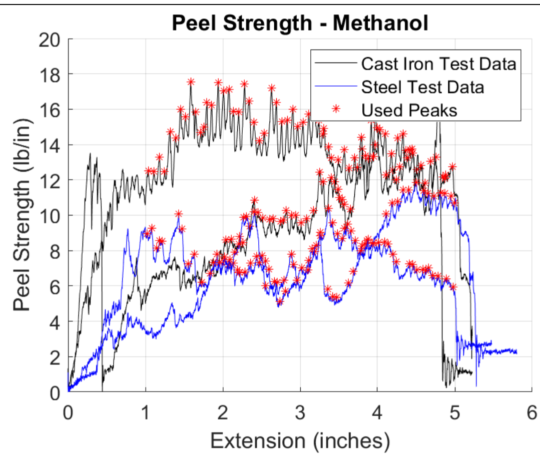
(b) Distilled Water



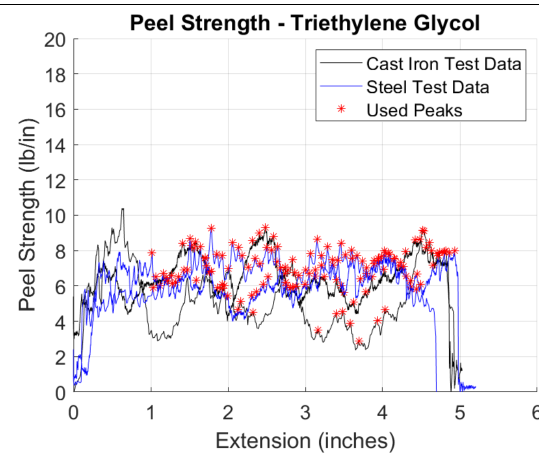
(c) Gasoline



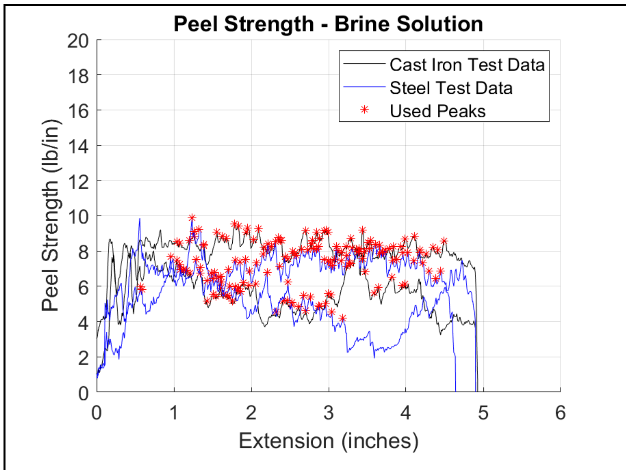
(d) Gas Condensate



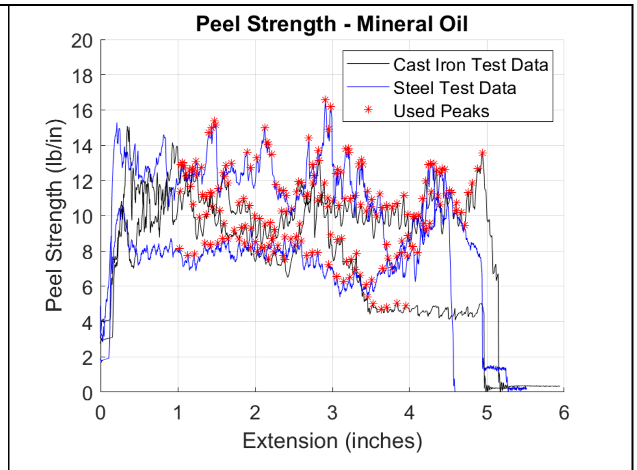
(e) Methanol



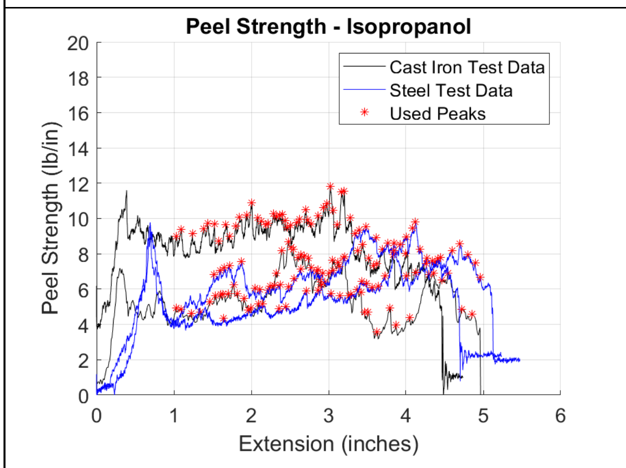
(f) Triethylene Glycol



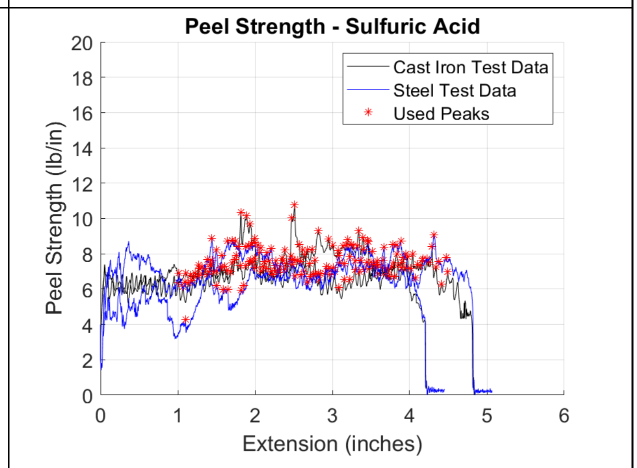
(g) Brine Solution



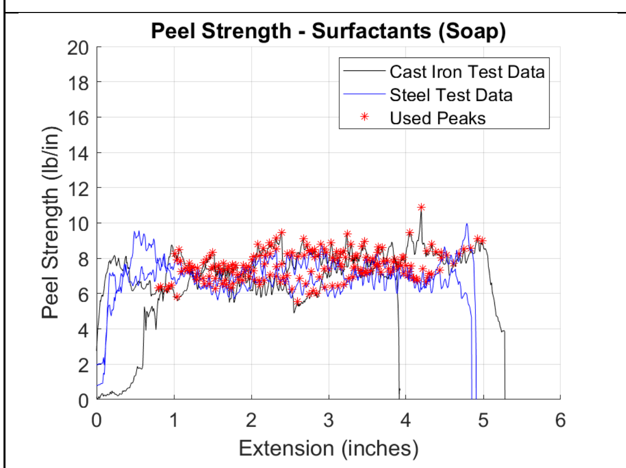
(h) Mineral Oil



(i) Isopropanol



(j) Sulfuric Acid



(k) Surfactants (Soap)

Figure 7.6: Peel test results showing the peel strength over a period of extension

During testing, it was discovered that the 5kN Intron load cell used for peel testing was no longer giving accurate readings. By testing the load cell with masses of known weights, it was found that the load cell still gave outputs in a linear pattern, and that a correction factor of 2.2591 amended the inaccurate outputs. **Table 7.1** denotes which tests required this correction factor, and more information regarding the correction factor can be found in **Section 12.3** of the Appendix.

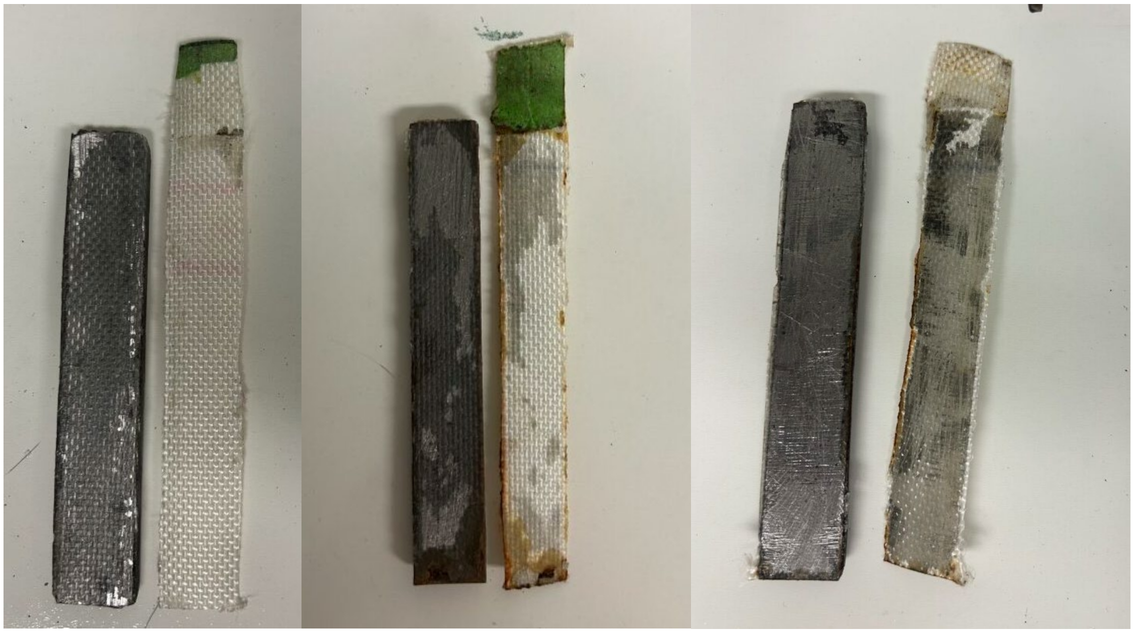
The average peel strengths were 8.19 lbf/in (1.43 N/mm) for all Steel samples, 8.98 lbf/in (1.57 N/mm) for all Cast Iron samples, and 8.58 lbf/in (1.50 N/mm) for all samples. The average peel strength values for each test type can be seen in **Table 7.2**. The highest average peel strength was 13.22 lbf/in (2.32 N/mm), experienced by the methanol cast iron coupons. The lowest average peel strength was 6.2 lbf/in (1.09 N/mm), experienced by the distilled water cast iron coupons.

According to ASTM F2207 Section 5.2.2.1, medium-pressure liners must have a peeling strength of 6lb/in (1.05 N/mm) or more in accordance with Test Method D316. At least two peel tests for each chemical tested had a peel strength greater than 6lb/in (1.05 N/mm), shown in **Figure 7.3** and **Table 7.2**.

Table 7.3 gives the type of failure for each peel test specimen. Cohesive failure indicates that the adhesive separated from the fabric of the liner, leaving adhesive on the host metal. Adhesive failure indicates that the adhesive separated completely from the host metal. A combination failure indicates that both cohesive and adhesive failure were present.

Table 7.3: Peel test results showing the average peel strength for each test type.

Chemical Treatment	Cast Iron (lbf/in)	Steel (lbf/in)
Control	8.32	7.96
Distilled Water	6.21	8.39
Gasoline	12.43	11.52
Gas Condensate	11.44	7.69
Methanol	13.22	8.11
Triethylene Glycol	6.71	6.92
Brine Solution	7.31	6.99
Mineral Oil	9.94	10.16
Isopropanol	7.89	7.05
Sulfuric Acid	7.61	7.5
Surfactants (Soap)	7.7	7.34



(a) (b) (c)

Figure 7.7: Examples of types of failure including: (a) Cohesive (b) Combination (c) Adhesive

Table 7.4: Type of peel failure per coupon

Chemical Treatment	Cast Iron Coupon 1	Cast Iron Coupon 2	Steel Coupon 1	Steel Coupon 2
Control	Cohesive	Cohesive	Cohesive	Cohesive
Distilled Water	Combination	Combination	Adhesive	Cohesive
Gasoline	Cohesive	Cohesive	Cohesive	Cohesive
Gas Condensate	Adhesive	Cohesive	Adhesive	Cohesive
Methanol	Cohesive	Adhesive	Adhesive	Adhesive
Triethylene Glycol	Combination	Combination	Cohesive	Combination
Brine Solution	Cohesive	Cohesive	Combination	Cohesive
Mineral Oil	Cohesive	Cohesive	Cohesive	Cohesive
Isopropanol	Combination	Combination	Cohesive	Adhesive
Sulfuric Acid	Cohesive	Cohesive	Cohesive	Cohesive
Surfactants (Soap)	Cohesive	Combination	Cohesive	Cohesive

(c) Hardness Tests (ASTM D2240)

a. Hardness Test Specimens

The hardness test samples were approximately ½-inch thick (12.7 mm), 1-inch-wide (25.4 mm), and 6-inch-long (152.4 mm) coupon samples, cut from both cast iron and steel pipelines. An 8-inch-long (203.2 mm) internal pipe replacement liner was adhered to all test samples of both types. One cast iron and one steel coupon were used for control hardness testing, and twenty-two more coupons were first put through chemical testing as described in Section 6.

b. Hardness Test Setup

Hardness testing was performed with a Rex Handheld Durometer, Model 1600-D (Type D) with a precision of 1 durometer unit (D). Each coupon was laid flat on a table with the inner face of the liner facing upwards. The durometer was pressed into the inner face of the liner for one second, and the value shown on the dial was recorded. This process was conducted five separate times on each coupon. Each test was conducted along the center line of the coupon and was at least 0.24 in. (6.0mm) away from any other hardness test sites on the same coupon.

c. Hardness Test Results

The average hardness of the control tests was 48.5D. **Table 8.1** shows the average hardness value for each chemical test type.

Table 8.5: Hardness test results showing the average hardness value for each test type.

Chemical Treatment	Average Hardness
Control	48.5
Distilled Water	47.5
Gasoline	44.6
Gas Condensate	48.6
Methanol	43.3
Triethylene Glycol	47.5
Brine	48.5
Mineral Oil	45.8
Isopropanol	43.6
Sulfuric Acid	48.3
Soap	51.7

(d) Lap Shear Tests (ASTM D5868-95)

a. Lap Shear Specimens

The lap shear test samples were approximately ½-inch-thick (12.7 mm), 1-inch-wide (25.4 mm), and 6-inch-long (152.4 mm) coupon samples, cut from both cast iron and steel pipelines. An 8-inch-long (203.2 mm) internal pipe replacement liner was adhered to all test samples of both types. Each coupon was measured to determine the length and width of the area of metal adhered to the liner. These measurements were taken using calipers with a precision of 0.0005 in (0.01 mm). The chemically tested coupons are the same as those detailed in Section 6.

b. Lap Shear Setup (ASTM D5868)

These tests were performed on an MTS Exceed Electromechanical Test System, model E43-504, with a load cell capable of measuring up to 11,240.45 lbf (50 kN). To prepare the specimens for testing, each coupon was peeled one inch from the end of the specimen with no excess liner. The liner was pushed away from the coupon and the exposed one inch of metal was placed in the lower tensile grips of the MTS. About one inch of liner from the other side of the specimen was placed in the top grips. The lap shear test setup can be seen in **Figure 9.1**. All specimens were subject to a steady loading rate of 0.5 in/min (13 mm/min).

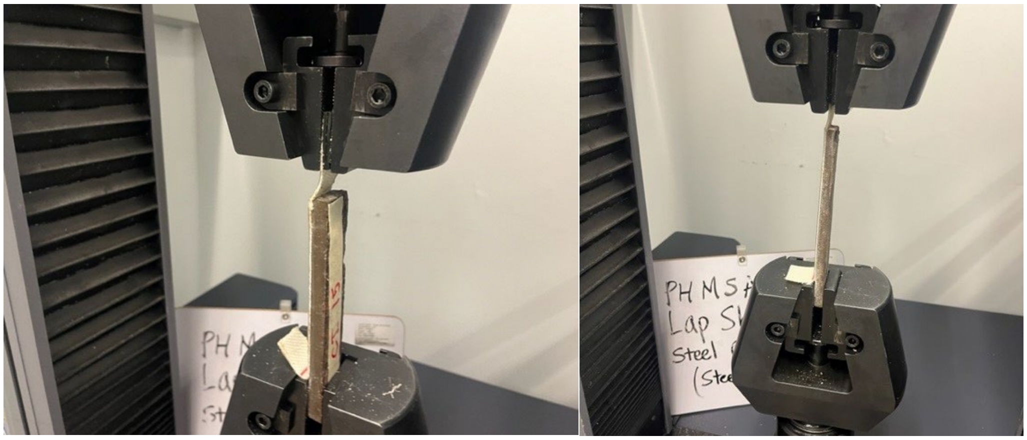
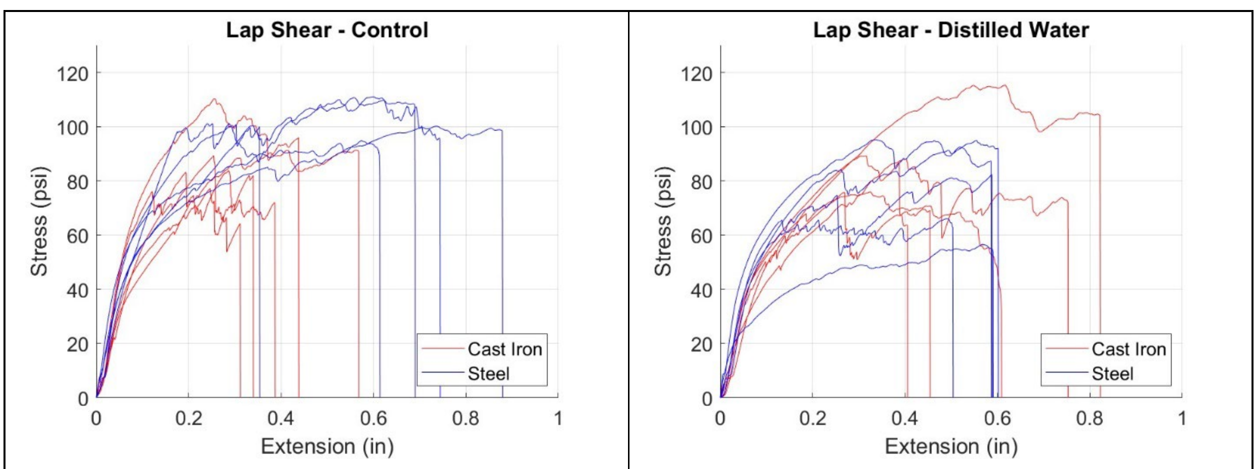


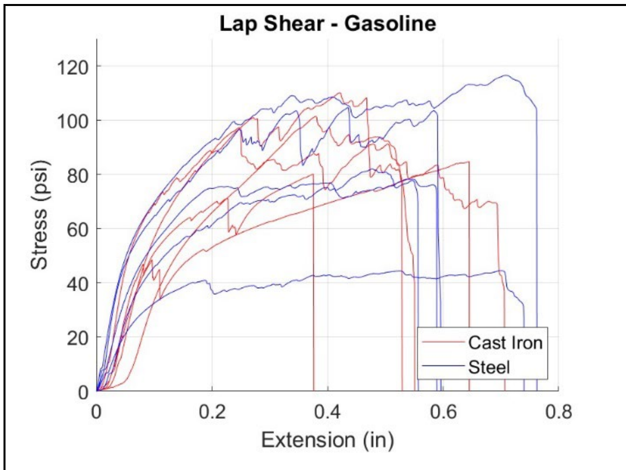
Figure 9.8: Lap shear testing setup

c. Lap Shear Results

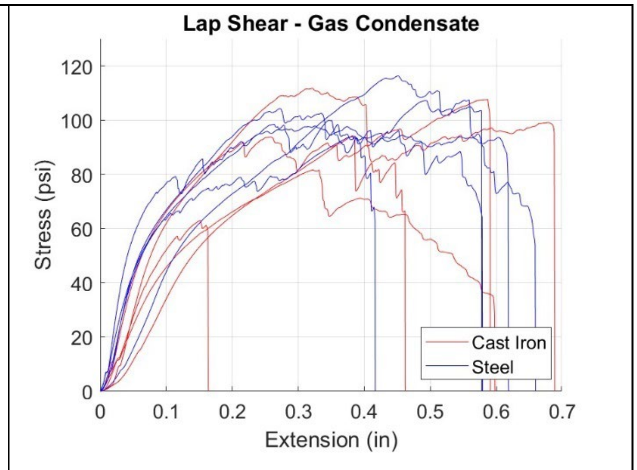
The Lap Shear testing results are plotted below in **Figure 9.2**. The chemically prepared samples did not perform significantly better or worse than the control samples under the lap shear test. The peak load attained by each coupon was recorded and stress was calculated based on the measured area where the host pipe was adhered to the liner of each coupon. The average peak stress was calculated to be 90.67 psi (625.1 kPa) for all Cast Iron samples, 88.43 psi (609.7 kPa) for all Steel samples, and 89.55 psi (617.4 kPa) for all samples. **Table 9.1** and **Table 9.2** give the maximum, minimum, and average peak stresses per chemical treatment and host pipe material. The lowest peak stress recorded was 44.50 psi (306.8 kPa) (Steel, Gasoline), and the highest peak stress recorded was 124.6 psi (858.8 kPa) (Steel, Mineral Oil).



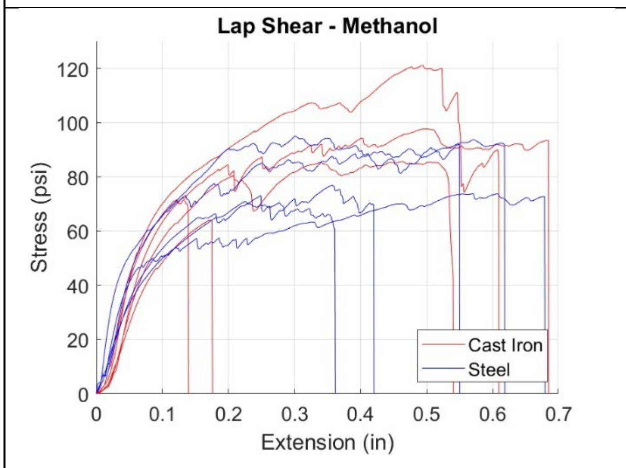
(a) Control	(b) Distilled Water



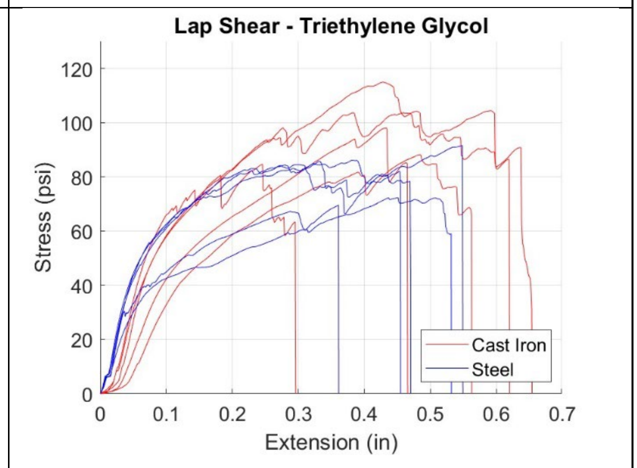
(c) Gasoline



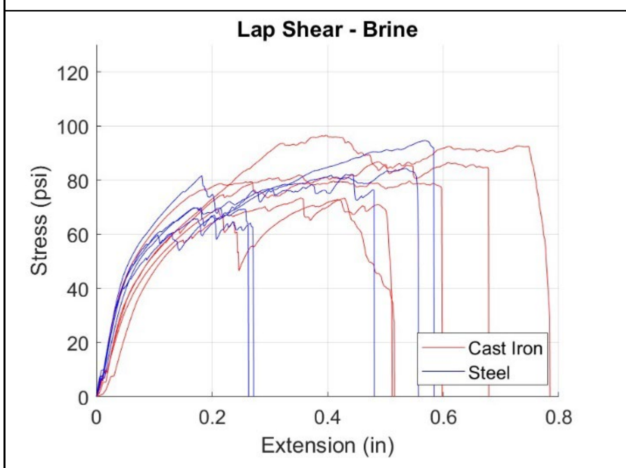
(d) Gas Condensate



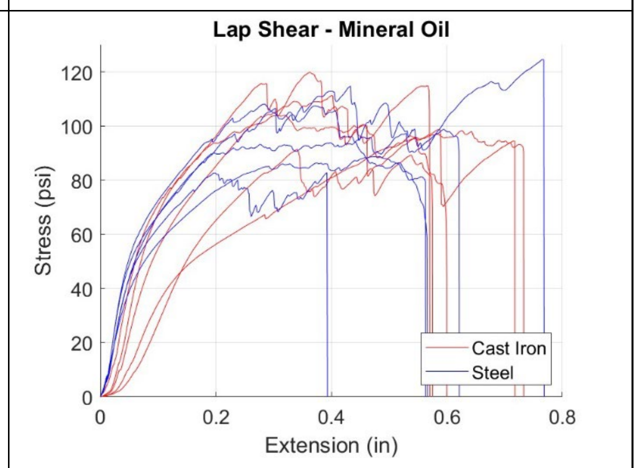
(e) Methanol



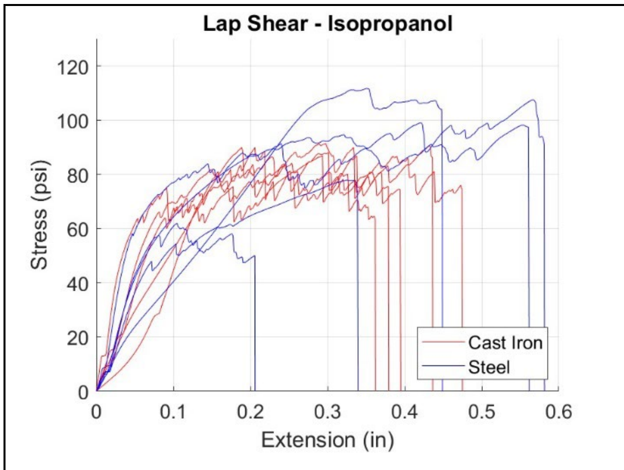
(f) Triethylene Glycol



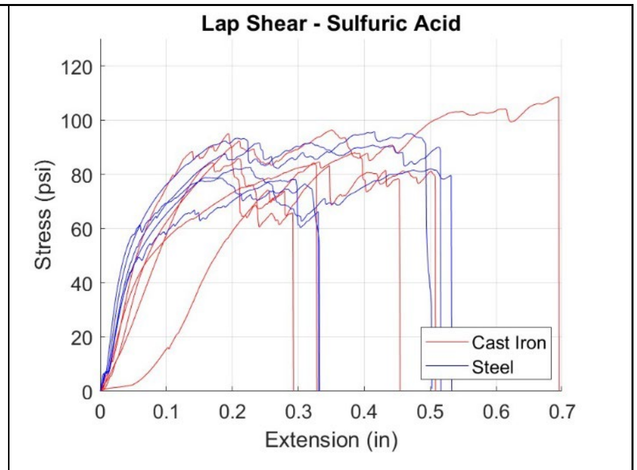
(g) Brine Solution



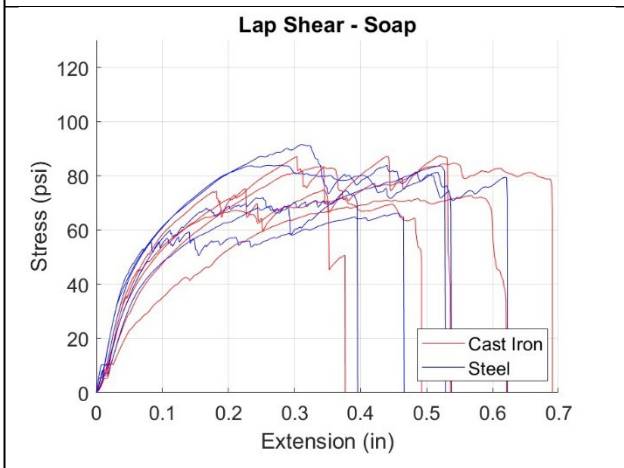
(h) Mineral Oil



(i) Isopropanol



(j) Sulfuric Acid



(k) Surfactants (Soap)

Figure 9.9: Lap shear results showing stress over a period of extension

Table 9.6: Lap shear test results showing the maximum, minimum, and average stress for each cast iron test type.

Chemical Treatment	Maximum Peak Stress (psi)	Minimum Peak Stress (psi)	Average Peak Stress (psi)
Control	110.28	77.14	90.39
Distilled Water	115.37	75.73	88.85
Gasoline	110.11	80.15	94.73
Gas Condensate	111.79	62.97	91.65
Methanol	121.02	64.01	88.01
Triethylene Glycol	114.96	84.67	98.06
Brine	96.6	72.85	81.87
Mineral Oil	119.89	91.47	105.07
Isopropanol	92.15	84.66	88.27
Sulfuric Acid	108.53	83.24	92.16
Surfactants (Soap)	87.34	71.71	78.35

Table 9.7: Lap shear test results showing the maximum, minimum, and average stress for each steel test type.

Chemical Treatment	Maximum Peak Stress (psi)	Minimum Peak Stress (psi)	Average Peak Stress (psi)
Control	111.07	94.83	103.59
Distilled Water	95.12	56.56	79.00
Gasoline	116.56	44.5	85.20
Gas Condensate	116.32	96.18	104.38
Methanol	95.07	70.46	81.68
Triethylene Glycol	91.57	69.57	81.07
Brine	94.64	69.23	80.05
Mineral Oil	124.56	82.77	100.61
Isopropanol	111.68	61.92	91.45
Sulfuric Acid	95.73	78.18	85.69
Surfactants (Soap)	91.63	66.19	80.01

This data gives no indication of any significant effect of different chemical treatments, or effect of metal host pipe used. One distinction between the cast iron and steel samples is that the steel samples were more likely to experience adhesive failure (the adhesive separates completely from the metal), as opposed to cohesive (the adhesive separates from itself or the liner). This is likely due to the smooth surface of the steel samples, whereas the cast iron samples had a porous surface. The type of failure experienced by each coupon sample is given in the tables below. Most specimens experienced cohesive failure.

Table 9.8: The type of failure observed for every cast iron lap shear test performed.

Chemical Treatment	Coupon 1	Coupon 2	Coupon 3	Coupon 4	Coupon 5
Control	Cohesive	Adhesive	Cohesive	Cohesive	Cohesive
Distilled Water	Cohesive	Cohesive	Cohesive	Adhesive	Cohesive
Gasoline	Cohesive	Cohesive	Cohesive	Adhesive	Adhesive
Gas Condensate	Cohesive	Adhesive	Cohesive	Adhesive	Cohesive
Methanol	Adhesive	Cohesive	Cohesive	Adhesive	Cohesive
Triethylene Glycol	Cohesive	Cohesive	Cohesive	Cohesive	Cohesive
Brine	Cohesive	Cohesive	Cohesive	Cohesive	Cohesive
Mineral Oil	Cohesive	Cohesive	Cohesive	Cohesive	Cohesive
Isopropanol	Adhesive	Adhesive	Adhesive	Adhesive	Adhesive
Sulfuric Acid	Cohesive	Cohesive	Cohesive	Cohesive	Cohesive
Surfactants (Soap)	Cohesive	Cohesive	Cohesive	Cohesive	Cohesive

Table 9.9: The type of failure observed for every steel lap shear test performed.

Chemical Treatment	Coupon 1	Coupon 2	Coupon 3	Coupon 4	Coupon 5
Control	Cohesive	Cohesive	Cohesive	Cohesive	Cohesive
Distilled Water	Cohesive	Adhesive	Cohesive	Cohesive	Cohesive
Gasoline	Cohesive	Cohesive	Cohesive	Cohesive	Cohesive
Gas Condensate	Cohesive	Cohesive	Cohesive	Cohesive	Cohesive
Methanol	Cohesive	Adhesive	Cohesive	Cohesive	Cohesive
Triethylene Glycol	Adhesive	Cohesive	Cohesive	Cohesive	Cohesive
Brine	Cohesive	Cohesive	Cohesive	Cohesive	Adhesive
Mineral Oil	Cohesive	Adhesive	Cohesive	Cohesive	Cohesive
Isopropanol	Cohesive	Adhesive	Adhesive	Cohesive	Cohesive
Sulfuric Acid	Cohesive	Cohesive	Adhesive	Cohesive	Cohesive
Surfactants (Soap)	Cohesive	Adhesive	Cohesive	Adhesive	Cohesive

(e) Full-Scale Testing

a. Full-Scale Specimen

The specimen for full-scale testing was prepared using two 12 in. (305 mm) diameter steel pipe segments, each 60 in. (1520 mm) long. The host pipe segments were set up such that an initial crack opening of 0.5 in. (12.7 mm) is present. The CIPL was then applied inside the host pipe across the initial gap opening, such that the two host pipe segments were joined to create one test specimen. One side of the specimen includes pipe defects along the host pipe, including varying sized holes and "existing" service connections.

b. Full-Scale Transverse Test Setup

The specimen was first tested in a four-point bending configuration with a 22-kip (100 kN) actuator. The specimen was centered about the crack opening with distances between supports and load points being 30 in. – 40 in. – 30 in. (762 mm – 1016 mm – 762 mm). At the support and load points along the specimen, testing saddles were attached to distribute applied loads and minimize localized stress concentrations. Strain gauges (SGs) were attached at the crown and invert of the host pipe over the middle 40 in. (1016 mm) (maximum moment) span in the vicinity of the crack. String potentiometer (SP) stands were fixed to a beam below the specimen and attached to the springline of the host pipe. Linear variable differential transducers (LVDTs) were attached to the same beam as the SPs, and rods were connected to the springline of the host pipe with brackets. Figure 10.1 shows a photo of the full-scale specimen in the frame prior to testing. Figure 10.2 provides a schematic for the instrumentation with detailed dimensions.

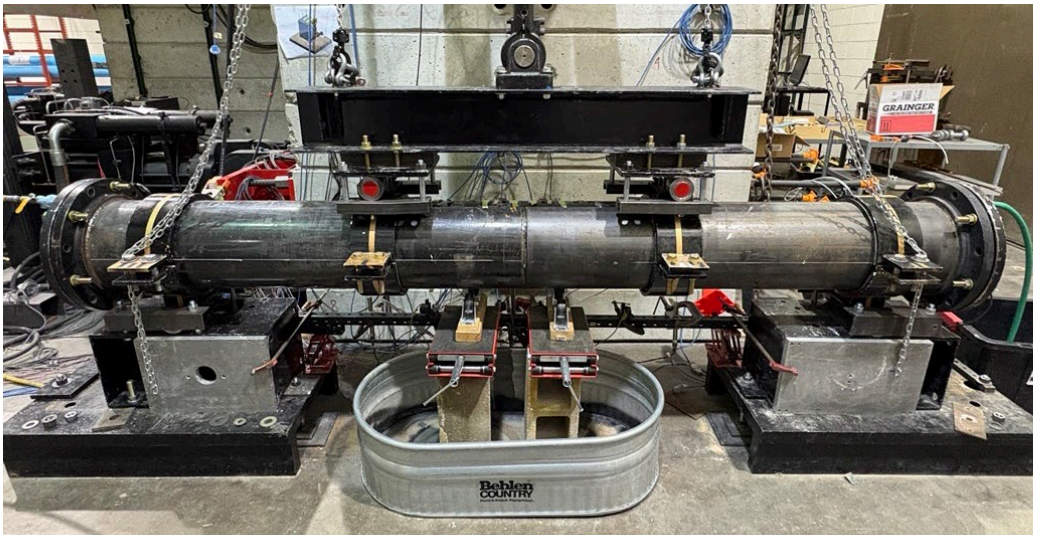


Figure 10.1. Full-scale specimen in frame with four-point bending configuration

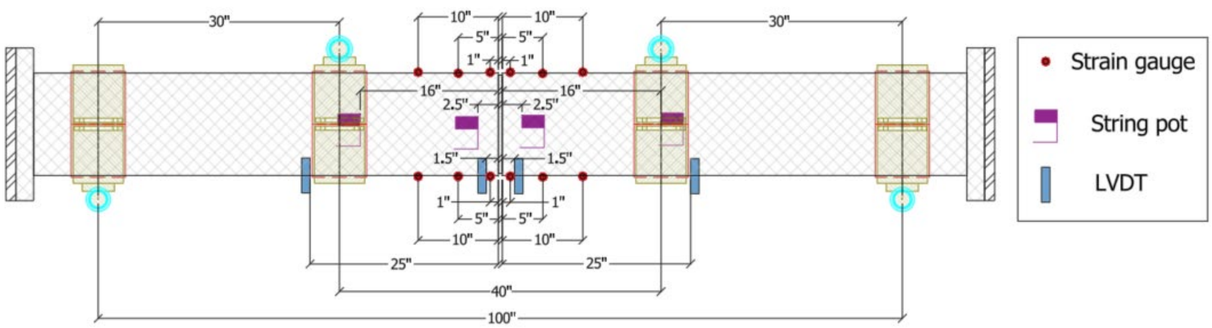


Figure 10.2. Full-scale test instrumentation schematic

(f) Conclusions

At least eight coupons were tested per chemical and pipe material type during chemical tests in accordance with Testing Method D543 Procedure B. Less than 5% change in dimensions and weight was reported in every category except liner thickness, which could possibly be due to measuring error of the very small thickness values. The chemically tested coupons were then used in mechanical testing. Peel testing was conducted in accordance with Testing Method D3167, hardness testing was done in accordance with Testing Method D2240, and lap shear tests were done in accordance with Test Method D5868. The average peel strength of all coupons was 8.58 lbf/in (1.50 N/mm), the average hardness was 47.1D, and the average lap shear peak stress was 89.6 psi (617.4 kPa). The peel tests reported were all over 6lb/in (1.05 N/mm), in accordance with ASTM F2207 Section 5.2.2.1.

5: Project Schedule –

- Items not complete in Q11, possibly to be included in the Q12 report are as follows:

Item #	***Task #***	***Activity/Deliverable***	***Title***	***Federal Cost***	***Cost Share***
46	39	Traffic Loading/fatigue & Parallel Excavation	Traffic Loading/fatigue & Parallel Excavation	$50,469.50	$50,469.50