the Energy to Lead

Establishing Permanence of Repair Systems for Above Ground Leaks

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List of Acronyms

ASTM	American Society for Testing and Materials
AGLR	Above Ground Leak Repair
AISI	American Iron and Steel Institute
CCT	Cyclic Corrosion Test
GIS	Gas Industry Standard
IPI	InduMar Products Inc.
PTFE	Polytetrafluoroethylene
RH	Relative Humidity
SAE	Society of Automotive Engineers

Executive Summary

The aim of this project was to conduct a thorough evaluation of repair methods for leaks of above ground piping in an effort to establish permanency of the repairs. Based on an in depth review of current repair systems for above ground leaks three manufacturers and four repair products were chosen as follows:

1) Manufacturer A
   a. Product #1
   b. Product #2
2) Manufacturer B
   a. Product #3
3) InduMar Products Inc. (IPI)
   a. Stop It®

The repairs were applied to unused 1" schedule 40 steel pipe samples per each manufacturer's procedure and evaluated per specific clauses of Gas Industry Standard (GIS) LC8-1:2006 *Specification for Methods of Repairing Leaking Ferrous Gas Mains*. Based on the testing and analysis performed in this project the performance of each repair product per each test method was ranked as shown in **Table 1**.

Table 1. Performance Ranking of the Evaluated Repair Products

Test Method	Product #1 (Live Joint Repair)	Product #2 (Non-Live Pinhole Repair)	Product #3 (Non-Live Pinhole Repair)	Stop It (Non-Live Pinhole Repair)
Cleavage Strength Test	N/A	N/A	Failed	N/A
Impact Testing	Failed	Passed	Passed	Passed
Accelerated Corrosion Testing	Rank: 2nd	Rank: Joint 1st	Rank: 3rd	Rank: Joint 1st
Short-Term Pressure Testing	Rank: 3rd	Rank: Joint 1st	Rank: 2nd	Rank: Joint 1st
Long-Term Pressure/Life Testing	Passed	Passed	Passed	Passed
Temperature Cycling[1]	Rank: 3rd	Rank: 2nd	Rank: Joint 1st	Rank: Joint 1st

[1] Temperature cycling is not a clause in GIS/LC8-1:2006 and was added to the test matrix at GTI's recommendation to test the temperature resistance of the repair method.

Various degrees of performance were observed for each repair product evaluated by each test method. The overall ranking of the repair products based on performance in all of the test methods utilized in this project can be summarized as follows:

Rank	Repair Product
1	InduMar Products Inc. Stop It®
2	Product #2
3	Product #3
4	Product #1

The repaired specimens of all four repair products met the 50-year lifetime integrity validation requirement of GIS/LC8-1:2006 Clause D.7. However, the number one ranking of Stop It® is based on it outperforming the other three repair products in all of the tests performed in this project.

Background and Overall Report Introduction

Many of the available pipe leak repair systems on the market today do not take into account specific requirements of the natural gas industry. Often these systems were designed for general pipe applications such as water and steam. For some repairs, the repair materials were never designed for outdoor atmospheric exposure. When used under these environments they may prematurely degrade, leading to reoccurrence of the leak. Some of these systems are deceptively complex to install properly, and their inherent design produces a large degree of variability in the installation quality.

Through an evaluation of leak repair methods, improvements would be seen in the efficiency of utility personnel at resolving leaks, the quality of leak repairs installed, and the longevity of the repairs. Utilities are now classifying and reporting leaks on above ground piping, and many have observed a significant number of the leaks occur at threaded joints between components. Removal or replacement of leaking components is not desired due to customer downtime and relights, time involved in conducting the repair, and many of the components (other than the thread area) are in good working condition. A plausible solution is the installation of an external leak repair system.

Though many leak repair systems are on the market, most are used only as a temporary repair. Several of the most popular mechanical and composite wrap systems in use today are more complicated and difficult to install consistently. Strict requirements for surface preparation and cleanliness, installation alignment, installation tension and torque requirements, cure time, and other factors all create variability in the final repair integrity.

Pipe dopes (e.g., PTFE) have been used as one method of ensuring proper sealing of threaded fittings for many years. Solvents in the pipe dope provide stability during application and ensure a proper cure. When the solvent evaporates, the product dries to form a tough seal. Unfortunately when dried, the bond can also become rigid and brittle in nature. Aging and temperature cycling can cause these rigid sealants to crack, creating small leak paths around the pipe on the unsealed threads. As the thermal cycling continues, crack propagation continues and increases the severity of the leak.

There are current and historic leak repair systems that come in the form of mechanical clamps, encapsulation tools, and composite repairs. The majority of the mechanical clamps work by compression of a gasket into the leaking area. Through time the gasket, a visco-elastic material, will “flow” or creep, possibly allowing development of a leak path. Often times these clamps seal the leak correctly when first installed, but due to this subsequent relaxation (flow) of the seal, they may fail in the weeks or months following installation. These systems can also be susceptible to excessive tightening (application of over-torquing) that may damage the seal resulting in a reduced service life.

This report is the culmination of the investigations performed in two different phases.

Phase 1

In this original phase the foundations were laid to evaluate three repair systems, namely Product #1, Product #2, and Product #3. The phase was initiated with an in depth review of current repair systems for above ground leaks. This was performed by reviewing current industry standards and practices, as well as conducting surveys of sponsoring utilities.

Phase 2

An additional repair system, namely InduMar Products Inc. Stop It, was added to the repair systems to be evaluated per the request of one of the project sponsors. On completion of Phase 1, a thorough evaluation of the chosen Above Ground Leak Repair (AGLR) systems was conducted to specified clauses of Gas Industry Standard (GIS) LC8-1:2006 *Specification for Methods of Repairing Leaking Ferrous Gas Mains.*

Scope

The aim of this project was to conduct a thorough evaluation of repair methods for leaks of above ground piping in an effort to establish permanency of the repairs. The project consisted of two main technical tasks as described below:

Task 1: Determination of Design Parameters
The project was initiated with an in depth review of current repair systems for above ground leaks. This was performed by reviewing current industry standards and practices, as well as conducting surveys of sponsoring utilities. Short-term hydrostatic burst testing was also performed for two of the repair products as part of Phase 1.

Task 2: Testing and Analysis of Available Repair Methods
On completion of Task 1, a thorough evaluation of the chosen Above Ground Leak Repair (AGLR) systems was conducted to specific clauses of Gas Industry Standard (GIS) LC8-1:2006 *Specification for Methods of Repairing Leaking Ferrous Gas Mains* as shown in **Table 2.**

Table 2. Specified Clauses of GIS/LC8-1:2006

Clause Reference	Title	Property Tested
Annex A	Cleavage Strength Test	Shear Strength
D.3	Impact Testing	Impact Strength
D.6	Accelerated Corrosion Testing – Small Scale Test	Corrosion Resistance
D.7	Pressure/Life Testing	Repair Integrity
-	Temperature Cycling[1]	Temperature Resistance

[1] Temperature cycling is not a clause in GIS/LC8-1:2006 and was added to the test matrix at GTI's recommendation to test the temperature resistance of the repair method.

Experimental

Based on an in depth review of current repair systems for above ground leaks three manufacturers and four repair products were chosen as follows:

1) Manufacturer A
    a. Product #1
    b. Product #2[1]
2) Manufacturer B
    a. Product #3
3) InduMar Products Inc. (IPI)
    a. Stop It®[2]

Sample Preparation

Product #1 is for live pressurized leak repairs, up to 60 psig. In Phase 1 all the repaired samples were prepared by Manufacturer A. It was decided to provide training to GTI operators so that all the repairs can be performed at GTI. Therefore, two GTI operators were trained and certified by a trainer from Manufacturer A and subsequently performed all the repairs in Phase 2.

The repairs were applied to 1" schedule 40 steel pipe samples per the manufacturer's procedure. Two pipe samples were connected by a coupling. To simulate a leaking joint a $\frac{1}{16}$" diameter hole was drilled on the threads of one of the pipes to one side of the coupling. The pipe assembly was pressurized to 60 psig and the repair applied while the sample was under pressure.

[1] This product was not added until the initiation of Task 2 per a sponsor's request.

[2] This product was not added until the initiation of Task 2 per a sponsor's request.

Product #2 is for non-pressurized leak repairs. The repairs were applied to 1″ schedule 40 steel pipe samples per the manufacturer's procedure. To simulate a leaking pipe a $^{1}/_{16}$″ diameter hole was drilled in the center of the pipe and the repair applied without pressure.

Product #3 is for non-pressurized leak repairs. The repairs were applied to 1″ schedule 40 steel pipe samples per the manufacturer's procedure. To simulate a leaking pipe a $^{1}/_{16}$″ diameter hole was drilled in the center of the pipe and the repair applied without pressure.

Stop It is for non-pressurized leak repairs. The repairs were applied to 1″ schedule 40 steel pipe samples per the manufacturer's procedure. To simulate a leaking pipe a $^{1}/_{16}$″ diameter hole was drilled in the center of the pipe and the repair applied without pressure, as shown in **Figure 1.**

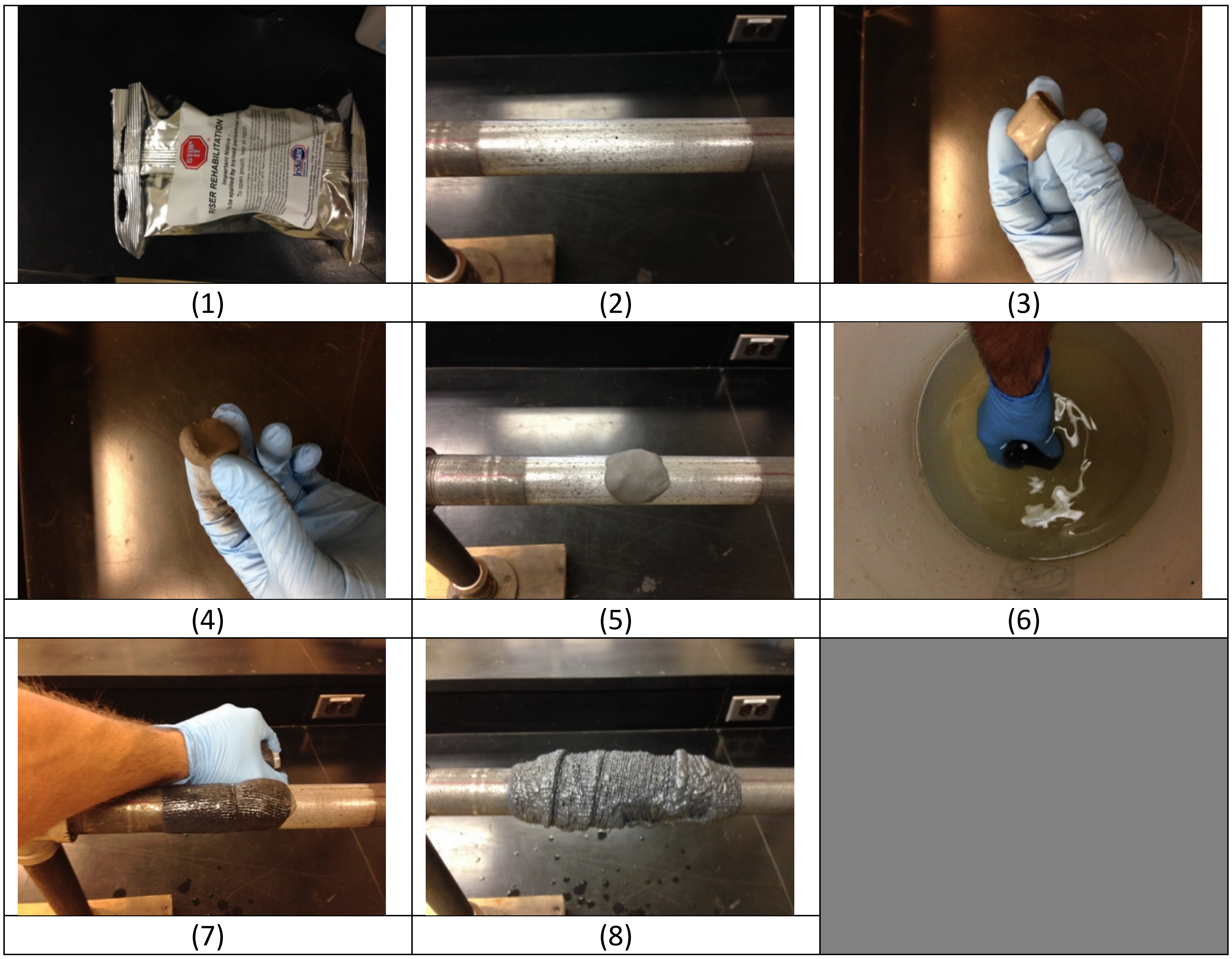

Figure 1. Example of Stop It Repair

Additional information about IPI Stop It repair product is provided in the **Appendix**.

Testing and Analysis of Repair Products

Testing was conducted to specific clauses of Gas Industry Standard (GIS) LC8-1:2006 *Specification for Methods of Repairing Leaking Ferrous Gas Mains,* as detailed below.

Cleavage Strength Test

Cleavage strength testing was performed on Product #3 repair product in accordance with Annex A of GIS/LC8-1:2006. This test is a measure of the shear strength for the repair material. Product #3 was applied to “L” shaped steel sections and cured. The specimens were then stored in a thermo-regulated conditioner at 23°C for 24 hours. Three (3) replicates were prepared and tested. A summary of the test results is provided in **Table 3** and **Figure 2**.

Table 3. Summary of Cleavage Strength Test Results (Product #3)

Replicate No.	Force at Break (kN)	Extension at Break (mm)
1	0.779	0.404
2	0.683	0.524
3	0.831	0.438
Mean	**0.765**	**0.455**
Standard Deviation	**0.075**	**0.062**

This test was performed by a third party. The test results do not meet the requirements of GIS/LC8-1:2006 which specifies that the cleavage strength of the repair system shall be not less than 2.7 kN from an average of three samples, and any one sample result shall not be less than 2.4 kN.

Note that this test was only performed for Product #3 repair product since the other three repair products do not lend themselves to be tested by this method given their nature.

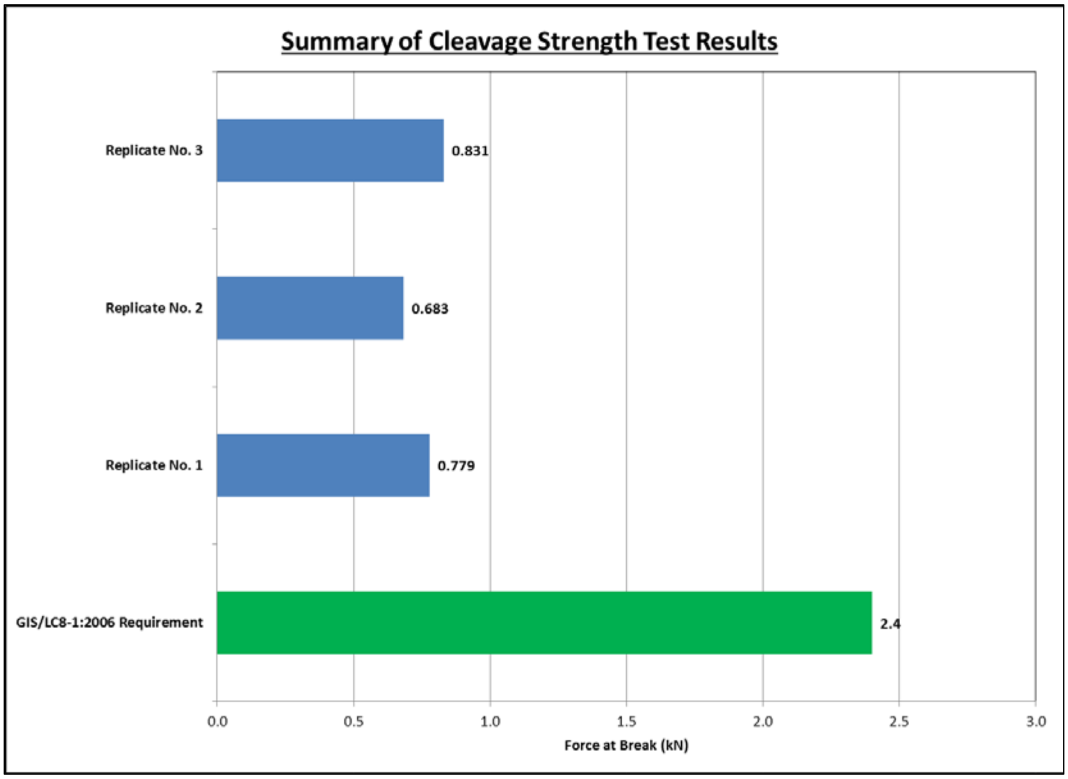

Figure 2. Summary of Cleavage Strength Test Results (Product #3)

Impact Testing

Impact testing was performed in general accordance with GIS/LC8-1:2006*,* Clause D.3 to evaluate the capability of the repaired pipe to withstand an impact load of the kind that it might experience during periods where the pipe is still excavated, as follows:

- Three specimens of each repair product were prepared.
- Each repaired specimen was mounted in the impact testing machine as shown in **Figure 3**.
- Each specimen was subjected to a blow of 135 J on the repaired location resulting from dropping a 24 lb tup (free falling weight) from a height of 4.2 ft. The tup nose geometry is provided in **Figure 4**.
- On completion of impact testing each repaired specimen was removed and pressurized to 120 psig for one month or until failure (leakage) occurred.

A summary of the test results is provided in **Table 4**.

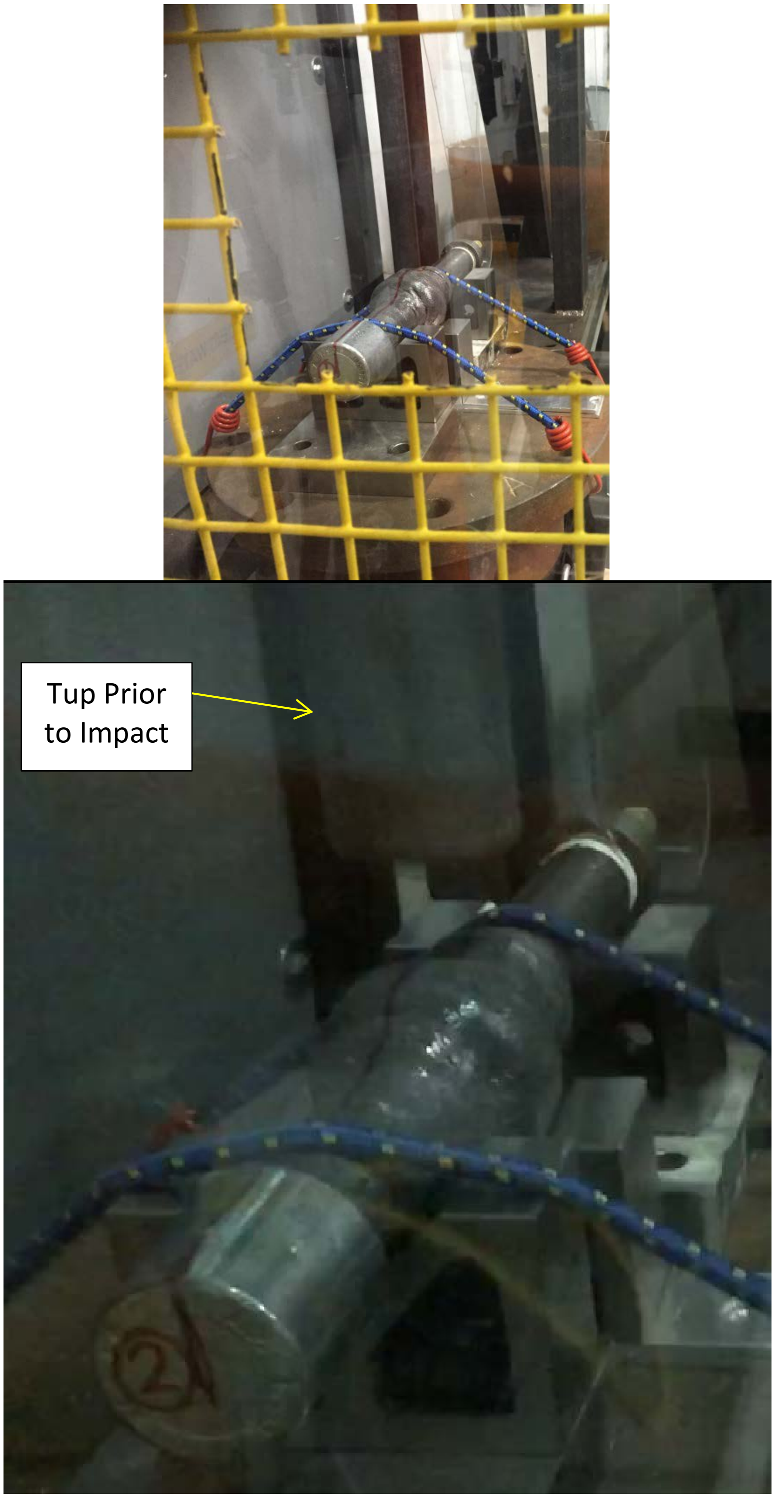

Figure 3. Impact Test Setup

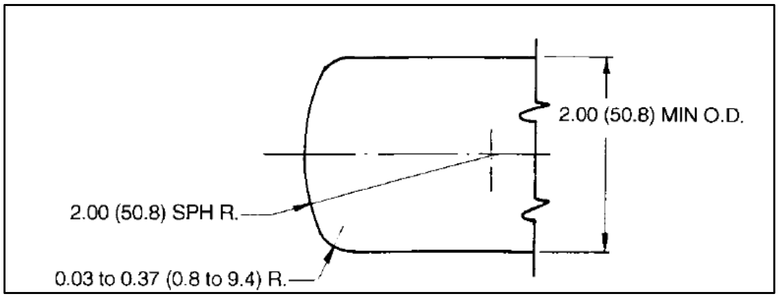

Figure 4. Tup Nose Detail

Table 4. Summary of Impact Test Results

Repair System	No. of Specimens Prepared	No. of Specimens Failed	Pressure at Start of Test (psig)	Status
Product #3	3	0	120	3 specimens reached 1 month without leakage
Product #1	3	2	120	2 specimens leaked prior to reaching 1 month
Product #2	3	0	120	3 specimens reached 1 month without leakage
IPI Stop It	3	0	120	3 specimens reached 1 month without leakage

The repair systems can be ranked in order of decreasing resistance to impact load as follows:

IPI Stop It **≈** *Product #3* **≈** *Product #2* **>** *Product #1*

Accelerated Corrosion Testing

This test measures the capability of the repair material to withstand the effects of a corrosive environment. Five specimens of each repair product were prepared. Repaired specimens were further prepared for cyclic corrosion testing. Those areas of the pipe not covered by the repair system were wrapped in wax tape to within ½" to 1" of where the repair system began. This was primarily performed in order to prevent corrosion of the end closures. The wax tape system used was Denso S105 Primer and Denso Tape. The cyclic corrosion test chosen for the project, CCT-IV is described in **Table 5** below. This cycle has been found to give good correlation with actual field results in SAE-AISI testing.

Table 5. Cyclic Corrosion Test Protocol

Step 1	Salt fog at 35°C for 10 min. (5% salt solution)
Step 2	Dry-off at 60°C for 2 hrs. 10 min.*
Step 3	Dry-off at 50°C for 15 min.
Step 4	Humidity at 60°C , 95% RH for 1 hr. 15 min.*
Step 5	Sub-cycle- steps 6-8 repeat 5X
Step 6	Dry-off at 60°C for 2 hrs. 25 min.*
Step 7	Dry-off at 50°C for 15 min.
Step 8	Humidity at 60°C , 95% RH for 1 hr. 20 min.*
Step 9	Dry-off at 35°C for 15 min.
Step 10	Final step – go to step 1

** The CCT-IV corrosion cycle ended on December 22, 2015. Two months later on February 23, 2015 before beginning another corrosion test, GTI's Q-Fog corrosion chamber temperature calibration was checked at four different temperatures. It was found to be in tolerance at three temperatures, but out of tolerance at the 60°C setting where it measured 55.7°C. While it is possible that this temperature deviation made the test less severe it is not believed that it impacted the test results significantly.*

The test specimens were placed in GTI's Q-Fog Chamber Model CCT 1100 for 2,000-hour exposure to the CCT-IV cyclic corrosion cycle.

The appearances of the IPI Stop It test specimens before and after testing are shown in **Figure 5**.

Figure 5. Repaired Specimens with IPI Stop It before (left) and after (right) Cyclic Corrosion Test

On completion of 2,000 hours of testing post-test leak evaluation was performed. Each specimen was pressurized to 90 psig and held at pressure for a minimum of six days. A summary of the test results is provided in **Table 6**.

Table 6. Summary of Leak Test Results Post Cyclic Corrosion Testing

Repair System	No. of Specimens Prepared	No. of Specimens Failed	Pressure at Start of Test (psig)	Status
Product #3	5	0	90	5 specimens reached 6 days without leakage at the repaired locations
Product #1	5	0	90	5 specimens reached 6 days without leakage at the repaired locations
Product #2	5	0	90	5 specimens reached 6 days without leakage at the repaired locations
IPI Stop It	5	0	90	5 specimens reached 6 days without leakage at the repaired locations

On completion of leak testing the specimens were evaluated per ASTM D610-08(2012) *Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces*. This standard is normally used to rate rust on coated surfaces. A rating number from 1 to 10 is assigned based on the degree of visible rust where 10 represents no visible rust. Note that the specimens were rated only on the rust found on the area covered by the repair system.

The repair systems can be ranked in order of decreasing rust protection as follows:

IPI Stop It **≈** *Product #2* **>** *Product #1* **>** *Product #3*

Pressure/Life Testing

The aim of this test was to determine the integrity of the repaired pipe over a 50-year lifetime. Hydraulic pressure testing was performed in general accordance with Clause D.7 of GIS/LC8-1:2006 as described below.

Three repaired specimens of each repair system were subjected to hydraulic pressure testing. Pressures were chosen to induce failures within 1-3 hours. A summary of the test results is provided in **Table 8**.

Table 7. Summary of Short-Term Pressure Test Results

Repair System	Short-Term Failure Pressure (T_p)* [psig]
Product #3	6,483
Product #1	5,900
Product #2	> 10,000
IPI Stop It	> 10,000

* Average failure pressure of three specimens

The repair systems can be ranked in order of decreasing resistance to short-term pressure resistance as follows:

IPI Stop It **≈** *Product #2* **>** *Product #3* **>** *Product #1*

For each repair system a second set of three specimens was placed on test at room temperature and pressure P_1. P_1 was determined by drawing a straight line, on a log/log plot of pressure against time, joining the short-term failure point (T_p) to the 1.5xP_{max}, specified maximum working pressure point of 90 psig (1.5 x 60 psig). P_1 is the pressure corresponding to six months on the time axis. An exemplar plot is provided in **Figure 6**.

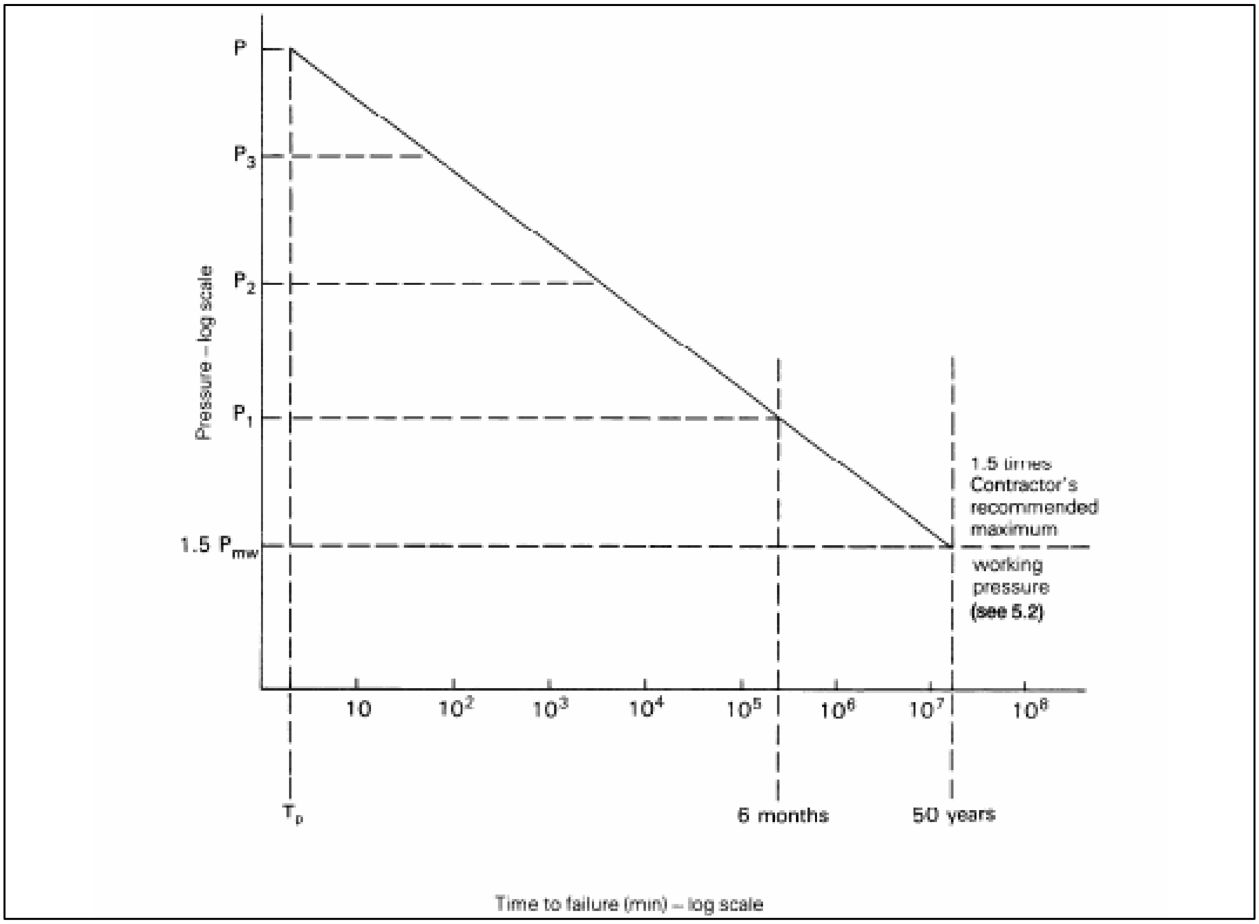

Figure 6. Pressure/Life Testing[3]

The repaired specimens were tested for six months or until failure occurred. The test setup is shown in **Figure 7**.

[3] Image courtesy of GIS/LC8-1:2006 Methods of repairing leaking ferrous gas mains Part 1: External encapsulation systems

Figure 7. Long-Term Pressure Testing Setup

None of the repaired specimens failed during this testing. A summary of the test results is provided in **Table 9.** Plots of IPI Stop It test results are provided in **Figure 8**.

Table 8. Summary of Long-Term Pressure Test Results

Repair System	No. of Specimens Tested	P_1 (psig)	Test Duration (hours / months)	Status
Product #3	3	472	5110 / 7	Non-Failure
Product #1	3	455	5110 / 7	Non-Failure
Product #2	3	558	5110 / 7	Non-Failure
IPI Stop It	3	558	5110 / 7	Non-Failure

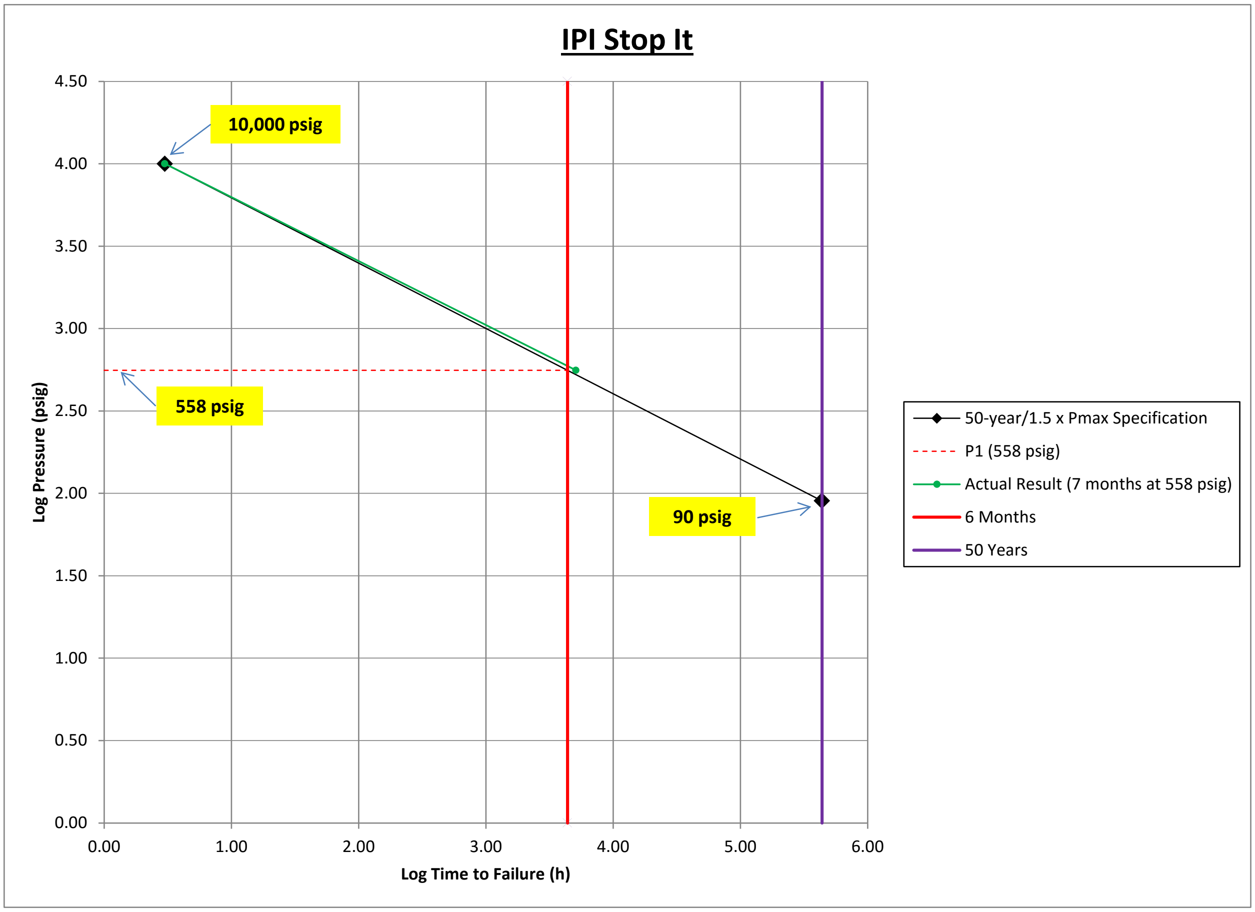

Figure 8. Long-Term Pressure Test Results for Stop It Repaired Specimens

For all four repair systems, the test times of the repaired specimens at each pressure level exceeded the six-month test time predicted by the 50-year/1.5xPmax line. Per GIS/LC8-1:2006 Clause D.7 this validates the integrity of all the repaired specimens over a 50-year lifetime.

Temperature Cycling Testing

This test measures the capability of the repair material to withstand the effects of a fluctuating temperature environment. Three specimens of each repair system were prepared and placed inside an environmental chamber, as shown in **Figure 9**. The specimens were pressurized to 60 psig ± 4 psig and cycled through -20°F to 120°F. The temperature cycling profile is shown in **Figure 10**. The repaired specimens were tested for six months or until failure (leakage) occurred.

A summary of the temperature cycling test results is provided in **Table 10**.

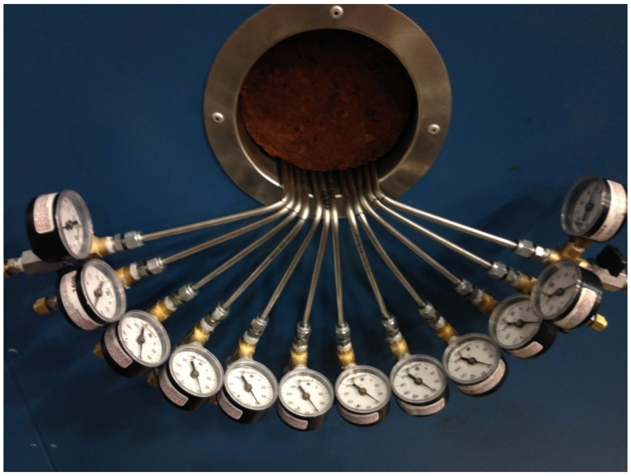

Figure 9. Repaired Samples in the Environmental Chamber

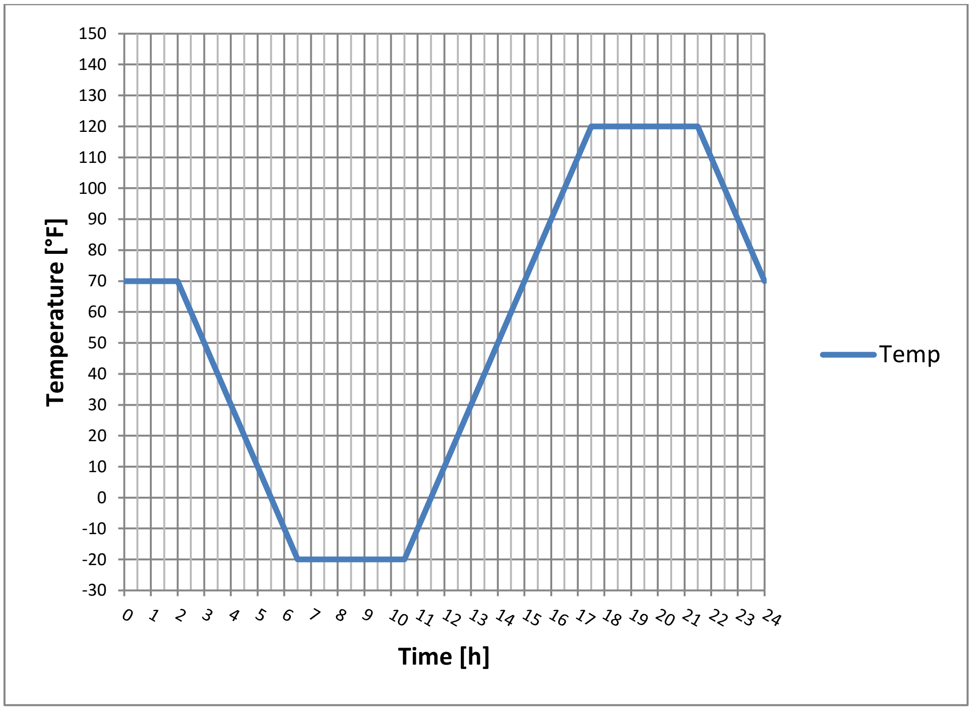

Figure 10. Temperature Cycling Profile

Table 9. Summary of Temperature Cycling Test Results at 60 psig

Repair System	No. of Specimens Prepared	No. of Specimens Failed	Average Test Time (h)	Status
Product #3	3	0	4,464	3 specimens reached 6 months without leakage
Product #1	3	3	360	3 specimens leaked prior to reaching 6 months
Product #2	3	2	1,640	2 specimens leaked prior to reaching 6 months. 1 specimen reached 6 months without leakage
IPI Stop It	3	0	4,464	3 specimens reached 6 months without leakage

The repair systems can be ranked in order of decreasing resistance to temperature cycling as follows:

IPI Stop It ≈ *Product #3* **>** *Product #2* **>** *Product #1*

Conclusions

Based on the testing and analysis performed in this project the performance of each repair product per each test method can be ranked as shown in the table below.

Performance Ranking of the Evaluated Repair Products

Test Method	Product #1 (Live Joint Repair)	Product #2 (Non-Live Pinhole Repair)	Product #3 (Non-Live Pinhole Repair)	Stop It (Non-Live Pinhole Repair)
Cleavage Strength Test	N/A	N/A	Failed	N/A
Impact Testing	Failed	Passed	Passed	Passed
Accelerated Corrosion Testing	Rank: 2nd	Rank: Joint 1st	Rank: 3rd	Rank: Joint 1st
Short-Term Pressure Testing	Rank: 3rd	Rank: Joint 1st	Rank: 2nd	Rank: Joint 1st
Long-Term Pressure/Life Testing	Passed	Passed	Passed	Passed
Temperature Cycling[1]	Rank: 3rd	Rank: 2nd	Rank: Joint 1st	Rank: Joint 1st

[1] Temperature cycling is not a clause in GIS/LC8-1:2006 and was added to the test matrix at GTI's recommendation to test the temperature resistance of the repair method.

Various degrees of performance were observed for each repair product evaluated by each test method. The overall ranking of the repair products based on performance in all of the test methods utilized in this project can be summarized as follows:

Rank	Repair Product
1	InduMar Products Inc. Stop It®
2	Product #2
3	Product #3
4	Product #1

The repaired specimens of all four repair products met the 50-year lifetime integrity validation requirement of GIS/LC8-1:2006 Clause D.7. However, the number one ranking of Stop It® is based on it outperforming the other three repair products in all of the tests performed in this project.

Appendix – IPI Stop It Repair Product Information

STOP IT® Pipe Repair System

The STOP IT® Pipe Repair System restores product flow and profit flow in minutes. Ideal for repairing pipe leaks, reinforcing pipe joints, rebuilding thinning pipe walls and corrosion proofing in virtually any situation – even underwater! It cures to a hard durable repair in 30 minutes.

The STOP IT® Pipe Repair System includes a strong knitted fiberglass tape coated with fast setting urethane resins that are water activated. The system also includes FIX STIX™, a steel filled hand moldable epoxy that sets rock hard in only 20 minutes.

The STOP IT® tape easily conforms to the pipe surface or complex parts and produces a hard protective coating. FIX STIX™ is perfect for plugging leaks, filling cracks and complex voids and offsets at couplings and fittings on any metal or plastic pipe. Using FIX STIX™ in combination with the STOP IT® urethane rich fiberglass tape greatly increases repair capacity. One person, with no special tools and no hot work can apply this quick in-field repair system in minutes.

Whether repairing a chemical process line or any other critical pipeline, the STOP IT® Pipe Repair System is your dollar saving ally in the battle against lost-production costs.

Compatibility and Chemical Resistance

The STOP IT® Pipe Repair tape combined with FIX STIX™ epoxy is compatible with a wide range of chemicals and may be used with any type of plastic or metal piping containing:

- Hydrocarbons (including petrochemicals, fuels, solvents, gases)
- Acids
- Bases
- Water
- Slurries
- Steam
- Organics
- Salts

STOP IT® is compliant with US DOT 49CFR parts 192 and 195. Testing was performed under the ASME PCC-2 Article for ASME B31.1, B31.4 and B31.8

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Technical Specifications

Shelf Life: 2 years from date of purchase

Pressure Retention Capacity: Recommended for pressures up to 400 psi (28 kg/cm², 27 bar)

Temperature/Heat Resistance: From -20° F up to 250 °F (-29 °C to 121 °C) – continuous. From 250 °F to 500 °F (121 °C to 260 °C) – intermittent

Set Time: Tack free in 3 to 5 minutes at ambient temperatures of 50 °F to 80 °F (10 °C to 27 °C)

Cure Time: Cures in 30 minutes at temperatures between 50 °F to 80 °F (10 °C to 27 °C)

Tensile Strength: ASTM D 6039, 24,950psi/in width 172MPa

Tensile Modulus: ASTM D 3039, 62,505psi 430.96MPa

Flexural Yield Strength: ASTM D790, 12,005psi/82.77MPA

Durometer Hardness: ASTM D 2240 63 Type D

Each STOP IT® Pipe Repair System Kit Includes:

- STOP IT® knitted fiberglass tape precoated with water-activated polyurethane resins
- FIX STIX™ hand moldable epoxy*
- Gloves for easy clean up
- Detailed directions

Packaged 10/Case:
2" x 4', 12' (5.08 cm x 1.2 m, 3.6 m)
4" x 12', 25' (10.16 cm x 3.6 m, 7.62 m)

*Included FIX STIX™ hand moldable epoxy is resistant to hydrocarbons and most chemicals and is NSF® certified for use on potable water.

End of Report