Pressure Activated Sealant Technology
Semi-Annual Technical Progress Report
October 1, 2003 to March 31, 2004

Michael A. Romano
April 2004

DE-FC26-03NT41858

Seal-Tite, LLC
500 Deer Cross Drive
Madisonville, Louisiana 70447
ABSTRACT

The objective of this project is to develop new, efficient, cost effective methods of internally sealing natural gas pipeline leaks through the application of differential pressure activated sealants.¹

In researching the current state of the art for gas pipeline sealing technologies we concluded that if the project was successful, it appeared that pressure activated sealant technology would provide a cost effective alternative to existing pipeline repair technology.²

From our analysis of current field data for a 13 year period from 1985 to 1997 we were able to identify 205 leaks that were candidates for pressure activated sealant technology, affirming that pressure activated sealant technology is a viable option to traditional external leak repairs.³ The data collected included types of defects, areas of defects, pipe sizes and materials, incident and operating pressures, ability of pipeline to be pigged and corrosion states. This data, and subsequent analysis, was utilized as a basis for constructing applicable sealant test modeling.
TABLE OF CONTENTS

Disclaimer ................................................................. i
Abstract ................................................................. i
List of Tables .......................................................... iii
List of Graphical Materials ........................................ iv
Executive Summary .................................................. 1
Experimental Apparatus .............................................. 2
Experimental Procedures .......................................... 8
Experimental & Operating Data ..................................... 9
  Task 1: Research Management Plan ........................... 9
  Task 2: Technology Status Assessment ......................... 9
  Task 3: Collection of Current Field Data ....................... 10
  Task 4: Analysis of Current Field Data ......................... 11
Data Reduction ...................................................... 12
Hypothesis and Discussion .......................................... 12
Conclusion ............................................................. 12
References ............................................................. 13
Acronyms and Abbreviations ....................................... 13
## LIST OF TABLES

Table 1: Test Fixture Dimensions ........................................... 3

Table 2: Comparison of Pipeline Sealing Methods ..................... 10

Table 3: Leaks By Cause ..................................................... 12
LIST OF GRAPHICAL MATERIALS

<table>
<thead>
<tr>
<th>Drawing</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test Fixture</td>
<td>2</td>
</tr>
<tr>
<td>Photo 1</td>
<td>Overview of Test Model</td>
<td>3</td>
</tr>
<tr>
<td>Photo 2</td>
<td>Close-up of Test Model</td>
<td>4</td>
</tr>
<tr>
<td>Photo 3</td>
<td>Pig Launcher / Receptor Assembly</td>
<td>4</td>
</tr>
<tr>
<td>Photo 4</td>
<td>Overview of Replaceable Defect Section</td>
<td>5</td>
</tr>
<tr>
<td>Photo 5</td>
<td>Overview of External Corrosion with Pinhole</td>
<td>6</td>
</tr>
<tr>
<td>Photo 6</td>
<td>Close-up of External Corrosion with Pinhole</td>
<td>6</td>
</tr>
<tr>
<td>Photo 7</td>
<td>Overview of Internal Corrosion Defect Section</td>
<td>7</td>
</tr>
<tr>
<td>Photo 8</td>
<td>External Pinhole</td>
<td>7</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

The objective of this project is to develop new, efficient, cost effective methods of internally sealing natural gas pipeline leaks through the application of differential pressure activated sealants. As detailed in the Management Plan this objective will be accomplished through 4 research phases.

At the time of this report we have completed Phase I – Collection and Analysis of Current Field Data. This phase included 3 tasks: Technology Status Assessment, Collection of Current Field Data, and Analysis of Current Field Data.

In the Technology Status Assessment we reported on the current state of the art for gas pipeline sealing technologies, providing pros and cons for those methods, and concluded that if the project was successful, it appeared that pressure activated sealant technology would provide a cost effective alternative to existing pipeline repair technology.

In collecting current field data we chose a 13-year period (1985 – 1997), starting with “Analysis of DOT Reportable Incidents for Gas Transmission and Gathering System Pipelines, 1985 through 1997” and adding additional data from the Office of Pipeline Safety reports as well as operator and service company input. We were able to identify 205 incidents from a possible 1,084 that would have been candidates for pressure activated sealant technology, affirming that pressure activated sealant technology is a viable option to traditional external leak repairs. The data collected included types of defects, areas of defects, pipe sizes and materials, incident and operating pressures, ability of pipeline to be pigged and corrosion states.

During the analysis of current field data candidates for pressure activated sealant technology were identified on the basis of several criteria: Accessibility/Economic Advantage, Leak Severity, Leak Geometry, Minimum Operating Pressure, and Leak Cause. The data collected, and subsequent analysis, was utilized as a basis for constructing applicable sealant test modeling.

During this phase, although overall we were disappointed with the response from customers in reference to leak rates experienced, we made several good contacts. These contacts will be targeted for Phase IV – Field Test of Formulas and Sealants.
EXPERIMENTAL APPARATUS

Our test model was constructed using 168.28 mm (6-5/8”) pipe. As previously reported\(^7\), 168.28 mm (6-5/8”), 323.85 mm (12-3/4”), 406.40 mm (16”) and 508.00 mm (20”) pipe accounted for 56.1% of the incidents. Since pipe size has no relevance for the success or failure of sealant repair we utilized 168.28 mm (6-5/8”) pipe for our test model in order to reduce cost and facilitate ease of handling.

Schedule 80 XS steel was utilized as the pipe material since 204 of the 205 incidents occurred on steel material\(^8\). This pipe has a wall thickness of 11 mm (0.432”), an internal diameter of 146 mm (5.761”) and a Maximum Operating Pressure of 12.36 MPa (1,793 psi) MAOP.

The valves were incorporated into the test model to simulate pressurizing against a closed downstream valve or plug in proximity of the leak site in non-piggable pipeline applications.

Twelve 25.4 mm (1”) nipples were placed in the system to allow for placement of pressure gauges, bleed-off valves, pressure pop-off valves, and ball valves for the injection and discharge of nitrogen, air, water and sealant.

**Drawing: Test Fixture**
Table 1. Test Fixture Dimensions

<table>
<thead>
<tr>
<th></th>
<th>OD, mm</th>
<th>OD, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>168.280</td>
<td>6.625</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>ID, mm</th>
<th>ID, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>146.000</td>
<td>5.761</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>Length, mm</th>
<th>Length, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig Launcher</td>
<td>543.000</td>
<td>21.375</td>
</tr>
<tr>
<td>Pipe Section</td>
<td>1780.000</td>
<td>70.125</td>
</tr>
<tr>
<td>Valve</td>
<td>565.000</td>
<td>22.250</td>
</tr>
<tr>
<td>Pipe Section</td>
<td>2530.000</td>
<td>99.500</td>
</tr>
<tr>
<td>Test Section</td>
<td>1003.000</td>
<td>39.500</td>
</tr>
<tr>
<td>Pipe Section</td>
<td>2530.000</td>
<td>99.500</td>
</tr>
<tr>
<td>Valve</td>
<td>565.000</td>
<td>22.250</td>
</tr>
<tr>
<td>Pipe Section</td>
<td>1780.000</td>
<td>70.125</td>
</tr>
<tr>
<td>Pig Receptor</td>
<td>543.000</td>
<td>21.375</td>
</tr>
</tbody>
</table>

Total Fixture Length 11,839.000 466.000

11.8 meters 38 ft 10 in.

Photo 1: Overview of Test Model
Photo 2: Close-up of Test Model

Photo 3: Pig Launcher / Receptor Assembly
Our test model includes replaceable 3 foot defect sections. Each defect section simulates a type of defect identified during the analysis stage; Defective Fabrication Weld (DFW), Defective Girth Weld (DGW), Defective Pipe Seam (DPS), External Corrosion (EC) and Internal Corrosion (IC). As previously reported\textsuperscript{9}, these defects accounted for 75.6\% of the incidents in our 205 incident base.

The DFW, DGW and DPS defects will simulate common irregularities associated with welds including cracks and wormholes. Since 68.3\% of the externally corroded pipe and 64.1\% of the internally corroded pipe is described as either “localized pitting”, “pinhole” or “pinhole with localized pitting”, the EC and IC defects will simulate localized pitting with pinholes\textsuperscript{10}.

\textbf{Photo 4: Overview of Replaceable Defect Section}
Photo 5: Overview of External Corrosion with Pinhole

Photo 6: Close-up of External Corrosion with Pinhole
Photo 7: Overview of Internal Corrosion Defect Section

Photo 8: External Pinhole
EXPERIMENTAL PROCEDURES

Since this report is being written prior to development of any detailed testing procedures, we will describe proposed general testing procedures.

There will be two phases of testing: Delivery Methods and Leak Sealing.

Since the data collected in reference to the ability of the pipelines to be pigged was considered inconclusive,\(^1\) we will test delivery methods that include piggable, semi-piggable (multi-diameter) and non-piggable pipelines.

The testing of sealant delivery between Polly Pigs represents delivery procedures in pipelines that are piggable. The Foam Pigs would be use for multi-diameter pipelines. The use of Gel Pigs or Gel Spacer would be used in pipelines where the restrictions would not allow even the compressibility of the foam pig to transverse.

We will also test against a closed valve to simulate delivery of the sealant to the leak site by pressuring against a downstream closed valve or plug. Again, we will follow the representative solution with polly, foam and gel pigs for the reasons previously described. The main purpose of the tests is to evaluate the different delivery methods in delivering sealant to the leak site with the least amount of fluid bypass. A short outline of the delivery testing procedures is as follows:

1. Delivery Methods (using colored water)
   a. Between Polly Pigs
   b. Between Foam Pigs
   c. Between Gel Pigs/Spacers
   d. Against downstream Plug/Closed Valve
      i. Followed by Polly Pig
      ii. Followed by Foam Pig
      iii. Followed by Gel Pig

For each type of defect we will attempt to establish a low pressure and a high pressure seal and retest the integrity of each seal after exposure to wire brush cleaning pigs. Since no leak rate data was collected in the collection phase of this project, we will work our way up by establishing a leak rate, test, and establish a larger leak rate and test, and so on until the maximum leak rate that we can seal for each type of defect is determined. A short outline of the sealant testing procedures is as follows:

2. Leak Sealing (using pressure activated sealants)
   a. For each defect
      i. Establish Leak Rate
      ii. Establish low pressure seal
         1. Flush/Remove remaining liquid sealant in system
         2. Measure amount of sealant recovered between pigs
         3. Measure/Observe amount of sealant remaining on pipe wall
         4. Run wire brush cleaning pig
5. Re-pressure test seal
   iii. Establish high pressure seal
      1. Flush/Remove remaining liquid sealant in system
      2. Measure amount of sealant recovered between pigs
      3. Measure/Observe amount of sealant remaining on pipe wall
      4. Run wire brush cleaning pig
      5. Re-pressure test seal
   iv. Evaluate the results seen in the first two steps. Repeat tests at higher leak rates to determine optimum pressure and leak rate ranges

EXPERIMENTAL AND OPERATING DATA

Task 1: Research Management Plan
With the Research Management Plan we defined the objective of the project, “… to develop new, efficient, cost effective methods of internally sealing natural gas pipeline leaks through the application of differential pressure activated sealants” and detailed how we will accomplish this objective. We divided the project into 4 research phases: Collection and Analysis of Current Field Data, Development of Sealant Formulas and Procedures, Laboratory Testing, and Field Test of Formulas and Sealants. We are on schedule with our tasks and at present are working on both Task 5 (Development of Sealant Formulas) and Task 7.1 (Creation of Simulated Leaks). We have the majority of the test model constructed and will be completing the purchase of equipment and supplies shortly. We will be ready to start Task 7.2 (Sealing Simulated Leaks) once sealant formulas and sealant procedures are completed.

Task 2: Technology Status Assessment
We researched the current state of the art for gas pipeline sealing technologies and provided pros and cons for those methods. This was submitted in our Technology Status Assessment. We concluded that if the project was successful, it appeared that pressure activated sealant technology would provide a cost effective alternative to existing pipeline repair technology. A summary of the benefits of pressure activated sealant technology along with a comparison of the sealing methods that was included in the original report is reproduced below.

The Benefits Realized by Development of Pressure Activated Sealant Technology
- Repair of inaccessible pipeline leaks
- Repair of pipeline leaks without a need to excavate
- Significant reduction in pipeline downtime
- Elimination of environmental problems caused by pipeline leakage and excavation
- Significant reduction in the cost of pipeline leak repairs
- Internal repair of pipeline leaks without restricting the host pipe ID
### Table 2 - Comparison of Pipeline Sealing Methods

<table>
<thead>
<tr>
<th>Repair Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>External</td>
<td>Restores Pipe Strength</td>
<td>Excavation Risks &amp; Costs</td>
</tr>
<tr>
<td></td>
<td>In-Service Pipeline Repair</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No Pipe ID Reduction</td>
<td></td>
</tr>
<tr>
<td>Remote/Robotic Welding</td>
<td>Internal, No Excavation</td>
<td>Short Working Ranges &amp;/or Unable to Transverse Bends</td>
</tr>
<tr>
<td></td>
<td>No Pipe ID Reduction</td>
<td>Out-of-Service Repair</td>
</tr>
<tr>
<td></td>
<td>Can Restore Pipe Strength</td>
<td></td>
</tr>
<tr>
<td>Fiber Reinforced Composite</td>
<td>Internal, No Excavation</td>
<td>Short Repair Sections</td>
</tr>
<tr>
<td></td>
<td>No Welding</td>
<td>Reduced Host Pipe ID</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low Pressure Rating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Out-of-Service Repair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time Consuming</td>
</tr>
<tr>
<td>Expandable Metal Patch</td>
<td>Internal, No Excavation</td>
<td>Reduced Host Pipe ID</td>
</tr>
<tr>
<td></td>
<td>No Welding</td>
<td>Coiled Tubing Deployed</td>
</tr>
<tr>
<td></td>
<td>High Pressure Rating</td>
<td>Limited Working Range</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Short Repair Sections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Out-of-Service Repair</td>
</tr>
<tr>
<td>Internal Repair Sleeve</td>
<td>Internal, No Excavation</td>
<td>Reduced Host Pipe ID</td>
</tr>
<tr>
<td></td>
<td>No Welding</td>
<td>Low Pressure Rating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Out-of-Service Repair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time Consuming</td>
</tr>
<tr>
<td>Pressure Activated Sealant</td>
<td>Internal, No Excavation</td>
<td>Dependent on leak size /rate</td>
</tr>
<tr>
<td></td>
<td>No Welding</td>
<td>Min. Pressure Requirements</td>
</tr>
<tr>
<td></td>
<td>Unlimited Working Range</td>
<td>Out-of-Service Repair</td>
</tr>
<tr>
<td></td>
<td>High Pressure Rating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No Pipe ID Reduction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Short Job Duration</td>
<td></td>
</tr>
</tbody>
</table>

#### Task 3: Collection of Current Field Data

We started with the report titled “Analysis of DOT Reportable Incidents for Gas Transmission and Gathering System Pipelines, 1985 through 1997”[14]. This 13-year period was chosen because this was the time frame with the most complete data available. Additional data from the Office of Pipeline Safety reports as well as operator and service company input was added to aid in identifying 205 incidents from a possible 1,084 that would have been candidates for pressure activated sealant technology. This number affirms that pressure activated sealant technology is a viable option to traditional external leak repairs.

In identifying these candidates we not only focused on incidents where Seal-Tite’s technology could have been utilized, but where it would have been the optimum repair method. A database of the 205 incidents and the leak characteristics that defined them as applicable candidates for sealant technology was submitted. This data included types of
defects, areas of defects, pipe sizes and materials, incident and operating pressures, ability of pipeline to be pigged and corrosion states.

During this stage of the project we made several good operator contacts by our participation in seminars, industry conferences and exhibitions and customer demos and presentations in the gulf coast and California. Although we were disappointed with the operators’ willingness to share information regarding leak rates, one operator in particular was extremely forthcoming with most of the other requested information. Some of the contacts made are being targeted for Task 8 - Field Test of Formulas and Sealants.

**Task 4: Analysis of Current Field Data**
The database constructed during Task 3 - Collection of Current Field Data was used as a basis in constructing applicable sealant test modeling.

For ease of reference, excerpts from the original Technical Topical Report, “Analysis of Current Field Data” is included below.

Candidates for pressure activated sealant technology were identified on the basis of several criteria: Accessibility/Economic Advantage, Leak Severity, Leak Geometry, Minimum Operating Pressure, and Leak Cause.

Accessibility/Economic Advantage: The more inaccessible the leak site, the greater the economic advantage. Our database focuses on leaks where accessibility is difficult, time-consuming and costly. 198 incidents (96.6% of our 205 incident base) were either underground, under pavement or underwater.

Leak Severity and Geometry: While no actual leak rates were collected, we know through previous field experience and testing that we can cure leaks in the range of 2.83 – 8.50 cubic meters per minute (100 – 300 scf per minute). Our incident base focused on cracks & pinholes, not ruptures, punctures or tears, which may be out of the range for sealant technology. Narrow leaks, which have more surface area to open area, are easier to seal and have longer seal longevity than circular leaks.

Minimum Operating Pressure: MAOP less hydrostatic (or atmosphere) needs to be near or greater than 200 psi for pressure activated sealant technology to be successful. Our testing will focus on curing leaks with differentials from 1.28 MPa (185 psi) to 9.93 MPa (1440 psi).

Leak Cause: Weld and corrosion leaks accounted for 75.6% of our incident base and 43.8% of all 354 leaks. By focusing our testing on weld and corrosion leaks we will be testing a representative sampling of the majority of leaks that are applicable candidates for pressure activated sealant technology.
Table 3 - Leaks By Cause

<table>
<thead>
<tr>
<th>Number of Leaks by Cause</th>
<th>% of 205 Incident Base</th>
<th>% of All 354 Leaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFW</td>
<td>9</td>
<td>4.4%</td>
</tr>
<tr>
<td>DGW</td>
<td>16</td>
<td>7.8%</td>
</tr>
<tr>
<td>DPS</td>
<td>12</td>
<td>5.9%</td>
</tr>
<tr>
<td>EC</td>
<td>41</td>
<td>20.0%</td>
</tr>
<tr>
<td>IC</td>
<td>77</td>
<td>37.6%</td>
</tr>
<tr>
<td></td>
<td>155</td>
<td>75.6%</td>
</tr>
</tbody>
</table>

DATA REDUCTION
This report contains no reduced data.

HYPOTHESIS AND DISCUSSION
This report contains no hypotheses.

CONCLUSION
To date, the project is on schedule. The time delays encountered in collecting current field data was negated by the reduction in time taken in completing other tasks.

Through research of current state of the art pipeline repair methods and the collection of current field data we conservatively concluded that there is a need and an opportunity for sealant repair technology. Through analysis of the data collected we have identified a representative sampling of the type of leaks and their characteristics that are experienced in gas transmission pipelines. This representative sampling will be the basis for our test modeling

Significant work has been completed in developing sealants and sealant delivery procedures to address the types of leaks and their characteristics previously identified. The second half of this project will conclude the developing of sealant formulas and delivery procedures, test model construction, and testing of sealant formulas and procedures.

Developing sealants to address the types of leaks and their characteristics previously identified will be accomplished by comparing existing formulas to the types of leaks that were identified as applicable candidates and if necessary, modify existing sealants. New formulas will be developed if needed. Analyzing job files and communicating with service companies and operators will aid in the development of piggable and non-piggable sealant delivery methods. These methods will focus on efficiently delivering the sealant to the leak site in an optimized concentrated form.

With the addition of increased air compressor capability, construction of the liquid injection phase of the test model will be complete. Nitrogen injection requirements are still being
evaluated. Sealing simulated leaks will be concluded with the issuance of a test summary report summarizing all test scenarios used in determining optimum formulas and procedures.

Finally, we anticipate evaluating the optimized sealant formula and delivery procedures in an operational pipeline. Field data will be correlated to laboratory data to evaluate the effectiveness of sealant technology as well as delivery methods on pipeline leaks.

If we are successful in our attempts at sealing these simulated leaks then we will be confident in our ability to repair similar leaks experienced in natural gas transmission pipelines.

References


Acronyms and Abbreviations

- DFW: Defective Fabrication Weld
- DGW: Defective Girth Weld
- DOT: Department of Transportation
- DPS: Defective Pipe Seam
- EC: External Corrosion
- IC: Internal Corrosion
- ID: Internal Diameter
- In.: Inches
- mm: Millimeters
- MAOP: Maximum Allowable Operating Pressure
- Min.: Minimum
- MPa: Megapascal
- N₂: Nitrogen
- OD: Outside Diameter
- Psi: Pounds Per Square Inch
- Scf: Standard Cubic Feet
- XS: Extra Strong
- " In.: Inches