THERMOPLASTIC LINERS FOR REHABILITATION OF OIL FLOWLINE AND WATER INJECTION LINES, INTEGRITY AND SERVICE LIFE

Vincenzo Savino[1]
Mauyed S. Mehdi[1]
Abdullah K. Al-Dossary[2]

[1] Saudi Aramco, Consulting Services Department, Dhahran Heights #9155, Dhahran, 31311, Saudi Arabia
[2] Saudi Aramco, Pipeline Department, North Park II #3301, Dhahran, 31311, Saudi Arabia

Keywords: Pipelines, Liners, Corrosion, Polyethylene, Polyamide, Polyvinylidene difluoride

Abstract

Materials selection for pipe and fittings used to convey corrosive fluids has often been a challenge. Traditionally, corrosion resistant alloys (CRA) has been used in corrosive environments despite their high cost. Furthermore, corrosion inhibitors and internal coatings have been also broadly utilized to mitigate corrosion with very variables results, which in some cases have compromised the reliability of the piping system. Plastic lined carbon steel piping offers a cost-effective alternative to these corrosion control methods by eliminating corrosion. Thermoplastic liners offer the combination of corrosion resistance and mechanical strength, which are unachievable with singular materials. Under pressure conditions, the liner is fully supported by the metalwork, while under vacuum conditions, the liner must be thick enough along with venting system to withstand the collapsing forces created by the negative pressure.

Plastic liners have been used successfully to line and protect metallic onshore pipelines for many years and have become an indispensable requirement of the oil and gas industry, particularly with water injection and hydrocarbon services. In the case of internally corroded pipes, the use of thermoplastic liners for rehabilitation is an option to extend the lifetime of companies’ assets, reduce maintenance cost and increase testing and inspection (T&Is) intervals. For new construction, plastic liners in carbon steel pipes can compete technically and economically with pipelines of CRA materials and other corrosion inhibition systems. This paper describes various design features, installations of thermoplasticliners and inspection techniques to ensure reliability during the plastic liner design life.
1. INTRODUCTION

Materials selection for pipes used to convey corrosive fluids has often been a challenge. Traditionally, expensive alloys, corrosion inhibitors and, in some cases, internal coated carbon steel pipes have been selected based on their initial cost against key performance indices (KPIs) of expected service life, corrosion resistance and lead time. Over the years, the utilization of this method to mitigate corrosion has proved to be uneconomical. The effects of continued deterioration of metallic flow lines and pipelines, particularly when the containment is hydrocarbon, could seriously affect the environment and the safety of individuals, in addition to being an extremely costly process to manage and bring back to safe operation.

Thermoplastic liners have long been used as an effective solution to combat corrosion, eliminate the use of toxic corrosion inhibitors, reduce heat loss, which reduces potential pipe buckling, and reduce pumping costs, resulting in a cost savings of up to 25%. Thermoplastic liners are used not only in new pipelines, but more importantly, in lining existing pipelines that suffer from corrosion. Replacement cost of corroded pipelines is often prohibitive, in addition to the extensive production loss, even when traffic disruption is not an issue. Field experience proved that lining is an optimum solution to many hydrocarbon and seawater injection lines.

The cost of a liner is directly proportional to the operating temperature of the fluid. Pipelines containing fluid at temperatures up to 60 °C can effectively be protected from corrosion using high density (HDPE) or medium density (MDPE) polyethylene liners. Those having temperatures up to 80 °C may be protected by Polyamide 11 (PA11) or Polyamide 12 (PA12). Polyvinylidene difluoride (PVDF) liners have been utilized at temperatures reaching 120 °C. The cost of these liners increases as their service temperature increases.

The use of thermoplastic liners for metallic pipe is well documented in NACE RP0304-2004. Service life of thermoplastic PA11 or PA12 is usually calculated using API RP 17B, Canadian Standards Association CSA Z662-03 Oil & Gas Pipeline Systems standard, while CSA Z662-03 addresses requirements for the design, manufacture, installation, operation and maintenance of lined pipelines.

Despite the topics covered in the above standards and the fact that nonmetallic liner solution is a reliable technology to control corrosion in pipeline, end users require techniques to inspect and assess the conditions of the lined carbon steel lines. This paper will describe the use of digital radiography to assess the lined pipe conditions. Furthermore, this paper also highlight the potential of using composite repairs to enhance the mechanical performance of the pipe and the main NDT technology, digital radiography, to inspect through wall defects in the repaired area of the lined carbon steel pipe.

2. PIPELINE REHABILITATION USING THERMOPLASTIC LINER

2.1 Pipeline Preparation

Before inserting the selected thermoplastic liner into the metallic carrier pipe, the inside of the pipe is examined to confirm suitability for insertion of the liner. Checks may include inspection using in-line tools and closed circuit television. This is often followed by passing cleaning pigs to clean the steel pipe to remove deposits, waxes, scales, water and oil. A sizing plate is then pulled through the steel pipe to insure that there are no obstructions due to weld protrusions, dents, ovality, etc. Finally, a section of the selected liner is pulled through the pipe and on its exit; it is visually examined for damage.
Once the carrier pipeline is proven clean, a cable from a winch in the receiving end pulls the liner at a fixed rate, provided the pulling force does not exceed 50% the strength of the liner. This process continues until the section of the liner exits the host pipe ready to be butt-fused together with the next section before pulling it again. The total length of the liner varies between 200-800 meters.

### 2.2 Liner Insertion Methods

Two main techniques are used to obtain a tight fit lining. One of these methods is called the Roller Reduction Box process, by United Pipeline Systems®, where a wire line cable is sent through a section of pipeline and is then attached to the liner pipe. The wire line pulls the internal pipe lining system through the Roller Reduction Box, which is positioned at the insertion end of the pipeline section. The liner pipe, which has an outer diameter larger than the host steel pipe, is temporarily compressed radially as it passes through the roller reduction box to provide sufficient clearance between the steel pipe and the liner pipe to allow insertion. Figure 1 shows the roller reduction insertion process.

While the liner is pulled through the swage, the liner may be pulled or pushed through the rollers in a roller reduction process. In some cases, an axial force, beyond that necessary to insert the liner, is further applied to the liner to prevent its premature recovery during installation. The pulling force will cause the liner to creep axially. Usually the diameter reduction is limited to less than 10% to avoid plastically deforming the liner. After the liner is inserted into the host pipe and any applied tension is relieved, viscoelastic recovery of the liner brings the liner into intimate contact with the host pipe.

The second method of insertion for pressure containing pipelines is the Advantica Swagelining process. The Swagelining process utilizes a thermoplastic liner which has an outside diameter slightly larger than the inside diameter of the pipe to be lined. After sections of the liner are fused together to form a continuous pipe, the pipe is pulled through a reduction die, which temporarily reduces its diameter. This allows the liner to be pulled through the existing pipeline. After the liner has been pulled completely through the steel pipe, the pulling force is removed and the liner returns toward its original diameter by pressing tightly against the inside wall of the host pipe. Figure 2 shows Advantica’s Swagelining process.
2.3 Liner End Termination Techniques

When connecting spools of lined pipe together, it is necessary to ensure that the corrosion protection provided by the liner is continuous across the connection. The end terminations are usually completed using the raised face steel flanges where the liner is flared around the two flanges to protect them from corrosion and to seal the connections when the two flanges are bolted, as shown in Figure 3.

![Figure 3. Flared liner for flange joints in thermoplastic lined carbon steel pipes.](image)

The WeldLink™ compression fitting is another end termination method that is often used when flanges are prohibited, such as in those in offshore applications. This technique permits lined pipe sections to be welded together, eliminating the need for flanges and the potential leaks, particularly in high-pressure pipelines in both onshore and offshore applications.

The WeldLink™ features short sections of the original carbon steel pipe, which are machined to enlarge the internal diameter and then weld deposited with a CRA, usually Inconel 625. These fittings have been proven in a wide range of severe tests, at pressures up to 5,000 psi, and in years of use with high-pressure applications often deep under the North Sea and offshore West Africa. Figure 4 shows the compression ring used in the WeldLink™ technique.
2.4 Gas Permeation through Liners

One of the main characteristics of plastic is its tendency to allow gases to permeate and when used as liners, these gases can be trapped in the annulus between the liner and the host steel pipe. The differential pressure of these gases, typically 4-5 bar (60-72 psi), can collapse the liner, when the pipeline is depressurized. Permeation is primarily a function of temperature, however, an increase in liner thickness, a decrease in system pressure, percent crystallinity, reduced gap between the liner and the host steel pipe can all reduce permeation rates. The liner collapse issue is a major operational problem, and certainly higher permeabilities translate to a faster buildup of annular pressure and greater potential for liner collapse. Lined pipeline where permeation is a concern must be vented.

At each flange pair, provision is made to check and/or bleed off pressure buildup in the annulus between the steel pipe and the liner. Usually, a small hole is drilled through the steel pipe where a tubing and valve are installed for venting of the annulus. These venting points are then interconnected to a common point to check for pressure buildup and bleed off when necessary. The upper limit for the operating pressure is around 5,000 psi and such connection has been qualified to 7,000 psi.

Two venting technologies were developed in a three-phase joint industry program to enhance the performance of plastic liners and to reduce resistance to its utilization\(^2\). The Grooved liner is similar to a smooth liner apart from grooves at its outer surface that were cut to introduce channels to guide permeated gas to the nearest vent, Figure 5. The overall design of this liner is believed to be strong enough to resist creep during its service life and avoid closing of these channels. The perforated liner has several holes that allow permeated gas to flow back inside the liner when the pipeline is depressurized. There are several grooved liners now in hydrocarbon and water injection services, onshore, that have been in operating pipelines for more than 3 years without any problem.

Boreas has introduced their patented venting device, Linervent, to reduce turbulence and enhance geometry of the liner as it ages, see Figure 6. The body of this vent is PEEK, while the micro-porous element is PEEK and PTFE. Corel JIP proved that Linervent was effective in eliminating corrosion.

3. LINERS INTEGRITY ASSESSMENT
To demonstrate the integrity of the liner throughout its life cycle, from construction and installation through commissioning and startup, and finally during operations, is paramount to having confidence in the ability of the liner to serve these purposes. Several different methods of confirming integrity are used throughout these stages, including: visual inspections, pressure testing, annulus pressure monitoring, nondestructive examination and fluid analysis. The integrity of a plastic liner can be manually monitored at each annulus pressure monitoring point, sweet hydrocarbon, or to continuously monitor the annulus pressure by installing pressure transmitters and data collection on a real-time basis. Figures 7 and 8 show radiography shadows for liner defects.

Nondestructive testing (NDT) systems, and in particular Radiography, were successfully used to examine the integrity of plastic liners for aboveground applications. This technique can also be used for underground applications at a riser, plant facility, etc. Intelligent pigging technology, including caliber and vibration measurement may also be used.

It becomes more critical to apply measures to effectively vent the annulus gases to prevent failure of the liners and to provide methods to demonstrate the integrity of the liner in service. It is of importance to have an annulus pressure maintenance strategy, including a system to monitor annulus pressures, and the ability to deal with blockages and restrictions in the venting system that may prevent effective venting.

4. RETROFIT OF THE CARBON STEEL HOST PIPE

As mentioned in the section 2.1, the first step in the installation of thermoplastic liners for the rehabilitation of the internally corroded carbon steel pipe is to inspect and assess the mechanical integrity of the host pipe. If it is found that the host pipe integrity has been jeopardized due to wall thickness loss, either internally or externally, then, composite repair systems can be considered as an excellent option to retrofit the mechanical integrity of the carbon steel pipe. The installation of the liner will mitigate further internal corrosion in the carbon steel pipe. On the other hand, the composite repair will act as a barrier to stop the development of additional external corrosion.

Composite repair systems consist of thermoset resin reinforced with glass, aramid, carbon or combination of these fibers, which are wrapped around the affected area. The use of this type of repairs for pipelines and pipeworks is already contemplated in the ASME standard PCC-2 Repair of pressure equipment and piping” and in the ISO 24817 “Composite repairs for pipework — Qualification and design, installation, testing and inspection”. Figure 9 shows
an example of the installed composite repairs to enhance mechanical integrity of a pipeline.

![Figure 9. Composite repair for pipelines and pipeworks.](image)

Many techniques have been evaluated to assess the conditions of the composite repair and/or the underneath metallic substrate. Digital and Gamma radiography has shown some promising results in identifying through the wall defects in the host pipes. This would allow to assess any change has occurred in the metallic substrate after the composite repair has been installed. Some samples of these techniques are shown in Figure 10 and 11.

![Figure 10. Example of use of digital radiography showing clearly underlying defects and state of the composite repair.](image)  
![Figure 11. Gamma radiograph of through wall defects under composite overwrap repair. Hole diameters are 10 mm, 5 mm and 3 mm.](image)

5. SUMMARY

This paper has provided an introductory discussion on the rehabilitation of a deteriorated metallic pipe structure by insertion and renewal with continuous lengths of a thermoplastic liner. Lining proved to be a cost-effective means by which a new pipeline is obtained. An inherent benefit of the technology is the installation of a new, structurally sound, leak-free monitored piping system with improved flow characteristics. The best feature of all is the vastly improved longevity of the thermoplastic liner, especially compared to the decay normally associated with piping materials of the past.

6. REFERENCES


