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FREE GUIDE: Robotic Sprayed-in-Place Pipelining: The Polyurea Goes Round & Round

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Learning Objectives: Discuss new advances related to polyurea spray used in pipelining applications, compared to traditional technologies of rehabilitation. Achieve an understanding that the polyurea products are: viable alternative to rehabilitation, offer superior abrasion resistance, enable faster production rates and quicker return to service.

ABSTRACT: The polyurea technology is not new to pipelining work, with earlier basic applications dating back more than 15 years. Much of this work was either performed by hand spraying (large diameter pipe) or simple robotic systems for individual joint sections of pipe. Continued work over the years has proven that in-place pipe lines can be commercially completed as well. Recent work has even shown that in addition to long, straight runs, robotic developments have allowed for lining both 45° and 90° radius bends in the pipe line system. Pipe lines of nominal 4" (10 cm) up to 96" (2.4 meter) can easily be accomplished using the polyurea spray elastomer technology and the robotic systems. Newer developments have also demonstrated pipelining of nominal 1" (2.5 cm) diameter with the polyurea technology. These robotic developments work hand-in-hand with special performance modified polyurea systems fine tuned to process on the robotic system, as well as allowing for application thickness of up to 1" (2.5 cm) in thickness in a single pass.

INTRODUCTION:

We Are In Trouble!

Our pipe-line infrastructure is in a sad state. In the US alone, it is estimated that over $1 trillion will be required over the next 25 years just to restore buried water and wastewater lines due to age / deterioration.[1-3]

Almost $350 Billion will be required just for potable / drinking water lines. This does not include all the buried and in-use steam and "chemical pipelines" that are also affected by age. Figure 1 is a typical cross-section of water pipe interior in neighborhood areas.

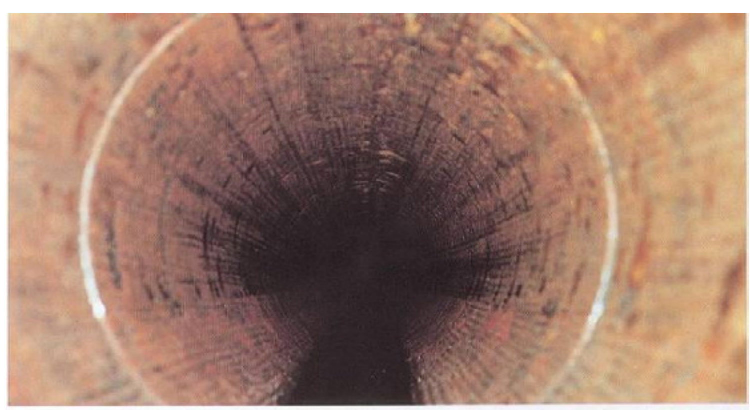

Figure 1:
Water Pipe Cross Section; Buildup / Cleaned

While some feel that corrosion is a large cause of pipeline failures, pipe line flow restriction due to tuberculin type growth is a major concern. This growth can significantly reduce the pipe diameter, thus affecting liquid flow through the pipe, flow back-up and in case of potable water lines, poor water quality and unhappy consumers.

Current pipe materials used in most utility sectors are composed of cast iron, ductile iron, concrete, steel, some asbestos cement or PVC (polyvinyl chloride), and will differ by regions of the country. It is noted that over 65% of all municipal pipeline systems are over 30 years old, with a vast majority being over 50. Some comments note that over 8% are beyond their useful life expectancy in the US market. PVC has been shown to have the lowest failure rates due to the fact that corrosion has been shown to be the leading cause of failures in pipeline system.[4]

Figure 2:
Reuters: Sinkhole in Ohio, 2013

The traditional method has been to dig up and replace the damaged pipe. This creates a very large footprint for excavation, is disruptive and can be a very expensive process. Given the fact that many pipeline systems are a complete maze of cris-crossing of various other pipe lines, many are underneath buildings and other structures, this can be a very impractical process.

Trenchless Methods of Rehabilitation:
Beside the conventional process of digging up and replacing pipeline systems, there are a number of trenchless technology options that are increasing in popularity and use. These options can be up to one-half the overall costs as traditional trenching methods, and as a result are advantageous methods to consider. [5, 6]

Pipe Bursting / Jacking:
This method employs pushing / shoving a slightly smaller diameter pipe into the existing host pipe sections. The "shoved" pipe can include steel, polyethylene (PE) / polypropylene (PP) or PVC. This requires a large "foot-print" of excavation for access to an end of the existing pipe, but not complete excavation. This process does not work well for pipe bends and is more suited for straight runs.

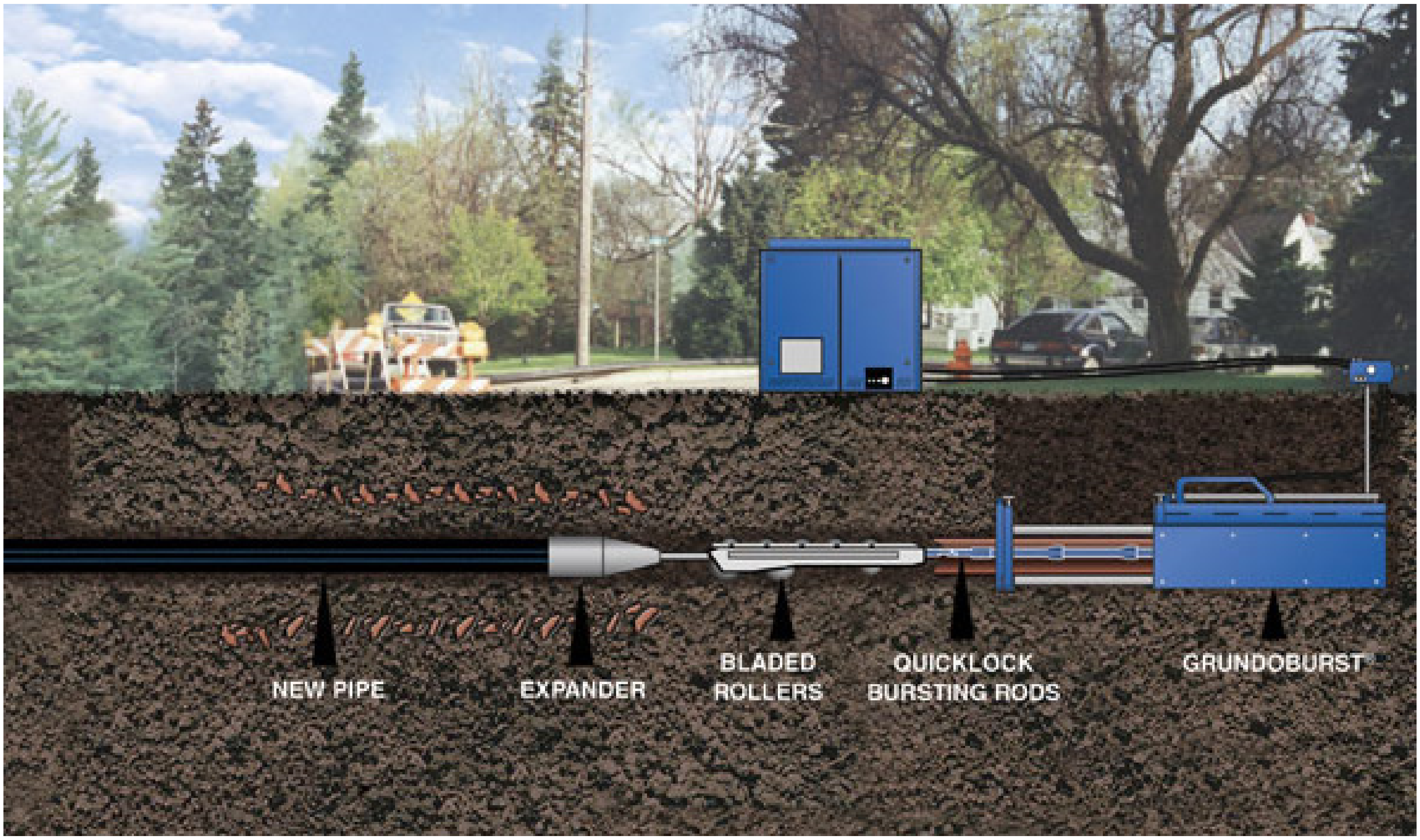

Figure 3:
Pipe Bursting [7]

Cementitious Lining:
This process does provide for a very economical advantage, and we all know that concrete is fairly sound. However, this can not be used in aggressive environments (highly acidic), or where highly abrasive / erosive actions are present. And the concrete can crack over time or in stressed areas. Cleaning of the host pipe is required, followed by minimal surface preparation procedures, SSPC-SP 13.[8]

Figure 4:
Cementitious Lining [9]

Cured-In-Place-Pipelining (CIPP):
An emerging technology that was introduced about 20 years ago and has been used quite extensively is CIPP. A polymer impregnated "fabric sock" is inverted into the end of a pipe section and formed in place to the existing pipe using hot air or hot water. The typical polymer systems are either epoxy or vinyl ester based materials. This process covers lateral intrusion, but does allow for pipe bends. Since the fabric sock is of one size in the run, varying pipe diameters in the system are not completely accommodated and annular space between the CIPP and the host pipe does exist and can lead to leakages.

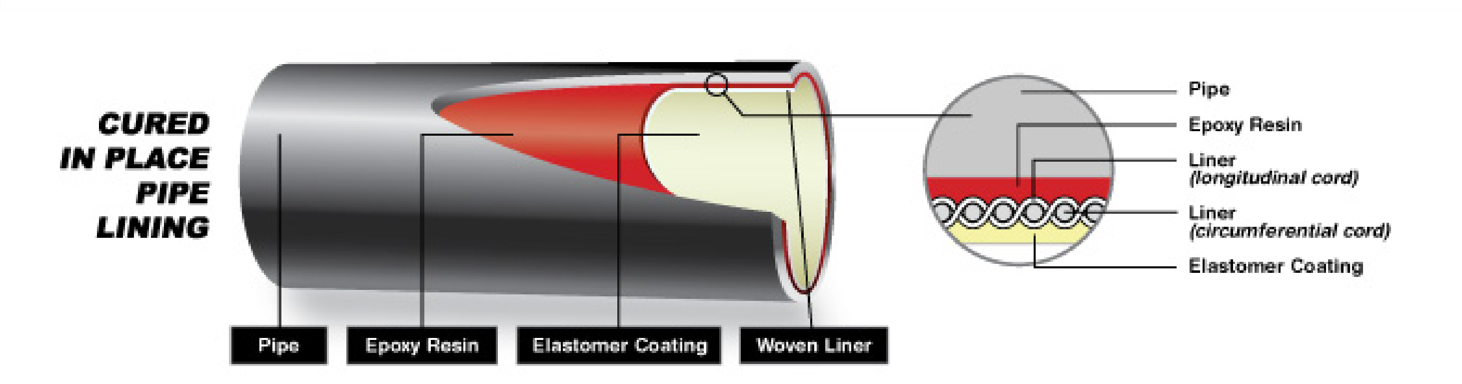

Figure 5:
Cured-in-Place Pipelining [10]

Sprayed-In-Place-Pipelining (SIPP):
A newer concept than CIPP employs the use of robotic application heads to deposit liquid, thin- & thick-film lining systems to the interior surfaces of prepared pipe. This procedure uses polymer technologies such as epoxy, vinyl ester, polyurethane and polyurea. Since the lining is deposited in a "spray" fashion, lateral tie-ins remain open / clear. This process can also accommodate various pipe diameters in length run, as well as radius bends.

SIPP & Polyurea:
The use of the polyurea spray technology is a successful solution for a variety of coating and lining applications. Given the fact of the fast reactivity, makes it ideal for pipe relining work. Couple that with the 100% solids formulation base, numerous environmental and safety concerns can be addressed.[11]

One method is hand spray application. This is well suited for large diameter pipe systems, but impractical for smaller diameter pipe sections. Figure 6 shows the "robotic" lining of a large diameter corrugated culvert pipe. A recent study has shown that when galvanized corrugated pipe is coated / lined with a "plastic" system, 75 year life expectancies can be realized with the pipe system.[12,13]

Figure 6:
Lining Galvanized Corrugated Pipe with Polyurea Spray

For pre-lining joint sections of pipe (Figure 7), a simple "robotic" spray head or a retractable lance spray gun can be used. The pipe is rotated and the spray lance pulled from the pipe. This is a very practical approach and is employed using not only polyurea systems, but also epoxies, polyurethane, etc.

Figure 7:
Lining Joint Sections of Pipe

One area of great concern here though is the use of more elastomeric systems and the point of termination in the pipe. For flanged pipe, the material must be carried out and onto the flange. Otherwise, hydraulic effect from liquid flow could disbond the applied lining causing collapse and plugging inside the pipe. Figure 8 shows an improper termination of applied polyurea inside a flanged joint of pipe.

Figure 8:
Uncoated Flange Area of Line Pipe

This process does work well for joint sections of pipe and is currently being employed for the tailing lines and oil movement for the Oils Sands Project in Ft. McMurray, Alberta. Polyurea lined pipe joints (applied at 150 mils / 3.8 mm) have been in service for approximately 5 years, whereas the carbon steel pipe is typically rotated 90 degrees at flange areas every 3 – 6 months due to erosion.[14]

Robotic In-Place Application:
So how does one effectively rotate a section of pipeline that is already in the ground?

The use of polyurea spray to line the interior of pipe was successfully demonstrated in 1989, with work in the early 1990's.[15] The polyurea system was dispensed onto a spinning disk, and the centrifugal force broadcast material onto the pipe. Contrary to what is thought, the polyurea system used was of a 3 – 6 second gel time. This concept was employed so as to have an "entry free" installation. Figure 9 shows one of the first spray gun / spinning disk setups.

Figure 9:
Spray Gun / Spinning Disk for Manhole Lining

A variety of configurations have been employed depending on pipe internal diameter. This includes rotating a spray gun on a pulled cart, multiple spray guns attached to a large slow spinning plate (vertical work mainly) and spray guns attached to a swinging arm for "ride-on" type units in large diameter application work.[16-20]

The most common methods used to deposit the fast set PUA is use of a high revolution per minute (RPM) spinning cup or with a high pressure, static mix tube fitted with a hollow cone spray tip. For larger diameter pipe work (> 48", 1.2 meter), a robot with rotating plural component spray guns is used. Each of these methods has its own set of characteristics. These are shown in Figure 10.

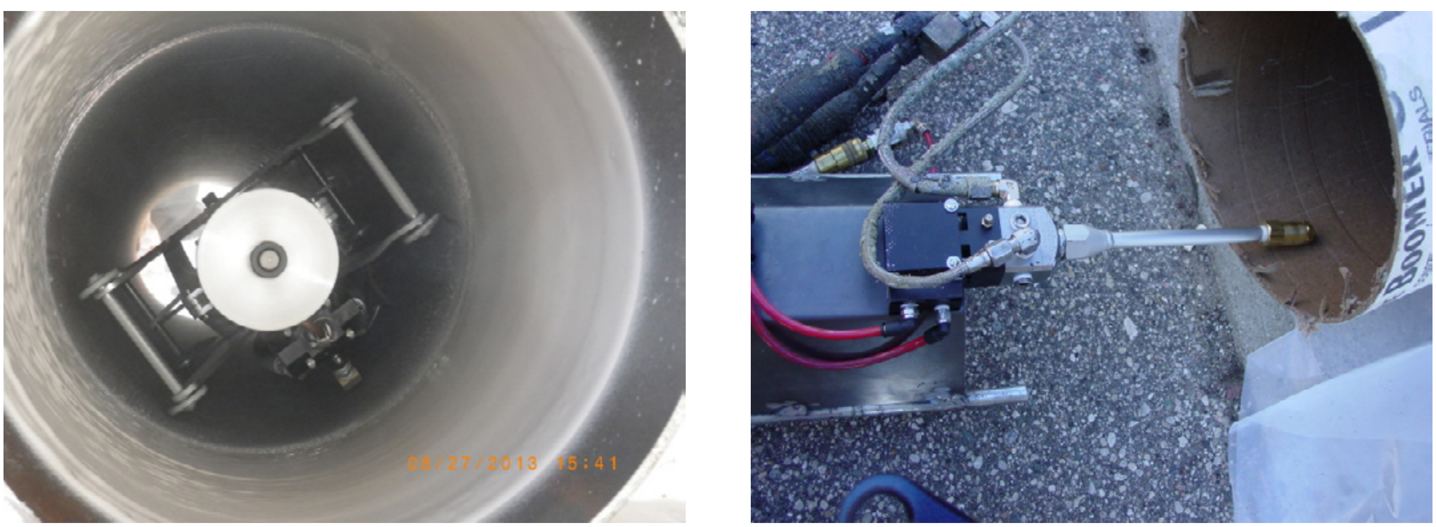

Figure 10:
Commercial PUA Pipelining Spray Head, Spinning Cup & Static Mix

For the spinning cup method, there is also oscillation with movement that simulates hand spray work. This allows for uniform application and keeps the spray orientation perpendicular to the host pipe substrate.[21-23]

Use of the high pressure static mix / hollow cone spray, the spray pattern is not perpendicular to the host pipe substrate. In some cases, depending upon condition of the pipe substrate, this may in fact require a secondary pull through in the opposite direction to insure uniform coverage.

The proportioning equipment used is standard high-pressure, high-temperature plural component equipment to feed the head. The hose bundle, up to 600' (183 meters), is on a computer controlled hose reel. Thus, speed of pull can be adjusted to provide required applied film thickness. Closed Circuit TV (CCTV) are used such that real time visual and recording can be made of the installation work.

Types of Polyurea Used in SIPP:
Depending upon the type of pipelining work to be performed, various polyurea systems can be used to meet the requirements of the application. As noted previously, the polyurea systems used are the fast gel time systems, so that varying thickness of application can be accomplished in one pass through the pipe.[24] Table 1 provides for the basic types of systems.

Table 1
Types of Polyurea for SiPP work

	"Standard"	Semi-Structural	Fully Structural
Flexural Modulus, MPa	~ 345	~ 690	> 1725
kpsi	~ 50	~ 100	> 250
Tensile Strength, MPa	~ 13-20	~ 20-34	~ 28-41
kpsi	2 - 3	3 - 5	4 - 6
Elongation, %	400	250	< 20
Hardness, Shore D	50	58	65
Tg, °C	~ 230	~ 260	~ 170*
Gel Time, sec	6 - 8	6 - 8	6 - 8

Note: relative unlimited applied film thickness
* One example is actually 60 sec gel; modified aliphatic / aromatic PUA, limited film thickness, Tg < 80°C

The following Table 2 provides for the application areas, and the polyurea type used for that work, no "one size fits all." Relevant to the specific industry use, polyurea is very well suited for multiple application options. Based on the water and chemical makeup that the coating will come into contact with, varying degrees of shore hardness and structural integrity of systems are utilized for the best performance needed.

Table 2
Types of Polyurea and Application Area

Industry Uses	"Standard"	Semi-Structural	Fully Structural
Potable Water	yes	yes	yes
Wastewater	yes	yes	yes
Process Water / Salt	yes	yes	yes
Power Generation	yes	yes	yes
Chemical Plants	conditional	yes	yes
Low Pressure Steam	no	yes	yes
Oil Sands	yes	yes	no
Mining / Processing	conditional	yes	no
Deteriorated Pipe	no	conditional	yes

In an effort to further improve application thickness and coverage of the SIPP systems, especially in small diameter pipe (1 to 6 in, 25.4 to 153 mm), equipment and systems have been designed to apply via electrostatic deposition.[25] For this electrostatic work, the polyurea systems must be a slower version to pass through the smaller spray deposition head. These are typically thin-film applications (10 – 20 mils, 254 to 508 μm).

CONCLUSION:

The use of the polyurea technology is a sound and valid solution for pipelining application work. The application of the thick-film system conforms to the interior surface of the pipe with no annular space, as with CIPP, as well as some of the pipe bursting processes. The fast set nature of polyurea technology allows for building nearly thickness of lining material in a single pass, and offers rapid return to service. Since this application process also benefits from the 100% solids nature of the polyurea technology, a safe and more environmentally friendly result is achieved. PUA technology is not experimental, and the lack of widespread, commercially available turn-key equipment will not impede the growth of this process.

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