Polyurea technology is not new to pipelining work, with basic application 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 pipelines can be commercially completed by robotic systems and 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 a pipeline system. Pipelines of nominal diameter (1 inch or 2.5 cm) up to 96 inches (2.4 m) can easily be lined using polyurea spray elastomer technology with robotic application systems. Robotic application development works hand-in-hand with special-performance modified polyurea systems, which have been fine-tuned allowing for application thickness of up to 1 inch (2.5 cm) in thickness in a single pass.

In the United States 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 and deterioration\(^1\)-\(^3\) and almost $350 billion will be required to restore potable and drinking water lines. This does not include all of 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 a residential area. While some feel that corrosion is a large cause of pipeline failures, pipeline flow restriction due to tuberculin-type growth is also a major concern. This growth can significantly reduce the pipe...
diameter, thus affecting liquid flow through the pipe, flow backup, and in the case of potable water lines, poor water quality and unhappy consumers.

Current pipe materials used in most utility sectors in the U.S. 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 percent of all municipal pipeline systems are over 30 years old, with a vast majority being over 50. According to a water main study by the Utah State University Buried Structures Laboratory, over 8 percent of these systems are beyond their useful life expectancy in the U.S. market. As corrosion has been the leading cause of pipeline system failures, PVC has been shown to have the lowest failure rates.

The traditional method of addressing these failures 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, crisscrossing with various other pipe lines, many of which are underneath buildings and other structures, this can be a very impractical process.

**Trenchless Rehab Methods**

Alternatives to digging up and replacing pipeline systems are a number of trenchless technology options that are gaining in use and acceptance. These options can save up to half of the overall cost compared to traditional trenching methods, and as a result are advantageous to consider.

**Pipe Bursting and Jacking**

This method employs forcing a slightly smaller diameter pipe into the existing host pipe sections. The forced pipe can include steel, polyethylene (PE) or polypropylene (PP), or PVC. This method requires a large excavation “footprint” for access to an end of the existing pipe, but not complete excavation. This process is more suited for straight runs and does not work well for pipe bends.

**Cementitious Lining**

This process provides a very economical advantage, and we all know that concrete is fairly sound. However, this method cannot be used in aggressive (highly acidic) environments or where highly abrasive or erosive action is present because the concrete can crack over time. To employ the cementitious lining method, cleaning of the host pipe is required, followed by minimal surface preparation procedures.
Cured-In-Place Pipelining (CIPP)

CIPP is an emerging technology that was introduced about 20 years ago and has been used quite extensively. 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. Because the fabric sock is of one size in the run, varying pipe diameters in the system cannot be completely accommodated. Annular space between the CIPP and the host pipe does exist and can lead to leakages.

Sprayed-In-Place Pipelining (SIPP)

A newer concept than CIPP employs the use of robotic application heads to deposit liquid, thin- and thick-film lining systems to the interior surfaces of prepared pipe. This procedure uses polymer technologies such as epoxy, vinyl ester, polyurethane and polyurea. Because the lining is deposited in a spray fashion, lateral tie-ins remain open and clear. This process can accommodate various pipe diameters as well as radius bends.

SIPP and Polyurea

The use of the polyurea spray technology has proven to be a successful coating type for utilization of SIPP for a variety of coating and lining applications given its fast reactivity and 100% solids formulation base.

One method, hand spray application, is well suited for large diameter pipe systems, but not very practical for smaller diameter pipe sections. A recent study has shown that when galvanized corrugated pipe is coated or lined with a general polymer or “plastic” system, 75-year life expectancies can be realized.5,6

For prelining joint sections of pipe, 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

Table 1: Type of Polyurea for SIPP Work

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>Semi-Structural</th>
<th>Fully Structural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Modulus, MPa</td>
<td>~345</td>
<td>~690</td>
<td>&gt;1725</td>
</tr>
<tr>
<td></td>
<td>kpsi</td>
<td>~100</td>
<td>&gt;250</td>
</tr>
<tr>
<td>Tensile strength, MPa</td>
<td>~13–20</td>
<td>~20–34</td>
<td>~28–41</td>
</tr>
<tr>
<td></td>
<td>kpsi</td>
<td>3–5</td>
<td>4–6</td>
</tr>
<tr>
<td>Elongation, %</td>
<td>400</td>
<td>250</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Hardness, Shore D</td>
<td>50</td>
<td>58</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Tg, C</td>
<td>~230</td>
<td>~170*</td>
</tr>
<tr>
<td>Gel time in seconds</td>
<td>6–8</td>
<td>6–8</td>
<td>6–8*</td>
</tr>
<tr>
<td>- relative unlimited applied film thickness</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 60 second gel; modified aliphatic/aromatic PUA, limited film thickness, Tg<80 C
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<table>
<thead>
<tr>
<th>Trend and Full Rate Graphs</th>
<th>Attribute Information</th>
<th>Actuator Skirts &amp; Dollies</th>
<th>ElcoMaster™ 2.0</th>
</tr>
</thead>
<tbody>
<tr>
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<td><img src="image2" alt="Attribute" /></td>
<td><img src="image3" alt="Actuator" /></td>
<td><img src="image4" alt="ElcoMaster" /></td>
</tr>
</tbody>
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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 1, (p 30), shows an improper termination of applied polyurea inside a flanged joint of pipe. This process does work well for 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 there for approximately 5 years, whereas the carbon steel pipe is typically rotated 90 degrees at flange areas every 3 to 6 months due to erosion.

**Robotic In-Place Polyurea Application**

To effectively rotate a section of pipeline that is already in the ground, the polyurea system is dispensed onto a spinning disk and the centrifugal force broadcasts the material onto the pipe. This method was successfully used in 1989 by the Texaco Chemical Company. The polyurea system used had a 3–6 second gel time. This concept was employed in order to have an entry-free installation.

A variety of configurations have been employed in pipeline polyurea application depending on the internal diameter of the pipe. These include rotating a spray gun on a pulled cart; multiple spray guns attached to a large, slow-spinning plate (primarily for vertical work); and spray guns attached to a swinging arm for ride-on type units in large diameter application work.

The most common methods used to deposit the fast set polyurea (PUA) are a high revolution-per-minute (RPM) spinning cup (Fig. 2, p. 30) or a high-pressure, static mix tube fitted with a hollow cone spray tip (Fig. 3, p. 34). For larger diameter pipe work (>48 inches or 1.2 m), a robot with rotating plural component spray guns should be used. Each of these two methods has its own set of characteristics.

The spinning cup method produces oscillation movement that simulates hand spray work. This allows for uniform application and
keeps the spray orientation perpendicular to the host pipe substrate.

With the high-pressure static mix and hollow cone spray, the spray pattern is not perpendicular to the host pipe substrate. In some cases, depending upon the condition of the pipe substrate, a secondary pull through in the opposite direction might be required to ensure uniform coverage.

The proportioning equipment used to feed the spray head is standard high-pressure, high-temperature plural component equipment. The hose bundle can be up to 600 feet (183 m) and operates from a computer-controlled hose reel so that speed of pull can be adjusted to provide the required applied film thickness. Closed-circuit TV enables real-time viewing and recording of the installation work.

**Polyurea Types Used in SIPP**

Depending upon the type of pipelining work to be performed, various polyurea systems can be used to meet specific application requirements. 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. Table 1 (p. 30) describes these systems.

Table 2 (p. 32) explains polyurea types appropriate for various industry applications. There is 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.

In an effort to further improve application thickness and coverage of SIPP systems, especially in small diameter pipe (1 to 6 inches or 25.4 to 153 mm), equipment and systems have been designed to apply via electrostatic deposition. 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 to 20 mils, 254 to 508 µm).

**Conclusion**
The use of polyurea technology is a valid solution for pipelining application work and the use of a thick-film system conforms to the interior surface of the pipe with no annular space. The fast set of this technology allows for thickness build of lining material in a single pass, and therefore, rapid return to service. Since this application process also employs the same 100%-solids nature of polyurea technology, a level of safety and more environmentally-friendly application results can be achieved. Currently, equipment such as robot spray heads is not prevalent in the commercial marketplace, but the technology itself is moving forward by being specified and used more often.
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