Environmental and cost constraint issues drive the use of liquid epoxies and liquid urethanes for the protection of girthwelds and joints on pipelines.

This article will use case histories to illustrate the field application of urethane and epoxy liquid coatings on girthwelds and appurtenances. Rehabilitation projects provide the backbone of the article. Specific requirements of liquid coatings and performance characteristics are included. The article also discusses why the use of liquid coatings is increasing and spells out the steps for their application.

**Why Liquid Coatings?**

An advantage of using liquid coatings in the place of FBE on girthwelds and joints on pipelines is that, unlike FBE or other powder coatings, under most conditions, liquid coatings do not require extra heat to achieve cure. On-site field application is therefore simplified because only cleaning and application equipment are needed. Recent developments in chemistry and technology have led to liquid coatings with performance characteristics that approach those of FBE coatings (Table 1).

**Fitness for Use**

Two types of information help determine whether or not a coating system is fit for use on a given project. Testing the performance and properties of the system is one source. The other source is performance history of the system in an exposure environment similar to what will be encountered in the upcoming project. Therefore, the first case history in this article reports on the long-term performance of liquid coatings on an underground storage tank. Subsequent cases in the article will report on the performance of similar coatings on pipelines in underground service.

**Case History:**

**Underground Tanks in Italy**

For protection of steel tanks for underground service, the end user originally planned to prime the steel tanks and

<table>
<thead>
<tr>
<th>Test/Property</th>
<th>FBE-Single Layer</th>
<th>Liquid Epoxy</th>
<th>Liquid Urethane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathodic disbondment resistance–14 days, 65 C, 1.5 V, mmr</td>
<td>4.3</td>
<td>6.5</td>
<td>9</td>
</tr>
<tr>
<td>Impact – ASTM G-14 16 mm tup, 24 C</td>
<td>2.4</td>
<td>2.8</td>
<td>3.2</td>
</tr>
<tr>
<td>Material cost per unit volume</td>
<td>X</td>
<td>3.1X</td>
<td>2.6X</td>
</tr>
<tr>
<td>Moisture vapor transmission</td>
<td>1.8</td>
<td>1.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Time to backfill – minutes @ 24 C</td>
<td>–</td>
<td>160</td>
<td>30</td>
</tr>
</tbody>
</table>

**Editor’s Note:** This article was presented at the 16th International Conference on Pipeline Protection in Paphos, Cyprus, November 2 – 4, 2005, and is published in the conference Proceedings.
apply a polyethylene (PE) tape as the corrosion coating. During trials, the application process took several days, and during that time, exposure to the sun caused the tape to disbond. In addition, wrinkling was a problem, as was application to irregularly shaped areas. Follow-up trials showed that a two-part liquid epoxy was a viable solution. Based on technical and application factors, a material was selected, and the tanks were coated. The tanks were transported 300 km, installed, and buried. This project was done in 1992.

Monitoring of the cathodic protection indicated that the coating was performing satisfactorily after 13 years. In April 2005, a support wall collapsed, allowing an opportunity for visual inspection of the coating (Fig. 1). All parties were satisfied with the coating performance.

Five years after the first tanks were coated, a second set of tanks was coated with an epoxy-tar material and installed. An inspection in April 2005 revealed severe disbonding of the coating.

While the project above is a specific case history that shows that liquid coatings can perform well, it also illustrates the importance of material selection and/or application. Liquid coatings have a track record of more than 40 years of performance in pipeline or similar underground situations.

**Application Principles of Liquid Coatings**

The application process for liquid coatings consists of simple steps—cleaning the substrate, applying the coating material, and allowing the coating to cure. Although the process is simple, details of each step are important.

**Cleaning the Substrate**

First, foreign materials, e.g., old coating, dirt, oil, and grease, should be removed. Sharp edges should be ground to approximately a 3 mm radius, and weld spatter should be removed with chipping hammers, files, or grinding wheels. Next, the area should be blast cleaned to an acceptable standard such as NACE No. 2/SSPC-SP 10, Near-White Blast Cleaning. Blast cleaning can be performed with automated equipment (Fig. 2A) or by hand (Fig. 2B).

Blast cleaning also establishes an anchor pattern or surface roughness. Typical specifications call for a surface profile depth of 40 to 100 µm.

Angular media, such as inorganic minerals or hardened steel grit, readily provide a profile depth in that range. Selection and testing of the specific blast media are important. Merely establishing a specified profile depth or peak count does not assure that the coating will perform well.

Removing inorganic salts from the steel surface is critical. Many standards call for reblasting if rust bloom occurs. If rust bloom occurs within a few hours of blast cleaning, it indicates the presence of salt on the steel. Blast cleaning alone is normally insufficient to remove salt. A water or acid wash may be required after blasting or between blast steps.

To prevent the blast cleaning process itself from contaminating the steel, condensate traps should be used to remove potential contaminants—oil and water—from the compressed air.

Fig. 1: Underground Tanks in Italy

Fig. 2: Cleaning the Substrate
that powers the blast cleaning system. After blasting, residual dust should be removed either by vacuum or by blowing down the steel with clean compressed air.

The blast process also roughens and feathers the factory-applied coating.

Application
With 100% solids materials, there are three methods of application—hand (brush, roller, or squeegee), manual spray, and automated spray. Each application technique has its advantages and disadvantages.

- Hand application: Hand application depends on the skill of the operator in both premixing and application. The process is slower than manual or automated spray, is more labor intensive, and brings the operators into closer contact with the coating material—thus increasing the risk of exposure if proper protective/respiratory equipment is not used. Because hand application is a slower process, slow-cure materials are typically used to increase the pot life. That means a longer cure time before burial or handling. Hand application is effective for small coating projects.

- Spray application: Without the addition of solvent, manual spray application requires the use of plural component spray systems (Fig. 3A). These systems are designed to properly proportion the two-component liquid coating, thus reducing the probability of error. There is less handling of the coating material, which reduces the risk of skin contact, but spray operations require respiratory protection for workers. Manual spray is generally faster than hand application.

Spray-grade coatings are designed to react faster than hand-applied coatings, reducing the probability of contamination from flying debris or insects. The process is well suited to large or irregularly shaped objects.

- Automated spray: Automatic spray application requires specialized fit-for-purpose equipment (Fig. 3B). It uses proportioning equipment similar to the type used in manual spray operation. Automated spray is usually suitable for uniformly mixed and shaped objects, such as girthwelds for pipeline coating rehabilitation. It provides greater control over coating thickness and uniformity, thereby saving material. This approach requires more set-up time, but can be much faster than hand or manual spray application.

Coating Cure
The time required for a coating to gel and cure depends on the specific material, the temperature of the steel, and the atmospheric conditions. Urethanes can be designed to cure faster and at lower temperatures than epoxies.

The manufacturer’s data sheet will give the lowest and highest allowable cure temperatures. If the steel or ambient temperature is below the cure range of the specific coating, the manufacturer’s instructions for reheating the steel part should be followed. Without specific instructions from the coating or material manufacturer, a good starting point to ensure cure is to heat the part to about 65 °C (18 F) if the ambient temperature is between -10 °C (14 F) and 10 °C (50 F). If the temperature is below -10 °C, the part should be preheated to about 90 °C (194 F).

If the temperature of the steel part is above 90 °C (194 F), then care must be taken in applying the coatings to prevent volatilization of coating components. One way to avoid the problem is to first apply a thin layer of the coating (250 µm or less) and allow it to gel before applying the remainder of the coating to attain the specified thickness.

Liquid Coatings for Girthweld Protection
Over one million girthwelds have been coated with liquid materials in environments ranging from the tropics to arid deserts8 to the frigid plains of Russia. While two-part liquid coatings have a long track record of performance on steel and as girthweld coatings for FBE, only in the past few years have they been used for girthwelds for PE and polypropylene (PP) three-layer pipe coatings. The critical issue is adhesion to the polyolefin material.

Adhesion Testing
To determine the achievable bond, adhesion tests were conducted recently on a urethane applied to PP. The PP surface was abraded during blast cleaning and thermally oxidized with a gas flame before the coating application. Pull-off adhesion ranged from 12.2 to 13.2 MPa for four tests.9 In all
cases, the failure was in the glue, not in the urethane or the PP, or at the interface between the two.

Case History: Girthwelds in Russia
A urethane coating was selected for this project because it provided a good bond to the three-layer PE pipe coating and performed well on steel pipe.10 Because of ambient temperature in the range of -40°C, additional heat was required to ensure full coating cure. Protective tents were used when blast cleaning and applying the urethane because weather conditions were often poor (Fig. 4A). Under the heating and cleaning tent, the joint was preheated with gas flame (Fig. 4B) and blast cleaned to an anchor profile depth of 80 to 90 µm (Figs. 4C & D). Blast residue was removed with a stream of compressed air. The cleaned joint was covered with PE film to protect it from moisture or other contamination. (Fig. 4E) The heating and cleaning tent was moved, and the application tent was placed over the prepared joint. The PE film was removed, and the joint was preheated with an induction heater to 80–90°C (176–194°F). The liquid coating was applied at 2 mm by automatic spray equipment. After the joint was again heated to 80–90°C (176–194°F), the application tent was moved to the next joint to begin the process again.

Initial issues with coating sag were resolved for a successful application.

Liquid Coatings for Complex Parts

What To Use in the Field
In a plant setting, FBE coatings can be efficient and effective as coatings for large, heavy, or awkward objects, which may require a heating source such as a large holding oven.

Conveniently shaped parts may need a portable induction coil. Large parts also may require the use of specialized application equipment such as a fluidized bed.11

However, except for girthweld coatings, FBE application in the field is normally impractical. Utilization of two-part liquid, ambient-cure coatings allows field application to complex parts.

Case History: Coating Valves in the Czech Republic
Large valves (Fig. 5A) required the in situ application of a corrosion coating. A two-part urethane was selected for application characteristics, cure time, and corrosion-mitigation performance.10 The valves were first blast cleaned to Near-White5 metal (Fig. 5B) and then coated using manual spray application with a plural-component spray unit (Fig. 5C).

Liquid Coatings for Pipeline Rehabilitation

There are many factors to be considered when deciding whether to rehabilitate (replace the coating) on an existing pipeline. These factors include regulatory considerations, unwanted publicity because of environmental damage from a leak, loss of product, customer dissatisfaction, and loss of revenue stream. Economic justification is a major consideration for rehabilitation, and all pipeline operators typically have risk engineering guidelines for operating a safe, reliable, and efficient pipeline system.

Once the decision is made to replace the coating, several factors in the material selection process must be considered, e.g., cost, performance, non-shielding to cathodic protection, application ease and efficiency, and time to backfill.

Cost
The cost of a pipeline rehabilitation depends on many factors, including terrain contours and soil types. Rugged terrain and rocky soil significantly increase rehabilitation costs. In the U.S., typical rehabilitation costs for a 620-millimeter (NPS 24) pipe is in the range of US $100 to US $250 per meter.12,13,14,15 These are generalized numbers; there is a major difference in
costs between rehabilitation in rural farmland and urban neighborhoods.

We have found that the material cost is less than 10% of a project's total cost. Although competitive coating materials must be reviewed, material selection is based on performance, not on cost.

Performance
Most of the requirements for coatings used for a new pipeline are the same as for replacement coatings. These requirements include resistance to soil stress and cathodic disbondment and the ability to retain adhesion in a wet environment. Because the pipe is normally in the ditch at the time of coating application, the ability of the coating to resist damage from handling is not as important as for coatings applied at the factory. However, the coating still needs to resist damage from backfill—impact resistance and gouge resistance are important.

Non Shielding
Cathodic shielding occurs when a barrier prevents current from reaching the pipeline. A disbonded coating that is closely fitting, but not adhering, to the pipeline can allow soil, water, and corrosive materials to flow along the metal surface between the coating and the pipe. If the dielectric strength of the coating is too high, it can prevent the cathodic current from protecting the steel beneath the disbonded coating. Properly designed epoxy or urethane coatings have balanced electrical insulating properties so that they allow enough current to protect the steel, even if the coating becomes disbonded.

The following factors affect the penetration of CP current under disbonded coatings:
- The type of coating
- The thickness and electrical resistivity of the coating
- The composition and conductivity of trapped water
- The presence of corrosion products

Many tests and much of the literature call for coatings used with CP to have high dielectric strength. To preclude shielding, the resistance must be high enough to minimize current flow through the coating, but low enough to allow sufficient current flow to penetrate the coating and protect the steel if disbondment or blistering occurs. Thick coatings with high electrical resistivity can result in cathodic shielding.

Application
All of the application techniques described earlier are used on rehabilitation projects. The method of coating application selected depends on the project size and equipment availability.

No matter what material is selected for rehabilitating pipeline coatings, the same general steps should be taken when applying the coatings in the field.
1. Expose the pipe.
2. Remove the old coating.
3. Inspect the pipe and make needed repair/replacement.
4. Prepare the surface.
5. Apply the new coating.
6. Hydrostatically test the pipe, if possible. If the pipe is removed from the ditch and mechanically worked, it is normally hydrostatically tested before being put into service. The pipe is pressure tested by being filled with water and internally compressed to test the steel strength.
7. Bury the pipe.

An advantage of using liquid coatings on pipeline is that the space below the pipe typically requires 0.5 m or less for blast cleaning and coating application. That means a substantial cost savings in earth removal compared to some coating application procedures that require greater clearance.

Time to Backfill
A rapid-cure coating is advantageous in pipeline coating rehabilitation projects because it allows faster pipeline reburial. This is particularly true where there may be a premium for getting roadways operational in a short time. In general, the chemistry of urethane coatings allows faster backfill times.

Case History: Liquid Epoxy in Alabama
In this case, close-interval surveys showed areas on a pipe that were not fully cathodically protected. Those areas were selected for coating rehabilit-
itation. The old coating was removed by a high-pressure wash; the pipeline was abrasive blast cleaned; and a two-part liquid epoxy was manually spray applied. The application process went well and resulted in a good-looking coating (Figs. 6A–D). The only concern was the amount of time required to achieve the specified cleaning standard, because it increased the time required for the coating operation to be completed.

Case History: Liquid Urethane in Kazakhstan

The object of a project in the Republic of Kazakhstan was to demonstrate the use of a liquid urethane to rehabilitate a pipeline coating at an oil-pumping station in Atyrau. A bell-hole was excavated to expose the buried pipeline. The above-ground portion required a coating that withstands sunlight exposure without chalking. A local contractor carried out the excavation and necessary abrasive blasting to remove the old tar-based coating (Fig. 7A).

The liquid urethane, a 3:1 mixture, was manually sprayed using a system of storage drums, a heating system, a mixing mechanism, and 50 foot umbilical hose with a solvent cleaning system. The equipment and material supplier carried out the spraying (Fig. 7B).

Observers were impressed with the ease with which the material was applied, the relatively short dry-to-touch time and the aesthetics of the surface obtained. Holiday tests at 12.5 Kv, and the 1–2 mm coating thickness passed inspection (Fig. 7C).

Conclusion

Performance characteristics of liquid coatings have shown significant improvement over the past few years. They have gained in acceptance and utility as part of the corrosion mitigation system for all parts of pipeline systems.

References

4. 3M Scotchkote 312 Data Sheet (3M: Austin, TX, 1992).
5. NACE No. 2/SSPC-SP 10, Near-White Metal Blast Cleaning, NACE International, Houston, TX, 1994.
10. 3M SkotchKote 352 Urethane Coating System Data Sheet and Application Instructions (3M: Austin, TX, 2001).
20. 3M ScotchKote 323/323i Liquid Epoxy Coatings Data Sheet and Application Instructions (3M: Austin, TX, 2000).
23. 3M USA, Austin, TX, 2000.
Alan Kehr, technical marketing manager of pipeline coatings for 3M, has 38 years of experience in the pipeline and reinforcing steel coatings industries including research and development of coatings, marketing, and technical service. Mr. Kehr earned his BS in chemistry from the University of Nebraska and an MBA from the University of Texas-Austin. He authored *Fusion-Bonded Epoxy (FBE): A Foundation for Pipeline Corrosion Protection*. He is active in NACE, ASTM, API, and CRSI.

Ray Hislop, graduated as a mechanical engineer and worked as a design & development engineer on diesel engines. During the development of the North Sea oil and gas fields he was involved in technical sales of a range of offshore E&P products. During this period he obtained an MBA (with distinction). Mr. Hislop had his own company for 8 years while working with the Offshore HSE, and consulting on various products. He joined 3M Corrosion Production Products (CPP) in 1999 as northern European sales manager.

Pio Anzalone received a Ph.D. in electronics (bio-engineering) at Naples University. He joined 3M Company’s Joint Copying Tech Department in 1973. In 1980, he moved to the Electronics/Electrical Sales Department. In 1992, Mr. Anzalone became part of 3M’s Corrosion Protection Products (CPP) Department, and he is presently 3M’s CPP South Europe sales & marketing operations manager. Mr. Anzalone is a member of UNI, ECISS, and ISO technical committees.

Alexey Kataev is sales and marketing manager, Oil and Gas Products in 3M’s Moscow, Russia, location. Mr. Kataev has a Ph.D. in polymer chemistry from Moscow State University. He has worked in 3M’s Specialty Materials Division, Corrosion Protection Products since 1993.

Ray Hislop, graduated as a mechanical engineer and worked as a design & development engineer on diesel engines. During the development of the North Sea oil and gas fields he was involved in technical sales of a range of offshore E&P products. During this period he obtained an MBA (with distinction). Mr. Hislop had his own company for 8 years while working with the Offshore HSE, and consulting on various products. He joined 3M Corrosion Production Products (CPP) in 1999 as northern European sales manager.

Pio Anzalone received a Ph.D. in electronics (bio-engineering) at Naples University. He joined 3M Company’s Joint Copying Tech Department in 1973. In 1980, he moved to the Electronics/Electrical Sales Department. In 1992, Mr. Anzalone became part of 3M’s Corrosion Protection Products (CPP) Department, and he is presently 3M’s CPP South Europe sales & marketing operations manager. Mr. Anzalone is a member of UNI, ECISS, and ISO technical committees.

Alexey Kataev is sales and marketing manager, Oil and Gas Products in 3M’s Moscow, Russia, location. Mr. Kataev has a Ph.D. in polymer chemistry from Moscow State University. He has worked in 3M’s Specialty Materials Division, Corrosion Protection Products since 1993.

Alan Kehr, technical marketing manager of pipeline coatings for 3M, has 38 years of experience in the pipeline and reinforcing steel coatings industries including research and development of coatings, marketing, and technical service. Mr. Kehr earned his BS in chemistry from the University of Nebraska and an MBA from the University of Texas-Austin. He authored *Fusion-Bonded Epoxy (FBE): A Foundation for Pipeline Corrosion Protection*. He is active in NACE, ASTM, API, and CRSI.

Ray Hislop, graduated as a mechanical engineer and worked as a design & development engineer on diesel engines. During the development of the North Sea oil and gas fields he was involved in technical sales of a range of offshore E&P products. During this period he obtained an MBA (with distinction). Mr. Hislop had his own company for 8 years while working with the Offshore HSE, and consulting on various products. He joined 3M Corrosion Production Products (CPP) in 1999 as northern European sales manager.

Pio Anzalone received a Ph.D. in electronics (bio-engineering) at Naples University. He joined 3M Company’s Joint Copying Tech Department in 1973. In 1980, he moved to the Electronics/Electrical Sales Department. In 1992, Mr. Anzalone became part of 3M’s Corrosion Protection Products (CPP) Department, and he is presently 3M’s CPP South Europe sales & marketing operations manager. Mr. Anzalone is a member of UNI, ECISS, and ISO technical committees.

Alexey Kataev is sales and marketing manager, Oil and Gas Products in 3M’s Moscow, Russia, location. Mr. Kataev has a Ph.D. in polymer chemistry from Moscow State University. He has worked in 3M’s Specialty Materials Division, Corrosion Protection Products since 1993.

At Indian Valley Industries, we produce containment tarps with a simple theme. Understand fabrics, provide standard and custom sizes, maintain quality workmanship, and offer value to the customer.

With 60 years experience, we practice this every day to ensure that the construction and painting contractors have what they need to get their job done. Contact us to see how easy it can be.

Indian Valley Industries, Inc.
Quality and Service Since 1940
Call Toll Free - 800.669.5111

Click our Reader e-Card at paintsquare.com