WHITE PAPER

Choosing a Coating for External Pipeline Protection

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Underground environments place harsh demands on buried metal pipes, making them vulnerable to corrosion and other forms of damage. Choosing the appropriate external coating to protect these valuable assets is critical.

External coatings are the first line of defense for buried metal pipelines. They serve as a barrier that separates the metal from the surrounding soil or water, which, acting as electrolytes, can set off corrosive electrochemical reactions. Furthermore, contact with abrasive environments can inflict mechanical damage to buried pipelines and shorten their useful life. Selecting coatings that protect pipeline integrity are therefore critical to pipeline reliability and longevity.

But no coating is perfect, even on day one, and all coatings degrade or become damaged over time. Because most pipelines are designed to operate for 20 years or more, and many are in the ground for much longer, a secondary form of protection, cathodic protection, may be needed to protect compromised areas of the pipeline coating.

Cathodic protection prevents exposed metal surfaces from oxidation (rusting) by providing a continuous direct current (DC) to a pipeline. The current is distributed to the pipeline via anodes buried in the ground nearby. By continuously supplying protective current to the pipeline, the current effectively halts the rusting process, protecting the metal from corrosion. Since only metal in direct contact with the soil requires additional protection, an effective coating system significantly reduces the amount of cathodic protection current needed. This synergy enables the use of smaller, less expensive rectifiers to supply current. It also allows for the possibility of using passive, galvanic protection methods instead of an external power source to provide cathodic protection, further optimizing operational costs.

Coating Properties to Consider

When choosing an appropriate pipe coating system for a given application, engineers evaluate multiple properties and performance factors that collectively determine the coating's effectiveness and durability:

- **Abrasion and impact resistance.** Pipelines face damage risks long before they become operational. For example, they can be scored or dented during transport or installation. Trenchless installations like horizontal directional drilling and open-cut installations in rocky areas can scratch, gouge and nick the pipe. Accidental strikes are also possible when third parties are installing foreign utilities or roadways nearby. All these installation and operation conditions point to the importance of selecting materials with the abrasion- and impact-resistance needed for pipeline longevity and reliability.

- **Environmental and chemical resistance.** A coating must be able to withstand the conditions of the underground environment as well as the process medium passing through the pipe itself. Potentially deteriorating conditions can include seasonal temperature changes and constant exposure to moisture. The coating should also be able to resist degradation from low or high pH soils and the chlorides, sulfates and other corrosion-inducing ions in the environment. Additionally, the coating must prevent water and oxygen from penetrating, which could accelerate corrosion and compromise pipeline integrity.
- **Adhesion.** To prevent the formation of corrosion-causing air or water pockets, it is crucial for a pipe coating to remain firmly adhered to the pipe surface. In pipelines with cathodic protection systems, strong adhesion is also essential for resisting cathodic disbondment, a condition where the electrical current causes the coating to detach from the metal surface, allowing moisture and corrosive elements to penetrate and the natural corrosion rate to accelerate.
- **Flexibility.** Flexibility is another critical property for external pipe coatings, as it allows the coating to withstand various physical stresses without cracking or creating weak spots. During installation, pipelines often need to be cold bent (field bent) to fit the terrain or routing requirements, or elastically bent during HDD operations or lowering in, and a flexible coating makes that possible. Additionally, soil settling and seasonal temperature changes can cause the ground or pipe to expand and contract, causing stress on the coating. A flexible coating can accommodate these movements, maintaining its protective seal and preventing cracks that could allow moisture and corrosive elements to reach the pipe surface.
- **UV resistance.** Sunlight poses risks to pipe coatings made of epoxy and other UV-sensitive materials. While not a concern for pipes installed underground, sunlight can break down and damage these coatings when pipes are stored outdoors prior to installation, creating considerable risks for projects facing long construction delays.
- **Weight for buoyancy control.** Coating weight is not usually a primary consideration for buried pipes. However, selecting a coating with the optimal weight can help control buoyancy for large-diameter pipes installed underwater or in flood-prone areas. For example, several inches of concrete coating applied to the pipe exterior may prevent the pipeline from shifting due to flowing water or changes in water level, thereby reducing the risk of damage, leaks or failure. Concrete-coated pipes also provide additional protection from scour and erosion in environments such as turbulent channelized water or tidally influenced zones.
- **Ease of application.** Coatings that are simpler to apply tend to result in fewer mistakes and result in a more uniform and reliable protective layer. For example, powder fusion coatings can provide a consistent finish without the need for additional solvents or primers, making them relatively easy to apply in controlled environments. Controlled shop conditions also make it easier to achieve the desired coating thickness and performance. Temperature and humidity requirements during application should also be considered, as they can affect coating adhesion and the curing process.

Common Types of Pipeline Coatings

To make an informed decision on coating choice, it's important to understand the options available and their advantages and disadvantages in the application under consideration. Solutions include:

- **Fusion-bonded epoxy (FBE).** These thermosetting coatings, which offer excellent corrosion, temperature and chemical resistance, are the standard choice for U.S. oil and gas pipelines. FBE coatings are formed by heating and fusing an epoxy powder onto the steel pipe surface. An epoxy topcoat can be added while the pipe is still hot. Commonly applied in a controlled shop environment, FBE can be used in either a pipe interior or exterior and is typically 12 to 18 mils in thickness. Major manufacturers of FBE include Sherwin-Williams, Valspar, 3M and Jotun.
- **Liquid epoxy.** Epoxy coatings are well-suited for virtually all applications, including field joints, welds and holiday repairs. They can be either spray-applied or rolled/brushed onto a steel surface. However, they are susceptible to damage from sunlight and UV radiation.
- **Abrasion-resistant overcoat (ARO).** Some applications benefit from an additional layer of abrasion, impact and friction protection in high-wear areas of a pipeline. An ARO provides targeted protection against mechanical

stress as a complement to broader protective coating systems. Often applied to pipelines installed in rocky soil or trenchless crossings, AROs provide an additional layer over an FBE. A variety of tapes and wraps are available that provide these protections. Common ARO manufacturers include 3M, Valspar, Sherwin-Williams and Powercrete. Canusa-CPS ScarGuard is a commonly used wrap.

- **Two-layer and three-layer polyethylene/polypropylene (PE/PP).** These coatings are the standard choice for European oil and gas pipelines. The first layer of these coatings can be an epoxy (FBE) or asphalt adhesive primer that adheres to the steel pipe surface. The outer layer is either PE or PP, sometimes with a copolymer adhesive sandwiched in between to provide strong bonding. These coatings are typically shop-applied using powder coating techniques and then fused together by heating, resulting in a thickness of 100 to 150 mils. Compared to FBE coatings, two- or three-layer PE/PP coatings provide better protection against corrosion and abrasion. However, they raise some concerns related to cathodic protection shielding, which must be carefully managed during installation and operation.
- **Coal tar, coal tar enamel, asphalt enamel, bitumen and tar set coatings.** Before the introduction of FBE, this category of similar protective coating materials was widely used to protect buried pipelines and metallic structures. Coal tar has strong adhesive properties and is highly resistant to moisture and chemicals. However, its effectiveness is limited compared to modern coatings, and it faces stricter regulatory restrictions. Additionally, these coatings may or may not be compatible with newer epoxy coating systems, so careful evaluation is needed prior to final product selection and application.
- **Wraps.** Vinyl, bitumen and wax tapes and heat shrink sleeves are often added on top of other coatings to provide an additional layer of pipeline protection, especially in areas where pipelines are exposed to harsh environmental conditions or mechanical stresses. Wraps are applied directly on-site during pipeline construction or maintenance. After an adhesive compound is applied to the host pipe, the tape or sleeve is added to create a continuous barrier of protection. While presenting fewer environmental and health concerns than liquid coatings, wraps have limited long-term effectiveness and are most appropriate when used as an additional layer of protection over other coating systems. Tape wraps can be applied more easily in the field than other coatings and may be an inexpensive option for some small repairs and other applications. However, due to the manual method of installation, field labor costs may be high for large wrap applications.
- **Asbestos.** Due to the health risks associated with asbestos exposure, the historic addition of asbestos fibers to coatings has been largely discontinued and is now heavily regulated or banned in many countries. Often found in legacy systems, asbestos may require specialized abatement when encountered.

Coating Application Considerations

Coating success takes a team effort. An effective pipeline coating strategy considers every step in the engineering, procurement, installation and inspection process. For example, appropriate handling procedures must be followed to maintain the coating's integrity. Pipes should be lifted, transported and stored using methods and equipment designed to minimize damage to the coating. Recommended practices are provided by the American Petroleum Institute.

A coating is only as good as the preparation of the pipe surface. In fact, most coating failures are attributed to poor surface prep and application. Repairs become necessary when coatings are damaged or when coating gaps and defects are detected. Surface preparation is best managed when pipe coatings are applied in a controlled, indoor environment. Residual magnetism (degaussing), dirt, dust, moisture, chlorides and all other contaminants must be removed from the pipe surface to provide good coating adhesion. In-shop repairs can also be performed with precision, using the same materials and methods as the original coating.

Not every coating, however, can be applied in a shop. Welds, joints and many repairs are typically performed in the field, where weather conditions, dirt and dust can affect coating performance and quality. Surface prep is especially critical in these field-applied repairs, starting with the removal of any prior coatings, corrosion and foreign material. It's also important for the installation contractor to develop a surface profile that promotes adhesion of the new coating to the pipe surface. In some cases, epoxy or metallic conversion coatings may be used as primers to bind the pipe to the topcoat.

No coating application is complete until a certified coating inspector has inspected the final product and documented the location of any damage, along with the thickness, adhesion, curing and other details about the repair. Inspections are necessary for new coatings and repairs in both shop and field applications.

Choosing an Appropriate Coating

Not all coatings are created equal. FBE may be favored for its excellent adhesion and corrosion resistance in a variety of environments. A three-layer PE coating, however, could provide the additional mechanical protection needed for harsh conditions. Liquid epoxies may be preferred for their usefulness in field applications. Tape wraps can be useful for temporary repairs or additional protection in aggressive soil locations.

Given these and other considerations, the engineering and specification of a coating system requires forethought and planning. This is especially true if the pipeline system is unique or the environment where it will be installed poses unusual environmental challenges.

When evaluating coating options, engineers consider the pipeline's operating temperature, along with anticipated soil or rock conditions, UV exposure and potential mechanical impacts. Air-to-soil transition zones can be particularly corrosive, as can pooling water or snow at grade. These expected operational and environmental conditions must be evaluated holistically for proper base coating system selection; in some cases, additional topcoats or other coating provisions may be required for extra protection.

Ultimately, coatings should be chosen for their ability to address the specific corrosion threats present at a given site. Care must also be taken to see that the coatings applied to pipe joints are compatible with those on the pipe body. For instance, an FBE-coated pipe body might have a liquid epoxy coating at its joints. Coating compatibility is necessary to prevent disbondment or other issues that can lead to corrosion. To avoid creating weak spots, repair coatings should have similar or better properties than the original.

Choosing the right coating for a given application, in other words, can be more complex than it appears. It depends on coordination between a pipeline operator's corrosion and integrity teams and their input on environmental conditions, corrosion risks and inspection findings. By selecting the appropriate coating, adequately preparing the host pipe's surface and following the manufacturer's application instructions, pipeline operators can significantly reduce the risks of corrosion, leaks and other failures.

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