Corrosion Under Thermal Insulation

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Corrosion under thermal insulation is a major problem in a variety of industries. Whether the pipe or other structure is buried or above ground, proper design and installation techniques can control corrosion. Insulation normally becomes wet as a result of poor installation practices or a failure to install sufficient vapor barrier and waterproofing materials. Moisture in insulation increases heat loss and deteriorates the insulation. This article discusses the proper selection, installation, and use of coatings on the metal before the insulation is applied.

Thermal insulation must remain dry to retain its insulating properties and to prevent corrosion of underlying metal. Saturated insulation is considered extremely detrimental, even dangerous, because of the potential for corrosive failure of the piping. Concentration cells, temperature differences, and wetter vs dryer areas cause corrosion—as do chlorides and other contaminants. Contamination may also be present on the metal surface before it is coated or insulated. Once these areas become wet, corrosion can occur.

NACE Standard RP0198-98[1] is a useful guide to preventing corrosion under thermal insulation.

Corrosion Control

The most effective way to control corrosion under insulation is to prevent the electrolyte from reaching the metal surface with a properly applied coating on the pipe. Pipe coatings have been used successfully for many years. Insulated underground systems have been well protected by first coating the pipe and then properly sealing the insulation with a vapor barrier or weather barrier jacket.

Coating Selection Criteria

OPERATING TEMPERATURE(S)

Some coatings work well in cold temperatures (–60 to 32°F [–51 to 0°C]) while others work well at high temperatures (150 to 300°F [66 to 149°C]). Most coatings function well in temperatures ranging from 32 to 150°F. The coating must be flexible enough to withstand the expansion and contraction of the piping when temperatures cycle. Temperature fluctuations can reduce adhesion between the coating and the metal, allowing water to penetrate to the pipe. High temperatures cause some coatings to flow, crack, or sag. Some coatings become brittle and less flexible as a result of low temperatures.

APPLICATION REQUIREMENTS

Some coatings require extensive surface preparations while others can be applied with minimal surface preparation and application equipment. If a new system is being built, the components can be easily coated in a plant before construction begins; only the weld areas or flanges need to be coated during construction. Existing piping can be coated in-place, but surface preparation and coating may be difficult.

Liquid coatings may be applied by brush, glove, or spray methods. Tape coatings may be applied in a cigarette wrap or by spiral wrapping—such coatings affect the inside diameter (ID) and fit of the insulation. Shrink sleeves and some tapes are applied by using heat. Fusion-bonded epoxy (FBE), applied to a hot (normally 450 to 488°F [232 to 253°C]) pipe surface, is normally plant-applied. Multilayer coatings, such as FBEs covered with polyolefins, are also factory applied.

Once piping is installed, coating application becomes much more difficult because of confined space, possible damage to other components, and safety and environmental constraints. Inspecting the pipe to ensure proper coating coverage and thickness is a very cumbersome process.

SURFACE PREPARATION REQUIREMENTS

Surface preparation is the most critical part of any coating process. Blasting helps to clean the surface, and it provides the proper anchor pattern for the coating. Before blasting, oil, grease, or other debris must be properly removed. Contaminants on the metal surface, such as chlorides and other salts, must be removed by proper washing and rinsing. Proper blasting usually removes mill scale, rust, and other such surface contaminants. Wire brushing by hand or machine is acceptable for some types of coating, and it may be the only method available for some situations. Water-blasting, with and without abrasives, may be used for other situations.

ENVIRONMENTAL REQUIREMENTS DURING SURFACE PREPARATION AND APPLICATION

If the surface preparation and coating process take place outside, weather conditions (temperature, wind, humidity, rain, snow, etc.) are very important. In plant applications, environmental conditions usually are controlled. It is also critical to consider health concerns of employees and the surrounding community during the process.

COATING MUST BE COMPATIBLE WITH THE INSULATING MATERIAL

Some types of insulating materials may be abrasive (e.g., cellular glass); as the pipe moves, the coating material could be damaged. Other materials may cause the coating to deteriorate, become soft or brittle, or lose other properties (especially if the insulation becomes wet). The thickness of most coatings is within the tolerance of the ID of insulation products. Insulation ID may have to be altered to provide products that fit over certain coatings. Consider both coating selection and insulation specification when specifying a system. Because some corrosion coatings attack fabricated foam insulations in their "wet" state, coatings must cure prior to insulation installation.

Coating Tests

Tests provide excellent information to assist in choosing a coating that will perform well. Although short-term testing gives limited results, it usually distinguishes poor coatings and their more effective counterparts. Long-term testing provides superior results, but time restraints can be a concern. There are, however, published test data that assist in preparing coating and insulation specifications. Actual results from field evaluations provide the best results. Tests should always be performed in conditions that are similar to, or worse than, the service conditions.

Vendor Selection

There is a wide variety of coating products and materials available today. Vendors are helpful in providing information, but some may only be trying to sell a product. Those who provide good outside test data and references or field resource people are the best choices. Technical support from the coating manufacturer is a must for new systems.

Coating Specifications

Another important factor is to provide a well-written set of specifications that details the coating process. Specifications should include surface preparation, application, and production testing. Consider industry standards; they normally provide basic surface preparation and coating application guidelines. Each coating system should have a specification that will give particular requirements for that coating.

Inspection

To ensure that the coating and surface preparation are properly performed, an inspector is essential. Management often questions the cost of inspection, but coating failures are much more costly.

Knowledgeable inspectors understand proper surface preparation, surface profile, and environmental conditions. They also ensure the coating is properly applied in the right conditions, at the correct thickness, and has been allowed to cure properly without defects or holidays.

Coatings should be holiday-tested with direct-current holiday detectors before installing the insulation material. Contact the coating supplier for the correct voltage and type of detector to use. The insulation procedure must also be inspected to ensure the coating is not damaged.

Coating Applicator

Choose a coating applicator who has experience with the particular surface preparation and coating, has the required equipment, and is willing to work within the specifications. If an owner applies the coating, the coating manufacturer usually provides on-the-job training. Selecting an applicator based only on cost is extremely unwise. Analyze the bidding process for cost, process, and competence.

Types of Coatings

LIQUID COATINGS: EPOXIES

Liquid epoxies are a good choice for insulated pipe. Basic epoxies are two-component materials that are mixed and normally applied by spray or brush. Epoxies must be mixed in the proper ratio. If the mixture is not correct, the epoxy will neither cure nor perform properly.

Most epoxies are flexible, cure quickly, and adhere well to the pipe surface. Most resist many chemicals and abrasion and can be applied in one coat. Epoxies do require very good surface preparation, and some can be very brittle and may crack during temperature fluctuations. One must study, test, and select the proper epoxy for the service temperature range.

Epoxy phenolics are excellent coatings for higher-temperature applications (up to 300°F). They are applied using heated plural-component equipment by experienced applications. One coating that has been used in other industries for years is a modified epoxy phenolic, which offers good abrasion resistance and is more flexible than most epoxy phenolics.

LIQUID COATINGS: URETHANES, POLYURETHANES, AND POLYUREAS

Urethane, polyurethane, and polyurea coatings are often ideal for high-temperature service, although most urethanes are unsuitable for temperatures >150°F. Urethanes are flexible and can be applied in one thick coat with a heated plural-component spray system, but moisture can be detrimental to some urethane applications. Moisture-cure urethanes do exist, however, and they perform well where moisture is a problem during application.

Polyureas are being developed for this application, but presently they do not adhere to steel as well as some other coatings. Polyureas are very flexible and are expected to perform well at higher temperatures (up to 300°F).

TAPES

Tapes can provide excellent corrosion protection for pipes that operate at 150°F or less. When surface preparation is difficult, tapes may be the best choice. Most tapes require a primer to adhere properly to the pipe. The primer must cure before the tape is applied. Proper overlap coverage and sealing are critical.

Tapes vary from 25 to 100 mils (635 to 2,540 µm) in thickness, being twice that at overlap areas. The insulation must be ordered with an ID that will properly cover the coating at the seams. A combination of liquid and tapes can be used for irregular shapes.

Polyethylene (PE)-backed tapes can be used on the external surfaces of insulation for waterproofing. If selected and applied properly, they provide good service—especially for underground applications. PEs are easily damaged by ultraviolet rays if they are used outdoors.

There are wax-based tapes that are easy to apply but are not used when temperatures get above 72°F (22°C). Furthermore, they are not abrasive-resistant.

BRUSHABLE COAL TAR OR ASPHALT-BASED COATINGS

Asphalt- or coal tar-based materials are easily applied by brush or paint glove in one or two coats. Their surface preparation requirements are less stringent than those of many other coatings. The coatings are very good for irregular shapes, are flexible, adhere well to steel, resist most chemicals, and can be easily repaired. They have fair abrasion and impact resistance, although they require time to cure properly. The coating should be cured before the holiday detector test is performed. At temperatures <0°F (–18°C), this type of coating may become less flexible. At temperatures >120°F (49°C), some of these coatings may become too soft or run to the bottom of the pipe. However, there are coal tar- or asphalt-based coatings that perform well at much higher temperatures; proper testing helps to identify such coatings.

MINERALIZATION COATING

A mineralization coating creates a mineralization bond 50 Å (5 nm) deep into the metal surface. It is effective between –50 and 160°F (–46 and 71°C). Corrosion cannot take place in this mineralized layer on the pipe.

Compromising the vapor barrier allows moisture to travel directly to the pipe surface and remain there, without corrosion taking place. Excess coating from the installation process reacts with the moisture, chemically buffering the water into a solution that does not corrode the pipe.

FBE AND MULTILAYER COATINGS

FBE and multilayer coatings normally are plant-applied because the process involves heating the metal surface to 450 to 500°F (260°C). The FBE powder is then sprayed on the prepared surface, where the powder melts, flows into the anchor pattern, gels, and cures. The entire cure process takes 1 to 3 min. FBE requires excellent surface preparation. Flanges, bends, and other irregular components can be easily coated.

FBEs are normally applied at 10 to 30 mils (254 to 762 µm). They provide excellent resistance to chemicals, abrasion, and impacts, and they work well at temperatures as low as –40°F (–40°C). At 12 mils (305 µm), FBE will perform well up to 150°F, and at 30 mils up to 200°F (93°C). Welded joints can be coated by heat-induction coils and on-site spray equipment.

Chemically modified polyolefins can be used over the FBE as an additional water barrier. Polypropylene is used for temperatures up to 300°F. PEs also can be used, but their temperature restrictions are lower. These coatings can also be used at very low temperatures. Furthermore, they are flexible and do not damage easily during construction.

Recommended Uses for Each Coating Type

REHABILITATION OF EXISTING SYSTEMS

Where only minimal surface preparation can be performed, tapes and brushable coal tar- and asphalt-based coatings may be used. If the surface can be prepared properly, a liquid epoxy is an excellent choice.

NEW SYSTEMS—COATED AT THE SERVICE SITE

If the pipe can be easily blasted or cleaned and adequately prepared, liquid coatings, brushable coal tar or asphalt coatings, and tapes are all acceptable. The insulation contractor should have access to the resources necessary to match insulation types, IDs, and vapor-sealing membranes.

NEW SYSTEMS—COATED OFF SERVICE SITE

Applying a coating off-site usually offers the best opportunity to prepare and coat the pipe properly. The first choice would be either a FBE or a FBE-based multilayer coating. Liquid epoxies, tapes, and mastics can also be applied and inspected easily.

Insulation

Because this article focuses on below-ambient-temperature piping, the range of insulation discussed is rather limited. Cellular glass, polyisosyanurates, polystyrenes, and phenolics are normally the best choices. Manufacturers of these products publish technical literature that describes uses and temperature limitations. The atmospheric conditions and plant environment should determine the insulation best suited for a specific job. The Midwest Insulation Contractors Association[2] publishes a reference tool, "National Commercial & Industrial Insulation Standards," which contains detailed drawings and tables for the insulation industry.

Insulation thickness is critical. Consider worst-case atmospheric and job conditions when calculating insulation thickness. A one-time event of this nature could create a corrosive environment and, eventually, a premature demise of the system.

Installation is critical. Improperly sealed insulation can allow moisture to contact the pipe. An insulation manufacturer's literature typically suggests perm-rated joint sealants. It is important to use joint sealants to slow the migration of vapor to the pipe if a breech in the vapor barrier occurs. On colder systems, installing multiple layers and staggering the joints decreases the risk of "cold spots" causing condensation. Consultation with the insulation fabricator is desirable.

If mineralization coating is used, it is applied in beads to the inside of the insulation. The insulation is then rotated around the pipe to distribute the coating onto the pipe.

The vapor barrier jacket is a critical component when insulating cold systems. Vapor barriers, or retarders, include ASJ paper, FSK paper, polyester film, saran, and glass fabric coated with vapor barrier mastic. Laminated composite membrane is one of the best retarders.

For a below-ambient insulation system to be successful and not contribute to corrosion, it must use a coating and be tailored to the application and environment. Furthermore, it must have adequate thickness, properly sealed joints, a superior vapor barrier, and, if necessary, a mechanical jacket over the vapor barrier to protect it from abnormal physical abuse.

Conclusions

Coating a pipe before insulation is applied will not solve 100% of the corrosion problems, but it will lead to definite improvements. Testing, proper selection of materials and methods, and well-written and detailed specifications result in tremendous improvements in controlling corrosion.

Industry needs to continue to develop better methods of waterproofing insulation to eliminate wet insulation; self-healing membranes are one success story. Such advances help to reduce the problems associated with the loss of insulation properties and help to control corrosion on the insulated pipes. If the waterproofing fails, the proper coating applied to the piping will protect against most corrosion problems.

The initial cost to properly prepare, coat, and install appropriate insulation and vapor barriers is minimal on most projects when compared to the overall project cost. The cost is insignificant compared to the cost of repairing and reinsulating corroded systems—not to mention the losses in production caused by downtime. Reducing corrosion failures yields significant long-term financial rewards, which include safety and environmental benefits.

References

1. NACE Standard RP0198-98, "The Control of Corrosion Under Thermal Insulation and Fireproofing Materials—A Systems Approach" (Houston, TX: NACE, 1998).

2. National Commercial & Industrial Insulation Standards (Omaha, Nebraska: Midwest Insulation Contractors Association, 1979).

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