

CONTROL OF CORROSION BASICS - CORROSION UNDER INSULATION

By

Richard Norsworthy
NACE International Corrosion Specialist
Lone Star Corrosion Services

Patrick J. Dunn
General Manager – Mechanical Products
Polyguard Products, Inc.

Corrosion under insulation is a major problem in a variety of industries. Whether the pipe or other structure is buried or above ground, using proper design and installation techniques can control corrosion. There are several very good articles on the correct way to install insulation and the problems incurred by the loss of insulating properties when the insulation becomes saturated with moisture. Insulation normally becomes wet due to poor installation practices or failure to install sufficient vapor barrier and waterproofing materials. Moisture in insulation increases heat loss and deteriorates the insulation.¹ This article will mainly discuss the proper selection, installation and use of coatings on the metal before the insulation is applied.

My corrosion control experience has been in the oil and gas pipeline industry, but my experience involves corrosion control in other industries. The corrosion process of metals is basically the same in all industries, yet, there are definite differences in the methods of corrosion control facing the “cold piping” industry. Many of the methods used in the pipeline industry can be used for controlling corrosion under insulation on either hot or cold pipes; we will deal primarily with cold systems.

CORROSION PROCESS

The corrosion of metals will occur when four things are present: an anode, a cathode, an electrolyte (moisture) and an electrical path (metal) joining the anode and cathode. An anode is the part of the metal where corrosion occurs, the anode actually ‘sacrifices’ itself when metal ions are discharged into the electrolyte and electrons are left in the metal to flow to protect the cathode. The cathode is the part of the metal where protection occurs because electrons are consumed by a variety of ions or compounds from the electrolyte. An electrolyte is a solution capable of conducting electrical current (ionic flow). An electrical (metal) path is a connection between the anode and cathode where current (electrons) can flow. Free electrons do not flow in the electrolyte, only in a metal path.

Saturated insulation is considered extremely detrimental, even dangerous, because of the potential for corrosive failure of the piping². Corrosion occurs because anodes and cathodes are inherent in all metals and all metals are electron conductors. Anodes and cathodes are electrically diverse areas (potentially) that are present in all metals and are present for a variety of reasons. These may be microscopic in size or, rather large in some cases. Therefore, three of the four requirements for the corrosion process of metal are inherently present in every metal. The fourth, and only remaining element required to corrosion to begin is an electrolyte, normally moisture.

Concentration cells, temperature differences and wetter versus dryer areas are conditions that cause anodic and cathodic areas to develop. Chlorides and other industrial contaminants in the electrolyte can cause an area to become anodic and corrode. The contamination may be present on the metal surface before it is coated or insulated. Once these areas become wet, corrosion can occur. The corrosion process sounds simple, but it involves very complex issues that are too complex to discuss

within the limits of this article. NACE (National Association of Corrosion Engineers) International offers several excellent courses on corrosion control and coating application and inspection.

There are important factors to consider when addressing metal corrosion. There must be an anode, cathode, electrical path and electrolyte present; all at the same time. The anode and cathode must be in the same electrolyte for corrosion to occur. The anode and cathode must be electrically connected (metallic) for electrons to flow from the anode to the cathode. The anodic (oxidation) and cathodic (reduction) reactions must be equivalent and simultaneous reactions.

CORROSION CONTROL

The most effective way to control corrosion under insulation is to prevent the electrolyte from ever reaching the metal surface with a properly applied corrosion coating on the pipe. The oil and gas pipeline industry has learned this lesson. Government regulations require these companies to properly coat any pipeline before it is buried. Cathodic protection is also required to further prevent corrosion in areas of coating damage or areas that may not have been properly coated.

The oil and gas industry has used pipe coatings successfully for many years. They have had success on insulated underground systems by first coating the pipe, then properly sealing the insulation with a vapor barrier and/or weather barrier jacket. There are differences in the two industries, but when we look at the success and growth in the pipeline coating industry, we wonder why other industries are not using this same knowledge and expertise to protect pipes which usually contain hazardous fluids and gasses. Oil and gas companies do not want to replace piping systems every few years. Imagine the chaos concerning the environmentalist groups, surrounding communities, and imagine the price increase to oil and gas products

COATING SELECTION CRITERIA

The proper selection of coating materials is very important. Some of the variables that must be considered when selecting coatings to be used on metals under insulation are:

Operating temperature(s) of the system

Some coatings work well in cold temperatures (-60 °F to 32 °F) and others work well at high temperatures (150°F up to 300°F). From 32°F to 150°F most coatings function well. The coating has to be flexible enough to withstand the expansion and contraction of the piping system when temperatures cycle. Temperature fluctuations can cause a loss of adhesion between the coating and the metal, allowing water to penetrate to the pipe. High temperatures can cause certain types of coating to flow, crack or sag. Low temperatures can cause some coatings to become brittle and less flexible.

Application requirements

Some types of coatings require extensive surface preparations and possibly even heating the pipe before the coating application. Other coatings 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 environment before the construction begins. Only the weld areas or flanges will have to be coated during construction. Systems that exist can be coated in-place, but this can be a problem in congested areas that may make the surface preparation and coating difficult.

Liquid coatings may be applied by brush, gloves or spray methods (air, airless or plural component). Tape coatings may be applied in a cigarette wrap or by spiral wrapping by hand or machine, however they will affect the ID and fit of the insulation. Shrink sleeve type applications and some types of tapes are applied by using heat, usually a propane torch. Powder coatings, such as Fusion Bonded Epoxies (FBE), are applied to a hot (normally 450 °F to 488 °F) pipe surface and are normally plant applied. Multi-layer coatings, such as FBE's covered with polyolefin's, are also factory applied.

There are several factories that can apply coatings on prefabricated pieces. Whether the coatings are liquid, powder or tapes, these companies can clean, blast and coat these structures in a controlled environment. Coating structures in a plant environment has several advantages to coating on-site. The pieces can be easily positioned for cleaning blasting, coating and inspection. For coatings such as FBE or multi-layer FBE based coatings, plant application is the preferred method because the pipe must be heated before the coating is applied.

After the pieces are installed in the service location, the application becomes much more difficult because of confined space, possible damage to other components, safety and environmental constraints. Inspection to ensure proper coating coverage and thickness is very cumbersome. All of these problems can be overcome with proper planning, good specifications and knowledgeable inspection.

Surface preparation requirements

This is the most critical part of any coating process. Care must be taken to perform the best possible surface preparation for the application. Experts in the coating industry advise that two-thirds of the cost of any good coating job should go into surface preparation. Blasting with an abrasive, not only helps to clean the surface, but also provides the proper anchor pattern for the coating to adhere. Before blasting, any oil, grease or other debris must be properly removed. Blasting will only spread oil and grease contamination, not remove it. Contaminants on the metal surface, such as chlorides and other salts, must be removed by proper washing and rinsing techniques. There are methods for detecting these and other contaminants on a metal surface. Mill scale, rust and other such surface contaminants can usually be removed by proper blasting. Wire brushing by hand or machine can be acceptable for some types of coating and may be the only method available for some situations. Water blasting, with and without abrasives, maybe used for other situations. Once again, this must be performed using the proper methods and equipment.

The introduction of mineralization technology to the insulation industry has greatly reduced the amount of surface preparation required before installing the coating. Sand blasting is not necessary at all, even on rusted pipes. The only requirements are the removal of any oil or salt films that may be on the pipe surface, and the removal of any scale rust with a wire brush.

The type of surface to be coated will dictate the type of surface preparation and coating to be used. New carbon steel can be cleaned and blasted easily when compared to corroded or pitted steel in used systems. Corroded or used metal systems may have surface contaminants such as chloride and salts that must be properly removed before blasting. Stainless steel surfaces can be very hard, making it difficult to create an anchor pattern. Certain types of stainless steels should not be blasted using steel grit or shot, because the carbon in the blast material can cause corrosion problems. Non-carbon blast materials, brushes or grinding discs

should be used during surface preparations of stainless steels. Exceptions exist, but consideration must be given to preparing all different types of substrate. Other types of metals should be studied and tested to determine the most effective method of surface preparation. Unless a “wet-cure” epoxy is being used, never coat a wet pipe or vessel!

Environmental requirements during surface preparations and application

What will the environmental conditions be during these processes? If the surface preparation and coating process take place outside, weather conditions (temperature, wind, humidity, rain, snow, etc.) are very important. During plant applications these environmental conditions can usually be controlled. When coating inside the process facility, hot or cold areas, humidity, contaminants and congested areas are all concerns. Health concerns for employees and the surrounding community must also be considered during the process. Clean up and disposal of all the blast and painting residue must be handled properly.

Coating must be compatible with the insulating material

Some types of insulating materials may be abrasive (Cellular Glass) and 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 tolerance of the inside diameter of insulation products. Insulation fabricators may have to alter some tolerances of the ID of their insulation to provide products that fit over certain coatings. Coating selection and insulation specification should be considered jointly when specifying a system. Some corrosion coatings will attack fabricated foam insulations in their ‘wet’ state, coatings must cure prior to insulation installation.

TESTING

Test results provide excellent information to assist in choosing a coating material that will perform well in a particular environment and operating temperature range. Short term testing gives limited results, but will usually and quickly, separate poor coatings from those that may work. Long term testing provides superior results, but time restraints can be a concern for projects that need to be completed quickly, extensive test results exist which can provide ‘out of the box’ solutions for coating and insulation specification. 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. Companies should always be willing to consider new products and processes, but not abandon those products and processes that have given satisfactory performance. In-house or outside testing laboratories with personnel who are experienced in coating tests provide the best test information.

One of the most effective ways to provide the necessary information to a particular industry is to develop an industry sponsored test program for coatings. Several companies can sponsor a program where vendor companies supply coating products and information for an independent testing facility to test under the conditions required by the sponsors. Representatives from each company meet to write the test parameters. All companies who sponsor the program receive a copy of the results. This program has been used very effectively in the pipeline industry.

VENDOR SELECTION

There is a wide variety of coating products and materials on the market today. It is easy to get confused about which product should be specified. Vendors are helpful in providing information, but

many are representatives trying to sell a product and may not be technically trained and experienced with the corrosion process or the actual coating materials and processes.

Vendors that provide good outside test data also provide references or field resource people are the best choices. Use this information coupled with specific project information to specify which particular coatings should be used. Technical support from the coating manufacturer is a must for new systems.

SPECIFICATIONS

Another important factor with any coating process is to provide a well written set of specifications that details the coating process. Specifications should include surface preparation requirements, application parameters and production testing. Persons experienced with coatings and corrosion should write these specifications. Consideration should be given to industry standards; these standards normally provide basic surface preparation and coating application guidelines. Standards should be written by committees made up of those who work in that particular industry and can be easily adapted for a particular process. Each coating system should have a specification written that will give particular requirements for coating that system.

INSPECTION

To ensure the coating and surface preparation processes are properly performed, a well-trained inspector is a must, be it the specifying engineer or coating manufacturers engineer or qualified representative! Inspectors may be third party, but must be trained and have a passion for ensuring that best system possible under the existing conditions. Management often questions the cost of inspection, but coating failures are much more costly.

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

These coatings should be “holiday detected” with DC holiday detectors to find any areas where voids or thin spots exist in the coating before it is covered by the insulation material. This equipment electrically finds unseen voids or “holidays” in coatings. Contact the coating supplier for the correct voltage and type of detector to use for this inspection. These areas can then be repaired before the insulation is installed. The installation of the insulation must be watched to ensure the coating is not damaged.

COATING APPLICATOR

Most people associate corrosion coating to house painting and assume that the process is quite simple; anyone can apply coatings! Choosing a coating applicator that has experienced with the particular surface preparation and coating to be used, has the required equipment and is willing to work within the specifications is important. In some cases, companies buy the equipment and train their own employees to apply the coating materials, manufacturers of the coatings usually provide adequate ‘on the job’ training to contractors using their products. Applicator selection considering the basis of cost only is extremely unwise when choosing a corrosion coating applicator. The bidding process for corrosion control coatings should be approached as an alternate so that it can be separated and analyzed as to cost, process, and competence of the sub-contractor or contractor.

TYPES OF COATINGS

Liquid Coatings: Epoxies

Liquid epoxies are a good choice for coatings on pipe that is to be insulated. There are several types of epoxies available. Basic epoxies are two component materials that are mixed and normally applied by spray or brush. Some epoxies are applied using plural component equipment that mixes quickset epoxies at the gun. Epoxies must be mixed in the proper ratio, whether for brushing or spraying. If the mixture is not correct, the epoxy will not cure properly or perform.

Epoxies usually provide an excellent coating system. Most are flexible, cure quickly and adhere well to the pipe surface. Most epoxies are resistant to many chemicals, abrasion resistant and can be applied in one coat. Epoxies do require very good surface preparations to perform properly. Some epoxies can be very brittle and may crack during temperature fluctuations. Since there are so many different epoxies, one must study, test and select the proper epoxy system for the service temperature range. Epoxies have been developed for high temperature operations (up to 300°F).

Epoxy phenolics are excellent coatings for higher temperature applications (up to 300° F). These are applied using heated plural component equipment and must be applied by experience applicators. One coating that has been used in other industries for years is a modified epoxy phenolic.³ This modified epoxy phenolic offers good abrasion resistance and is more flexible than most epoxy phenolics.

Liquid Coatings: Urethanes, Polyurethanes and Polyureas

Urethanes, polyurethanes and polyureas are also excellent coatings for this service. Most urethanes have limited use for higher temperature (above 150°F) operations. Urethanes are flexible and can be applied in one thick coat with a heated plural component spray system. Moisture can be detrimental to some urethane applications. There are moisture-cure urethanes that do perform well for applications where moisture is a problem during application. Moisture-cure urethanes are one component coatings that cure using the moisture that may be present in the surrounding atmosphere.

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

Tapes and shrink sleeves

Certain types of corrosion control tapes can provide excellent corrosion protection for pipes on systems that operate at temperatures of 150°F or less. When surface preparations are difficult, tapes may be the best choice, even though one should always provide the best surface preparation possible. Tapes are relatively easy to apply. Most require a primer to adhere properly to the pipe. The primer must properly cure before the tape product is applied. Applicators need to be properly trained to apply tapes. Some applicators tend to hurry the process and do not properly apply the tape product, leaving gaps or sags that can allow water to penetrate. Proper overlap coverage and sealing is critical.

Tapes vary from 25 to 100 mils in thickness. The thickness will be twice that at overlap areas. Note that the insulation material must be ordered so that the ID of the insulation will properly cover the coating at the seams. Thicker tapes can be difficult to apply around bends and fittings, but some manufacturers offer tapes specifically for this application. A combination of liquid and tapes can also be used for irregular shapes.

Polyethylene backed tapes can also be used very effectively on the external surfaces of insulation as water proofing materials. If selected and applied properly, they will provide years of good service, especially for under ground applications. Polyethylene's are easily damaged by sunlight (ultra-violet rays) if used out doors.

There are wax-based tapes that are easy to apply, but are not used when temperatures get above 72°F. They are not abrasive resistant. Wax-based tapes are excellent for some applications and should not be totally ruled out.

Brushable Coal Tar or Asphalt Based Corrosion Coatings

These asphalt or coal tar based materials do not require mixing, thinning or other special requirements. They are easily applied by brush or paint glove in one or two coat applications. Surface preparation requirements are not as stringent as for many other coatings. These coatings are very good for irregular shapes, are flexible, adhere well to the steel, resistant to most chemicals and can be easily repaired. They have fair abrasion and impact resistance. They do require a certain amount of time to cure properly. The amount of time for proper cure will be dependent on the metal and air temperature, but mastics will cure even if covered or buried. Since all coatings should be holiday detected before they are put into service, the coating should be cured before the holiday detector test is performed. At temperatures below 0°F, this type of coating may become less flexible. At temperatures above 120°F, some of these coatings may become too soft or tend to run to the bottom of the pipe. There are coal tar or asphalt based coatings that will perform well at much higher temperatures. Proper testing will help to separate those that perform at the higher temperature.

Mineralization Coating

New to the insulation industry (introduced in December of 2001) is a new preventative coating (Rust-Guard®) which, when applied to the pipe, creates a mineralization bond to the pipe 50 angstroms deep into the metal surface. This coating is effective on systems with temperature ranges of -50 to +160 °F. Excess coating from application acts as a reservoir in the event of mechanical damage to the mineral layer. Corrosion cannot take place in this mineralized layer on the pipe.

The greatest benefit of this coating is that if the vapor barrier is compromised and moisture enters the system, it can travel directly to the pipes surface and remain there, without corrosion taking place. The excess coating from the installation process (approximately 10-20 MILS thick) reacts with the moisture, chemically altering the water (or buffering) into a solution which *cannot* corrode the pipe even if the solution contacts bare metal. Only the removal of the excess coating with cleaner can alter the protection provided to the piping system.

A Mineralization coating can be applied to all types of pipes, and will not only prevent corrosion of those pipes, but will also prevent stress cracking on Copper and Stainless Steel systems. (application of this type of coating will be covered in the insulation section of this paper)

This coating is effective on new piping, valves, tanks, vessels, and appetences. This coating is equally effective in the retro-fit market, where re-insulation of compromised systems requires replacing corroded pipe, fittings, valves, or other elements of a system. Great savings can be realized if it is determined that the physical integrity of the metal is such that the system could remain intact if no further corrosion occurs. In the past, this was not a consideration. If the metal has the physical integrity, it can be wire brushed or water blasted to remove any rust scale or corrosion scale which exists, then the pipe can be coated with Rust-Guard® and then re-insulated. This coating will create the

same mineral bond as on new piping, stopping corrosion and the excess coating will provide the insurance against future moisture infiltration.

This amazing product will revolutionize corrosion control on above ground, below ambient systems which require insulation. The life expectancies of these systems will be increased greatly, and with proper insulation and vapor barrier, and mechanical protection, they will outlive the equipment that they supply.

Fusion Bonded Epoxies and Multi-layer Coatings

The most popular coating in the oil and gas pipeline industry at this time is the Fusion Bonded Epoxies (FBE's). There are many types of FBE coatings. Companies must use a corrosion control quality FBE to be successful. These coatings are normally plant applied because the process involves heating the metal surface to temperatures in a range of 450° F to 500° F. The FBE powder is then sprayed on the prepared surface where the powder melts and flows into the anchor pattern, gels and cures. Gel times and cure times are related to the metal temperature, but total cure only takes one to three minutes. FBE requires an excellent surface preparation. Flanges, bends and other irregular components can be easily coated in the same manner. One must be sure that these high temperatures will not damage other components on these structures.

FBE's are thin film coatings that are normally applied in thickness ranges from 10 to 30 mils. They provide excellent resistance to chemicals, abrasion, and impacts. They work well at temperatures as low as -40°F. When applied to a thickness of at least 12 mils, FBE will perform well up to 150°F. Service temperature can be increased up to 200°F when the thickness is increased to at least 30 mils of FBE. Weld connections during the actual assembly in the plant can be coated by using heat induction coils and on site spray equipment or using other materials.

There are FBE based coating systems that use chemically modified polyolefin's over the FBE as an additional water barrier. These are probably the best coating systems for high temperature service. Polypropylene is used for temperatures up to 300°F. Polyethylene's can also be used, but have lower temperature restrictions. These coatings can also be used at very low temperatures, are flexible and do not damage easily during construction.

The application is similar to that of FBE. After the surface is prepared and the pipe is heated (450°F to 500°F), the FBE is "flocked on" to the correct thickness, immediately followed by the powdered chemically modified polyolefin. The polyolefin can be applied by hand flocking or thermal spray. If applied properly, these are excellent coatings. The application cost for these coatings are more than any other coating mentioned, but the benefits may far outweigh all other choices.

RECOMMENDED USES FOR EACH COATING TYPE

Rehabilitation of Existing Systems

Rehabilitation of insulated piping systems can be performed with a variety of coatings. For systems where surface preparation is difficult and minimal surface preparation is performed tape coatings used to offer the best option. The new mineralization technology is now the most viable option, tapes second, and brushable coal tar and asphalt based coatings the third choice for rusted surfaces. If the surface can be prepared properly, liquid epoxies are excellent choices (when selected properly for the service). Some conditions may not allow spray application, so a brush grade epoxy must be used.

The most cost effective method for rehabilitation would be the minimal cleaning required by the mineralization technologies. Removal of loose scale with a brush or water jet is sufficient preparation prior to installation of the mineralization coating.

New Systems – Coated At the Service Site

In most cases these systems can be easily blasted or have the pipe surfaces cleaned and adequately prepared by other methods. In these cases, liquid coatings, brushable coal tar or asphalt coatings and tapes are all acceptable. Jurisdiction of the coating process should be the insulation contractor, he will possess or have access to the knowledge base necessary to match insulation types, ID's, and vapor sealing membranes.

New Systems – Coated Off Service Site

This method usually offers the best opportunity to properly prepare and coat these systems. In these cases, the first choice would be FBE or FBE based multi-layer coatings. Liquid epoxies, tapes, and mastics can also be applied and inspected much easier in these situations, therefore providing the best coating possible. This method must be addressed in the mechanical piping section of the specification, and the correct "factory coated" system specified.

INSULATING

We have sporadically mentioned insulation throughout the coating process; let's get a little more specific. Since we are mainly concerned with below ambient piping systems, the types of insulation becomes limited; cellular glass (Cell-U-Foam[®] or Foamglas[®]), polyisocyanurates (Dow Trymer[®]), polystyrene's (Dow Styrofoam[®]), and phenolics (Ecophen[®] or Kool-Phen[®]) are normally the insulations of choice on below ambient piping systems. The manufacturers of these products publish technical literature which describes uses and temperature limitations. The job criteria, i.e. atmospheric conditions and plant environment should determine the insulation best suited to a specific job. The fact that an 'ammonia system' is the type system being designed is not enough information to base an insulation specification on, the properties of the system may be known facts (temperature etc.), but the environment the system is being installed into must be considered before specifying an insulation or an insulation thickness. The Midwest Insulation Contractors Association (402-342-3463) publishes an excellent reference tool, 'National Commercial & Industrial Insulation Standards' manual (available in book and CD form) which contains detail drawing plates and informational tables for the insulation industry.

Insulation thickness is critical to the success of the system. 'Worst case' atmospheric and job conditions should be used when calculating insulation thickness. This condition may only exist one day per year, but that one time event could create a corrosive environment, and eventually a premature demise of the system.

Installation of the insulation is as critical as the insulation itself; improperly sealed insulation can allow moisture to contact the pipe, providing the electrolyte necessary to begin the corrosion process. Insulation manufacturer's literature will suggest perm rated joint sealants for their insulation. It is important to use joint sealants to slow the migration of vapor to the pipe if a breach in the vapor barrier occurs. On colder systems, multiple layers and staggering

the joints during the installation will decrease the chance for 'cold spots' causing condensation. Consultation with the insulation fabricator is advantageous given how closely fabricators work with the insulation manufacturers, and how frequently they deal with insulation specifications on cold piping systems.

The mineralization coating mentioned previously in this paper have been designed to be bead applied to the bore of the inside layer or insulation by the insulation fabricator to minimize installation cost. The number of 1/8" beads in the ID of the insulation is dependant on the pipe size being insulated. A 1" ID would require two beads; a 6" ID would require 5-6 beads. A bead is also applied at one end of the insulation piece to act as a moisture dam at every joint.

The installation process is quite simple, the insulator installs the pipe cover as he normally would, and the insulator simply rotates the insulation around the pipe 180° and back and longitudinally 1" as he rotates it, to distribute the coating onto the pipe. The beauty of the buffering system is that 100% coverage is not critical, using this installation method, testing shows that over 98% coverage is achieved with this rotation and sliding of the insulation.

Insulation covers for valves, fittings, and appurtenances cannot be rotated, so either the entire bore of the insulation fitting cover must be coated or the fitting or valve itself coated by brush. Coating the valve or fitting by brush would be the most effective method, ensuring that coating gets brushed into creases and crevices on fittings and valves. Vessels can be coated by brush, or the material can be thinned to a thick spray grade and then applied with special spray equipment designed specifically to apply thick coatings. The vessel would then be insulated, sealed, and jacketed.

A critical component of insulating cold systems is the vapor barrier jacket. Vapor barriers (or retarders if you will) come in many types. They include products such as ASJ paper, FSK paper, Mylar[®], Saran[®], glass fabric coated with vapor barrier mastic, and laminated composite membranes. The best vapor barrier membrane available today is the laminated composite membranes. The recent introduction of a zero-perm, peel 'n stick, *self-healing* membrane should reduce the use of lesser alternatives. Costing approximately three times the price of ASJ paper and approximately the same as Saran[®] 560, cost shouldn't deter the specification of self-adhesive membranes. Being UV stable indoors, they can even eliminate the need for an additional mechanical jacket where mechanical protection is not required.

Outdoors, self-sealing membranes have been produced with various 'skins' to make them impervious to the elements. These membranes eliminate the need for expansion 'slip joints' by providing 400% elongation before rupture; they will expand and contract with the system! Insulation can be applied, and then one peel 'n stick jacket provides an excellent perm rating (as low as a .00046 US Perms), UV stability, and sealed weather protection. The seal on a metal or PVC jacket is only as good as the insulator is with the glue or caulking gun!

For a below ambient insulation system to be successful and *not* contribute to the corrosion process, it must be specified utilizing a corrosion control coating, tailoring the insulation to the application and environment, calculating adequate insulation thickness, properly sealing the

joints, applying a superior vapor barrier, and if necessary installing a mechanical jacket over the vapor barrier to protect it from abnormal physical abuse.

To be specific, the ultimate 'system' available today would be a joint sealed expanded foam insulation (thickness calculated correctly), bore coated with *Rust-Guard*[®] mineralization coating, sealed with a SELF-HEALING, Zero Perm vapor barrier (Polyguard's Fabwrap 20[™] in white or aluminum) and then mechanically protected with an Aluminum or PVC jacket where necessary for mechanical abuse protection. Exterior systems would be jacketed with Alumaguard 60[®] or Alumaguard 60 White[®] self-healing membrane instead of Fabwrap 20[™], without any mechanical jacket. The cost of such a system is approximately 20% higher than lesser systems being installed today. A small price to pay.

ADDITIONAL COMMENTS

Several comments have been made about the insulation industry and how difficult it is to change the way things are being done. We disagree with this comment. If the industry wants to solve this serious problem, they have to change the specifying and installation processes to overcome these problems.

Engineers must work closely with fabricators to find solutions to this aspect of the problem; it is not beyond a fabricators capability. Communication levels between engineering entities and insulation fabricators, installers, and manufacturers must be increased. Alternate products are not always submitted under the guise of increasing someone's profit margin. There are better, alternative methods in the industry which must be considered on their merit, not perceived intent of the presenter of such alternatives.

INDUSTRY SUGGESTIONS

- The industry must be committed to preventing corrosion (primers or no coating is unacceptable!).
- Testing specifications and insulation specifications outlining specific coating systems for each particular application must be developed.
- Inspection and testing must be performed
- Ensure that coating applicators are well trained, have the proper equipment and understand the coating product and purpose.
- Only the best vapor barriers, waterproofing materials, and insulations should used.

CONCLUSIONS

Coating the pipe before insulation is applied will not solve 100% of the corrosion problems that exist in this industry, but definite improvements will be seen. Through the use of testing, proper selection materials and methods, well-written and detailed specifications, tremendous improvements can be seen in controlling corrosion problems.

The industry needs to continue to develop better methods of waterproofing insulation materials to eliminate wet insulation; self-healing membranes are one example of this progress. This will help prevent or at least control the problems associated with the loss of insulation properties as well as help to control corrosion on the insulated pipes. If the waterproofing fails, the proper coating applied to the system will provide protection against most corrosion problems.

The initial cost to properly prepare, coat, and install proper insulation and vapor barriers is minimal on most projects when compared to the overall project cost, it is invaluable when considering the cost of repair and re-insulation of corroded systems; not even considering the losses in production due to system downtime. By reducing corrosion failures, the long-term financial benefits will be significant. The safety and environmental issues related to these failures must also be factored into the cost savings.

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