MITIGATING CORROSION UNDER INSULATION AND SUPPORTING THE LONGEVITY OF INDUSTRIAL PIPE INSULATING SYSTEMS

Corrosion under insulation (CUI) is a serious and expensive problem for industrial pipes that costs an estimated $276 billion – possibly more – in the U.S. annually in direct and indirect costs.[1] CUI threatens process performance, system longevity and operating costs. However, there are proactive strategies to defend against CUI. A systems approach that includes impermeable insulating materials and accessories combined with proper installation techniques can help keep moisture away from process pipes and support the system's longevity, even in harsh conditions.

EXECUTIVE SUMMARY

- CUI is a costly problem that threatens metal piping exposed to wide temperature ranges or temperature cycling.
- A primary cause of corrosion is liquid or vapor moisture under insulation. An insulation system can be exposed to moisture due to ineffective materials or incorrect installation, via processes such as cleaning and maintenance, or by environmental factors including weather and geography.
- Impermeable insulation, installed as part of an insulating system, can help protect pipes from moisture ingress.
- Specifying impermeable components in the insulating system can provide for long-term system performance and moisture mitigation, helping pipes remain damage free and functional.

INTRODUCTION

Piping systems in industrial facilities transport a range of process materials, such as steam, gas or petrochemicals, at different temperatures and pressures. To function safely and efficiently, industrial pipes require effective insulating systems. However, the presence of moisture in the industrial environment introduces the threat of corrosion under insulation (CUI). CUI cannot be seen underneath the insulating material, so the problem can get worse over time, ultimately threatening the integrity of the insulating system. Undetected CUI that compromises or weakens pipes can cause leaks that threaten piping processes and equipment, even becoming dangerous to employees.

Insulated metal pipes are always at risk of CUI developing, but harsh environments, like offshore locations or humid geographies, can provide additional risk. The presence of salt can also accelerate corrosion if a permeable insulating material is used, or if moisture penetrates the insulating system, reaching the pipe's surface. A sealed insulating system with impermeable insulation helps prevent CUI by keeping moisture out of the system from the outset and away from covered pipes.

Figure 1 – CUI develops when moisture penetrates insulation or remains in contact with metal piping.

CUI FORMATION AND DEVELOPMENT

CUI occurs naturally when moisture penetrates an insulated system and oxygen in the water reacts with the steel pipe, causing it to degrade. High temperatures and the presence of dissolved minerals, such as chloride, in the moisture can accelerate the rate of corrosion. The danger zone for corrosion is 25°F to 350°F (-4°C to 177°C), so even pipes operating at the boiling point of water (212°F/100°C) and above may not be hot enough to evaporate moisture that permeates the insulation. This means that permeable insulation can become saturated over time, allowing moisture to stay in constant contact with the pipe surface.

Pipes running at temperatures significantly below freezing or above 350°F (177°C) are at risk of damage during or following shutdown and restarting cycles, especially when this cycling is routine.

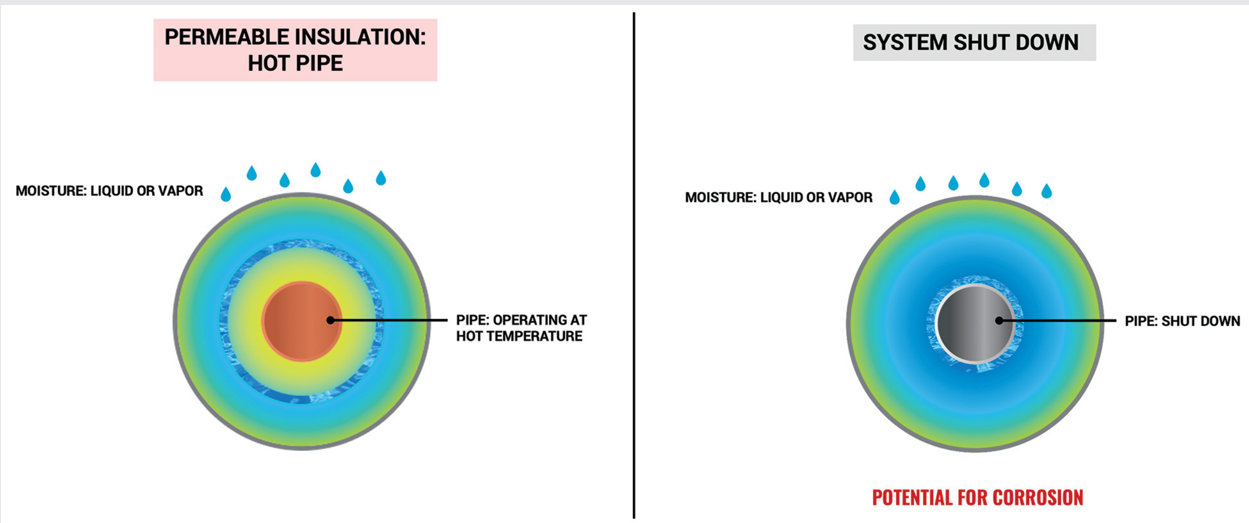

Figure 2 – Pipe temperature and temperature cycling play roles in allowing CUI to develop, especially when permeable insulation is used on above-ambient piping.

Below-ambient temperature pipes are particularly problematic, as they may collect ice that becomes moisture as the pipes rise to ambient temperatures. Any ice ball formations should be inspected for the potential development of CUI or other ice buildup damage to the insulated system.

Above-ambient temperature piping presents similar problems, since moisture entering a hot system might evaporate away until the pipe cools for maintenance or a shutdown period, then condense on the pipe surface as temperatures cool. Checking external layers or jacketing for cracks or physical damage is one way to identify areas at greater risk of CUI development. This oversight becomes especially important if hot pipes are insulated with permeable insulation that offers little protection against condensation.

Even insulated systems can be exposed to moisture due to sprinkler systems, plant maintenance and cleaning operations, as well as severe weather events. The climate where a plant is located can also contribute to the risk of CUI, with areas experiencing year-round high humidity posing a challenge for pipes operating at below-ambient temperatures. These below-ambient systems, such as chilled water applications, face an additional challenge from vapor drive – a pressure imbalance that pushes moisture from warmer airspaces into insulation and toward colder areas with lower vapor pressure, such as cold pipes. If an insulating system that has been damaged uses permeable insulation or insulation that is incorrectly installed, this vapor pressure can allow insulation to become saturated, creating conditions where moisture can condense or freeze on the pipe surface and CUI can develop.

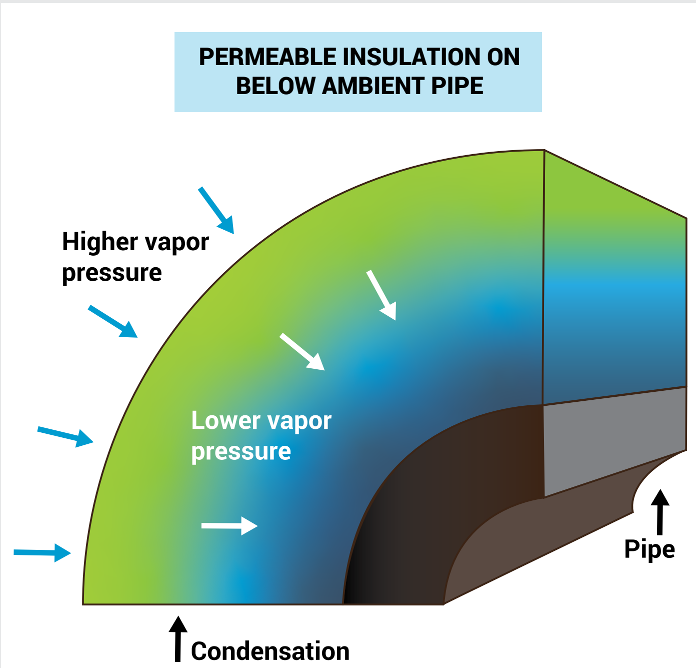

Figure 3 – Warm, high-humidity regions create special challenges for insulated pipes operating below the ambient temperature.

THE COST OF CUI

Corrosive damage to insulated pipes is costly and dangerous. According to the Association for Materials Protection and Performance (AAMP), metallic corrosion costs U.S. businesses approximately $276 billion per year, with indirect costs potentially doubling that amount.[1] The total expense tied to CUI can be difficult to calculate, because it could cause multiple process interruptions, including unanticipated facility downtime while repairs are made. Information presented to the European Federation of Corrosion indicated that CUI is the cause of most pipe leaks, with about 60% of pipe maintenance costs related to CUI.[2] Additionally, CUI may present an on-site safety hazard, such as chemical leakage. Coupled with corrosion costs, energy consumption can increase if temperature is compromised due to saturated insulation.

DEFENDING AGAINST CUI

There are three approaches for protecting piping from moisture that could result in CUI. Changing the chemistry of the moisture to make it less corrosive and giving water a path for egress away from the piping are two options. But the most effective method is to prevent moisture from ever getting in.

When planning for moisture prevention, it is most effective to take a system-wide approach that includes choosing the right insulation, utilizing the proper accessories to ensure an enclosed system and applying proper installation techniques.

INSULATION SELECTION

An insulation system's design and the type of insulating material specified can help protect against the development of CUI. Using an impermeable insulation, like FOAMGLAS® cellular glass insulation, helps prevent moisture from reaching covered pipes. Cellular glass is impermeable to water, either as a liquid or a gas, and is non-absorbent as demonstrated by ASTM C552 – Standard Specification for Cellular Glass Thermal Insulation testing.[3] Cellular glass is resistant to most industrial reagents, is non-corrosive, non-combustible and fire-resistant and has a high compressive strength, plus it does not support the growth of mold or bacteria.

THERMAL CONSIDERATIONS

Thermal performance is a common metric for evaluating insulating materials across a range of environments. For instance, constant thermal performance over the long term can help lower energy demands. But in industrial environments, an insulating material should be evaluated against a broad set of criteria, including moisture resistance, compressive strength and the continued performance of the material over its lifespan. Cellular glass insulation offers a strong k-value with a long life expectancy, high compressive strength and dimensional stability. Once it is installed, facilities can rely on the k-value remaining constant for an extended service period, regardless of temperatures or harsh conditions. For example, while the k-value of some materials may decline over a span of five or six years, cellular glass insulation will maintain its thermal performance while its impermeability protects against water vapor traveling into the insulation.

Beyond longstanding thermal performance, cellular glass offers other benefits for industrial pipes. The closed-cell insulation remains dimensionally stable through a range of temperature and humidity conditions. During shifts in temperature, cellular glass insulation has a coefficient of expansion similar to carbon or stainless-steel piping. This allows it to expand and contract with pipes and prevents the formation of gaps in the insulation when pipe size changes from fluctuating temperatures.

Figure 4 – Cellular glass insulation is made up of multiple closed-cell glass beads, making it impermeable and non-absorbent.

CORROSIVITY CONSIDERATIONS

When moisture penetrates an insulated system, contaminants or elements of the system can shed electrolytes, salts or acidic or basic components into the liquid, changing its pH and generating either galvanic or alkaline corrosion. However, cellular glass insulation does not generate or absorb corrosive components, mitigating this issue.

EMISSIVITY CONSIDERATIONS

When evaluating jacketing materials for an insulating system, emissivity should be considered, since it can influence the outermost surface temperature. For example, when insulating chilled water lines, a low emissivity jacketing, like aluminum or steel, will conduct less heat from a warm environment, resulting in a lower temperature on the piping surface. A jacket with high emissivity, such as PVC or ASJ, will be required to absorb more heat in the same setting, resulting in a higher surface temperature on the pipes.

DESIGNING FOR LONGEVITY

Given the dangers CUI poses, it is important to take proactive steps to help mitigate moisture intrusion throughout a piping system's life. Selecting accessories that are compatible with impermeable insulation, such as cellular glass insulation, provides a multi-pronged approach to protecting a piping system. Cellular glass insulation is impermeable, but it is important to also protect it with jacketing to prevent physical damage caused by maintenance or routine traffic. Applying cellular glass insulation over a pipe covered by a gel, mastic or coating provides a "belt and suspenders" approach, providing an additional layer of moisture protection as a backup for the insulation. This approach is particularly effective for insulating systems applied on hot pipes like steam lines.

CREATING A SEALED SYSTEM

A sealed insulation system that includes cellular glass insulation can protect industrial piping from moisture ingress. Combining FOAMGLAS® cellular glass insulation with high-temperature, neutral cure PITTSEAL® Hi-Temp LV RTV sealant helps ensure a solid closure around piping, including addressing any joints or protrusions. External jacketing can also be added to the system.

Figure 5 – A sealed insulation system helps prevent moisture ingress.

PITTSEAL® Hi-Temp LV RTV is a low-viscosity sealant that performs across a wide temperature range, from -238°F (-150°C) to 450°F (232°C). When applied on the inner edge of the insulation bore, it provides a full-cover joint seal for both longitudinal and butt joints. This application method creates segmented sections for each piece of insulation added, which isolates the segments. This compartmentalization helps defend the entire system from moisture intrusion and reduces the potential for any errant moisture that does enter the system – such as following physical damage or when a section of insulation is removed for maintenance – to move to other areas of the pipe.

Figure 6 – For the best protection, sealant needs to be correctly applied.

The system approach can be used in various locations where CUI is a concern. In below-ambient situations, it can help prevent vapor drive pushing moisture toward the pipe, while in above-ambient setups, the system can keep evaporating moisture from saturating insulation. Additionally, a sealed insulation system can function in underground piping systems and at facilities anticipating frequent shutdowns or cyclical applications, though it is not intended for use during continuous immersion.

TESTING AND RESULTS

To demonstrate insulation function, pipes of two different diameters – 16" (40.64cm) and 2" (5.08cm) – were insulated with cellular glass insulation and a neutral-cure sealant. The sealed pipe segments were then exposed to a modified ASTM B117 test – Standard Practice for Operating Salt Spray (Fog) Apparatus. The pipes were situated in a corrosion chamber for 28 days, where they faced either a temperature of 70°F (21°C) and a rain solution with 5% salt applied for 1 minute every 20 minutes, or a temperature of 95°F (35°C) with a constant fog of 5% salt and a rain solution with 5% salt sprayed once a minute every 20 minutes. Non-insulated pipes were exposed to the same conditions.

Figure 7 – Insulating systems were examined for the protection they provided against corrosive elements in a harsh environment.

At the end of the testing period, the insulation was removed and the protected pipes were inspected and compared to non-insulated pipes. No rust was found on any of the insulated pipes. The unprotected pipes displayed significant exterior damage. This demonstration showed the sealed system's ability to help protect pipes from harsh environments and corrosive elements.

Sample ID			Notes
Rain Only Sealed System 16" Pipe			**No rust**
Rain + Fog Sealed System 16" Pipe			**No rust**
Rain Only Sealed System 2" Pipe			**No rust**

Figure 8 – Cellular glass insulation protected pipes from damage in a corrosive atmosphere; non-insulated pipes showed significant damage following the test's completion.

CONCLUSION

Corrosion under insulation is a significant and costly problem for industry and can create potentially dangerous situations for site employees. Steps can be taken to help mitigate moisture penetration into insulation and keep it away from critical components. A system approach using an insulation system that includes impermeable insulation, like FOAMGLAS® cellular glass insulation, along with the correct sealants and accessories and proper installation techniques can help prevent moisture from reaching pipes even in harsh conditions and when high vapor drive or cycling temperatures generate periods of increased risk potential.

CASE STUDY

INSULATING FOR LONGEVITY – INSIGHTS FROM A PETROCHEMICAL FACILITY IN SOUTH AMERICA

What happens when spheres and pipes containing liquefied content at cryogenic temperatures and located in a warm, humid environment are insulated with an open-cell insulating material? A petrochemical facility in a tropical South American climate provides a cautionary tale of the risks posed by open-cell insulating materials installed on processing equipment.

The problem

The risk of corrosion forming under insulation installed on metal surfaces is elevated in locations where the warmer exterior environment allows moisture to drive toward the cooler surface of metal equipment. Any breach in the vapor barrier of an insulating system offers a path for insulation to enter and reach the metal substrate. "In the case of an open-cell insulating material, water will inevitably get in, potentially freezing and ultimately leading to ice build-up," says Brandon Stambaugh, Director, Technical Services, Technical Insulation, Owens Corning. "During different cycling processes, ice can form, thaw and re-freeze, exacerbating the damage and reducing the life of the system." At the petrochemical company, the rigid polyurethane (PUR) insulation installed on its vessels contributed to premature failure of the insulating system after approximately 10 years.

The solution

The South American plant chose to invest in the longevity of FOAMGLAS® cellular glass insulation after the premature failure, replacing the PUR insulation on its three large, 65-foot-diameter spheres with two three-inch-thick layers of FOAMGLAS® cellular glass insulation. The closed-cell impermeability of FOAMGLAS® insulation was an important consideration when selecting insulation to protect vessels containing process materials at cryogenic temperatures. The facility instituted a multi-year repair program for reinsulation of the tanks. Over an eight-year period, experts removed the old PUR insulation, inspected each sphere for CUI and other damage, made necessary repairs, sandblasted and recoated each sphere and, finally, installed a pre-engineered FOAMGLAS® spherical tank insulation system fabricated by an authorized FOAMGLAS® distributor.

In selecting FOAMGLAS® cellular glass insulation, the owners of the facility took a long-term look at how the insulating system would support operational efficiencies, reduce operating costs and avoid lost energy from boil-off. The owners anticipate the installed FOAMGLAS® insulation will deliver a service life of 20 to 25 years and that the closed-cell insulation will help minimize long-term operational and maintenance costs. An additional benefit of FOAMGLAS® insulation is that it is easy to cut and contour to fit the design nuances of vessels. For the South American facility project, FOAMGLAS® insulation was pre-engineered to fit the contours of the vessels, cutting down on labor time and costs. The pre-engineered system is laid out with unique identification numbering. Each piece is precision cut to provide an exact fit and tight joints for superior performance.

The results

10 years after installation of the FOAMGLAS® cellular glass insulation system, thermal imaging of the first sphere showed little to no thermal performance loss, and the other two spheres showed similar performance after being reinsulated. The FOAMGLAS® system also showed no signs of CUI. The plant manager believes the additional cost of the FOAMGLAS® system is negligible compared to the long-term operation cost savings and asset preservation.

The owners of the petrochemical plant have been so pleased with the success of the FOAMGLAS® cellular glass insulation system that they specified the same pre-engineered system for a new 82-foot diameter tank constructed last year. The company is also using FOAMGLAS® for new piping work connecting marine transfer lines from the plant to the marine berth and only specifying FOAMGLAS® products for its cryogenic service.

Sources

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