Mitigating Corrosion Under Insulation with Polysiloxane Coatings

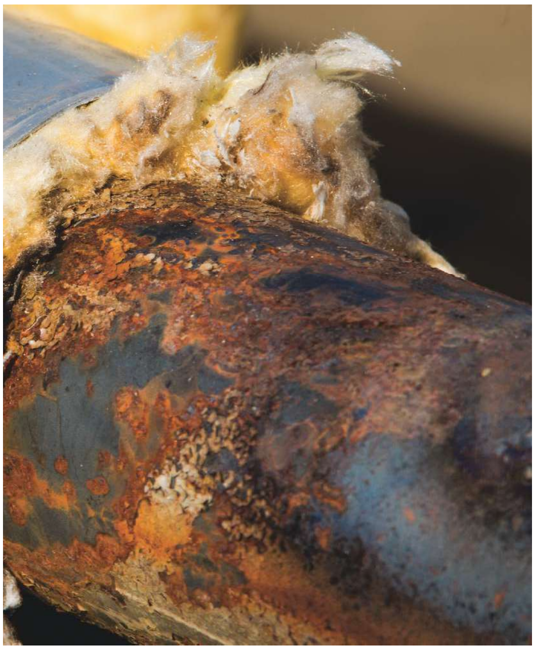
Corrosion under insulation (CUI) is a severe form of localized external corrosion that attacks the surface of very hot or very cold steel equipment insulated for thermal protection, energy conservation, or process stabilization. Corrosion occurs when the insulation absorbs moisture that, in turn, wets the steel surface in the presence of oxygen. Attempts to prevent water from entering insulated systems, however, are not sufficiently reliable to prevent CUI, so protective coatings are recognized and accepted as a highly effective method of protecting insulated carbon steel and austenitic and duplex stainless steel surfaces from CUI.

During the Oil and Gas Coating Technology symposium at CORRROSION 2018 in Phoenix, Arizona, USA, a presentation by NACE International members James Reynolds and Peter Bock with Performance Polymers (Amsterdam, The Netherlands) discussed CUI and the advantages of third-generation polysiloxane coatings for mitigating it.

Insulation on equipment typically includes a top layer of cladding that provides an additional level of protection against moisture and chemical ingress from the environment. In practice, Reynolds and Bock note, the cladding system is not completely sealed from the atmospheric elements, and rain, deluge water, or steam are often able to penetrate the system through access points in the cladding material—generally it is a challenge to create a watertight system on complex structures. Once water has penetrated the system via breaks, seams, gaps, unsealed valve sections, etc., it is absorbed by the insulation and causes saturation that promotes corrosion of the steel. Potential contaminants such as acid and leaching chemicals (chlorides/sulfides) can form acidic compounds in insulation systems that accelerate the corrosion rate.

According to Reynolds and Bock, careful materials selection is vital for providing protection in aggressive environments where CUI could be a threat. Requirements for coatings under insulation include corrosion and chemical resistance, when

A third-generation polysiloxane coating is shop-applied to equipment prior to transport and installation. Photo courtesy of James Reynolds and Peter Bock.



exposed to temperature stability, and thermal cycling and hot saline-water immersion properties. The coating's properties should be present upon application without stoving or curing at elevated temperatures. If a coating requires heat curing, specification and use of that coating in conditions below its cure temperature should be avoided as CUI protection will be limited.

Polysiloxane is an inorganic polymer with superior properties that include temperature tolerance and ultraviolet (UV) resistance. Reynolds and Bock comment that polysiloxane polymers have demonstrated particular characteristics that enable them to withstand the harsh conditions that can lead to CUI, including hot water immersion, high temperatures, and chemical and UV exposure. The polysiloxane polymer's silicon/oxygen bonding mechanism is very resistant to heat and UV degradation due to its higher bond dissociation energy (452 kJ/mol) and oxidized state. The traditional carbon/carbon bonding of organic-based polymers has lower bond dissociation energy (346 kJ/mol) and the potential to oxidize further, making the organic polymers more susceptible to degradation. When heat and UV resistance (either individually or combined) are required, polysiloxane chemistry demonstrates a greater degree of suitability over organic-based polymers.

In their presentation, Reynolds and Bock note that a first-generation polysiloxane coating, comprised of an epoxy-siloxane hybrid that cures in ambient temperatures, was introduced in the mid-1990s. It was developed for use as an elevated-temperature coating, either exposed or under insulation, and is usable on substrate

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temperatures up to 1,100 °F (593 °C). The polysiloxane hybrid chemistry still contained a densely cross-linked organic polymeric structure. In cyclic ambient-hot-ambient service on small-diameter piping or convoluted small shapes, this first-generation polysiloxane coating tended to crack and disbond from the substrate due to internal stresses caused by the inherent two-component, highly cross-linked hybrid chemistry. In the intervening two decades, this polysiloxane has continued in ambient temperature service, but is rarely used on high-heat equipment.

During the last 15 years, inorganic copolymer (IC) and inert multipolymeric matrix (IMM) coatings have been widely used for CUI mitigation. Reynolds and Bock explain that these coatings, which cure at temperatures between 300 to 360 °F (~150 to 180 °C), fall into the category of second-generation polysiloxanes. For these coating chemistries, the surface temperature limits are normally in the region of 1,200 °F (649 °C). The higher level of temperature tolerance is mainly due to the elimination of organic counterparts, the high concentration of inorganic siloxane-based polymers, and higher flexibility.

The introduction of the second-generation polysiloxane coatings was a step forward for providing protection to substrates under insulation; however, there are issues with the coatings' usage in the field, such as a soft film before they are heated to curing temperatures. The necessary heating step not only affects the mechanical properties of the coating but also corrosion, UV, and chemical resistance, as well as adhesion—all of which are required to ensure maximum CUI protection. Multiple failures have been identified in the field, either before service temperatures reach >300 °F or during use below curing temperatures.

Now, a third-generation polysiloxane for CUI mitigation is available. Launched in 2015, this coating is a single-component, fully ambient-temperature cure, inorganic polysiloxane. Developed and tested under multiple laboratory and field test protocols, the third-generation polysiloxane eliminates the field issues experienced with the second-generation polysiloxane coatings, including decreased film hardness, anticorrosion properties, and weathering resistance prior to post-application curing. For example, Reynolds and Bock explain, removing the heating requirement to obtain properties for CUI protection, which is necessary for the second-generation coatings, facilitates full protection in ambient application temperatures as low as 50 °F (10 °C) and specification temperatures that range from –320 to 1,200 °F (–196 to 650 °C).

Additionally, they comment, a new liquid-applied thermal insulation coating (TIC) was commercialized in early 2017. TICs have been used for more than 10 years in a range of different applications including thermal insulation and personnel protection. The low thermal conductivity (λ) properties of the coatings reduce the hot or cold surface temperatures of processing equipment such as pipe, ductwork, or tanks to within safe-to-touch limits (for personnel protection), maintain temperatures in storage units, and provide thermal insulation properties. In some cases, the coatings have either partly or completely replaced traditional insulation cladding systems and wire cages for both hot and cold processing temperatures. If any corrosion is occurring, it is visible and easily rectified during a maintenance program. The TIC technologies can be applied at ambient or elevated temperatures for in-service applications and adhere to a range of anticorrosion primers, which results in a high-performance coating system that provides both corrosion-resistance and insulation properties.

Until recently, TICs were formulated from predominately organic-based polymers (acrylics or epoxies) and filled with ceramic/glass microspheres or silica-based insulation media, which influence the resulting low thermal conductivities of TICs. Two major drawbacks with the organic-based TICs include relatively low film-build capabilities—between 20 to 40 mils (508 to 1,016 µm)—which may require up to 10 or more coats to achieve to the required thickness for providing insulation properties. Also, the organic-based polymers limit the coatings' temperature resistance range to –40 to 356 °F (–40 to 180 °C).

According to Reynolds and Bock, further research and development of the polysiloxane matrix resulted in a water-based (low VOC), single-component, ambient-cure, third-generation polysiloxane TIC technology. These coatings are designed for ultra-high-build dry film thicknesses that can exceed 800 mils (20 mm) and a temperature tolerance range from –76 to 752 °F (–60 to 400 °C). Additionally, the polysiloxane polymer facilitates high weathering resistance and thermal cycling properties in ultra-high film thicknesses >800 mils—film thickness capabilities needed for efficient thermal insulation and personnel protection.

With these new developments in polysiloxane coatings for both anticorrosion and insulation applications, Reynolds and Bock conclude that assets can be protected with thermal insulation and corrosion control via a two-coat system—a third-generation polysiloxane TIC applied over a third-generation polysiloxane CUI primer. This system enables a coating system to replace traditional coating/insulation systems that are prone to CUI. By using a coating system that doesn't need a protective cladding, asset owners can visually assess equipment during inspection programs, which eliminates the hidden corrosion threat of CUI.

More information on polysiloxane coatings and CUI can be found in CORROSION 2018 paper no. 11415, "Third Generation Polysiloxane Coatings for CUI Mitigation," by J. Reynolds and P. Bock.

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