Corrosion under Insulation: Basics and Resources for Understanding

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Over the past 25 years or so, problems with corrosion under thermal insulation (CUI) have been recognized by the chemical and petrochemical industries, leading to the need for effective corrosion protection for piping, vessels, and equipment encased in thermal insulation. The first part of this article briefly reviews how the environment for CUI is created. The review also explains how piping, vessels, and equipment are typically insulated and notes the historical circumstances that contributed to CUI. The second part of the article describes two recently published consensus documents about CUI and reports on three recent studies on CUI.

The article is not intended to be a comprehensive discussion of CUI. Previous articles have addressed in varying detail many issues associated with CUI, including approaches to preventing it, performance of various coatings under insulation, and when coatings are needed under insulation (see examples, References 1–8). An upcoming article will address the issue of deciding when to coat before insulating, taking into account more than the operating conditions.

Creating the Corrosive Environment under Insulation

Corrosion of steel occurs when steel is in direct contact with water and oxygen. In most atmospheric services, corrosion occurs at such a rate that application of a protective barrier in the form of a coating system significantly extends the life of exposed piping, vessels, and equipment. The environment created when a steel surface is encased under thermal insulation is often more conducive to corrosion, resulting in significantly higher corrosion rates, than an analogous uninsulated surface.

Corrosion under insulation is of particular concern because many insulating materials trap and hold moisture against the steel so that insulated surfaces are subject to a wetted environment for greater lengths of time than uninsulated surfaces, which more readily dry out. Many surfaces are insulated to retain heat, so the time in the wetted environment is also at an elevated temperature, resulting in an increased corrosion rate. Because the progressive corrosion of insulated surfaces is not readily observed, and therefore not allowing for regular maintenance when corrosion is minor, CUI often proceeds unnoticed until consequences are severe.

The Insulation System

Insulation is typically applied to piping, vessels, and equipment in the petrochemical industry to maintain process temperatures. (In some facilities, insulation is also used to protect personnel from hot surfaces, but this topic is beyond the scope of this article.) Thermal insulation materials are generally porous materials (capable of absorbing moisture), including mineral wool, foam glass, aerogels, and polymeric foams. Insulation is clad or jacketed to prevent physical damage. Insulating and cladding materials are selected based on performance versus cost. The insulation system (insulation and cladding) must perform so that its cost at an effective thickness is more than offset by the savings resulting from maintaining process temperatures. The economics do not allow for systems with insulating materials that are highly impermeable to moisture ingress and with cladding that is moisture tight. Additionally, damage to the external cladding on the insulation can be caused at installation, over time as personnel walk on the insulation or drop...
heavy objects, or through deterioration with time. Therefore, most thermal insulation systems are subject to moisture ingress, and CUI is a possibility.

Common external sources of moisture are humidity, fog, rain, testing of fire safety deluge systems, and washing down of equipment and facilities. Salt and chemical contamination from industrial pollution and coastal proximity can also be present in the water, further increasing its corrosivity to carbon and stainless steels.

A Historical Note on CUI
Up until the 1970s, CUI was not generally a problem. Economics at that time were such that piping, vessels, and equipment were not insulated unless the operating temperature was above 150 C (302 F). Insulated steel surfaces that were 150 C or higher much of the time remained dry, so significant amounts of corrosion did not occur.

The oil shortage of the 1970s changed industrial insulation practices. Escalating energy prices changed the economics such that efforts to retain heat in processes operating below 150 C were now beneficial. At these lower temperatures, insulated surfaces were wetted more often and subject to corrosion. Coating systems that had been used successfully on uninsulated surfaces were subsequently used under insulation. These systems performed poorly in the hot, wetted environment created under thermal insulation below 150 C; problems with CUI started to emerge; and their significance increased.

The fact that a hot aqueous environment was present under the insulation (due to water penetration, as described above) was not originally appreciated. The conventional atmospheric coating systems of the day could not protect adequately against corrosion in what are essentially immersion conditions. Corrosion under insulation continued unobserved until the steel was so seriously damaged that it became evident by leaks or structural failure.

These problems led to the use of immersion-grade coating systems capable of providing effective corrosion protection in a hot, wetted environment and resisting maximum operating temperatures up to approximately 220 C (425 F). Mitigating CUI became the subject of a NACE International guideline, published over a decade ago and updated in 2004 (Recommended Practice RP0198, “The Control of Corrosion Under Thermal Insulation and Fireproofing Materials - A Systems Approach”).

The Problem Persists
Despite advances in understanding the corrosive nature of the environment associated with an insulated structure and the kinds of coatings that can withstand the exposure, the problem persists, as evidenced by the issuance in 2007 of an ASTM guide to laboratory tests for CUI; by the publication of a 176-page guidance document on CUI from the European Federation of Corrosion (EFC); and by some of the types of research into protection against CUI.

ASTM Issues CUI Lab Testing Guide
From ASTM Subcommittee G01.11 on Electrochemical Measurements in Corrosion Testing came the 2007 consensus document, ASTM G189, “Standard Guide for Laboratory Simulation of Corrosion under Insulation.” As noted in the Scope, the Guide addresses laboratory simulation of general and localized CUI. It calls for test specimens to be insulated sections cut from pipe and exposed to a corrosive environment that includes elevated temperature. Described in the standard are a testing apparatus for CUI exposure, specimen preparation, procedures for simulating temperatures, as well as wet and dry conditions of a CUI environment. While the guide is intended mainly to help establish acceptable approaches to simulating CUI on carbon steel or low alloy steel for pipe, the Scope states that the test procedures might be useful for assessing other metals, anti-corrosion materials on pipeline, and other aspects of CUI, as long as the samples are suitable for the test apparatus.

EFC Guideline
The EFC Working Parties WP13 and WP15 issued Corrosion under Insulation (CUI) Guidelines: (EFC 55) in March 2008. Edited by Stefan Winnik of ExxonMobil Chemical and published by Woodhead Publishing, the volume represents the work not only of the working parties but also of major European oil refining, petrochemical, and offshore companies that collaborated with WP13 and WP15.

The volume covers everything from economics to materials, practices, inspection, testing, and more. Among the chapters are the following.
• “Economic consideration”
• “Ownership and responsibility”
• “The risk-based inspection (RBI) methodology for CUI”
• “Inspection activities/strategy”
• “NDE/NDT screening techniques for CUI”
• “Recommended best practice to mitigate CUI”

A wealth of appendices to the document amplify topics such as cost analysis, quality assurance, types of insulation, suitable coatings, including thermal spray, application methods, cladding, protection guards, and inspection techniques. Continued
Industry Research

Several industry research studies from petrochemical, pipeline, and other interested companies were presented at NACE International’s Corrosion 2008 Conference and Expo (New Orleans, LA).

Researchers from ExxonMobil and Honeywell Process Solutions conducted a laboratory investigation of CUI on steel in three conditions: uncoated, coated with thermal sprayed aluminium (TSA), and coated with TSA but with defects that exposed the steel. Two types of insulation were also tested over the coated and uncoated steel: mineral wool and calcium silicates. Researchers followed ASTM G189 to approximate field conditions of cycling temperatures and alternating wet and dry conditions. Of the three types of steel samples, specimens protected with TSA (with no coating defects) showed the lowest corrosion rates under each type of insulation tested. The test methods, specimens, procedures, and results are detailed in “Evaluation of Steel and TSA Coating in a Corrosion under Insulation (CUI) Environment,” by Russell D. Kane, Monica Chauviere, and Keith Chustz, and published in the NACE Corrosion 2008 proceedings (Paper No. 08036).

A study conducted by Shaw Pipe Protection Limited looked at an epoxy coating for its suitability for use under insulating foam with resistance to high heat, at or above 150 C. The structure studied was buried pipeline. The high service temperature is needed for moving bitumen extracted via thermal recovery from the oil sands in Alberta, Canada. M. Batallas and P. Singh reported on the methods they used to test the epoxy and their results in “Evaluation of Anticorrosion Coatings for High-Temperature Service,” Paper No. 08039 NACE Corrosion 2008 proceedings.

Because CUI can be hidden for a long time beneath cladding and insulation, it often is not recognized until damage to a pipe or vessel is dramatic. Systematic inspection of insulated equipment is an approach to reducing damage from CUI by catching it sooner, before the damage is dramatic, extensive, and expensive. Two approaches to inspecting equipment and structures for CUI were the subject of a study that two ConocoPhillips refineries undertook. One approach involved direct initial and then thorough inspection and maintenance as needed of insulated equipment. The initial inspection helped isolate equipment that needed refurbishment. The second approach omitted a direct initial inspection and instead used a software pro-
gram to identify insulated equipment for inspection and maintenance as needed to prevent or mitigate CUI. Authors Rob Scanlan, Ricardo Valbuena, Ian Harrison, and Rafael Rengifo report on the differences in the effectiveness of the methods in identifying and remediating or preventing CUI (“A Refinery Approach to Address Corrosion under Insulation and External Corrosion,” NACE Corrosion 2008 Paper No. 08558.

Further Information

References

Brian Goldie, JPCL’s Technical Editor, worked in the oil industry for many years. Karen Kapsanis is the Editor of JPCL.
Concerned about Corrosion Under Insulation?

Concern about corrosion under insulation is shown by major oil companies who operate above the Arctic Circle. Here a leak can cause safety and environmental concerns, and international headlines as well.

Food processing engineers are also concerned. When an ammonia refrigeration system in their plant develops a leak from CUI, it creates an immediate safety and environmental emergency for both the plant and the community surrounding it.

Both major oil producers and major food and beverage processors are turning to Polyguard RG2400™ for previously unsolved corrosion problems. The “RG” stands for “reactive gel”.

Polyguard’s unique reactive gels, covered by 13 U.S. and international patents, are not protective coatings. When you spread or spray these gels onto a steel surface, elements in the gel react with elements in the steel surface, and a thin glasslike mineral layer is formed. This mineral layer blocks corrosive activity.

Visit www.ReactiveGel.com to learn more.

For CUI applications, we also strongly recommend that insulation be waterproofed with one of Polyguard’s weather barrier systems, such as Insulrap™, ZeroPerm™, or Alumaguard™. These barriers block water and moisture from penetrating the insulation system.