CORROSION UNDER INSULATION
WHY CUI IS NOT THE PROBLEM

A TOPICAL DISCUSSION ON THE CHALLENGES THAT DRIVE THE PROBLEM OF CORROSION UNDER INSULATION

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ABSTRACT

There is no doubt that industry has taken the issue of corrosion under insulation (CUI) seriously over the last 40 years. The volume of data on the history, causes and challenges associated with CUI is expansive. That data, as comprehensive as it is, has not lead to a discernible decrease in the instances of CUI. This is reflected in the investment and research that continues today by OEMs, research institutes and mechanical integrity teams. These facts lead some to conclude the issue is in fact unsolvable. Better technology is needed that can evaluate components through insulation more accurately or monitoring systems that can predict the failure before it happens. CUI does not have to be a perennial issue. Preventing moisture ingress may be, but CUI happens over time and with the right strategies moisture can be detected before it initiates CUI.

CONTENTS

I. EXECUTIVE SUMMARY

Corrosion under insulation presents a unique problem for Non-Destructive Testing Companies. Traditionally a customer's asset and responsibility to the decisions regarding care and maintenance of that asset are outside the scope of work. To this end a report only delivers the findings that are immediate to the inspection. What has happened or will happen plays no role in the report. Conversely an auditor is very concerned with what has happened and provides recommendations or findings for actions that should happen.

In a normal NDT inspection, while historical data may help reveal the nature of a defect, in an audit, the historical data reveals the actions, normally driven by process, which influenced the result. Those actions may need to change or be codified so they can be replicated. This speaks to the very different cultures that are created. An auditor is concerned with why a thing happened where an inspector only describes it.

These concepts became very apparent and important as the research into the topic of CUI progressed. Initially it was strictly a focus on how to detect corrosion that has developed under a substrate that was one to four inches thick. What became apparent as the research proceeded was that what the customer needed from the NDT community was more than just another inspection.

Dealing with the challenge of CUI can be daunting even for the most seasoned mechanical integrity manager. CUI can be an invisible process under insulation. Both the service industries and asset owners have leveraged millions of man hours to address the problem of CUI. The results are better technologies for detection of CUI and insulation products that provide layers of protection against it.

Based on findings of this study the efforts to address the corrosion while important, do not address the root causes of CUI. They address the contributing factors, or seek to find effects while leaving causes unanswered. To build a more effective solution, an NDT company has to look outside of the traditional model and provide support beyond a report.

II. THE UNIVERSAL SOLVENT

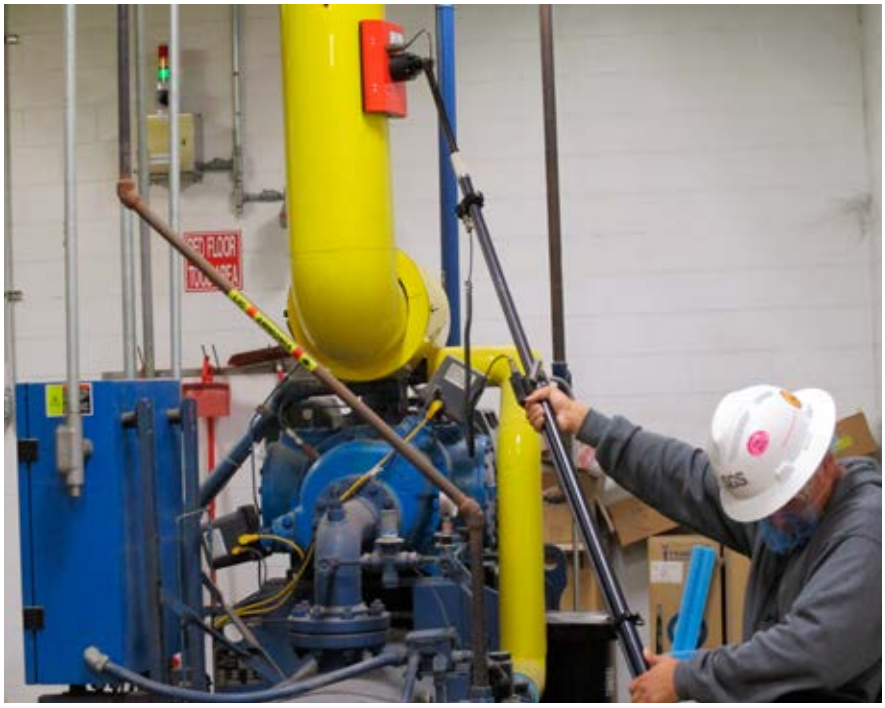
CUI like all failure modes is a complex issue driven by factors that permeate every step in the asset life cycle. Potential failure points exist that provide the opportunity for CUI from design to manufacturing and on through installation, operation and maintenance. CUI is an unintended consequence, however; insulation is installed understanding CUI is an inevitable risk with little opportunity to stop it from happening. The problem is water.

Water is the universal solvent known as such due to its ability to dissolve more substances than any other liquid. A water molecule has a polar arrangement allowing for attraction to other molecules and their respective ions. In corrosion science, its ability to dissolve salts into their respective elements sodium and chloride make it a great conductor of electricity, which is the catalyst for corrosion product to move from anode to cathode. Compounding this property of water is the atmospheric conditions that hold the molecules and ions that will dissolve in water and increase conductivity.

A range of corrosion inhibitors and hydrophobic products address the moisture issue by adjusting the pH levels, creating passivity and/or repelling moisture. They strive to add layers of protection that will stem the tide of moisture ingress or prevent it. These solutions exist under the cladding and do not address the core issue. They are solutions engineered to compensate for the systemic deficiencies in insulation upkeep.

III. MANAGING AN INSULATION SYSTEM

The challenge of the moisture barrier leads to an acceptance of the issue and a lack of prioritization in the face of other risks that take precedence. When an integrity manager has to direct resources, issues with the highest immediate risk are prioritized above a slow degradation of insulation that will lead to CUI in the future. Once found, CUI is prioritized. However; CUI can be invisible to the surface of the insulation and not all damaged insulation results in CUI. This further complicates the decision making process and bolsters strategies that keep insulation damage low on the priority list. CUI poses the greatest immediate risk to the system, but it is impossible to remediate the causal factors by detecting and remediating CUI.



A further disconnect comes from the division in responsibilities regarding insulated systems. While mechanical integrity departments have responsibility of the component, maintenance has responsibility over the condition of the insulation. There are few routine inspections of the insulation system for deficiencies outside of the required visual inspections. These inspections only address immediate visual damage to the insulation system and do not include tools to detect insulation damage or moisture ingress. CUI will only become evidenced on the exterior of the insulation when weathering or physical damage of the moisture barrier is breached and excess moisture leaves the system. This is usually at the lowest point and not always directly beneath the corrosion cell. These corrosion signs drive unplanned inspection and maintenance activities. If the corrosion cell has reached the T_{min} of the component additional construction and engineering activities drive up the cost of remediation.

Because of the long cycles in which this takes place, the cost of insulation replacement and component repair are hard to quantify and go unseen as moisture patiently wicks under the insulation cladding. A small insulation breach costs significantly less to fix than a short length of piping and insulation replacement, yet insulation breaches go unmanaged as the cost increases imperceptible day after day. Focusing on CUI puts too much emphasis on one of the consequences of wet or damaged insulation

IV. THE EPC INFLUENCE

The insulation industry has met the challenge their products create head on, but there is more than one school of thought around addressing the issue of CUI. From the perspective of process management, it is logical to assume that the maintenance and integrity programs are designed well enough to address the integrity of the system to avoid CUI. Thus, material selection should be more focused on material that demonstrates appropriate performance for corrosion and thermal insulation without additional cost due to inhibitors or higher cost rigid systems.

From the perspective of what has been evidenced by experience, maintenance and inspection practices are not enough to address the problem. Additional layers of protection are needed; higher-grade coatings, hydrophobic treatments, corrosion inhibitors, rigid pipe, and block products that resist corrosion and destruction. These products give maintenance and inspection more time to identify and remediate the issue of moisture penetration before it becomes CUI.

Neither of these lines of thinking is incorrect and both have potential failure points. It is clearly evidenced by the occurrence of CUI that the current schema of inspection and maintenance has not been able to address the issue. Additional layers of protection only buy time and can lead to a false sense of security allowing issues to propagate longer than would be allowed with a higher risk system.

Regardless of the philosophy, a strategy change is required in inspection and maintenance. Higher quality insulation products can provide advantages but those advantages are lost when insulation damage and moisture ingress is not adequately addressed.

V. THERMAL PROTECTION VS. CORROSION UNDER INSULATION

In the 1970s, the United States had an energy crisis. Before the 1970s, any system below 300 degrees did not make economic sense to insulate. It cost more to put the insulation on, than it cost to run without it, but that equation changed.

To reduce the cost of sales, process engineers began to insulate and design systems with insulation to take advantage of the thermal insulating properties of certain materials below 300 degrees. To this day, the cost of energy has never reached a point where the ROI for insulation was less than the cost of installing it. The National Insulation Association estimates the typical ROI for insulation at six months to two years.

This return on investment is directly proportional to the health of the insulation system. Damaged insulation loses its thermal insulating properties and has a direct impact on the operating costs and environmental emissions. While CUI is the end state when insulation fails, long before that failure, additional costs have been realized in the loss of thermal protection. This cost can be quantified and, if the area of thermal loss is large enough, may outpace any inspection and remediation activity due to CUI. Beyond the cost of sales, there is the environmental impact of damaged insulation. Increased energy to maintain temperatures through process cycles requires additional fuel, thus, increasing the carbon footprint of the system.

VI. THE CONSEQUENCES

The current philosophy around addressing CUI focuses on finding CUI. This is understandable as CUI can cause catastrophic results when undetected. Any approach requires a strategy that includes CUI detection, but what are the current and future ramifications if we stay focused on CUI?

STAYING THE COURSE

In the current schema for CUI, some consequences will persist into the future.

- The cost to manage CUI will fluctuate with spikes and falls relative to unplanned maintenance and inspection events.
- The probability that you will detect and include defects in an inspection will continue to be low. Without 100% volumetric inspection probability indexes can be well below 50%.
- Future performance of the thermal protection system will continue to degrade and ROI from energy savings will continue to depreciate as system performance degrades.
- Personnel behaviors that contribute to insulation damage may not change. (i.e. foot traffic, physical damage, and wanton destruction.)
- RBI strategies that can reduce volumetric inspection are missed due to insufficient data collection.

CHANGING THE PARADIGM

The antithesis to the current course of action requires a shift in the priority and focus of integrity. This focus does not change the mission of integrity. An inspection on a vessel full of H_2S rich gas is done to ensure containment. Likewise, instead of addressing the end state of insulation failure, where the thermal energy is "leaking" out of the system, the inspector will be more concerned with ensuring containment. Keeping heat and cold in, and keeping moisture out. The consequences for this course of action are:

- The cost to manage CUI goes down as improved system performance and security is demonstrated in RBI assessments tailored to the behavioral, process and environmental conditions that contribute to CUI. This reduces volumetric inspection in favor of targeted inspection. Thus increasing probability of inclusion and reducing overall inspection cost.
- The probability that you will detect and include defects goes up as your understanding of the influencing factors on a specified system drives ITP planning.
- The performance of the system improves as insulation issues are addressed with a higher priority and maintenance activities reduce the volume of damaged insulation improving efficiency and decreasing operating cost.
- The awareness and importance of insulation is increased as insulation damage is addressed as a correctable action (behavior) not just a maintenance or integrity issue.

It is clear that continued improvements in material sciences for insulation and metallurgy will reduce the occurrence of insulation damage and ultimately CUI. However, that will not solve the challenges of the current infrastructure. With a CUI solution that delivers the aforementioned benefits it is possible to address the root causes that contribute to the conditions where CUI can exist.

VII. CONCLUSION

RECOMMENDATIONS

Based on the finding of this research the following recommendation can be made.

ENGINEERING AND PROCUREMENT

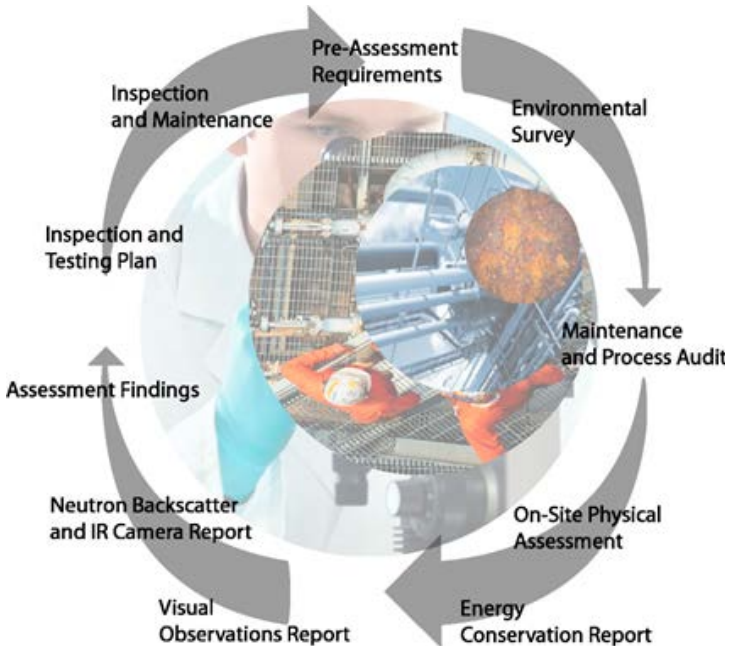
High-grade coating and insulation products can provide additional protections that are important to the successful mitigation of CUI. None of these products replaces proper care and maintenance of insulation, but they can delay corrosion processes. Hydrophobic treatments can degrade due to excessive heat. Corrosion inhibitors are integrated into the insulation substrate providing protection for the life of the insulation. At lower temperatures, hydrophobic treatments can delay the moisture ingress from reaching the surface. Likewise, Thermal Spray Aluminum (TSA) coating can provide superior adhesion and cathodic protection over conventional epoxy coatings. In combination or alone, all of these materials and treatments can provide additional protection that should be considered during new construction or replacement of existing systems.

CONSTRUCTION

During the construction phase of insulation products, an important component of the QA/QC process should include third party insulation inspection. A third party inspector should scrutinize best practices for valves, protruding structural components, straight runs, angled piping and vessels. Strategies for these various components and the insulation products used on challenging geometries are a critical component to avoiding CUI within the first ten years of life.

ATTITUDE CHANGES

There are insulation products that can handle foot traffic if walking on the piping. However, in most cases, solutions should be engineered to avoid foot traffic. Insulation must be seen as an integral part of the component. Education and corrective actions can change the behaviors and attitudes that contribute to the problem.



INSPECTION AND MAINTENANCE

Inspection strategies should focus on maintaining the moisture barrier, and root cause analysis of moisture ingress areas. Cyclical or intermittent services need special attention especially in high or low temperature areas where CUI is not usually anticipated. Temperature surveys done periodically at various times of the process cycle give accurate pictures of how temperature is influencing corrosion rates. API RP 583 outlines a CUI Assessment process that can be an effective part of any CUI program. Maintenance programs must prioritize insulation damage and remediate problems before they become CUI. It is recommended that any CUI solution have these basic parts.

- Environmental Survey
- Maintenance and Process Audit
- On-Site Physical Assessment
- Visual Observations Report
- API RP 583 Assessment Findings
- Inspection and Testing Plan

Inspection and maintenance must work closely to remove the moisture ingress before it becomes a true mechanical integrity issue. RBI strategies must include behavior factors related to process adherence that can influence conditions that will lead to CUI.

The new paradigm for CUI solutions must include key assessments and findings that cover both the health of the system and the specific locations where CUI can and will propagate. The current inspection strategies for addressing CUI are not sufficient to eradicate the problem. This creates inertia for process owners which lead to additional investment and unpredictable cost. CUI is preventable. It is the consequence of multiple points of failure in the life cycle of the insulation product. With a significant change in the strategy to address CUI process owners can realize the full benefit of their insulation with reduced cost of ownership.

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