Creating Value with NDT for Corrosion under Insulation (CUI)

Effective assessment through proper CUI recognition and mitigation available at TÜV Rheinland

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Abstract

This paper addresses the corrosion under insulation (CUI) issue, which occurs under most circumstances in industrial plants be it power plants, onshore and offshore oil and gas installations, petrochemical plants, and paper fabrication plants. Effective assessment and management requires proper CUI recognition and mitigation, involving various competencies offered by TÜV Rheinland. These include corrosion assessment, inspection, and non-destructive testing (NDT) as well as risk and safety evaluation. Screening and monitoring insulated piping and vessels can value to your plant operations, through increasing plant availability, limiting unexpected breakdowns and by supporting the effective planning of turnarounds. assessment and mitigation strategy in order to give you best support. Several NDT solutions are described in this paper, including the value that they add in relation to corrosion under insulation assessment. Plant operators benefit from cost reduction, productivity increase, and mitigation of plant shutdowns. The suggested methods work side by side in a complementary manner.

Creating Value with NDT Methodology for Corrosion Assessment under Insulation

INTRODUCTION

Corrosion under insulation (CUI) is a commonly occurring problem in many industries and among different types of assets including piping systems and pressure vessels in onshore and offshore environments. The most severe form of CUI is the localized type that often occurs in carbon and low alloy steel components. The main cause is **water that is absorbed by or collected in the insulation**. Although its consequences can be devastating - and in extreme cases can lead to a completely **unexpected plant shutdown** - CUI is often not managed effectively. The main reason is that CUI is difficult to locate **as insulation typically masks the underlying substrate corrosion** until it is too late. In short, CUI presents a **major threat to asset integrity** because it can be very detrimental if it goes undetected. Traditional detection methodologies are expensive and often not a viable solution. Furthermore, it is an extremely expensive exercise to remove insulation for visual inspection, particularly in cold service or where asbestos may be involved. A well-defined non-destructive testing (NDT) methodology combined with a risk-based approach is of high added value to the end users because the facility can remain in operation as profitably and safely as possible. The authors will show that it is not necessary to shut down the entire plant or a portion of it to implement **CUI assessment methodology**. The methods presented in this paper help you avoid collateral costs associated with scaffolding erection and insulation removal. Starting with a fit-to-purpose risk-based analysis of the CUI issue, processes and materials involved are taken into consideration as well as behavior predictions of expected damage and degradation mechanisms. This risk-based analysis leads to the identification of a set of **NDT solutions** required to properly address the different types of CUI issues. Different NDT methods such as **pulsed eddy current, guided waves,** and **real time digital radiography** are used to inform strategical maintenance plans. Additionally, **visual examination** and **thermographic measures** can provide important information about the state of damage and degradation mechanisms. The evaluation of the collected NDT data is then used to make a set of recommendations related to the integrity of the object inspected. The applied NDT solutions are typically complementary and are applicable during service.

OUR METHODOLOGY FOR CUI ASSESSMENT

A proper CUI strategy involves the definition and utilization of measures to properly deal with the CUI issue, taking into account the different circumstances of occurrence. Our approach starts with the risk assessment of each insulated component and defines individual CUI risk. Then the targeted NDT solution and inspection schedule for that component is identified. TÜV Rheinland specialists help to properly document the CUI issue and to identify the root cause of potential CUI failures. Our specialists are also trained in providing failure assessment as per legal or internal requirements. The above-mentioned expertise paired with our extensive experience in NDT and materials analysis allows us to deliver comprehensive CUI service which can be engaged at any stage of corrosion development.

The well-known risk-based approach to inspection plans is also recommended for effective CUI assessment and management. While conducting risk-based inspection (RBI) for CUI for the first time, risks will not be known; at least not to the extent that would be required for an appropriate RBI assessment. Insulated pipe systems must be assessed in order to determine risk levels and the associated inspection plans. In most situations, it will be impossible to conduct such a task on all insulated systems at once. Prioritization is therefore required, mainly due to limited resources and budget. TÜV Rheinland specialists can help set up unit level prioritization of the RBI efforts for the different insulated systems. This way, a larger resource input is directed to those insulated systems that feature the highest risks for operations.

Once the units have been prioritized with respect to CUI failure, it is recommended to carefully challenge the need for insulation. The RBI-CUI methodology recommended here makes use of actual operational and structural conditions of insulated systems, and not of their designed conditions. Typically, the RBI-CUI approach consists of a condition assessment of insulated systems by using complementary NDT methods and potential damage analysis assessment, a risk level determination according to the probability of CUI failure and its consequences, and the resulting CUI inspection plan based on that risk level. Once established, this inspection plan contains a set of complementary NDT methods to be applied at specified times. The RBI-CUI plan as such is to be used periodically to assess the condition of the insulated systems, where the frequency and extent of NDT inspection efforts will depend on the determined risk level. It is a dynamic RBI process that takes into account future NDT inspection results to reassess and adjust initial risk levels. This dynamic process might lead to decreased spending and reduced risks.

NDT METHODS FOR CORROSION UNDER INSULATION ASSESSMENT

There are different NDT methods and solutions for the examination and inspection of closed off components through their insulation. Some of these methods such as pulsed eddy current (PEC) and digital radiography are non-intrusive (NII), others like ultrasonic testing (UT) and guided waves require the local removal of a very small section of the insulation to access the pipe to be examined and inspected.

PULSED EDDY CURRENT (PEC)

PEC equipment is based on electromagnetism and helps effectively determine the average wall thickness (AWT) of low-alloyed carbon steel components through their insulation, enabling the detection and localization of CUI. PEC is successfully used in the industry for detection and semi-quantitative sizing of CUI. The main advantage of PEC is its ability to ascertain general wall thinning in insulated objects without removing the insulation and without any object surface preparation. The technology is characterized by its extensive penetration depth and relatively low sensibility to lift-off. PEC is a complementary solution to other NDT solutions for CUI and has been used in a number of different applications, including the detection and measurement of corrosion under fire-proofing (CUF) in skirts of process columns, in the support legs of spherical storage tanks, and on various types of insulated pipes and vessels in on- and offshore installations. Most of these objects are insulated and water ingress may cause corrosion underneath the covering. The deterioration process cannot be seen from the outside. Using PEC to indicate the affected areas can lead to significant cost reduction, especially because this non-intrusive inspection method may be applied on stream and far before a turnaround has to be performed. This approach assists the prioritization and efficient planning of all related turnaround activities helping reduce risks, shorten task duration and minimize installation downtime. Companies like Shell also rely on this technology for CUI protection and assessment programs.

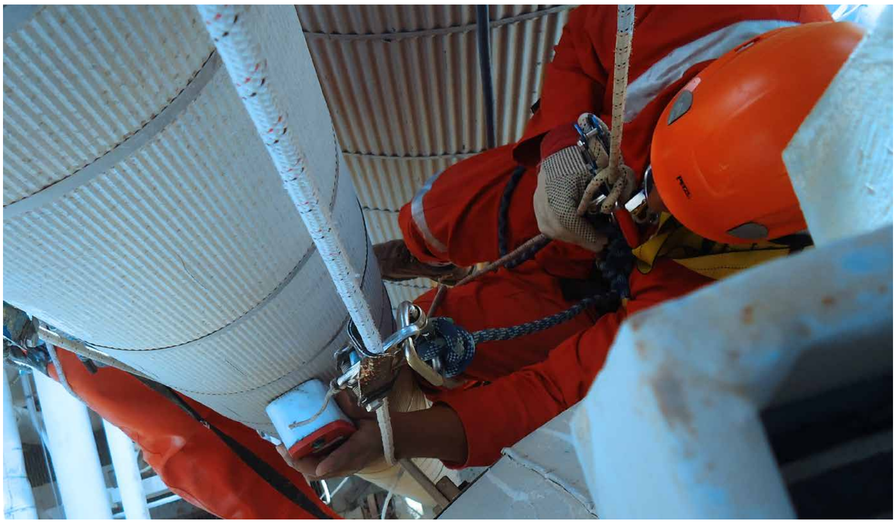

Fig. 1. PEC CUI examination of a vertical pipe using rope access operator to cut down scaffolding costs and reduce preparation time to access the object

Position [mm]	Clock Position [hours]					
	2	4	6	8	10	12
0	16.5	12.5	17.2	16.9	15.1	16.5
-100	16.8	12.4	17.0	16.7	13.8	16.4
-200	16.7	10.4	16.4	16.7	11.3	16.1
-300	16.5	10.5	14.3	16.5	12.2	15.9
-400	17.1	9.6	13.3	16.4	11.1	16.4
-500	16.9	9.7	12.9	16.3	12.5	16.6
-600	16.5	10.2	13.9	16.3	15.3	16.7
-700	16.9	9.1	13.4	16.0	16.5	16.4
-800	16.6	8.6	11.9	16.1	16.4	16.7
-900	16.9	8.4	11.9	16.3	16.5	16.8
-1000	16.5	7.9	12.0	16.4	16.4	16.7
-1100	16.1	8.0	13.5	16.2	14.2	16.6
-1200	14.9	8.1	13.0	16.2	16.5	16.3
-1300	13.9	8.5	13.8	16.3	16.7	16.1
-1400	14.7	8.6	14.0	16.3	16.9	16.6
-1500	15.8	9.1	13.3	16.3	17.0	17.4
-1600	16.5	9.5	12.8	16.3	16.9	16.8
-1700	15.3	11.7	13.2	16.4	16.8	16.8
-1800	16.4	11.6	16.7	16.5	16.7	16.4
-1900	16.4	12.0	16.9	16.4	16.6	16.5
-2000	16.7	12.7	17.0	16.4	16.6	16.5
-2100	16.8	13.7	17.0	16.3	16.6	16.5
-2200	16.8	16.0	16.9	16.3	16.5	16.7
-2300	16.6	16.8	16.9	16.2	16.2	16.3
-2400	15.5	16.5	17.1	16.3	16.5	16.6
-2500	15.2	16.5	16.0	16.3	16.5	16.5
-2600	15.7	16.6	16.9	16.2	16.5	16.5
-2700	16.4	16.5	16.9	16.1	16.6	16.5
-2800	16.8	16.6	16.9	16.2	16.5	16.4
-2900	16.8	16.7	16.7	15.9	16.2	16.3
-3000	17.1	17.2	17.5	16.7	17.1	17.0

Fig. 2. Results of a PEC inspection: wall thickness in mm as function of vertical and circumferential position; Color-coded plot highlights differences in wall thickness

GUIDED WAVES (GW)

Guided waves measurement is one of the key complementary technologies for the assessment of corrosion under insulation for long lengths of pipe. Typically, it uses low-frequency guided ultrasonic waves that propagate along the pipe wall and can detect external or internal corrosion. The technology requires insulation be removed, however, only in a very small circumferential location. This part is used to attach the ring with the ultrasonic sensors onto the pipe. This way, long and difficult to access pipes can be examined from a single location with minimal preparation and without further removing the insulation. A test range of 50m (25m in each direction) or more is commonly obtained from a single transducer position.

Our guided waves technology is often used to assess CUI on sleeved road crossings, buried pipe, wall penetrations, pipe racks, corrosion under supports, offshore risers and caissons, previously unrecorded weld locations, subsea lines and similar.

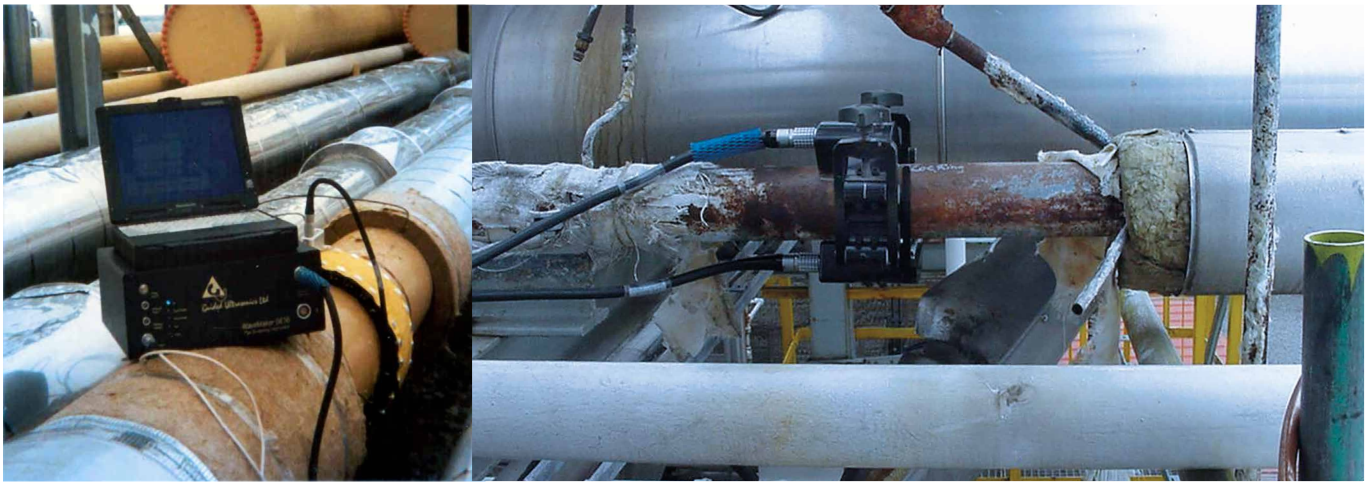

Fig. 3: Guided wave technology applied on pipe racks

Guided waves technology can be affected by signal attenuation, which directly influences the length of pipe which can be inspected. The causes for signal attenuation arise from several sources including: material attenuation, due to using high-loss coatings such as bitumen as insulation material; scattering that may be produced by general corrosion; signal reflections from features such as welds and clamps; or mode conversion at bends and branches.

There are cases where the cost of gaining access to the pipes can far outweigh the cost of inspection. Whenever it is anticipated that multiple inspections will need to be performed at the same location, a set of guided waves sensors (or PEC sensors) can be deployed permanently. An additional advantage of permanently mounted guided waves sensors is the consistency of future inspections in terms of accurate condition monitoring.

REAL TIME DIGITAL RADIOGRAPHY

This technology makes use of a radiation source and an X-ray detector (often a linear array of radiation detectors). These are positioned in such a way that an on-stream X-ray inspection can be conducted, resulting in real-time imaging of potential anomalies under the insulation. With this technology, both internal and external corrosion defects on stretches of pipe can be detected while the pipe remains in service and without removing any insulation. As the unit and/or scanner are positioned onto the pipe, X-ray data is acquired and displayed on the monitor in real time. Straight piping segments as well as locations with bends and elbows can be inspected using this technology. The system is sensitive enough to detect corrosion defects as small as 0.25 inch in diameter and 0.05 inch deep.

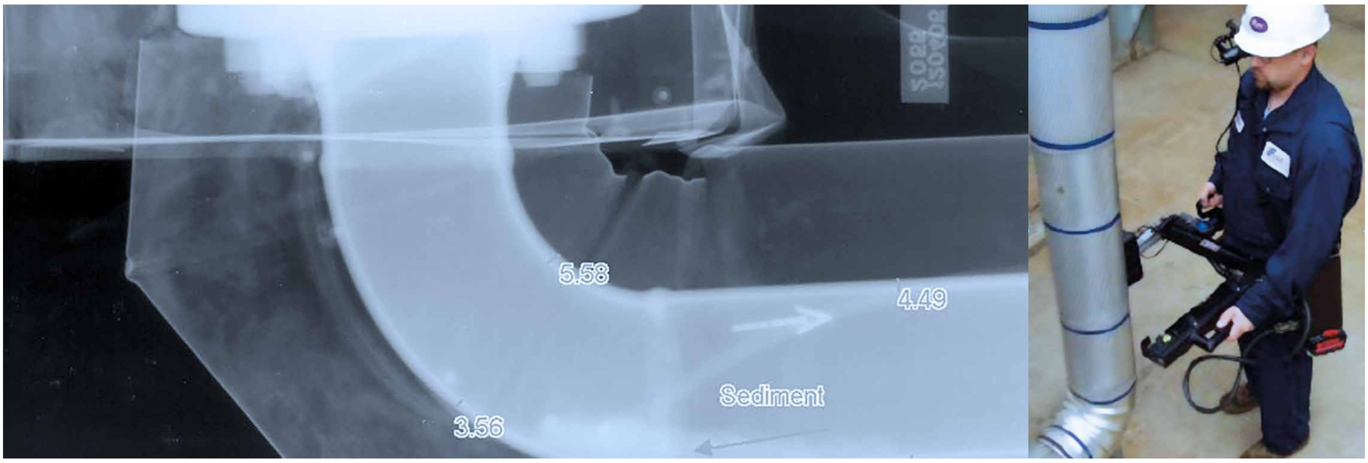

Fig 4: Digital radiography (right); Real time video profilometry (left)

REAL TIME DIGITAL RADIOGRAPHY

Most recently newer lightweight digital X-ray technologies have been introduced to the market. These systems are characterized by extremely low radiation levels and only a very small area of operation has to be cordoned off to carry out the procedure as compared with conventional radiography techniques. Operations can continue with minimal disruption to ongoing adjacent activities. These newer units project real-time digital X-ray images onto a handheld LCD and head-mounted display. The imager itself is highly sensitive, minimizing required levels of X-ray energy. This ensures that this tool is safe to hold. Rapid in-motion scanning of pipes with a range of material densities allows for continuous imaging. These include carbon/stainless steel, cast iron products, aluminum, plastics and composite materials.

VISUAL EXAMINATION

Visual examination is an effective method for locating CUI and it helps identify potential CUI hazards resulting from damaged weather proofing, cladding and/or insulation layers. Weather proofing protection in the form of cladding dents, sealing, junctions and overlapping are potential penetration points for (rain)water, therefore this "barrier" needs to be monitored for effectiveness.

THERMOGRAPHY

Thermography and thermal imaging has been successfully used in the petrochemical industry for inspecting and monitoring system performance as well as the integrity of insulated pipelines and vessels for many years. Thermal imaging easily shows temperatures of materials and objects, and it is an effective method for the detection of energy waste. It therefore contributes to determine the insulation quality condition. Thermography can help locate water penetration and even leakages and any anomalies in insulation performance.

Fig. 5: Insulated pipes

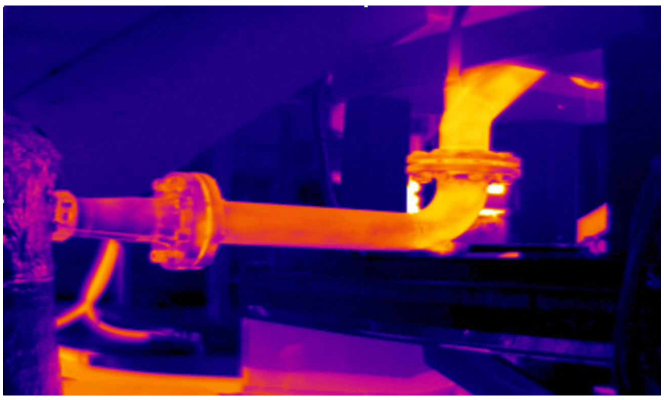

Fig 6: Object temperature, insulation quality condition and energy waste shown using thermography

Summary

Corrosion under insulation is a severe yet common problem that occurs in all types of industrial plants. CUI in the form of **leaking pipes in high-risk areas** has been the cause of various **major economic losses** and **accidents**. A proper way to deal with CUI starts with a strategic, **CUI risk-based assessment** followed by the identification of **CUI inspection plans** and the **implementation of NDT** work aimed at identifying the current condition of the insulated pipes and vessels. Non-destructive testing methods are complementary and their selection depends on various factors such as location, component material, type of insulation and type of expected corrosion degradation, among others. TÜV Rheinland specialists can assist you throughout all phases of CUI assessment and NDT implementation ensuring safety and efficiency for your industrial plants.

Acknowledgments

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Sergio Ferreira[1](*), Dr. César Buque[2], Riccardo Scottini[3]

[1] TÜV Rheinland Portugal,
Rua Dr. António Loureiro Borges, n.° 9, 3.°,
1495-131 Miraflores, Algés
Portugal

[2] TÜV Rheinland International,
Am Grauen Stein 1,
51105 Cologne, Germany
(*)Email: Sergio.Ferreira@pt.tuv.com

[3] TÜV Rheinland Sonovation,
Elschot 30,
4905 AZ Oosterhout,
The Netherlands

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