IBP1134_13
CORROSION MONITORING IN INSULATED PIPELINES
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Abstract

Present techniques for corrosion monitoring in insulated pipelines. The pipelines with heat insulation can be affected by corrosion caused by different dilations and temperatures at which the pipelines and their respective layers of insulating material are exposed throughout the days. This difference between the expansions and the difference in environmental temperature may cause the appearance of condensation (appearance of moisture) between the wall of the pipeline and the layers of insulating material. This moisture starts the corrosion process of the outer wall of the duct that normally cannot be visually monitored. The main objective of this paper is to present innovative techniques for monitoring corrosion as is occurring so that you can schedule maintenance of these pipelines will occur before a leak fluid at high temperature which can have serious consequences for the plant or for people.

1. Introduction

Corrosion Under Insulation (CUI) is recognized as a major corrosion problem, which costs the oil & gas, chemical & petrochemical and food processing industries millions of dollars a year in inspection, repair and replacement costs. CUI can be detrimental to the integrity of an insulated pipeline or vessel if not detected early on, causing leaks leading to possible catastrophic events.

CUI is a form of general and localized corrosion that may occur between the insulation and the outer surface of a thermally insulated and poorly coated pipeline or vessel. CUI can occur under the most common types of thermal insulation eg Rockwool, foam rubber, polyurethane, calcium silicate, and fiberglass. Those insulation materials that have higher adsorption properties of water, oxygen and leachable chlorides are more likely to exacerbate or accelerate the corrosion process. The main cause of CUI is the penetration of water and acids or acid gases like chlorine, through the outer protective seal or cladding to the metal surface where it becomes absorbed by the insulation, causing a corrosion cell adjacent to the pipe wall. Warm temperatures, normally between 30-200°C (32-390°F) along with the ingress of any form of moisture and oxygen, create an environment that may accelerate corrosion. The type and rate of corrosion under insulation will vary depending on certain factors, including insulation type, temperature variance, coating protection, pipe metallurgy and environmental influences eg a severe rain storm.

As the pipe surface is not normally accessible, the current methods of detecting CUI can be expensive and may require the removal of the insulation and cladding. These include visual inspection, radiography, thermal imaging, moisture detectors, and moisture removal methods (eg. drain plug). These techniques in general, do not give reliable results or a direct indication of corrosion, even if there is moisture present in the insulation.

Below we can see in Figure 1, a pipeline which was affected by CUI during a long time.

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Figure 1. Severe outer pipe wall corrosion due to CUI

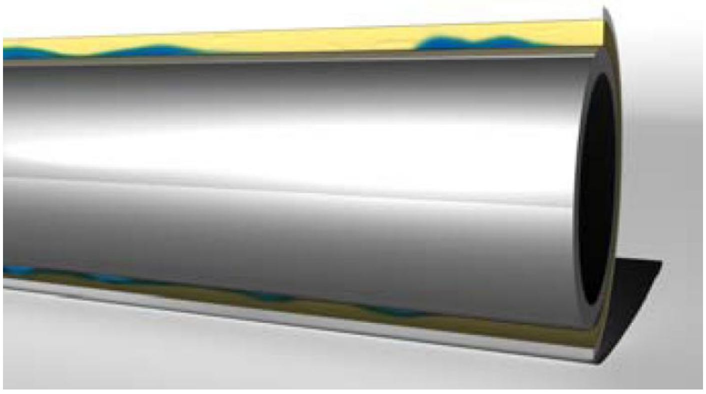

Figure 2. Moisture trapped in the insulation can create a corrosion cell on the pipe surface

2. Possible Solutions

The major problem when CUI is a problem present in plants due because it's too difficult see that pipelines are corrode or not. This occurs because the insulation covering the pipeline prevents the directly operators vision. Figure 2 shows the moisture accumulated between pipeline and insulation creating corrosion areas on the pipeline surface. So I would like present some techniques to help the operational people to keep up with and detect if corrosion is attacking or not the insulated pipelines. So, I will present 03 methods of monitoring CUI including, Continuous Insulated Braid "corrosion fuse" Wire (Type 1), Inserted "corrosion fuse" probe array (Type 2), and CUI Corrosometer® Probe (Type 3). These three techniques offer direct corrosion detection and may be customized to meet individual requirements and applications to fit with any plant integrity management program

2.1. Type 1 – Insulated Braid "Corrosion Fuse" Wire Sensor

2.1.1 Overview

A The Insulated Braid Wire Sensor is designed to detect corrosion that has occurred over a relatively large area. Figure 3 show "Corrsion Fuse" Wire Sensor. A single insulated carbon steel wire of a certain element thickness, or multiple wires of varying thickness, eg 5 mil, 10 mil, 15 mil, and 20 mil thick wires, may be installed. The single wire can be used as a 'corrosion fuse' to indicate that an amount of corrosion has occurred. Multiple wires can be used as step measurements, giving an indication of the rate at which corrosion is occurring. The time between the first wire corroding and the second (thicker) wire, and so on can be used to estimate the approximate rate at which the pipe surface is corroding. This method is best used as a part of a preventative maintenance program. This type of sensor is advantageous in determining if corrosion has occurred over a relatively large surface area of pipe anywhere along its length. If installed under a tape coating, it can help determine the integrity of the coating and the corrosion on the pipe surface that may occur due to the coating breakdown.

2.1.2 Operation

The Insulated Braid Wire Sensor consists of a thin strand of wire, typically carbon steel (or similar material as the pipe or vessel being monitored) with an outer braided insulation. The wire can be wrapped around the pipe as a continuous spiral from one point to another and back as shown in the diagram below. The wire loop circuit will be measured using a simple resistance meter or multimeter from the outside of the insulation and the cable extended to a convenient monitoring point. If an insulating tape or coating is applied on top of the bare pipe and sensor wire then it could be used to detect the effects of a coating breakdown resulting on possible corrosion of the pipe surface.

2.1.3 Installation

The Braided Wire Sensor would typically be fitted at the same time as the initial installation of the insulation or when the insulation has been removed for replacement or pipe repairs, as showed at figure 4. The wire is wrapped around the pipe in a continuous spiral pattern along the selected length of pipe and then spiraled back the in the other direction. A small circular cut is made through the cladding (protective jacket) and insulation and the sensor wires fed through and sealed. Alternatively a gland and plug can be inserted into the insulation and sealed in. Both the lead and termination of the wire will exit through the gland, where the measurement can be taken. When not in use, the plug is replaced and the wire lead and termination are protected and any moisture is sealed out.

Figure 3. "Corrsion Fuse" Wire Sensor

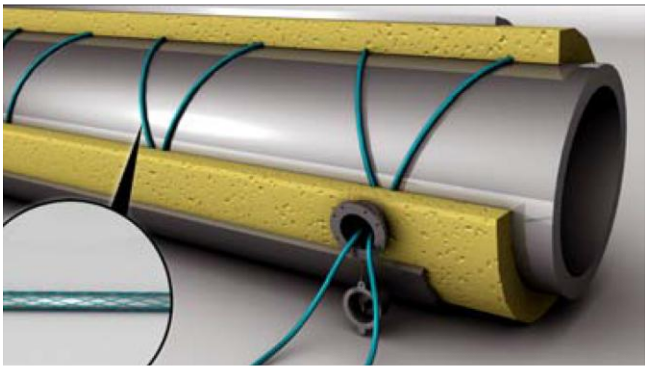

Figure 4. Example of Wire Sensor installation

2.2. Type 2 – Inserted "Corrosion Fuse" Probe Array Sensor

2.2.1 Overview

The Inserted Probe Array Sensor acts as a 'corrosion fuse' detector that will provide an indication of corrosion occurring at the pipe surface, at known discrete locations. It was originally designed to be installed during the remediation and mitigation of corrosion damage under thermally insulated pipeline field joints. There are two common types of pipeline insulation repair processes. The first requires the old cladding to be removed with the insulation left in place. Insulation tape eg Densyl, is wrapped around the affected area and a new protective cladding is strapped in place. The second involves removing an entire section of insulation from a damaged area. The pipe is repaired and cleaned, and new insulation is installed. Insulating tape, typically Densyl, is then applied and a protective outer cladding is strapped in place. The 'Corrosion Fuse' sensor array is designed for installation in either of these remediation process, on pipelines or insulated process lines.

2.2.2 Operation

The Type 2 Inserted Probe Array Sensor, according figure 5, is a chain of four (or more) discrete probes connected in series by two circuits. Each sensor chain is made up of four molded probe housings, each with two measuring elements and a different companion resistor set. When an element wire corrodes through completely, an open circuit will occur in the sensor circuit which will read the companion resistor value, thus allowing the user to identify which probe or probes in the chain have corroded. Typically the four sensors are installed at the 12, 3, 6, and 9 o'clock positions around the pipe as shown above. The two circuits are fed through the outer cladding and terminated on the outside of the insulation. Measurements are made on the two separate sensor resistance circuits using a standard resistance meter or multimeter.

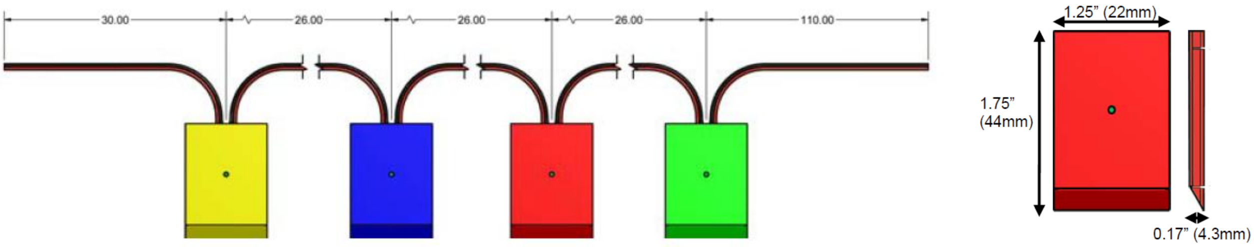

Figure 5. Example of probes and dimensions

2.2.3 Installation

The probes may be inserted perpendicular with reference to the pipe, typically in the 12, 3, 6, and 9 o'clock positions. To install the sensors, the outer cladding is removed and each probe is pushed through the insulation with an insertion tool (shown below) until it makes contact with the outer pipe wall. The probe is then sealed in with a waterproof sealant and the cladding is replaced. The circuit wires are fed through the cladding and sealed. However, for applications that require only spot readings or in instances where it is preferred not to remove the cladding, a single sensor may be used or the wires can be run on the outside of the cladding and protected by a tape wrap. In this case a slit hole (22x4.5mm) in the outer cladding will be required. In the second type of remediation process, where a section of the insulation is removed, the probes are inserted in the same 12, 3, 6, and 9 o'clock positions, but are installed in line with the pipe wall and as close to the pipe surface as possible. There are two elements in the probe, one located near the cable entry and the other near the tip of the probe. The sensor is sealed in and the new insulation is installed. The wires are then exited through the insulation and cladding and the open end wires then inserted into a protective tube. This installation can be viewed at figure 6.

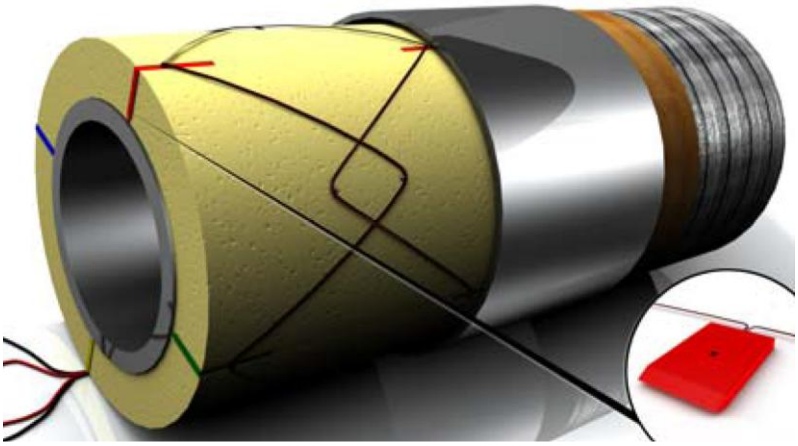

Figure 6. Example of probes inserted at 4 clock positions around pipe

2.3. Type 3 – CUI Corrosometer® Probe Sensor

2.3.1 Overview

The CUI Corrosometer® probe sensor, according figure 7, is an individual electrical resistance (ER) probe that provides a measurement of the corrosion rate near the pipe surface. It is useful in determining the underlying cause of corrosion and the ability to measure changes in corrosion conditions, ie the effectiveness of repairs, temperature cycles or environmental changes eg after a severe rain storm or effects of sprinkler/deluge systems.

Figure 7. Example of Corrosometer probes

2.3.2 Operation

The CUI Corrosometer® Probe is an adaptation of the Type 2 'Corrosion Fuse' sensor but to work like a Corrosometer® ER probe. It has the standard probe connector and is measured by any of the portable Corrosmeter® ER Probe measurement instruments, including the Checkmate, Checkmate Plus, and Mate II. Remote interrogation via extension cable up to 150 ft (50m) is possible.

2.3.3 Installation

The installation of the CUI probe does not require removal of the cladding or insulation. A clearance hole, approx. 35mm, is required for insertion of the probe. The probe can be fitted in any orientation around the pipe and then sealed in place using a standard sealastic or silicone to prevent any external water leak path. The probe length can be designed to suit the insulation thickness and allow access to the connector. For remote or inaccessible locations an extension cable can be run to a convenient monitoring point. Figure 8 shows the detail and installation of a CUI probe, and also as the measure is made using a handheld.

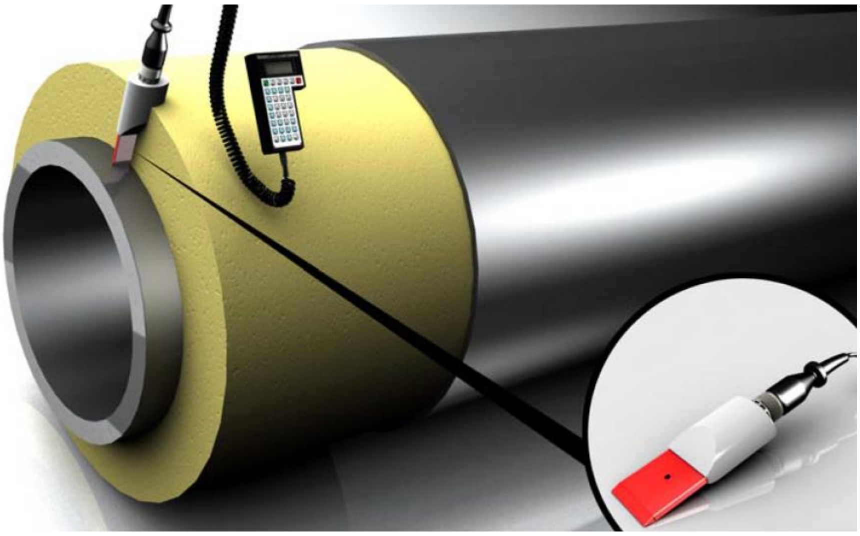

Figure 8. Example of Corrosometer probes inserted in the insulation with the handheld to measure the corrosion rate

3. Table – Applications and Benefits

Table 1. Comparing applications and benefits for 03 techniques

Comparison	Type 1 Insulated Braid “Corrosion Fuse” Wire Sensor	Type 2 Inserted “Corrosion Fuse” Probe Array Sensor	Type 3 CUI Corrosometer® Probe Sensor
Type of sensor	Single or multiple, continuous wire	4 probe sensor array with two ‘corrosion fuse’ elements per probe	Based on established Electrical Resistance (ER) technique
Covering area	Relatively large area of cover	Punctual at a discrete position	Punctual at a discrete position
Mouting	Applied to surface of pipe as a continuous spiral or wire loop	Inserted perpendicular with reference to pipe	Inserted through insulation, Sensor element positioned near surface of pipe
Detection	Multiple wire thickness option for determining corrosion rate	Detects corrosion at pipe surface at known discrete position	Provides a direct measurement of corrosion vis metal loss, corrosion rate and trends

Comparison Cont.	Type 1 Insulated Braid "Corrosion Fuse" Wire Sensor	Type 2 Inserted "Corrosion Fuse" Probe Array Sensor	Type 3 CUI Corrosometer® Probe Sensor
Interrogation	Using a simple resistance or multimeter	Simple resistance meter or multimeter	Using standard ER corrosion probe instrumentation (Handheld)
Removal insulation to install	Require	Does not require	Does not require
Operational temperature	85°C (185°F) or 220°C (428°F)	85°C (185°F) or 220°C (428°F)	N. I.
Others			Data used to identify key events causing corrosion eg effect of heavy rain storms, check on insulation repair performance, effects of operating temperature cycling etc.

6. Conclusion

We can conclude that corrosion under insulation (CUI) is big problem for refining, petrochemical, power, industrial, onshore and offshore industries. CUI can result in sudden and hazardous leaks (safety concern), and plant shutdowns with high losses of production-volumes (economical concern). Also CUI can result in accidents involved people those plants because CUI tends to remain undetected until the insulation needs to be removed to allow inspection or when leaks occur. This paper shows some techniques to detect, measure, and know the CUI evaluation in insulated pipelines, places which normally we can't know what is happening. These tree techniques presented in this paper, if applied correctly for each particular configuration, can contribute to operators, maintenance and inspection equipment people keep the plant and pipelines operating and having the necessary knowledge about the better moment to exchange the pipeline avoiding accidents and damage to the lives and businesses.

7. Acknowledgements

The author would like to thank the owners and management of ROHRBACK COSASCO SYSTEMS and ASELCO for allowing the publishing of this paper and participation in the Rio Pipeline 2013 Exhibition.

8. References

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ROHRBACK COSASCO SYSTEMS, catalogues and manual of products.