

Review of test methods for CUI coatings and introduction of a new, small scale, accelerated test method

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ABSTRACT

Corrosion Under Insulation (CUI) is widely acknowledged to be a critical issue facing plant operators in the oil, gas and chemical industries. CUI studies from a petrochemical facility have shown that 40-60% of pipe maintenance costs are due to CUI and approximately 10% of the total maintenance budget is spent repairing damage from CUI, mainly on pipes. The risk of corrosion under insulation is considered high in the temperature range 50 – 175°C (122 – 347°F) and extreme when in cyclic temperature service between -20 and 320°C (-4 – 608°F).

If CUI is not found in time, then the consequences can be severe for personnel, the environment and company reputation.

This paper will review the current test methods used for determining the suitability of coatings to prevent corrosion under insulation when the insulation, inevitably, gets wet. We will introduce a new, small scale, method for testing coatings using the parameters adopted in ASTM G189-07 (cyclic testing wet 60°C (140°F) and dry at 150°C (302°F) and Classification CUI-2 within ISO 19277 that can rapidly screen the suitability of a coating to withstand the test conditions.

We will show how the use of embedded sensors in the coating can be used to accurately determine the temperature, the amount of water in the coating and the barrier properties of the coating during the whole test cycle. Failures such as delamination, blistering, cracking or corrosion can be distinguished easily and onset of failure can be accurately determined.

Key words: CUI, test methods, new accelerated test.

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INTRODUCTION

Corrosion under Insulation (CUI) costs industry millions of dollars. Water ingress into conventional insulation systems can result in accelerated corrosion of the steel substrate which, if unchecked, will result in structural failure of the vessel or pipe. If the structure is operating under high pressure then this failure would be catastrophic. CUI can result in significant loss of revenue from downtime, maintenance and replacement of corroded structures.

Choosing the right coating for protection against CUI is a complex process. Most operators understand that it is not if but when the insulation material gets wet. This water gets trapped and can then cause localized corrosion. Selecting the right protective coating is essential as this is the barrier that can prevent CUI. To specify the correct coating we need to understand the operating temperature range, the surface preparation available at either new build or maintenance, the proportion of insulated v uninsulated service and the maintenance program.

Testing of coatings for combating CUI has evolved over the last few years to demonstrate fitness for purpose because of the cost of CUI being so high. The consequence of failure is high and there is a big focus on reducing the cost of CUI. The evolution of CUI testing reflects this.

This paper will review the testing methods used in determining fitness for purpose of coatings designed to prevent CUI and show how the test methods have evolved into a suite of tests included in the new ISO19227 standard. We want to introduce a new test method that can quickly show the effectiveness of coatings to prevent CUI.

TEST METHODS FOR CUI

Heat Resistance

Heat resistance of coatings was one of the most common tests used to show a coating was fit for purpose to prevent CUI. ASTM D2485 is the most common method used to determine the resistance of a coating to heat. In this test, coated panels are exposed to a variety of temperatures for a period of time and then cooled in air or water. The cooled panels are then inspected for visual damage like blistering, cracking and flaking. The panels are then subjected to short term salt fog testing or long term natural exposure and then examined for rusting, chalking and adhesion.

ASTM E2550 describes the use of thermogravimetric analysis (TGA) to examine the effect of heat on a coating. The instrument can measure mass loss from a small coating sample very accurately as the coating is heated. We can use this to characterize the coatings resistance to heat and indicate the temperature at which degradation of the coating begins. Differential scanning calorimetry (DSC) can also be used to highlight key thermal events such as glass transition temperature and degradation onset. These techniques help paint a picture of the coatings behaviour when heated.

Water Resistance

Resistance of a coating to immersion has often been seen as a worst case scenario and has been used as a standalone test to determine if a coating can prevent CUI. NACE TM0174 method B is most often used which involves either the complete or partial immersion of coated panels at high temperature. Care must be taken with the data as this test does not factor in the interaction of the insulation material with the coating or that the transport of water through the insulation can change the composition of the corrosive media.

Cyclic Testing

Many coatings manufacturers have developed a cyclic test to incorporate both heat and immersion resistance. A typical cycle would be heat at 200°C (392°F) for 16 hours, quench in cold water (5°C, 41°F) and then immerse in water for 8 hours at 96°C (205°F). This test does not factor in the impact of the insulation material as mentioned above.

ASTM G189-07 has been designed to as a Laboratory simulation of CUI. The test uses a CUI cell where multiple samples can be tested under insulation, in both wet and dry conditions and at various temperatures. A pipe is filled with oil and a number of metallic ring specimens are placed over the pipe so that they are in thermal contact with the pipe and separated by nonconductive spacers. The assembly is then wrapped in insulation and sealed allowing an annular space to form where the corrosive fluid can collect. This fluid is then repeatedly pumped into the cell at a controlled rate. A typical cycle is wet insulation for 20 hours at 60°C (140°F) followed by 4 hours dry at 150°C (302°F). This cycle is repeated for 21 days. This test is essentially isothermal and the setup is shown in Figure 1:

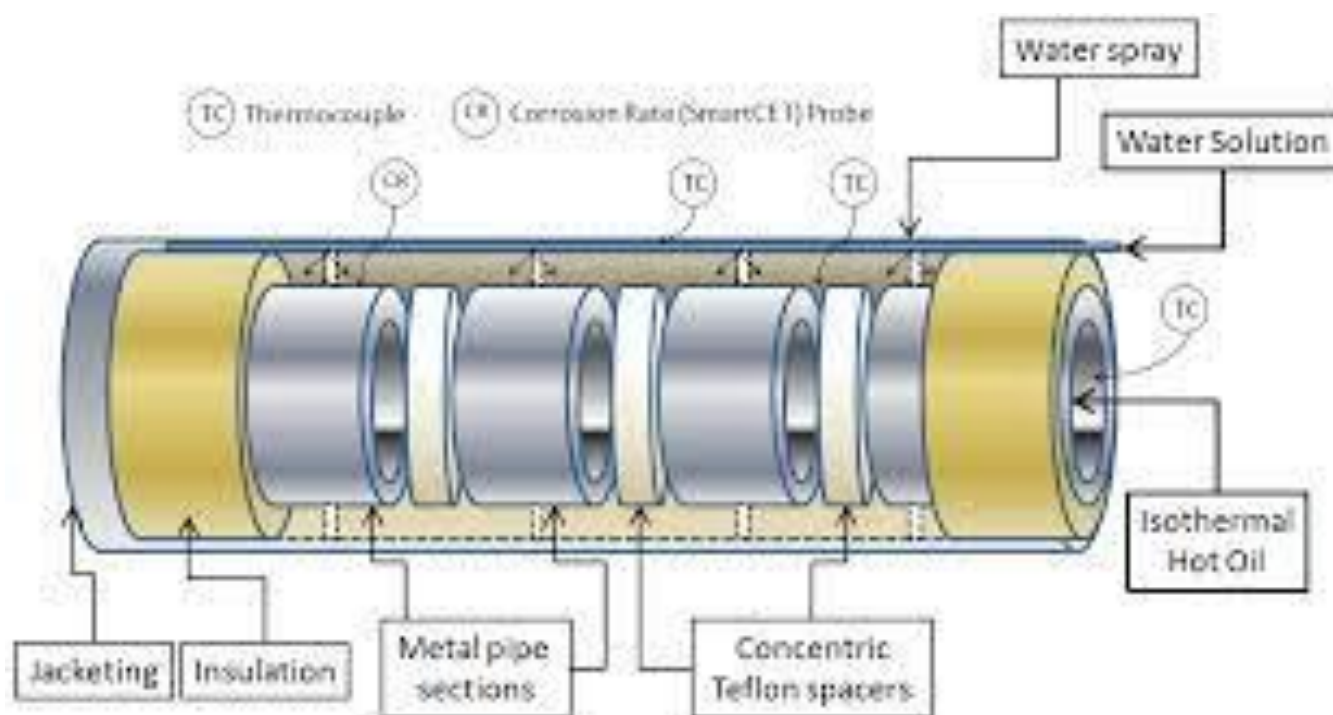


Figure 1: Schematic of test setup for ASTM G 189

The “Houston pipe test” was designed to rapidly determine information about a coatings performance at different temperatures in a single test. A coated pipe, typically 50mm or 2 inch diameter, is stood vertically on a hot plate set at the temperature required to achieve the desired test temperature over the length of the pipe. The pipe is insulated and the insulation is saturated with a salt solution before the hotplate is switched on. Once the temperature of the test is reached the heat is maintained for 8 hours and the salt solution is topped up prior to cooling. After 16 hours the cycle is repeated and continued 30 times. Thermocouples are used along the pipe to measure the temperature of the pipe during the test. There are two main drawbacks with the test as the type of insulation can have a big impact on the temperature profile of the steel pipe and as the level of saturation increases in the insulation the test temperature drops.

The test set up is shown in Figure 2:



Figure 2: Houston pipe test showing insulated pipe sections on hotplates

ISO 19277:2018

ISO 19277:2018 Petroleum, Petrochemical and natural gas industries – Qualification testing and acceptance criteria for protective coating systems under insulation.

This relatively new standard seeks to address all the factors which help to determine the suitability of a coating for use under insulation. The standard introduces the concept of CUI categories based upon temperature:

Classification	Minimum Temperature	Peak Temperature
CUI – 1	-45°C	to 60°C
CUI – 2	-45°C	60°C to 150°C
CUI – 3	-45°C	150°C to 204°C

Table 1: CUI classification environments

The standard describes procedures for sampling, application and heat conditioning of coatings prior to testing. Heat conditioning is extremely important, as CUI does not generally occur the instant that a plant becomes operational. Therefore, the effects of heat/temperature on a coating must be considered, before the coating's exposure to a CUI environment. Dry film thickness measurement and adhesion testing are carried out before and after each kind of exposure.

The standard proceeds to examine the following areas in detail:

Artificial ageing – whilst not an immediately obvious choice for a CUI testing programme, it is very important to consider 1) the exposure of the coating during transport and installation before plant start-up and 2) situations such as extended shutdowns where the insulation may be removed. Additionally, it is useful when considering bulk pipework; which may subsequently be insulated or left exposed.

The artificial ageing process uses a combination of salt spray and water immersion. Afterwards, checks for blistering, cracking, rusting and flaking are carried out according to ISO 4628 specifications. This is a common feature throughout the standard.

Cyclic Testing - Cyclic testing involves the repeated heating and cooling of coated panels over multiple cycles from the maximum temperature of the relevant CUI category then quenching into cold water at 5°C.

CUI cyclic corrosion test (mandatory) – perhaps the most controversial part of this standard is the selection of the condensation chamber as an indication of CUI performance. This test is not widely used in the industry and numerous other, larger-scale testing methods are currently being evaluated. The absence of any insulation in this test makes it an arduous task to form conclusions that would closely reflect real-world performance under insulation.

Besides the mandatory test programme, there are several optional tests:

Cryogenic exposure – optional cryogenic cyclic testing is described for those cryogenic categories described in the standards.

Vertical pipe/Houston Pipe test – the vertical pipe test faces criticism because of the temperature gradient that exists throughout the pipe samples. This test is also highly dependent upon the testing conditions, notably the insulation type.

Although this standard is a very positive start to prescribe a documented and reproducible CUI coating test methodology, the CUI testing element faces significant push back from the industry.

With many test programmes active in this area, it seems probable that this standard will be refined as time passes by. Additionally, with a handful of key oil and gas standards such as NORSOK M-501, currently due for revision, it seems likely that there will be continued activity in this important area. The performance of protective coatings under a wide range of CUI conditions is important, which is why such a plethora of testing methods exists, to help avoid choosing the wrong coating specification.

The process of testing the effectiveness of coatings on their ability to prevent or delay CUI is complex, although necessary. Combining these test methods into a coherent standard with clear acceptance criteria is what ISO 19277 seeks to do. Further refinements to this document as improved test methods for CUI become available will allow even better coating selection decisions to be taken in the future.

Hempel test method

Hempel has designed a new test method to investigate the suitability of coatings utilizing the guidelines for testing established in ASTM G189-07 and CUI-2 from ISO 19277:2018. We have used a simple test method, which will be described in the next section, which uses EIS sensors and crack detection sensors to monitor the performance of the coating during the test and enable us to see water uptake in the