

Corrosion Under Insulation Performance of Insulation Stand-Offs and Non-Metallic Membranes

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ABSTRACT

CUI (Corrosion Under Insulation) is among the key damage mechanisms affecting equipment and piping in hydrocarbon processing facilities, as well as pipelines. The key reason behind CUI is the contact of soaked insulations with the metal(s). Insulation stand-offs and membranes can keep the soaked insulation off the pipe and mitigate CUI risk. This research study addresses the CUI simulation tests to characterize the corrosion behaviors of carbon steel under isothermal wet and cyclic wet conditions, in the presence of insulation stand-offs, low point drains, and Teflon membranes. The corroded coupons were characterized using microscope and surface topography to investigate the damage modes namely pitting, uniform corrosion, localized damage. Insulation stand-offs with low point drains showed uniform corrosion in comparison to closed-contacting insulation, which mainly caused localized corrosion and pitting. Teflon membrane with low point drains caused the least corrosion rate among candidate configurations and did not show any noticeable surface damage from pitting or even uniform corrosion.

Key words: Insulation, Corrosion under insulation, Corrosion management, Optical microscopy, Contact-free insulation, low-point drainage

INTRODUCTION

Corrosion under thermal insulations namely CUI (Corrosion under insulation) is among the key damage mechanisms which poses integrity risk to the hydrocarbon facilities. ¹ CUI is reportedly

known as the reason behind 40-60% of failures in the facility piping whereas small bore piping (i.e., NPS < 4") are even more sensitive to CUI failures, where up to 81% of reported failures in small-sized piping are known to be from CUI. ² Monetary spending to inspect and fix CUI-related failures cost 10% of overall maintenance budget in a typical medium-sized oil refinery. ² CUI risk is influenced by numerous operational and environmental factors which impedes its management in a typical AIM (Asset integrity management) program. The key driving factor behind CUI is the aerated moisture on the metals that comes from soaked thermal insulations. ³ The type and condition of insulation materials have significant impact on their moisture absorption tendency and subsequent CUI rate(s). Other than triggering CUI, the absorbed moisture degrades thermal insulations via increasing the thermal conductance. Reportedly, moisture content of 5% within stone wool insulation causes a 25% increase in thermal loss(es). ⁴

Recommended practices suggest drainage of trapped moisture via low point drains (alongside 6'o'clock) to reduce the time of wetness and consequentially reduce CUI risk(s) in thermally insulated systems. ⁵ A previous study by Rana et. al. addresses the influence of low point drains and insulation stand-offs on moisture removal behavior of fibrous stone wool insulation. ⁶ Insulation stand-offs help to keep the insulation off the pipe which reduces the probability of moisture trapping that may otherwise result in permanent adsorption of moisture to the metal's surface via surface tension and capillary action. Previous studies by Rana et. al. and Pojtanabuntoeng et. al., have reported the influence of insulation stand-offs and low point drains on CUI performance of uncoated carbon steel. ⁷⁻⁸ CUI rates of carbon steel were found substantially lower when applied with contact-free insulation and low point drains. ⁷

Various known measures for CUI management used today include protective-coatings, material upgrades to corrosion-resistant alloys, use of water-repellent (i.e., hydrophobic) insulations etc. Materials upgrades require significant capital investment which can also become unviable due to environmental conditions e.g., austenitic stainless steels are prone to Cl⁻ stress corrosion cracking in marine and high chloride environments. Although water repellent insulations resist moisture intrusion due to their hydrophobic nature, the hydrophobicity of such insulations can be compromised under immersion conditions, a condition which can likely happen at a low point (i.e., 6'o'clock) in the event of moisture trapping between jacketing and insulation. ⁹ Although protective coatings offer surface protection under thermal insulations, their long-term performance gets compromised especially when subjected to thermal cycling in oxygen-starved moist conditions. This is a likely situation under soaked thermal insulations, which in turn causes partial detachment of coating and even holidays via full delamination. Previous study by Yang et. al., has reported the failure of conventional phenolic epoxy coating under CUI simulation conditions. ¹⁰

This study addresses the concept of non-metallic (i.e., Teflon) membranes under thermal insulations which by virtue of wrapping and dimpled stand-offs stay on the pipe and are meant to withstand moisture intrusion as well as impede the oxygen starved corrosion reactions. Candidate configurations namely (a) closed-contacting insulation (b) point-contact spacer with drain and (c) Teflon spacer membrane with drain were tested for CUI performance via CUI simulation tests followed by surface characterizations using optical microscopy and surface topography (2D & 3D) via confocal laser microscope.

EXPERIMENTAL WORKS

Carbon steel A106 Gr. B (UNS K03006) coupons were cut (width 2") from a pipe with 3" NPS (nominal pipe size). The coupons were weighed precisely using a weigh scale with an accuracy of 0.01 gm. The coupons were then installed in CUI test cell over an oil filled barrel with heating element as per arrangement shown in Figure 1. The test coupons were separated from each other by spacing rings and were wrapped with fibrous stone wool insulation and Aluminum jacketing. Figure 2 (a) through 2

(c) shows the cross-sectional views of candidate configurations/ designs of the insulations that were applied to the coupons in the test cells namely closed-contacting, point-contact spacer with drain and TEFLON spacer membrane with drain, respectively. To achieve the configuration shown in Figure 2 (b), point-contact spacers were installed on the inner circumference of insulation to create a stand-off between insulation and steel coupons. On the other hand, Teflon spacer membrane in Figure 2 (c) was installed via wrapping (in two segments allowing a circumferential seam) on the steel coupons followed by insulation wrapping over the Teflon membrane. Teflon membrane employed dimples with 6 mm height to create stand-offs against the surface of steel coupons. Drain shown in Figure 2 (b) and 2 (c) were installed along the 6'o'clock position via coring out the jacketing and insulation. The electrolyte was prepared by mixing de-ionized water (type IV) with 100 ppm NaCl solution. The electrolyte was introduced via funnel from the 12'o'clock position as shown in Figure 1. CUI simulation tests were conducted under IW (isothermal wet) and CW (cyclic wet) conditions for a duration of 72 hours and 96 hours, respectively as per the criteria of applicable ASTM standard.¹¹ For IW tests, the temperature was kept at 100°C for the entirety (i.e., 72 hours) of testing whereas for CW tests the temperature was cycled between 100°C and 40°C (for 96 hours testing) after 24 hours intervals (each).

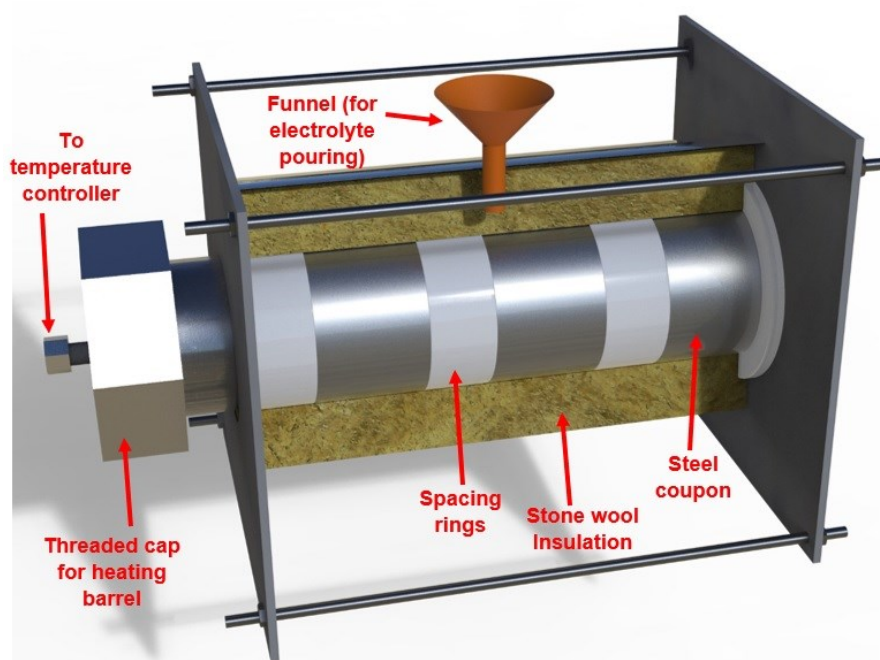


Figure 1 – Arrangement for CUI simulation test

After completion of the CUI test(s), the insulation was stripped off followed by visual examinations of coupons as well as insulations. The corroded coupons were washed to remove the loose scale and corrosion products. Coupons were characterized by weight loss measurements and microscopic examinations. Corrosion rates were calculated by incorporating the average weight loss (gm) of the coupons in the below equation (1):¹¹

$$CR = \frac{K \times M}{A \times T \times D} \quad (1)$$

Where K = constant i.e., 8.76×10^4

M = mass loss (gm)

A = area of exposure (55.9 cm^2)

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T = time of exposure (hours)

D = density of carbon steel coupon (7.87 g/cm^3)

After weight loss measurements, the coupon surfaces were examined via visual and microscopic checks using an optical microscope equipped with confocal laser (Keyence VK X-1000). Laser scanning was conducted using high magnification scanning followed by stitching to generate 2D and 3D topographic images to account for surface features and defects (pits, uniform corrosion, etc.).

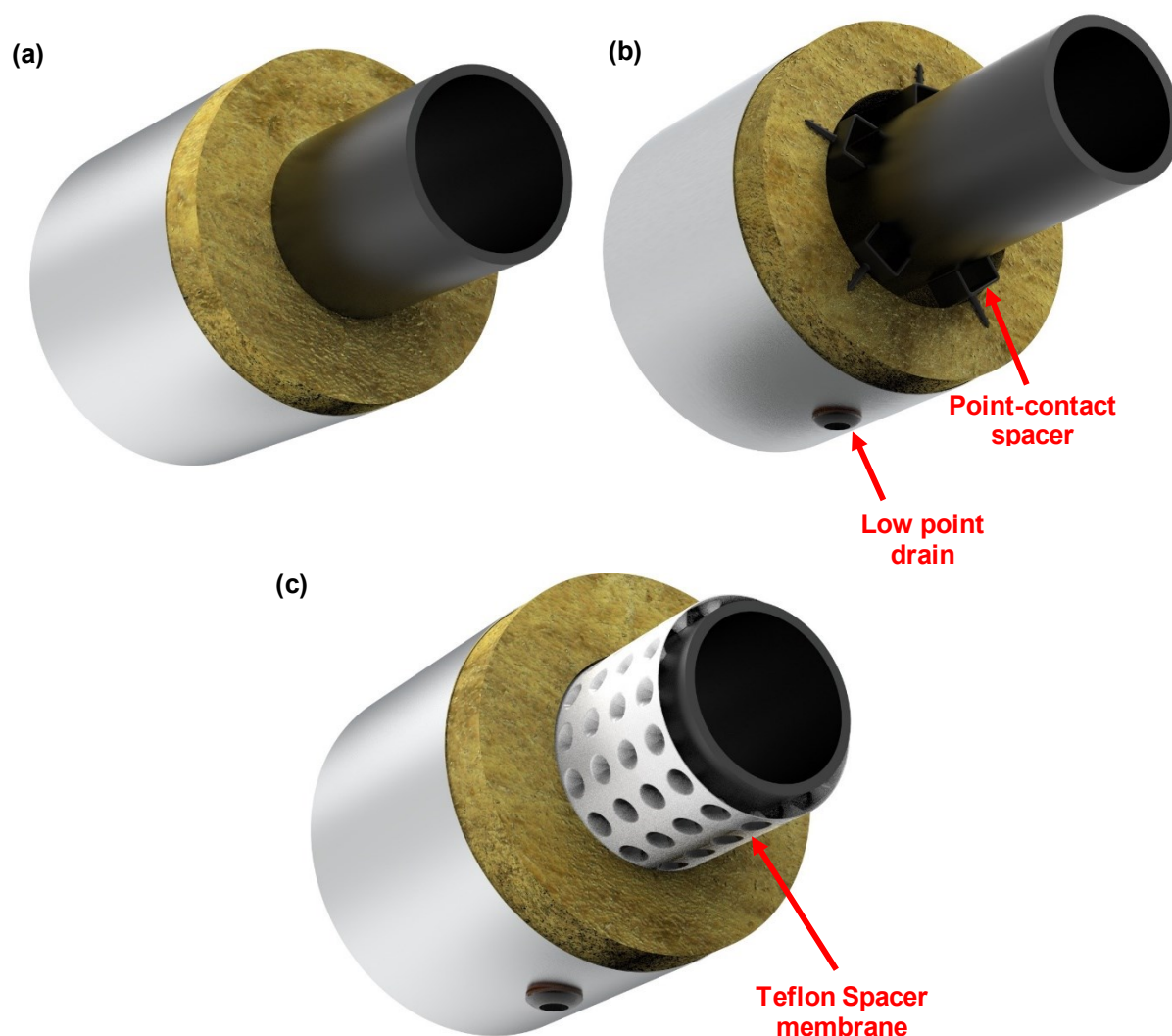


Figure 2 – Candidate Insulation Configurations (a) Closed-contacting Insulation (b) Point-contact spacer with Drain (c) Teflon spacer membrane with drain