Influence of Insulation Stand-Off Membranes and Moisture Drainage on the Corrosion Under Insulation Behavior of Out-of-Service Carbon Steel Piping

Ahmad Raza Khan Rana,[‡,] Omar AlChaar,[**] Jamal Umer,[***] Camille Dromby,[****] Marino Nader,[*****] Graham Brigham,[*] and George Jarjoura[**]*

Corrosion under insulation (CUI) is reported as being the driver behind the majority of failures in thermally insulated process piping and poses significant maintenance expenditures and service interruptions. Small-bore pipes are more prone to failure from CUI due to their lower wall thickness and lower surface area in comparison to larger diameter pipes. This research work simulates the CUI behavior of small-bore piping over a 12-month period in outdoor settings to mimic the out-of-service conditions in an industrial field setting. For this, two sets of assemblies were made which comprised fibrous stone wool insulations applied over the carbon steel coupons with and without stand-off membranes and low-point drain. Both assemblies were presoaked via submerging in water and tested in outdoor conditions for 12 months followed by insulation removal and detailed characterizations. Corrosion behaviors of steel coupons were studied using weight loss, pit depth measurement, surface profile topography, and scanning electron microscopy, whereas chemical compositions of the corrosion products were investigated using x-ray diffraction. Corrosion rates derived from mass loss data were compared with those calculated using the semi-quantitative risk-based inspection method. The kinetics behind the formation of various corrosion products are also discussed. The stand-off membranes and low-point drain resulted in the reduced time of wetness (i.e., moisture exposure time) that in turn resulted in the domination of lepidocrocite (γ- FeOOH) along with reduced uniform metal loss rate and reduced pit depth in comparison to conventional closed-contact insulation system.

KEY WORDS: contact-free insulation, corrosion under insulation, low-point drain, pitting, thermal insulation, uniform corrosion

INTRODUCTION

Pipelines and process piping in industrial facilities rely on thermal insulations for heat conservation. The trapped moisture under thermal insulations triggers corrosion under insulation (CUI) and stress corrosion cracking (SCC) at the external surface of a metallic pipe/pipeline.[1-2] Both of these damage mechanisms, namely CUI and SCC pose significant maintenance expenditures along with reducing the service life of process pipe/pipelines. Reportedly, 40% to 60% of process piping failures in a typical oil refinery are from CUI. Moreover, small-bore piping is extremely vulnerable, whereas 81% of reported failures for small-bore pipes are from CUI. The consequential maintenance spendings (from CUI) in a typical oil refining facility constitute 10% of the overall maintenance budget.[3-4] The key driver behind the CUI is the aerated moisture at the metal's surface which along with metal's degradation increases the thermal conductance.[5] Reportedly, a moisture content of up to 5% in fibrous stone wool insulation increases thermal conductance by 25%.[6]

Industry practices suggest that the CUI risk is highly prevalent in the range of 90°C to 120°C and gets reduced as the temperature exceeds 170°C, only because the moisture is speculated to boil-off (as vapor drive) away from the metal's surface.[1] On the contrary, a significant portion of the boiling off moisture (as vapor drive) condenses on the inside surface of the jacketing followed by pooling alongside the 6 o'clock position unless it is drained out of the system via low-point drains. Stagnated moisture alongside the 6 o'clock gets re-drawn into insulation via capillary action and re-soaks the pipe, leading to continuous heat loss from the pipe and increased CUI risks.[7-8] There have been numerous failure incidents from CUI and SCC for thermally insulated pipelines containing crude oil emulsion, despite those pipelines being designed to operate around 170°C.[2] Generally, the moisture saturated insulations by the virtue of wicking against the pipe skin reduce the pipe skin temperature significantly, thereby bringing the pipe skin's temperature down within the range of 90°C to 120°C, which is favorable for the highest CUI rates. As the CUI management programs generally do not call for increasing the operating

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‡ Corresponding author. E-mail: ahmaduetian141@gmail.com.
* Integrity Products & Supplies Inc., Sherwood Park, T8H 0B8 Alberta, Canada.
** Department of Mechanical Engineering, Dalhousie University, Halifax, B3H 4R2 Nova Scotia, Canada.
*** Department of Mechanical Engineering, University of Engineering & Technology, Lahore 54890, Pakistan.
**** ICAM School of Engineering, 6 rue Auber, 59000 Lille, France.
***** Department of Mechanical and Aerospace Engineering, University of Central Florida, 12760 Pegasus Drive Orlando, Florida 32816.

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