Influence of Robust Drain Openings and Insulation Standoffs on Corrosion Under Insulation Behavior of Carbon Steel

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Corrosion under insulation (CUI) is among the key concerns for the integrity of process equipment and pipelines. Various measures to detect and fix the damages from CUI pose significant maintenance expenditures in hydrocarbons processing facilities. The key reason behind CUI is the limitation of thermal insulations to absorb the moisture and soak the underneath metal from wicking action. Other than CUI, trapped moisture in the soaked thermal insulations causes heat loss from process systems, thereby posing the risk of additional damage mechanisms and increased operating expenditures. This study addresses the impact of robust drain openings and insulation standoffs on the CUI rate of carbon steel under four different testing conditions, namely isothermal wet, isothermal wet-dry, cyclic wet, and cyclic wet-dry, respectively. Corroded specimens were further characterized using surface topography and scanning electron microscope. The impacts of temperature and moisture cycling on the corrosion attributes were also characterized using the linear polarization resistance method followed by an investigation of corrosion modes via optical microscopy. Insulation standoffs in conjunction with robust drain opening resulted in the lowest corrosion rate. With insulation standoffs and drain openings, the cyclic temperature conditions caused higher metal loss than that in isothermal conditions.

KEY WORDS: contact-free insulation, corrosion under insulation, drain opening, thermal cycling, thermal insulation

INTRODUCTION

CUI (corrosion under insulation) is reportedly a driver behind 40% to 60% of overall failures in the piping systems. Smaller-sized piping (diameter < 4 in) is even more prone to CUI, whereas reportedly 81% of failures in small-sized piping are due to CUI.[1] Various measures to address and fix CUI-related failures constitute 10% of a facility's maintenance budget.[1] Despite the first reporting of CUI back in the 1950s, the earliest guideline to address this concern was issued from ASTM (American Society for Testing and Materials) during the mid 1980s.[2] There has been a significant uncertainty toward the prediction of the CUI rate due to its inherent complexity and variety of insulation materials. Type of insulation material drives the possibility of moisture absorption and subsequent CUI rate. Fibrous insulations are well known for the moisture absorption followed by the propagation of moisture molecules due to wicking action.[3] In addition, moisture presence retards the insulative ability of thermal insulations. It has been reported that a 5% increase in the moisture leads to a 25% increase in thermal loss from the fibrous stone wool insulations.[3] Also, the modern recommended practice has revealed that the primary cause of CUI is the direct contact between a metal and moist insulation.[4] Another industry practice has consolidated various parameters to predict CUI rate that includes but is not limited to coatings factors (thickness, aging), insulation condition, insulation type, base material's composition (e.g., carbon steel), environment (marine, dry, etc.), interface factors, and design-related complexity factors, etc.[5] Despite considering the abovesaid factors, there have been many instances of unanticipated CUI failures making this damage mechanism difficult to predict, and one of the greatest "known-unknown damages" in the hydrocarbon industries.

Until now, various preventive measures have been proposed to minimize the risk of CUI in the insulated piping and process equipment. These include protective coatings, material upgrades, as well as the use of water-repellent insulations, etc. Protective coatings are considered as the last line of defense, so the compatibility and longevity of coatings are crucial toward protection against CUI. Any workmanship defects (e.g., porosities, holidays, etc.) and inconsistency of protective coatings and substrate surface can create a CUI vulnerable spot, especially at field-applied weld joints. In certain instances, the intruding moisture may vary in terms of chemistry especially when it is coming from nearby process leaks, chemical/marine vapors, and maintenance works. Such a variation in the chemistry of intruding moisture can jeopardize the coatings under insulation, leading to CUI. There has been a reported incident where the falling water from an overhead heat exchanger's cleaning activity triggered CUI on a pipe underneath the heat exchanger, despite the fact the pipe was adequately coated and was already declared of low CUI risk.[6] Materials upgrades to corrosion-resistant alloys require

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