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CUI Management Through Moisture Barrier System and Field Assessment

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ABSTRACT

CUI (Corrosion Under Insulation) is a key degradation in plant assets and contributes 40% - 60% failures in the piping systems. CUI is known to trigger from soaked insulation that are held in-contact with the metal(s). This article presents a case study of moisture management where a hydrocarbon operator faced challenge of frequent soaking of thermal insulations that caused the operator to replace the entire insulation on a multi-kilometer pipeline twice within an operating period of 10 years. The newer insulation was installed with and without various combinations of moisture barrier devices. The various moisture barrier devices included low point drains, ventilation windows, as well as standoffs between insulation and jacketing. The assessment was made via monitoring of moisture content (Vol.%) in the insulation for which moisture readings were taken at the pipe's surface as well as alongside the thickness of insulation on a bi-weekly basis over a period of 7 months. The standoffs between jacketing and insulation significantly reduced the moisture content of the entire insulated system. This article also addresses the modular management via termination gaskets for compartmentalization and assessment of trapped moisture within any insulated system.

Key words: Thermal insulation, CUI, moisture assessment, contact-free insulation, perforated dimple wraps, low point drain

INTRODUCTION

CUI (corrosion under insulation) is reportedly a dominant damage mechanism in the hydrocarbon industries that arises from aerated moisture under the insulation and is known to cause localized corrosion and pitting on the insulated pipes and process equipment.¹⁻² It is reported that up to 81% of piping failures in hydrocarbon facilities are from CUI, and the expenditures for inspection and fixing of CUI damages constitute 10% of the maintenance budget.³ Modern RBI (risk-based Inspection) practices

suggest the determination of POF (probability of failure) and COF (consequence of failure) for the assessment of CUI risks. Quantitative RBI practices suggest the assessment of various factors related to the design of assets and insulation attributes such as type, quality, and condition etc. for the prediction of POF for CUI. Since RBI studies rely on the recorded information and documented events, so any missing information and inadequate record-keeping can compromise the effectiveness of RBI assessment(s).⁴ A previous study by Rana has revealed that how a neighborhood event of water spillage from frequent hydro blast cleaning of an overhead heat exchanger remained unreported in the inspection records, that lead to unprecedented CUI failure on an insulated pipe (underneath heat exchanger) which was deemed as of low CUI risk during RBI assessments.⁵

The moisture intrusion is the key driver for CUI probability, and moisture is known to come from various sources such as rain, fog, snow, dripping moisture from maintenance/ cleaning works, cooling tower drifts, marine vapors, firefighting canons (e.g. in forest fires), deluge systems etc. Also, the assets which operate at swing temperature and (or) have damaged jacketing can draw the moisture leading to condensation over the metal's surface. In general, the protrusions (pipe clamps, saddles, and brackets etc.) at insulated pipes turn out to be sweet spot for moisture intrusion, and subsequent CUI.⁶ Jacketing(s) are generally applied over the insulations to provide a moisture barrier for the insulated systems regardless of the type(s) of insulations. The metal jacketing also adds to the mechanical strength/ rigidity of fibrous insulations, thereby preventing insulations from sagging. The annular gap (though very minimal) between outer periphery of insulation and inner surface of jacketing can trap the moisture from the surroundings via unsealed (or those with damaged caulking) jacketing laps, protrusion openings etc. The trapped moisture in this annular space is absorbed by the insulation via capillary action which in turn leads to CUI. Other than CUI, soaked insulations result in thermal losses thereby defeating the purpose of installing the thermal insulations. It is reported that only 5% of moisture within a fibrous insulation is enough to retard its thermal insulative ability by 25%.⁷

Various water-repellent insulations are commercially available that are aimed to prevent the moisture ingress due to their hydrophobic nature. Majority of hydrophobic insulations are hydrophobic from inner and outer surfaces, along with some vapor permeability. Any moisture intrusion underneath insulation due to mechanical damages or from any openings left due to inadequate workmanship will stay trapped on the inside of insulation and over the metal, without getting absorbed back into the insulation due to hydrophobic nature of insulations. This in turn increases the CUI risk due to higher POF. Majority of high temperature insulations in the existing oil & gas infrastructure are either stone wool or calcium silicate, that are quite prone to moisture absorption and subsequent transmission to the metallic surface. Standard practices recommend the use of low point drains to remove the trapped moisture for CUI mitigation, which is in fact becoming common across the global hydrocarbon industry.^{2, 6, 8} Previous studies by Rana et. al. and Pojtanabuntoeng et. al. revealed the role of low point drains on the insulation wetting and CUI performance, respectively.⁹⁻¹⁰ Although drain openings can drain a portion of trapped moisture, there has always been a less (or even non-existent) focus in the past to completely dry the insulation materials on in-service piping via cost-effective maintenance efforts. There have been reported incidents where the soaked insulations had to be replaced multiple times during the lifespan of insulated assets due to the absence of any effective drying method.

Hence presence of system(s) or hardware(s) that can constantly stop the moisture intrusion and remove the readily trapped moisture in a timely manner from insulation can help mitigate CUI risks and thermal losses concurrently. In addition to the desired performance, the technologies or barriers should have provisions to allow their assessment through viable NDE means without interfering with existing inspection and asset integrity programs. This study addresses the use of various insulation configurations employing perforated stand-offs in the form of perforated dimpled wrap underneath jacketing, ventilation windows (openings) on the sideways of insulated pipe (i.e., 3'o'clock & 9'o'clock) along with low point drain (at 6'o'clock). These proposed hardware(s) were installed on an in-service pipeline carrying liquid hydrocarbon in the province of Alberta in Western Canada. The moisture contents in the insulation were recorded on bi-weekly basis for seven months starting the date of installation, followed by assessment of systems for moisture trapping tendencies.

EXPERIMENTAL WORKS

The field assessment was aimed at the moisture trapping and drying behavior of stone wool insulations with and without combination of moisture barrier devices. For this, the perforated dimpled wrap was used as breathable moisture barrier and was installed in between insulation and jacketing. The perforated dimpled wrap contained equidistant 900 Nos through-holes (diameter: 4.6 mm) per square ft. which equates to 16.6 % open area over 1 square ft surface. Perforated dimpled wrap also contained 25 Nos. equidistant dimples per square ft. to achieve a consistent stand-off between the outer periphery of insulation and inner surface of metal jacketing. Figure 1 (a) shows typical perforated dimple wrap revealing the morphology and pattern of dimples and perforations. For the sake of installation, the jacketing was stripped off from the pipeline. Perforated dimple wraps were installed on the outside of soaked insulation via banding, followed by re-installation of jacketing over the perforated dimpled sheets.

To achieve air-circulation (for drying), the rectangular shaped ventilation windows (dimension: 165 mm x 118 mm) were installed in an alternating manner on the sideways (i.e., at 9'o'clock & 3'o'clock) of jacketing. Ventilation windows were installed in the cut-out rectangular slot(s) in the jacketing which were equi-spaced (i.e. after every 6 meters) along the entire length of pipeline segment. Ventilation windows were placed in those rectangular slots, followed by securing via silicon adhesive and metallic screws. Each ventilation window had horizontal and louvered openings (Length: 108 mm, Qty: 04 Nos) which were meant to aid the air circulation alongside the outer periphery of insulation without introducing the liquid moisture from rain, snow falls. Figure 1 (b) shows ventilation window with louvered slots. In addition to ventilation windows, rectangular tray-shaped perforated drains (dimensions: 137 mm x 67 mm) were installed in an equidistant manner after every 6 meters alongside 6'o'clock position of the pipeline segment. Rectangular tray-shaped perforated drains contained equi-spaced 18 holes (diameter: 3.2 mm) per square inch to allow for the drainage of trapped moisture. Figure 1 (c) shows the arrangement for perforated drain. Unlike drain plugs and drain holes which are generally installed/ made via coring out insulations, the rectangular tray-shaped perforated drains were rather mounted along the surface of jacketing. Perforated drains were also installed via cutting rectangular slots in metal jacketing (without insulation removal) and secured in place via silicon adhesive and metallic screws. This placement of ventilation windows and low-point drains allowed linear offset of 3.0 meter between low point drain and adjacent ventilation window. Various candidate configurations were prepared with and without these moisture barrier devices. Table 1 summarizes the configuration of each candidate insulated system, whereas Figure 2 is the visual elaboration of each candidate configuration(s) mentioned in Table 1.

Each candidate insulation systems were installed during fall of year 2019 on the pipelines that were carrying liquid hydrocarbon service at an operating temperature of 176 °C. As the insulated system(s) were in Western Canada, they were exposed to cold and later hot climate conditions during the seven months trial period starting the time of installation. The insulation systems were assessed for the moisture trapping tendencies from the moisture readings (Vol. %) that were collected using moisture meter. The moisture readings were taken by placing moisture meter probes at three different depths of the insulation alongside 5'o'clock, 6'o'clock, 9'o'clock, and 12'o'clock positions, respectively. The test points (for moisture readings) were secured using inspection ports to ensure the consistency of data collection point(s). Figure 3 shows the arrangement of moisture meter and three insulation depths namely (A), (B) and (C) for moisture measurements. After completion of moisture assessments for seven months, the insulation was stripped off followed by visual examination of insulations, jacketing, and pipe(s).

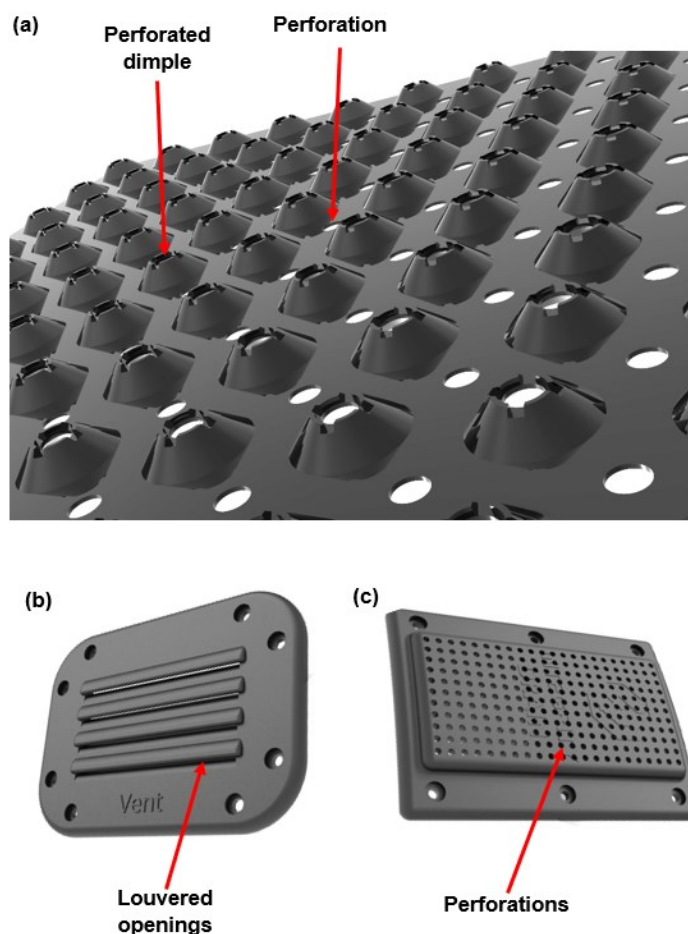


Figure 1: Candidate moisture barrier devices namely (a) perforated dimple wrap (b) ventilation window (c) low-point drain

Table 1: Configuration of various insulated systems

System type	Moisture barrier components	Test location No.
Type A	Not applicable (conventional)	Locations 1-3
Type B	Perforated dimple wrap	Locations 4-6
Type C	Low point drains and ventilation windows	Locations 7-9
Type D	Perforated dimple wrap + low point drains + Ventilation windows	Locations 10-12