

Moisture Management in Thermal Insulations for In-service and Out of Service Pipelines

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ABSTRACT

CUI (Corrosion Under Insulation) is a key degradation in facilities and pipelines and known to drive 40% - 60% failures in the piping systems. CUI is known to trigger from the soaked insulations that are held in contact with the metal(s). Although high operating temperatures are perceived to reduce CUI risks, integrity issues happen due to condensation or sweating once the pipe/ equipment is brought through cyclic temperatures or transient conditions. With lower or even ambient temperatures, the content of liquid moisture within the insulation increases which ends up exploiting CUI risk. This issue of soaking becomes more pronounced in mothballed equipment/ pipes as there is no moth-balling method known that can keep the insulation dry once the pipeline is out of service. This article addresses the case study where the soaked insulations on pre-existing operational and out-of-service multi-kilometer pipelines were trialed for moisture retention affinity. Moisture readings were taken on candidate configuration on a biweekly basis over a period of 7 months. Both i.e., operational, and mothballed lines were also trialed with a novel moisture removal system namely Insulation Ventilation System employing low point drains, ventilation windows, and perforated stand-offs between the insulation and external jacketing. The operational segments of the pipeline with moisture removal systems in place exhibited the least moisture trapping and reduced TOW (time of wetness).

Key words: Insulation, corrosion under insulation, corrosion management, deterioration

INTRODUCTION

Thermally insulated pipelines have wide networks globally that are used to transport various chemicals, hydrocarbons as well as steam. CUI (corrosion under insulation), external SCC (stress corrosion cracking) and corrosion fatigue are some of the prominent damage mechanisms which may occur on the external surface of insulated pipes/ pipelines that in turn jeopardize the long-term integrity and operations. The moisture is undoubtedly the key contributor behind the above said external degradations of metallic surfaces and can come under thermal insulations via seepage and/ or condensation. Various factors that influence the extent of moisture intrusion are the design of insulated system(s), type and age of insulation, operating temperature of pipeline(s) as well as environmental and neighborhood conditions.¹⁻³

The field experience and standard practice(s) have suggested that the propensity of moisture presence in thermally insulated systems and subsequent CUI risks get reduced with increased operating temperature (i.e., ≥ 175 °C).⁴ On the other hand, the hot pipelines may experience wide range of swing temperatures by cycling below the rated temperature which not only introduces the moisture (via condensation) but also aggravates the corrosion rate(s) due to damage of protective/ passive oxide scales.⁵⁻⁶ There have been advents in the insulation industry where hydrophobic insulations are considered as candidate for CUI mitigation. Despite hydrophobic nature, the hydrophobic insulations can absorb the moisture under immersion conditions, a condition which is likely alongside the low points and behind the jacketing in thermally insulated pipes/ pipelines.^{1,7} In addition to CUI, external SCC (stress corrosion cracking) has been reported for carbon steel lines due to soaked thermal insulations.⁸ Other than increased risk of damage mechanisms (CUI, SCC, etc.), the soaked insulations increase thermal conductivity thereby defeating the purpose of thermal insulations. Reportedly, the moisture content up to 5% (by volume) increases the thermal conductivity by 25% in fibrous stone wool insulations.⁹

Although the pipelines at high operating temperatures may see some reduction in the moisture levels due to moisture boil off and resulting vapor drive, the subsequent condensation of vapors within thermal insulation and/ or on the inside surface of jacketing leads to resoaking of insulations via moisture pooling at low points and re-intrusion, as has been discussed in the previous study by Rana et al.¹⁰ This study has proposed a novel design namely IVS (insulation ventilation system)[†] which by virtue of low point drains, insulation vents, perforated stand-offs between insulation and jacketing reduced the moisture level in the pre-saturated thermal insulations. Another study by Rana et al. has addressed on how the use of insulation stand-off and low point drains can maximize the moisture removal from thermally insulated systems via reducing the surface tension at the metal-insulation interface.¹¹

There are many pipelines in today's era that are out of service due to maintenance, demographics, political, and economic reasons. With recent sophisticated advents like IOW (integrity operating windows) in the hydrocarbons industry, the commissioning and de-commissioning strategies may be well established and documented, which are likely more applicable to the internal corrosion, mechanical degradations (brittle fracture, Hydrogen induced cracking, etc.) with less regard to thermal insulations and associated external damage mechanisms. In the absence of adequate operating and decommissioning strategies, the thermal insulations on the out of service pipelines can stay saturated which increases future's operational costs as well as integrity concerns. Until now, there is no reported study that addresses moisture assessment and mitigation strategies via differentiating between in-service and out of service thermally insulated pipelines. This study addresses the moisture behaviors for both in-service and out of service via reporting various key performance indicators namely TOW (time of wetness), moisture trends at pipe skin as well as comparison of moisture levels through the various depth profile of insulation. Four candidate configurations namely IVS + operative, IVS + out of service, Conventional + operative, Conventional

+ out of service were tested on multi-kilometer pipelines in Western Canada. Each configuration was tested for moisture trapping behaviors over a period of seven months during 2020/ 2021.

EXPERIMENTAL WORKS

The pilot study was aimed at understanding the moisture affinity as well as drying behaviors of in-service and out of service thermally insulated systems. The pilot study was carried on operative (Temperature: 176 °C) and out of service loops of 20-inch carbon steel pipeline (service: emulsion). Various test locations were allocated on the test loops with candidate designs for thermal insulations. Figure 1 and Figure 2 show the details on the candidate designs namely conventional insulation and Insulation ventilation systems (IVS), respectively. Table 1 summarizes the candidate configurations considering both designs and operating condition for test loops.

CONFIGURATION	DESIGN	OPERATING CONDITION
Type 1	IVS - Insulation ventilation system	Operative line
Type 2	Conventional system	Operative line
Type 3	IVS - Insulation ventilation system	Out of service
Type 4	Conventional system	Out of Service

The conventional system comprised fibrous stone wool insulation which was placed in contact with the pipe and wrapped with Aluminum jacketing. In addition to stone wool insulation and jacketing, the three component IVS system comprised: (1) Vents, to allow the air circulation at the interface of jacketing and insulation, (2) Perforated dimple wrap, for creating a perforated standoff between insulation and jacketing and (3) Drains, to allow the drainage of moisture from thermally insulated systems. Each test location was equipped with inspection plugs to allow the access to insulation located under the jacketing, see Figure 3 (a). The moisture readings were taken on frequent intervals via handheld moisture meter (Make: Delmhorst, BD 2100[†]), see Figure 3 (b). The prong(s) were pushed through the insulation (at test locations) to have the moisture readings at three different depths namely: at the outer periphery, at the middle of insulation, and at the pipe skin.

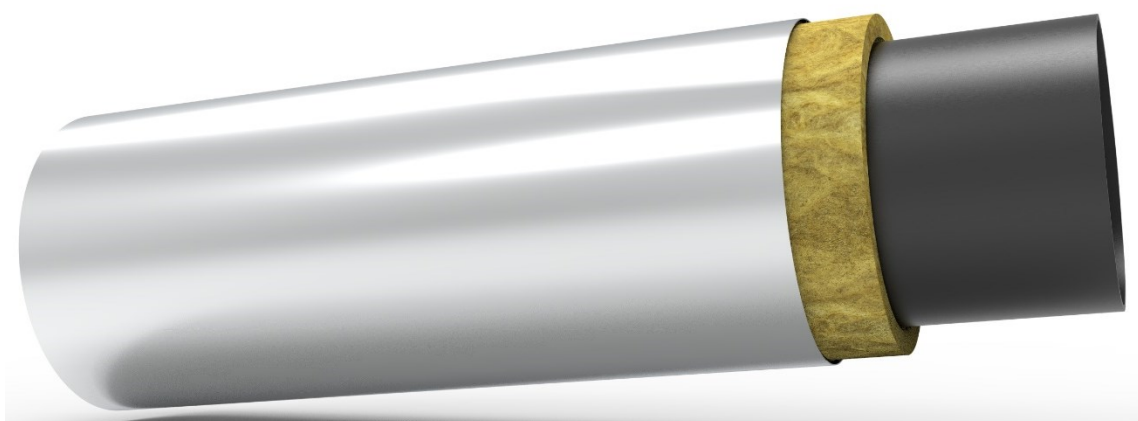


Figure 1 – Conventional Insulation design having fibrous stone wool insulation and Aluminum jacketing



Figure 2 – Proposed insulation ventilation system (IVS) for in-situ drying of insulation