Inspectioneering Journal

ASSET INTEGRITY INTELLIGENCE

A Hybrid Approach for Effective CUI Management

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VOLUME 29, ISSUE 5
SEPTEMBER | OCTOBER 2023

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Introduction

Corrosion under insulation (CUI) is a common damage mechanism in the hydrocarbon production and processing industries, typically manifesting as localized corrosion/pitting [1]. CUI is generally triggered by moisture-saturated thermal insulation, where the time of wetness (TOW), in addition to other factors (chemistry, design, temperature, etc.), govern the rate of CUI propagation [2-3]. In addition to CUI, moisture-soaked thermal insulation can cause heat dissipation from thermally insulated assets. It is estimated that moisture content as low as 5% within thermal insulation can increase heat loss by 25% in a typical thermally insulated system wrapped with fibrous stone wool insulation [4]. Heat conservation in piping is crucial to the efficiency of processing facilities such as steam-assisted gravity drainage (SAGD) facilities since the heat/enthalpy of the steam is directly proportional to the heavy oil recovery rate.

In addition, there have been numerous reports from the Alberta Energy Regulator that refer to incidents of novel stress corrosion cracking (SCC) on thermally insulated pipeline grade steels (e.g., X52, X60, X70) where wet insulation was discovered [5]. The heat of the pipe may boil out a small portion of trapped moisture (which may escape from the jacketing laps), but any remaining moisture within thermally insulated systems poses heat loss, CUI, and even SCC risks. Industry codes and standards recommend the use of low-point drains to allow for drainage of trapped moisture. However, moisture in the insulation is bounded by the surface tension between the insulation and the pipe, which generally requires more than gravity-assisted drainage to clear [6]. Low-point drains can partially remove moisture, but they may not be effective enough to mitigate CUI risk(s) and thermal losses [7]. Recent advancements in insulation manufacturing have introduced innovative products that purport to absorb less moisture than traditional fibrous stone wool insulations. Unfortunately, for most owner-operators, upgrading their existing thermally insulated infrastructure with new insulation materials is not practical or feasible from an economic and/or environmental standpoint.

Due to the technology gaps for insulation drying measures, CUI and thermal losses continue to be an industry challenge. Recently, the American Petroleum Institute (API) introduced a climate action framework (CAF) to facilitate initiatives and technologies that can help reduce carbon emissions/footprints from the operation of hydrocarbon facilities in various sectors (i.e., upstream, midstream, and downstream) [8]. In the authors' opinion, finding solutions to safely and effectively remove moisture from existing insulation, as opposed to replacing with new materials, is an important step in furtherance of the CAF initiative. The primary reason being that insulation is generally single-use and made of non-degradable materials. So, when looking at the vast amount of insulation used in existing operations around the world, destroying it or depositing it in landfills would have a significant negative impact on the environment and companies' carbon footprint. In the case study presented in this article, we field-tested a hybrid design insulation ventilation system (IVS) that utilizes low-point drainage and insulation breathability to remove moisture from moisture-saturated thermal insulation [9].

Hybrid IVS Case Study

A heavy oil-producing facility faced the frequent issues of moisture saturation on thermally insulated pipelines. The moisture build-up events were quite frequent despite the facility being operated in a dry and land-locked area. Historically, the facility had two revamping projects for the replacement of thermal insulation on the crude oil emulsion pipeline sections spanning over 32 kilometers. Despite the very recent replacement of thermal insulation, many sections of the insulation on that pipeline were saturated with moisture. Instead of proceeding with another replacement project, the owner-operator decided to deploy and test the IVS moisture removal technology on a few sections of the pipeline. The sections installed with IVS (later referred to as *IVS design* in this article) were tested for moisture content using a hand-held moisture meter. Also, the sections without IVS (referred to as *conventional* design in this article) were also tested for moisture content, followed by a comparison with IVS design. Since the moisture dwells alongside the thickness of the insulation, the moisture readings were taken at three different positions: (a) at the pipe skin, (b) at the middle of the insulation, and (c) at the outer circumference of the insulation. **Figure 1** shows the as-found condition of the moisture-saturated thermal insulation. **Figure 2** shows the field shot of the IVS design indicating the three components: perforated stand-off membrane, vent, and low-point drain, respectively.

After the installation of IVS, the candidate locations were tested for moisture content on a bi-weekly basis over a period of seven months. **Figure 3** shows a comparison of the candidate designs (from the representative locations) in terms of moisture readings on a scale from 0 to 99.9, where 0 stands for dry insulation and 99.9% refers to liquid moisture.

Discussion

Referring to **Figure 3**, a significant reduction in the moisture content is evident for the IVS at all three depths of the insulation. The IVS locations show almost zero moisture, indicating the complete drying of the insulation. Visual examination of the candidate sections at frequent intervals showed evidence of moisture removal. **Figure 4** shows the icicle alongside the 6 o'clock position, which

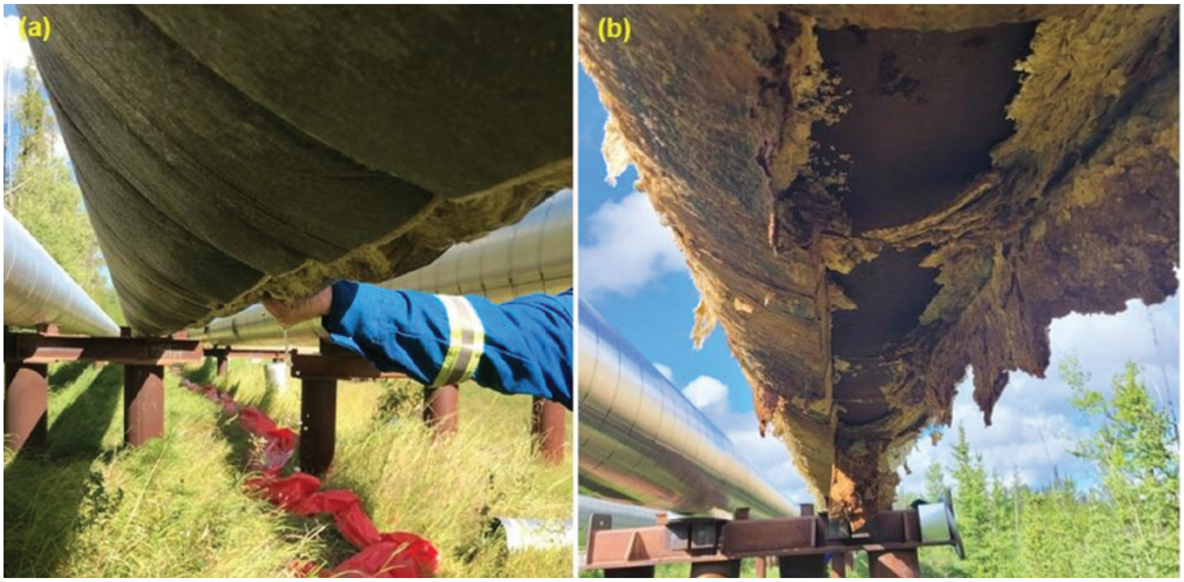

Figure 1. Moisture-saturated insulation.

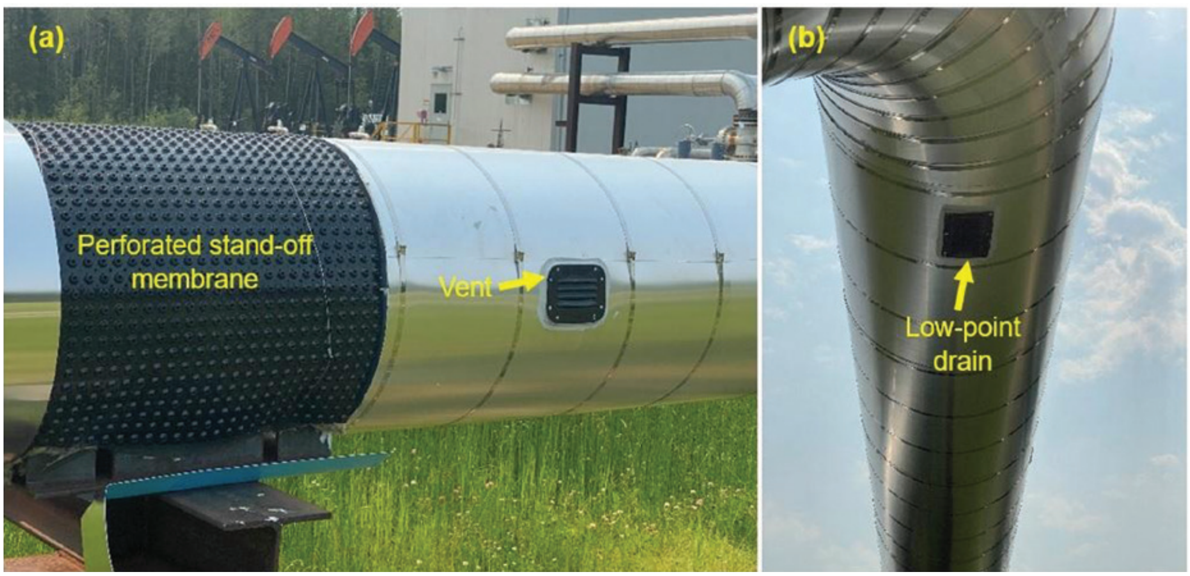

Figure 2. Field shots for insulation ventilation design (IVS).

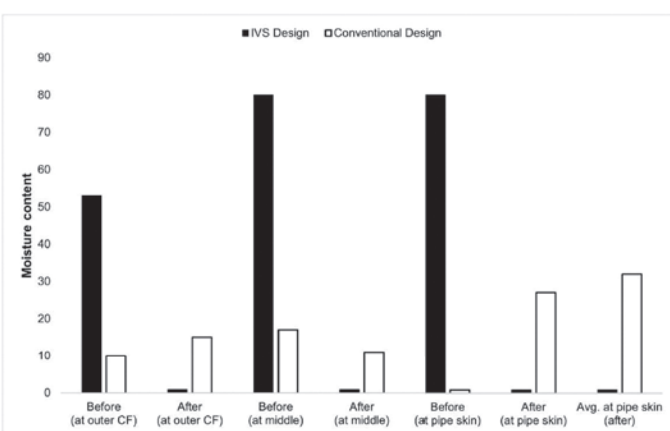

Figure 3. Moisture readings.

was formed due to the freezing of the draining moisture. The perforated stand-off membrane acts as a second barrier against incoming moisture, unlike the conventional design, where the jacketing is the only barrier against the moisture. This led to minimizing any further moisture build-up in the IVS design (over the course of the pilot trial). In a typical hot application, the moisture on the pipe skin tends to boil off, which moves radially through the insulation and may re-condense as liquid moisture within the insulation or at the inside of the jacketing, wherever it reaches its dew point. The liquid moisture pools at the lowest point (i.e., 6 o'clock position), followed by re-intrusion into the insulation via capillary action. The gap from the stand-off membrane and low point drainage allows the re-condensed moisture to drain out before it can pool at the low point, followed by re-intrusion into

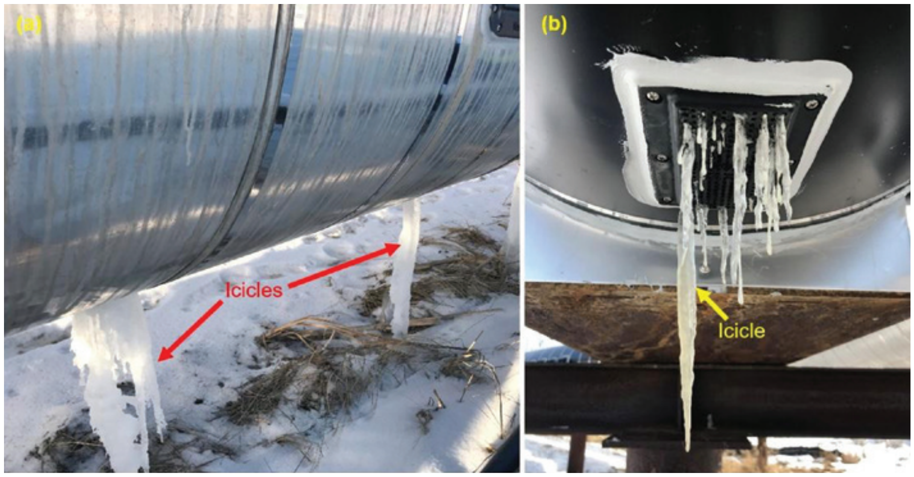

Figure 4. Icicles forming at 6 o'clock position.

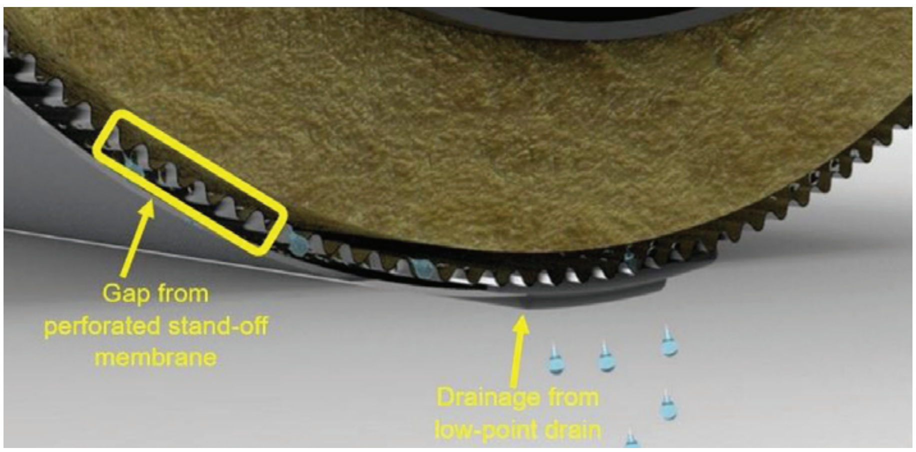

Figure 5. Moisture breath-out and drainage mechanism.

the insulation. **Figure 5** shows the moisture removal mechanism achieved with the IVS design.

Conclusions

The following conclusions were deduced from this study:

1. Moisture build-up under thermal insulation can result even in a dry ambient environment, causing CUI and heat dissipation on thermally insulated systems.
2. Perforated stand-off membranes underneath the jacketing, along with low point drainage, is an effective way to reduce the time of wetness (TOW) for the insulation and the pipe skin.
3. A CUI management program deployed with moisture detection and mitigation technologies can help reduce carbon footprints from the thermally insulated assets. ■

For more information on this subject or the author, please email us at inquiries@inspectioneering.com.

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Graham has a wealth of knowledge, 15 utility patents on CUI mitigative technologies, and experience from his 20-year career in the heat and frost trade, where he worked his way from the field to various management positions within the industrial contractor sector. Graham serves as Integrity Products' CEO and is the creative force that leads the company toward our vision and goals. His main passion and priority is directing the Research and Development team with the invention of new products, which provides many opportunities to use his creativity to solve problems for Integrity Products' customers. Graham also manages key business relationships and contributes valuable support to our growing Business Development team.

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Along with a MASc Degree in materials engineering, Ahmad has over 40 publications of peer-reviewed journal papers, magazine articles, and conference papers. His research focus has been on corrosion, wear, thin-film coatings, epoxy coatings, and risk-based inspection (RBI). Ahmad has invited numerous research grants worth CAD $900,000 to date. He is the chair of the technical symposium for AMPP's upcoming CORROSION 2024. Previously, Ahmad served as chair of the Technical Symposia for the AMPP during CORROSION 2022 and CORROSION 2023. Ahmad received the MP Innovation of the Year award from AMPP for innovation aimed at CUI mitigation. He has also received the Most Impactful Publication award (2021) from AMPP and NACE Graduate Student Book award (2019). He is a voting and contributing member of standards refining committees with API, ASTM, and AMPP.