TECHNICAL ARTICLE 1

Thermal Insulative Coating in Combating Corrosion Under-Insulation (CUI)

Jason Yap Haw-Shin, Brain Lim Siong-Chung
Pluperfect Technology Sdn. Bhd. (PTSB)

Corrosion Under Insulation (CUI) is a major common problem on a worldwide basis that is shared by all the refining, petrochemical, power, industrial, onshore and offshore. The term "Corrosion Under Insulation" describes the external corrosion of piping, vessels and other equipment that occurs beneath conventional insulation system follow water ingress. CUI tends to remain undetected until the insulation is removed for inspection or when corrosion damage progresses to the point of failure and leak occurs as a result of Loss of Containment (LOC). Figure 1 - A serious process fire safety incident.

Figure 1: CUI failure on piping leading to a process fire safety incident

Many studies have shown that the highest incidence of leaks in the petroleum industry is due to CUI failures and not due to process corrosion. This phenomenon is known to be highly random in nature and tends to remain undetected until complete removal of insulation to thoroughly inspect the condition of insulation/metal surfaces. Figure 2 - CUI exposed under insulation and Figure 3 - Grossly reduced wall thickness loss due to CUI after opening up insulation.

The best CUI mitigation measure is to avoid insulation on equipment and piping that does not require thermal insulation in the first place. This article discusses the general overview of corrosion under insulation (CUI), an environment that is often overlooked until a loss of containment occurs in the operated phase of facilities. Thermal insulation is usually employed due to process reasons:

- to minimize heat gain or loss, personnel protection – from heat or cold burns, acoustic reason
- to manage noise control and fire protection
- to protect equipment and piping from heat radiation.

Traditionally, conventional insulation system usually consists of insulating materials such as mineral wool, cellular glass, calcium silicate, phenolic foam, and etc. followed by an outer layer of jacketing or cladding.

Insulation system is designed with aims that water ingress and capillary action is not possible and that potential leaked product and water vapour or condensation can escape or drain off. Despite a carefully designed insulations and great emphasis given to sealing joints, termination system and protrusions during insulation, water ingress over time is inevitable and is a given. Mechanical damage such as personnel stepping on it (Figure 4) and degradation of sealants will contribute to the water ingress through the insulation system. CUI can also occur if equipment and piping sweat.

Once the insulation is breached, a highly aggressive environment beneath the insulation materials is created, in combination with the lack of visibility; CUI can lead eventually to catastrophic and expensive failures (Figure 1).

Figure 2: CUI exposed under insulation

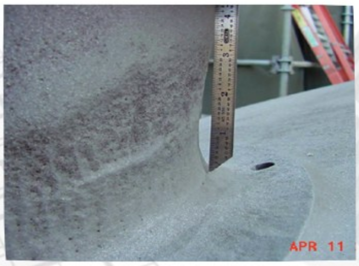

Figure 3: Wall thickness loss due to CUI

2. DESIGN OF INSULATION SYSTEM

There are three combinations that lead to CUI, susceptible temperature, susceptible material and ineffective barrier (water ingress). Therefore, it is imperative to identify the needs for and the criteria in designing an insulation system as a good engineering practice. Typical considerations during the design stage are the application of the proper protective coating system, insulation system specific to the environment and proper insulation installation.

A high CUI corrosion rate is anticipated in the temperature region between 50 degrees Celsius to 110 degrees Celsius and a reasonably low corrosion rate as the temperature goes below 50 degrees Celsius or higher than 110 degrees Celsius. (c.f. Figure 5).

Other than technical requirements, economic consideration plays a vital role to ensure the insulation system is capable of remaining under the expected conditions of service life. There are numerous cases where insulation is designed on equipment and piping even though it is not required. This will add to the maintenance cost for inspection activities which could be time-consuming and expensive. One of the reports shows that most piping leaks (81%) occur in a diameter smaller than 4" nominal pipe size. Hence, this goes back to the basis of design consideration; do the equipment or piping need thermal insulation in the first place.

Figure 4: Personnel stepping on and damaging the cladding

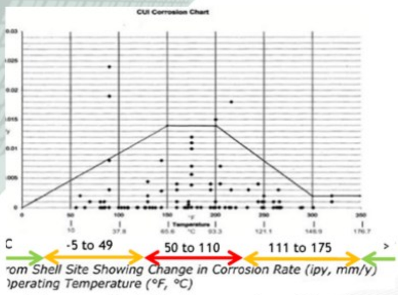

Figure 5: CUI Corrosion Chart

During the design stage, it is crucial to understand the potential risk and the barriers management associated with the failure of CUI. Risk management requires a systematic approach of analyses from various technical disciplines in order to support any decision. Meanwhile, barrier management is established to maintain barriers at any given time by preventing an undesirable incident from occurring or by limiting the consequences in case of unwanted incident happens.

3. NON-DESTRUCTIVE EXAMINATION METHODS

To date, there are numerous non-destructive methods available to inspect the presence of CUI without removing the insulation. Neutron backscatter, thermography, radiography (real-time or computed radiography), ultrasonic thickness measurement (guided-wave testing), pulse eddy current, magnetostrictive sensor technology to mention a few. However, none of them is 100% reliable.

4. SUSCEPTIBLE MATERIALS AND PROCESS SAFETY

CUI can occur in carbon steel, low nickel steels and low alloy steels. The primary consideration is temperature. External CL-SCC can occur in austenitic stainless steel typically SS304L, SS316L, SS321, SS347 and associated weldments. Alloys containing more than 32 % Ni are generally not susceptible to external CL-SCC. e.g. Alloy 825 CUI failure can often lead to process safety incidents where the management of hazards that covers major accidents involving the release of potential dangerous material, release of energy (such as fire and explosion) or both is not effective.

5. CUI MITIGATION - AN ALTERNATIVE OPTION

The most common CUI mitigation plans include one or more of the following: application of protective coating, periodic stripping of cladding for visual inspection and periodic Non-Destructive Evaluation (NDE) activity for maintenance. In recent years, with the availability of thermal insulative coatings in the market. One of the CUI mitigation approaches is through the application of protective thermal insulative coating (e.g. fluid-applied acrylic). Thermal insulative coating has additional advantages compared to conventional insulation systems as follows:

- Resistance to moisture infiltration which is a primary cause of CUI. The insulating value does not drop after exposure to water.
- Exceptional corrosion under insulation resistance. Most conventional forms of insulation are not bonded directly to the substrate, thus creating air gaps where moisture can collect to initiate corrosion under insulation.
- Excellent substrate bonding and durability. The durable, water resistant barrier effectively resists moisture infiltration.
- Trouble-free labour saving touch-up/repair via visual inspection on the conditions of the thermal insulative coating.

Figure 6: Pictures of Aerolon thermal insulative coating application on vessel and piping.

Until today, the key challenge with corrosion under insulation (CUI) mitigation programme is still to do with the issue that there is no cost effective and no 100% reliable non-destructive examination to inspect or detect corrosion under insulation. The most effective and lowest cost to prevent CUI is to avoid insulation on equipment and piping that does not require thermal insulation in the first place. The design consultant and the client engineer have to work closely together to ensure compliance.

Essentially, CUI cannot be entirely eliminated; however, it can be managed with the most cost effective mitigation approach depending on the situation. Hence, applying thermal insulative coating on vessels, tanks, valves, structural steel, and piping within the thermal insulative coating upper temperature limit is a cost effective alternative option to effectively mitigate and combat the risks of CUI in the plant facilities during project design phase where thermal insulative coating is specified upfront by client engineer and in operate phase where conventional insulation system is replaced by thermal insulative coating within its upper temperature limits during asset turn around.

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INSTITUTE OF MATERIALS, MALAYSIA

Suite 1006, Level 10, Block A, Kelana Centre Point,
No. 3 Jalan SS 7/19, 47301 Petaling Jaya, Selangor.
Tel: 03-76611591
03-76611592

secretariat@iomm.org.my
www.iomm.org.my
+60 18-911 3480
Institute of Materials, Malaysia