Corrosion Under Insulation (CUI) Management

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ABSTRACT

Corrosion Under Insulation (CUI) is external corrosion due to the collection of water in annulus spaces, between the insulation and the metal surface. CUI cannot be eliminated, but it can be managed. This paper reviews the industrial community’s efforts toward managing CUI, through addressing field experience derived from the CUI Management Program deployed by Saudi Aramco’s Yanbu’ NGL Fractionation Department (YNGLFD). A safe workplace at YNGLFD industrial facilities is supported through safeguards and promotion of asset integrity. The YNGLFD CUI program is set as a lifelong inspection exercise, covering all YNGLFD plant facilities, with extensive CUI inspection on the insulated equipment and piping, for hot and cold services. This paper disseminates lessons learned from the encountered constraints at the beginning of the CUI Management Program, the applied inspection methodologies, the identified inspection finding classifications, and the employed repair procedures for each finding classification. Along with sharing the measures for managing CUI, YNGLFD dedicates its resources to maintaining a safety culture that corresponds to Saudi Aramco’s corporate vision for being an industry leader in safety.

1. OVERVIEW

1.1 CUI Definition and Associated Potential Risks:

Generally, corrosion is the deterioration of a metal due to it electrochemical reaction with the surrounding environment which is usually water or moisture; however, corrosion under insulation (CUI), which is localized corrosion occurring at the interface of a metal surface and the insulation. The enclosed environment of the insulation material creates conditions that encourage buildup of moisture, resulting in corrosion. CUI is not only limited to systems operating in cold services, it can take place in hot service and be caused by the operating nature as a damage mechanism. CUI can be more severe than the corrosion of the exposed equipment and piping due to that the insulation can trap moisture not allowing its evaporation. Also, insulation can act as a transporter, moving moisture occurring in one area through the insulation to another area causing the spread of this phenomenon (Figure 1).

In effect, CUI could lead to product or hydrocarbon leaks possibly causing fires, since the insulated equipment and piping are always shielded from the naked eye and corrosion often go unnoticed (Figure 2). Researches in CUI reported that:

- The highest incidence of leaks in the petroleum industry is due to CUI and not to process corrosion. (1) (4)
- Most piping leaks (81%) occur in diameters smaller than 4” nominal pipe size. (4)
- Between 40% and 60% of piping maintenance costs are related to CUI. (1) (4)
1.2 CUI Susceptible Systems:

CUI can occur in all insulated cold and hot services; however, there are factors that promote its likelihood, which if present, the operating system can be classified as a system susceptible to CUI. These factors are:

1.2.1. Construction Material
Carbon steel and 300 series stainless steels are commonly used in the industry. CUI can manifest as localized wall loss on carbon steels. On stainless steels, it is often pitting and corrosion-induced chloride stress corrosion cracking (SCC).

1.2.2. Continuous or Intermittent Operation
The length of time and frequency of down time spent at ambient temperature may well contribute to the amount of CUI that occurs. This can be as a result of condensation ingress on the metal surface because of temperature variation. Also, the operating system is classified as susceptible if it operates between 25 °F (−4 °C) and 250 °F (121 °C). Therefore, a system that continuously operates out of this range is out of the susceptible classification; otherwise, it could still be classified as susceptible if in intermittent operations.

1.2.3. Geographical Location
It is well-known that there are harsh corrosion environments at the shoreline, enabling misted air to seep through the insulation and cause corrosion. This is not limited to the seaside, indeed some inshore areas can also be classified as susceptible if the insulated pipes and equipment are subjected to mist overspray from cooling water towers or steam vents.

1.3 CUI Vulnerable Locations:

The susceptible systems for CUI include high risk locations because of their geometrical shape or insulation condition leading to more CUI damaged compared to other locations. Those are known as CUI vulnerable locations. Subsequently, CUI inspection programs should survey and monitor these locations, which will represent the general condition of the insulated section of the facility. Industry codes, such as API 570 and NACE RP0198, provide a long list of vulnerable locations. Examples for the CUI vulnerable locations include:

- Low points where the condensation tends to accumulate.
- Bulges or staining of insulation where deformation may exist.
- Irregular insulation surfaces at valves and fittings.
- At the opening in the insulation jacketing for the On-Stream Inspection (OSI) points or other types of breaches where the moisture can seep through.

2. SA YNGLFD CUI INSPECTION PROGRAM

2.1 Program Objective, Setup and Scope:

A safe workplace at Saudi Aramco’s Yanbu’ NGL Fractionation Department (SA YNGLFD) industrial facility is supported through safeguards promoting asset integrity. Therefore, this deployed CUI program at YNGLFD strives to uphold Saudi Aramco’s position in the marketplace as a trusted energy provider and an industry leader in safety.
The program is set as a lifelong inspection exercise that covers all YNGLFD plant facilities with extensive CUI inspections on the insulated equipment and piping in hot and cold services. The program derived its mission from the Saudi Aramco Safety Management System (SMS) fifth element, which underpins maintaining the operating facility Asset Integrity throughout its life cycle, and from Saudi Aramco Inspection Procedure 00-SAIP-74 “Inspection of Corrosion Under Insulation and Fireproofing” that is well anchored in international industry codes API 570 and NACE RP 0198.

The program covers all plant operating areas. It began with an initial survey to identifying CUI susceptible systems. The goal was obtaining an administrative platform for the planning and availing of the required resources. The survey concluded by categorizing the susceptible systems and dividing the plant into five main areas (Figure 3) with each area having a certain number of insulated systems that were categorized based on susceptibility. On the other hand, each insulated system categorized as susceptible was divided into smaller sections. For example, in a propane loading system with three pumps, each pump that can be isolated without affecting the whole propane loading system was considered as an independent section. The intent of this surveillance was to ensure that the execution of the CUI program will not disturb the plant operation and vice versa.

2.2 Potential Execution Constrains:

There are a number of constraints and pitfalls that may hinder the execution of this long-term program. Yet, any projected CUI program can be well improved through the identification and resolution of all potential constraints prior to its execution. In general, such constraints may include:

2.2.1. System Availability
This is apparent especially during the outage of the back-up facility of the one planned for CUI inspection. This is a real concern for the plant facility that cannot be totally shut-down for maintenance.

2.2.2. Contract Procurement
Securing insulation specialized and experienced contractor may negatively impact the program start if not given priority. Maintenance has to procure qualified contractor who can mobilize timely for the execution.

2.2.3. Contractor Manpower Allocation and Quality of Workmanship
The program may experience a shortage in contractor manpower because it is normally executed along with other planned maintenance activities. Also, the quality of the contractor labor workmanship, which demands extra attention to assure quality work is done.

2.2.4. Employed Coating Systems
Time is consumed to cure each coat as well as the re-insulation process, which is a delicate process requiring time to be completed.

2.3 Deployed Inspection Techniques:

Nondestructive Testing (NDT) is the primary tool for inspecting for CUI. Therefore, throughout the YNGLFD CUI program, visual testing (VT) inspection was employed as a main technique, where its findings were reviewed against the insulation removal criteria outlined in 00-SAIP-74; however, Thermo-Camera and Radiography Testing (RT) were also utilized. Use of Cobalt-60 as a source for the RT is one of the successful experiences YNGLFD had in inspecting for CUI. Essentially, YNGLFD carried out NDT inspection consumed Cobalt-60 source that was recommended by Saudi Aramco Inspection Department Technology Unit as a reliable technique to check for CUI in a large diameter piping. This inspection exercise was performed over representatively selected locations at piping
systems extending about 3.5 km with a diameter range from 16” and 48” and operating at low temperatures, -44 °F.

The Cobalt-60 RT target locations were chosen since they had the worst condition over the piping in terms of the insulation’s physical shape and the evident signs of condensation through the insulation jacketing (Figure 4). Subsequently, the interpretation of the RT films showed evidence of a clear surface with no signs for CUI, which was further confirmed with insulation removal exactly at those locations.

Other NDT techniques were used, such as Ultrasonic Thickness (UT) test, which was performed upon the insulation’s removal to determine the remaining thickness where corrosion was observed. Also, Magnetic Particle Testing (MT) and Penetrant Testing (PT) were employed, as required, to examine the welds’ integrity.

3. ILLUSTRATION FOR CUI FINDINGS AND MITIGATION

The findings from the CUI inspection vary based on the associated factors that promote the likelihood of CUI. Each inspection organization could develop its own classification for the findings to help track the CUI findings and provide classifications for the CUI severity and the required repair. Therefore, YNGLFD made use of three main classifications for the findings. Those classifications can be described along with the employed mitigation practices as follows:

3.1. First Classification
Severe thinning and leak source findings were not widely spread at YNGLFD; however, CUI was considered at a serious level that must be given priority by performing the necessary NDT. Immediate permanent and/or temporary repairs were required according to the granted outage and carrying out the revalidation for the exposed portions through recoating as per the recommended protective coating system specified in Saudi Aramco Engineering Standards.

3.2. Second Classification
This was for common aging CUI findings in which the exposed portion was still in sound condition, yet general corrosion may have been observed on the metal surface. This finding classification was classified at a moderate severity level; therefore, inspection and revalidation were carried out.

3.3. Third Classification
This classification was for CUI-free surfaces where no sign of corrosion was observed and the applied coating was found intact. CUI free surfaces was a common finding at YNGLFD because of the continuous operation at a low temperature, almost throughout all the plant facilities. Therefore, the inspection scope was limited to VT and UT inspection and repair was required for the scratches occurring on the existing coating during the insulation removal.

4. CONCLUSIONS

CUI remains as a prevalent problem in many industries. Indeed management of CUI risks is a critical part of proper process safety hazard management leading to acceptable safety performance. There are several process safety management systems and best practices that are difficult to rank as best for incident elimination. Subsequently, an effective mechanical integrity program would certainly be among the top, because failures prevented by deploying a CUI inspection program is often the most dangerous, since they can occur in areas where there were no previous indications of a problems. Essentially, CUI cannot be eliminated, but it can be managed with typical mitigation measures that include:
- Application of the proper protective coating system.
- Designing insulation systems specifically for their environments.
- Proper installation of the insulation system so it would last longer with minimal maintenance.
- Recognizing the early signs of CUI and insulation maintenance needs.
- Performing maintenance promptly to eliminate compounded concerns in the facility due to CUI.

5. Figures

**Fig. 1**

Illustration for Water Spread and CUI Development

![Illustration for Water Spread and CUI Development](image1)

**Fig. 2**

Nipple Weld Failure Due to CUI

![Nipple Weld Failure Due to CUI](image2)
Fig. 3

NUMBER OF CUI PROJECTED SYSTEMS & FACILITIES

Fig. 4

Condensation through the Insulation Jacketing
6. REFERENCES


