ENGINEERING APPROACH TO CONTROL CORROSION UNDER THERMAL INSULATION (CUTI) IN PETROCHEMICAL INDUSTRIES

Ali A. Al Beed
Saudi Petrochemical Company (SADAF)
P. O. Box 10025 Jubail, KSA

ABSTRACT

Corrosion under thermal insulation (CUTI) in the petrochemical industries is one of the forgotten problems that threatens all insulated equipment and piping system which have been in service for several years. Most industries in this area may not have the proper plan and tool to inspect, control such problem and prevent major failure due to this type of corrosion.
This paper discusses a case history on CUTI failure that initiated actions to develop short and long-term solution to detect CUTI and minimize failure in the future.

INTRODUCTION

Chemical plants and other industries have many thousands of meters of pipe that are insulated to prevent heat loss or heat absorption but CUTI is threading the pipe under the insulation. Corrosion of steel under insulation is consider to be one of the problem which caused severe damage to petrochemical industries especially to all insulated equipment and piping system which may cause at the end failure and accidents.
Most industries have taken into consideration the CUTI problem during the design stage, although the awareness of CUTI started late 70s and 80s, but there was no big concern at this time about this problem. The effects is starting to be obvious now and during the next few years when plant is getting old and corrosion is getting worse. A basic reason why CUTI remains serious and costly is that it occurs out of sight thermal insulation and its jacketing material hide the problem until it gets bigger and too late to fix it.
During one of technical Corrosion meeting in Jubail about the CUTI problem, we found out that the corrosion problem under the insulation is getting started in almost all old plants.

Steel does not corrode, simply because it is covered with insulation. It corrodes when it contacts water and free oxygen. The primary role of insulation in this type of corrosion is to produce annular space in which water can collect on the metal surface and remain with full access to oxygen (air).
The most active sites are those where the steel posses through the insulation and on horizontal metal shape, for example, insulation support rings where water can collect [1].
Cyclic temperatures that could cause wet and dry environment beneath the insulation is another way to cause corrosion. In addition, insulation material itself could be a factor causing corrosion to the austenitic stainless steel if it contains chloride, bromide or fluoride.

Corrosion Mechanism and its affect:
Any corrosion process depends into two factors, temperature and oxygen in addition to the concentration of dissolved species. Corrosion increased by increasing both factors, if the oxygen is not available then corrosion may not occurred. This means that if we keep the environment beneath the insulation is dry all the time, then no corrosion will occur.
When precipitation becomes trapped on the metal surface by insulation, corrosive atmospheric constituent such as chloride and sulfuric acid can concentrate to accelerate corrosion. In some cases, chlorides are present in the insulation itself, which promote corrosion.
Pitting and general thinning occurs in carbon steel while stress cracking occurred in 300 series stainless steel. Therefore, when corrosion occurred to the equipment, leak will develop. This means losing money. Study shows that if one drop per second for a product is leaking for one month, 34 Gallons of production will be lost. While 1.6 mm continuous stream will cause 2500 gallons of production loss for the same period. This indicates the importance of preventing corrosion and leak.

PIPING SYSTEM SUSCEPTIBLE TO CUTI

Water is one of the factors that caused CUTI; its source could be from rain, leak, condensation and deluge system. The following are the susceptible systems to CUI [2]:

- Areas exposed to mist over spray from cooling water towers.
- Areas exposed to steam vents
- Areas exposed to deluge system
- Areas subjected to process spills, ingress of moisture, or acid vapors
- Carbon steel piping systems, including those insulated for personnel protection, operating between –4 to 120 degree C. CUI is particularly aggressive where operating temperatures cause frequent of continuous condensation and re-evaporation of atmospheric moisture.
- Carbon steel piping systems that normally operate in service about 120 Degree C. but are in intermittent service.
- Deadlegs and attachments that protrude from insulated piping and operate at different temperature than the operating temperature of the active line.
- Austenitic stainless steel piping system operating between 65 and 204 degree C. (These systems are susceptible to chloride stress corrosion cracking)
- Vibrating piping systems that have a tendency to inflict damage to insulation jacketing providing a path for water ingress.
- Steam traced piping systems that may experience tracing leaks, especially at tubing fittings beneath the insulation.
- Piping systems with deteriorated coatings and/or wrappings.

It is important to know the locations of where you can find CUI to easily identify the problem and perform the suitable inspection and repair. The followings are the common locations on piping systems susceptible to CUI:

a) All penetrations or branches in the insulation jacketing system, such as:
    - Deadlegs such as Vents, drains
    - Pipe hangers and other supports
    - Valves and fittings (irregular insulation surface)

- Bolted-on pipe shoes
- Steam tracer tubing penetrations

b) Termination of insulation at flanges and other piping components.
c) Damaged or missing insulation jacketing as shown in figure 1
d) Termination of insulation in a vertical pipe
e) Caulking that has hardened , has separated or missing
f) Bulges or staining of the insulation or jacketing system or missing bands

Figure 1 Missing Insulation Jacketing

During the design stage and maintenance practice, attention should be paid to the common piping locations susceptible to CUI to ensure they are well sealed and no moisture gets into the insulation and they are not collecting water. If this practice is applied, then CUI will be controlled in the plant.

INSPECTION PROGRAM AND TECHNIQUES

Classifications of equipment and all piping system in the plant as per API 570 are very useful to easily identify the most dangerous process to start with. API 570 classifies piping system into three classes. Class 1 service with high potential of resulting in an immediate safety or environmental emergency, class 2 includes the majority of unit process and selected off-site piping and class 3 services which are not flammable [2].

Inspection for CUI should be concentrated on those areas where water can pass through insulation covering and where it would collect after it passes through. Because CUI inspection is very expensive and provides only an indication of the condition of the steel unless 100% visual inspection is done and repairs needed because of CUI damage can be very expensive. Therefore, we believe that CUI problem can best be handled by proper preventive maintenance (PM). CUI can be prevented by keeping the steel surface dry, this is done by maintaining an adequate seal of insulation sheathing and maintaining appropriate protective coating on the steel surface.

Before starting performing inspection for CUI, it is a good practice to prioritize those locations where CUI has the strongest potential. The equipment and piping classification make this job easy. Inspect 100% of all class 1 and 2 piping and equipment in the highly suspect areas especially if the piping system is very old, and 50 % of all class 3 piping in the highly suspect areas. Inspection can be visual of the pipe surface or combination of appropriate non-destructive exam (NDE) methods.

NDE techniques for CUI:

The following are the common NDE techniques:

1. Visual without insulation stripping. This is the most common method by cutting a plug in the insulation that can be removed to allow for thickness measurement. However, many times plugs can be the source of moisture leakage. The main problem with this technique is the possibility miss poisoning of the plug in the right spot of corrosion.
2. Stripping the insulation and use Ultra sonic thickness measurement (UT). This method also required knowing the possible location of CUI such as rust stain before stripping the insulation or you have to strip all insulation if you know there is a CUI.
3. Profile Radiography, is effective but it becomes technically challenging in pipes over 10 inch (254 mm) in diameter.
4. Real-time Portable Radiography, this technique shows the presence of external corrosion under the insulation but not wall thickness, it is limited up to 24 inch pipe (610 mm).
5. Infrared thermograph and Neutron backscatter (NBS) could be used to identify the wet insulation, but it required qualified technician.[3]

Inspection Procedure:

During inspection of carbon steel system when all insulation removed, use the following procedure [3]:

1. Clean off surface rust and foreign matter by high pressure water or wet abrasive blast
2. Locate and mark areas of corrosion such as pitting and make it in piping inspection sketch
3. Measure remaining wall thickness
4. Record the result

If the insulation is in place and corrosion areas were found by thermal image scanning, then cutting windows is required to measure the wall loss.
When inspecting stainless steel 300 series with all insulation removed, use the following:

1. Visually inspect for evidence of external stress corrosion cracking
2. Clean surface area with high pressure clean water
3. Use liquid dye Penetrant around all nozzles and welded attachments.
4. If dye Penetrant tests are questionable, the presence of cracking can be confirmed by ultrasonic shear wave.

If the insulation is in place, use thermal scanning or neutron backscater (NBS) to identify the suspected areas. By acoustic emission (AE), locate the presence of stress corrosion cracking (SCC). Then cut windows in the insulation to repair the affected areas.[3]

CASE HISTORY

In the Ethylene unit, The wet cracked gas from the caustic treating section is dried in the process gas dryers to prevent freezing in the downstream cold section of the plant. The wet process gas is dried so that it will contain less than 0.1 ppmw water when it flows to the demethanizer feed chilling section.
The dryer is made of killed carbon steel SA516 Gr70 with cellular glass insulation. The design conditions are 4300 kPa at 0°C to 219°C and 3700 kPa at 340°C.
The dryer feed is at 15.6°C design (12.5°C in existing operation) and 3548 kPa with a molecular weight of 18.9.
When the dryer spends 130 hrs in service or the percentage weight of water content reaches about 5 ppm, the dryer will be isolated, regenerated, and purged. Then, tail gas (T. G.) heated to about 230°C is introduced into the isolated dryer. After that, T. G. cooled to about 65°C is introduced into the dryer.

- A leak was found during the unit start up on a 38.1 mm (1.5 inch) start up line coming from 355.6 mm (14 inch) line. This leak was located at the top platform of the process gas dryer 11V70. Visual inspection revealed damaged insulation and Corrosion Under Thermal Insulation (CUTI). The depth of the CUTI appeared to be very significant, down to paper thin around the leak area while the original thickness was 5.08 mm (0.2 inch) as shown in figure 2. The 1.5 inch line was some times used as a step by persons on the plat form, which may cause bending stress. This stress

Figure 2 Failure of the 1.5 inch pipe due to CUI

could be one of the contributing causes to the final failure of the pipe. The leaking line was insulated by Cellular Glass,

and coated by Inorganic Zinc. Moreover, number of probable root causes were found as follows:

- The line subjected to cyclic temperature. As mentioned above, there was tail gas introduced into the dryer at two different temperatures 230°C and 65°C other than the normal process gas temperature 12.5C. This means that there was a cyclic temperature (12.5°C to 230°C).
- Corrosion under thermal insulation (CUTI). Once there was a cyclic temperature, there was moisture generated under the thermal insulation and above the line surface. This moisture worked as a media connecting the anodic areas to the cathodic areas especially since there was an electric connection between both of them, which was

the pipe its self. As a result, corrosion under thermal insulation (CUTI) started to take place.

- The line was more than 12 years in service specially if it is known that there was improper inspection monitoring program, and

No enough CUTI awareness among all personals.

As a result of the above, Corrective action & Recommendations were generated as the following:

- Replace the pipe
- Use proper coating for cyclic temperature
- Strip all system insulation for inspection
- Apply the same repair for the identical line on 11V69 to avoid a leak in the near future
- Identify all susceptible CUTI areas in Ethylene & other units
- Add all CUTI lines in the piping monitoring program
- Strip the insulation when NDT shows problems
- Establish CUTI procedure
- Prepare a plan to inspect all susceptible CUTI lines, and
- Increase the awareness among the Inspectors & Operations.

This leak cost about 50,000 SR. So, by applying the new CUTI program for just two other identical pipes, about 100,000 SR was saved. As the process inside the leaking pipe is high flammable process, so that, there was a high possibility to have a fire if the leak was large which may cause unit shut down for at least three days. This means three days production looses. In other words, about four to five millions SR could be lost.

In other word, applying CUTI program for the Ethylene unit only, saved more than this amount. Imagine, how much money applying the CUTI program for the whole SADAF plant was saved!

CONCLUSION AND RECOMMENDATIONS

We conclude that the moisture is the main responsible factor which develops CUI. Therefore, keeping the insulation dry is a most important step to avoid this problem.

Based on the discussed case history, it is important to have well documented inspection program for all piping and equipment including CUI. As we can see that CUI failure’s trend is increasing, this indicates the need for such program.

The followings are recommendation in order to minimize CUI failure:

1. Establish piping and equipment inspection program and include CUI inspection
2. Inspect class 1 and 2 equipment and piping system as per API 570 recommendation as a minimum to avoid major loss in the plant when failure occurred.
3. Maintain the insulation outside jacketing condition by having an effective preventive maintenance (PM) and quick repair program in order to prevent water getting in the insulation.
4. Use proper protective coating system
5. Provide awareness sessions to operation, maintenance and field people on the CUI and the importance of keeping the outside jacketing intact with no damage.

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ABOUT THE AUTHOR

Ali A. Al Beed *,

Currently is a Corrosion and Material technical advisor Engineer and group leader in the Equipment Engineering department at Saudi Petrochemical Co. (SADAF).
He has over 25 twenty five years of experience in corrosion, material selection, failure analysis, cathodic protection specification development and design. He has authored and co-author more than 17 technical papers for local and international conferences, he is a chairman for SABIC corrosion subcommittee , Vice chairman for NACE Jubail section and served as a chairman for ASNT-APSA chapter from 1996 to 1998.
He holds a B.Sc. degree in Mechanical Engineering from King Abdulaziz University in Jeddah- Saudi Arabia.
He is a certified API 653 Tank inspector, he is a member of NACE,.

Figure Captions

Figure #	Description
1	Missing Insulation Jacketing
2	Failure of the 1.5 inch pipe due to CUI