CORROSION UNDER INSULATION - CAUSES,
DETECTION & PREVENTION

C.H. O'MALLEY,
Altona Petrochemical Company,
Altona, Victoria, Australia.

ABSTRACT Corrosion under insulation is a nagging, high cost problem in the petrochemical industry. Typical mechanisms are explained and preventative measures outlined.

1 INTRODUCTION

Corrosion under insulation has always been a problem in those processes where insulating equipment is exposed to the weather or to water. However the problem has become even more serious with the drive for more thermal efficiency in the late 1970's and the consequent insulation of equipment operating closer to ambient temperatures. At our plant we have some hundreds of insulated vessels and many kilometres of insulated piping, both cold and hot, and so costs of detection, correction and prevention can be very high. Over the past few years in the petrochemical industry a major effort has been underway to find the most cost effective ways to locate corroded areas and to prevent attack.

2 TYPES OF INSULATING MATERIALS

Insulation types are normally broken down into two broad classes, cold and hot. A major difference between them is that, in addition to being a heat barrier, cold insulation system must also prevent moisture condensation and ice formation on the surface of the equipment or in the insulation itself. No one insulating material has properties suitable for the complete temperature spectrum and so different alternatives are used to cover specific temperature ranges. The choice is normally based on thermal conductivity, decomposition temperature, mechanical strength, chemical resistance and cost.

The most commonly used low temperature materials are cellular glass and polyurethane foam. As manufactured they have a relatively closed cell structure which is beneficial in preventing moisture absorption. During installation they are covered with a vapour barrier (typically a low permeability elastomeric coating or a metal jacket with sealed joints) to further prevent moisture ingress into the insulation itself. If water penetrates past this barrier and ice forms, the cellular structure of the foam is broken down and thermal efficiency is rapidly lost and corrosion of the underlying metal can eventually occur.

Ambient and high temperature materials include fibreglass, mineral wool, calcium silicate and, for the highest temperatures, ceramic fibre. Weatherproofing to prevent external moisture entering is necessary and this is normally achieved with either metal jacketing or mastic coatings. Note that a vapour tight seal must not be obtained as any trapped water, e.g. from the installation phase, can generate steam when the equipment is warmed up and the pressure generated can damage the covering.

3 MECHANISM OF CORROSION

The most common mechanism encountered is general aqueous corrosion of carbon and low alloy steels. Water trapped at the equipment - insulation interface attacks the metal. Dissolved impurities in the water either from external sources or leached from the insulation can increase the corrosiveness. As equipment temperature increases the rate of corrosion increases until all liquid is vaporized. At this point corrosion ceases. 120 deg. C is the equipment temperature we take as a reasonably safe cutoff point above which corrosion is unlikely. Conversely at the lower end corrosion does not occur under ice, and so we assume that equipment operating below -5 deg. C will also not be attacked.

Although the mechanism is simple and straightforward the corrosion can be very localized and can occur at unexpected areas. For hot insulation particularly, the worst corroded area is often an appreciable distance from the water entry point, and at a location where the insulation is in seemingly good condition. The reason for this phenomenon is that the water enters at a break in the weatherproofing and travels by gravity to a low point where it collects and can only be dissipated by vaporization. The metal loss occurs at this point where the surface is continuously immersed in hot water, rather than along the relatively dry path which the incoming water travelled. With some thought and effort these locations can be fairly reliably predicted. Another cause of transferred localized corrosion which is much harder to predict is "wicking". Here water is transferred through the insulation by capillary action to above the entry point. A typical situation where this occurs is at vessel insulation support rings or stiffening rings; the metal loss may be significantly greater than rings rather than at the ring itself where the water entered (Figure 1).
The other common type of corrosion is chloride Stress Corrosion Cracking (SCC) of stainless steels and it normally is only a problem with hot insulation. Here chlorides from either the insulation itself or from external sources e.g. rainwater or process fluid spillage, collect at the equipment surface and when combined with warm, moist conditions, can produce a SCC environment. It should be noted that cracking can occur even when the bulk chloride content of the incoming fluid is very low, as liquid evaporation at the hot equipment surface is an ideal mechanism to concentrate any dissolved salts.

4 DETECTION

Once there is a concern that corrosion under insulation has occurred then an inspection programme is necessary to find it. Complete stripping of all vessels and piping is one straightforward alternative however it is extremely expensive and time consuming and in most cases unnecessary. Informed evaluation of the process conditions and equipment configuration can limit the amount of inspection required and give meaningful results which have a high degree of reliability.

4.1 Where to Inspect

4.1.1 Process condition guides

As mentioned in the previous section the temperature range in which corrosion under insulation occurs is -5 to 120 deg. C and so inspection is concentrated on equipment operating in this range. However this is easier said than done. Equipment Design Temperatures (DT's) are set by extreme conditions and normal operating temperatures are usually below the DT (or above in low temperature service). Some types of equipment e.g. fractionating towers have a temperature gradient along them and part may be within the corrosive range. Other equipment regularly cycles through the corrosive range. Therefore good plant knowledge is required to highlight the areas to look at. When reviewing a process unit we consider the pressure vessels first as operating data is more readily available for this type of equipment. High risk vessels are identified. Based on these results we can then decide which interconnecting piping is also in the high risk category.

Another influencing factor is the climate. As would be expected hot, humid weather at a coastal location is the most corrosive. However "microclimate" conditions within a plant site can override the general conditions. At our site we find that even though the overall climate is mild, at certain sections e.g. near cooling towers or steam vents, the corrosion potential is very high and equipment in these sections must be reviewed carefully.

4.1.2 Physical configuration guides and insulation types

After the vessels and piping systems which are in the high risk category have been identified, we have to decide where to look. From experience we can narrow down the inspection to the most susceptible areas. These vary depending on the type of equipment and the insulation used. Figures 2 and 3 show areas where corrosion is most likely in hot and cold insulated piping. They highlight the differences in attack which can occur between different insulation materials. We use similar sketches for vessels, tanks, etc.

![Figure 1. Corrosion of vessel wall due to wicking.](image)

![Figure 2. CUI piping inspection ambient to 120 deg. C.](image)
areas and consequently cost can be similar to stripping. Flash radiography, which uses a hand held X-ray pulse generator to give a profile of the outer diameter of the pipe/vessel plus an indication of scale buildup if present, is much more adaptable and faster than conventional radiography. We are using it extensively to screen high risk areas of piping to determine whether further inspection is necessary.

4.2.3 Other methods

Other methods of detection are being investigated, including remote control radiography, magnetic flux linkage and eddy current testing. However none is commercial at their present stage of development.

5 PREVENTION

5.1 Equipment Design

The design of equipment can have a major influence on whether corrosion under insulation occurs. Attention to detail at the design phase is very important. A common example of bad practice is brackets which protrude through insulation and allow water to drain towards the shell and become trapped there. Appurtenances are sometimes added with little thought how the shell can be satisfactorily insulated around them.

More consideration by the mechanical design engineer can easily overcome this type of deficiency.

5.2 Improved Conventional Insulation Systems

The most logical method of preventing corrosion under insulation is to make sure that water or moisture cannot enter the insulation and contact the underlying metal. This is an area in which we have put a lot of effort and we have developed detailed insulation application procedures to try and ensure that the quality of the job is satisfactory. Figure 4 is an example. We plan training sessions for applicators before projects as their skill and thoroughness in following the procedures are also extremely important. However it never seems possible to get a perfect result; damage to the outer protection always occurs even by such unanticipated means such as scaffolders removing poles after the job is complete.

Inhibition of insulation is sometimes used particularly to minimize chloride SCC of stainless steels. For calcium silicate type materials we specify a minimum silicate/chloride ratio of 10. However there is some question on the long term reliability of this type of protection as the inhibitor leaches out of the insulation and so protection will eventually cease. In fact for stainless steels we now normally use low chloride insulation and concentrate on keeping the water out.

Figure 3. CUI piping inspection - 45 deg. C to ambient.

4.2 How to Inspect

4.2.1 Stripping

Removing equipment from service and stripping off all insulation is the simplest method to determine whether the underlying metal is corroded. But it is very expensive and has practical difficulties if the equipment is only out of service for limited periods. As well as cost, the short shutdown time normally available makes planning inspections, carrying out repairs if necessary then reinsulating a major drawback for this type of inspection.

Hot equipment can be stripped on line in most cases provided care is taken to protect the maintenance personnel. Normally full stripping of equipment is not carried out as the lack of insulation can affect process operations as well as being a personnel safety hazard. Stripping in selected areas as per the guidelines given above is more practical and we use this method extensively particularly on vessels. Note that stripping is also the only practical way of detecting SCC of stainless steels.

Cold equipment is more difficult to strip on line as deicing is necessary both for inspection and reinsulation. Therefore we use on line stripping of cold insulation only as a last resort.

4.2.2 Radiography

Conventional radiography is extensively used to determine wall thicknesses of insulated piping and smaller vessels up to 500 mm, approximate diameter. Although it can give a good idea of condition at the location examined, it is slow and cumbersome to scan large
5.3 Protective Coatings

For all carbon and low alloy steels we assume that the insulation system is going to break down or be damaged in some way and so we apply a protective coating if the metal temperature will be in the -5 to 120 deg. C range. The service can be very aggressive ranging from immersion in boiling water at one extreme to physical abrasion due to ice repeatedly forming and melting at the other. We usually use a one coat epoxy-polyamide system for maintenance and repair work as this tolerates some relaxation in surface cleanliness if abrasive blasting is not possible. For new work we prefer an epoxy-phenolic system as it has a better high temperature limit. We do not use inorganic zinc silicates as affiliate experience has shown rapid breakdown and limited protection.

Equipment in high temperature cyclic service is more of a problem. Coatings which have good high temperature resistance e.g. silicone acrylics do not have particularly good corrosion resistance at the lower temperatures. We have used a bitumastic paint with reasonable success for intermittent temperatures up to 200 deg. C.

5.4 Routine Maintenance

An extremely important part of the overall corrosion under insulation prevention programme is upkeep of all existing insulation. Weatherproofing and vapour barriers break down for a variety of reasons, such as mastic hardening, non-replacement after equipment maintenance, non-replacement of ultrasonic thickness test point plugs, damage due to physical abuse. Unless the damage is identified and rectified early, all the effort put into designing the equipment correctly and installing the insulation carefully is wasted.

5.5 Alternative Systems

In some cases conventional insulation systems can be replaced with different techniques. Often insulation is installed on equipment for personnel protection. It is only applied on surfaces where contact can be made and very often the seal at the insulated to noninsulated junction is poorly designed and breaks down rapidly and corrosion under insulation progresses. From a corrosion viewpoint it is much better to use a protective guard to prevent personnel contact and, if the necessary routine maintenance of the insulation is added to its initial cost, the guard becomes more economic in the long term.

When several cold service equipment items can be grouped into a relatively compact space they are sometimes built into a sealed container or cold box. The cold box is then filled with loose insulation and can be purged with a dry gas to prevent moisture condensation thus corrosion under insulation is eliminated. Maintenance is difficult after initial installation and so only high service factor non fouling equipment is suitable. This type of design is extended to double wall storage vessels for cold liquids in which the annular space is filled with insulating material under a dry gas blanket. Again corrosion of the cold surface is prevented.

6 REFERENCE

ASTM Special Technical Publication 880 (1985)
Corrosion of Metals under Thermal Insulation.