Journal of Materials Science & Surface Engineering Vol. 1 (2), 2014, pp 36-43

Contents lists available at http://www.jmsse.org

Journal of Materials Science & Surface Engineering

Corrosion under Insulation (CUI): A review of essential knowledge and practice

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Article history

Received: 27-Feb-2014
Revised: 06-April-2014
Available online: 10th June 2014

Keywords:
Corrosion-Corrosion under insulation (CUI) - Carbon steel-Stainless steel-Coating.

Abstract

Corrosion under insulation (CUI) is a very important issue in industry and its importance is being more and more acknowledged. This review will look at the underlying mechanisms of CUI within the context of four important factors (equipment material, skin temperature, coating/insulation and atmosphere). A short review of Thermal spray Aluminium (TSA) coating as well as some practical tips regarding design and inspection factors contribution to CUI is also given.

Introduction

Under the umbrella of electrochemical corrosion, one may accommodate a rather wide range of seemingly different corrosion processes from atmospheric corrosion to corrosion under insulation. Two seemingly different corrosion phenomena, corrosion under insulation (CUI) and microbiologically influenced corrosion (MIC), for instance, share at least three features:

1. Both are electrochemical reactions, meaning that they are treatable with the conventional ways by which any electrochemical corrosion process will be managed. However, these treatment technologies will be required to be tailor-made for each: while application of biocides only for MIC cases makes sense, application of induced current cathodic protection may be useful for MIC but not applicable to CUI.
2. In both phenomena, it is the liquid form of water that is the main source of the predicament: if water does not exist, no growth medium for the bacteria and no electrolyte for the corrosive species will be provided.
3. In both CUI and MIC phenomena, there is a "poultice factor" that assists in increasing the local concentration of corrosive species: in CUI cases, it is the trapped water under the insulation and in MIC cases; it is the biofilm that carry out this process.

In fact, the similarities don't stop here: they are both costly and remain to be hidden until-in most cases-it is too late to go for a sustainable treatment solution. By mentioning these similarities, once again, we want to emphasize upon this ostensibly evident fact that corrosion phenomena do have similarities and therefore, may also have the same "broad spectrum" solutions: use of hydrophobic coatings can solve both MIC and CUI problems in a plant, for example.

In this review, we will be only dealing with CUI, especially from a practical point of view. What it is, how it is caused, and while doing inspection, what factors must be taken into consideration.

The importance of CUI

Insulations are important in the sense that they protect the underlying materials (normally steels) from adverse environmental effects. An example is given by *Kim et al*[1] where a super austenitic stainless steel part without proper insulation after being exposed to fire lost its corrosion resistance superior features to a high extent.

Perhaps the definition for Corrosion under insulation is so obvious that even a well known standard such as NACE SP 0198-2010[2] does not define it. CUI has been a recognised problem for more than 60 years now (although it is about 40 years that the first CUI- related standard (ASTM C692-1971) appeared) and it seems that the first motivation to technically recognise and define it has been the cost that it induces.

As an example, in 2006, in the USA, an aging petrochemical plant had a leak from a 4 in. hydrocarbon line. The leak resulted in a massive fire that in turn destroyed half the unit and cost the company US$ 50 million[3]. The cause was CUI. Another figure that is frequently referenced is apparently based on a study by ExxonMobil in 2003. This study showed that between 40 and 60 percent of piping maintenance costs are related to CUI[4]. A good review of case histories related to CUI has been given elsewhere[5]. As Risk is defined as the product of LOF (likelihood of failure) and COF (consequences of a failure), in case of CUI, as seen, both LOF and COF are high. COF becomes a critical issue when the equipment contains toxic or inflammable material.

A common belief is that CUI is more a serious problem in aging facilities than in relatively new ones. In fact, some professionals believe that CUI will start to become an issue if the equipment is more than 5 years old[2]. While this may sound sensible, in fact it is the impact of working conditions and the exposed atmosphere that have to be taken into consideration: if the equipment is located in a coastal atmosphere, for the same skin temperature and working conditions, this equipment* will have a lower risk than being

The term "Equipment" in this context is to what is used in NACE SP 0198-2010. That is to say, equipment "includes all objects in a facility with external metal surfaces that are insulated or fireproofed and subject to corrosion".

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located in a rural atmosphere where the concentration of pollutants is less. Corrosion and integrity engineers should base their assumption on the fact that CUI is a significant issue, no matter if the facility is "new" or "aging". In addition, it must be noted that the complexity of factors involved in CUI and their interrelationships may differ from industry (environment) to industry, for example CUI factors in marine environment can be much more complex than the simplified scheme presented here due to various failure mechanisms (pitting, uniform corrosion and stress corrosion cracking) that can be involved in CUI in such environments[6].

Factors important in CUI

There are five important factors in any CUI problem:

i. Insulation material
ii. Coating material
iii. Substrate metallic material of the equipment
iv. Atmosphere
v. Design

We will briefly explain these factors.

Insulation material

Some of Insulation materials of common use are listed in the NACE SP0198-2010 as follows:

- Calcium Silicate
- Expanded Perlite
- Man-made mineral fibers
- Cellular Glass
- Organic foams
- Ceramic Fibers
- Asbestos and magnesium-based material

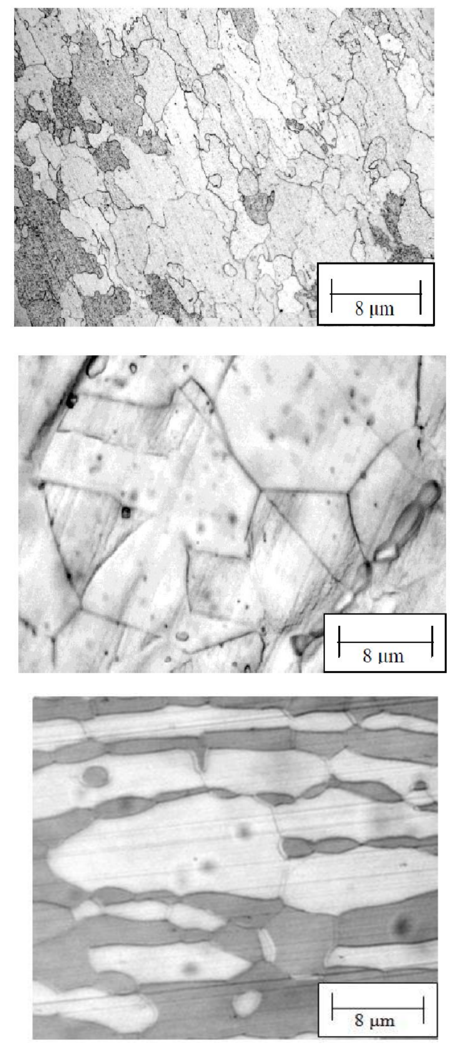
Some of these coatings for substrates such as carbon steel and stainless steel have been given in Tables 1 and 2 of the NACE standard SP0198-2010. It must be noted that some insulation materials such as asbestos actually contain chlorides. Therefore, they can act as one of sources of contamination of the water accumulated under the insulation. Of interest examples such as thermal sprayed Aluminum (TSA), aluminium foil wrap and epoxy phenolic may be mentioned. In the related section about coatings we will briefly explain TSA.

Coating material

Coating, it is always recommended that coatings must be also available under the insulation. The importance of such a coating will be discussed in the next section in relation with the CUI mechanism. In general, immersion-grade protective coatings are highly recommended against CUI for both carbon steel and austenitic/duplex stainless steel substrate materials[7]. If in addition to CUI resistant coating (especially at high temperatures), use of cathodic protection (CP) is recommended, it must be noted that the introduction of higher temperatures can alter the CP protection criteria: laboratory experiments to investigate the effect of temperature on CP protection criteria of steel pipelines within temperature range of 25-95^{o} C in synthetic ground water has shown that at high temperatures (80^{o}C), potentials much more negative than -0.85 V_{CSE} will be required to achieve protection[8]. This is despite what had been earlier (1992) advised by NACE and reported by *Choi et al.*[9] regarding ineffectiveness of coating to CUI.

Substrate metallic material of the equipment

Regarding the substrate material, as the most popular materials in industry are carbon steel, austenic stainless steel and duplex stainless steel, therefore CUI on these materials have been studied more. It must be noted that these three types of steels have different crystal structures, making them different from each other, both from cost and performance point of view: duplex stainless steel with 22% chromium (SAF 2205) costs about 10 times more expensive than carbon steel. Figure 1 show typical microstructures for carbon steel, stainless steel 316L and duplex stainless steel SAF 2205:



(a)
(b)
(c)

Figure 1: (a): Carbon steel with fully ferritic microstructure (etching by immersion in 2% Nital for 20 sec, (b): stainless steel 316L with fully austenitic microstructure (etching by electrochemical etching by 60% Nitric acid solution, voltage: 1.1 V for 120 sec, (c): duplex stainless steel 2205 with ferritic- austenitic microstructure (etching by electrochemical etching by 60% Nitric acid solution, voltage: 1.5 V for 60 sec[10].

As seen from Figure 1, these steels are all different in microstructure and therefore, they show different mechanical and electrochemical responses to corrosion, especially CUI. This is indeed what is expected and observed in field experiences: while in carbon steel CUI can be manifested as both general and localised corrosion, for austenitic and duplex stainless steels, corrosion is manifested as pitting and stress corrosion cracking.

Table 1 summarises the critical temperature ranges for these materials. It must be noted, though, that the "red alert" temperature zone for CUI is between 48°C to 93°C (120-200° F), practically speaking, no matter the ferrous material.

Table 1. Susceptivity temperature ranges for Carbon steel, austenitic stainless steel and duplex stainless steels due to CUI

Material	Critical skin Temperature range
Carbon Steel	-4 to 175 °C (especially 93°C) [2]
Austenitic and duplex stainless steels	50 to 175 °C

When the substrate material (that is, the material of the equipment) is carbon steel, corrosion happens by the accumulated water under the insulation dissolving in it corrosive species such as waterborne chlorides and sulphates become more and more concentrated as the water evaporates. Therefore, the aerated water contaminated with the corrosive species is a great threat to the carbon steel. While these contaminants lower the pH and therefore cause corrosion (either as general or localised) on the carbon steel substrate, in austenitic and duplex steel substrates, these contaminants-especially chlorides-will damage the protective chromium oxide film and therefore will intensify corrosion as pitting, most probably later leading into stress corrosion cracking. For austenitic and ferritic-austenitic steels, the industry accepted chloride stress corrosion cracking temperature limits depends on the alloy type: while for austenitic stainless steel 316 this temperature limit is 50-60°C, for austenitic 6Mo, this temperature range will be 100 to 120°C, the temperature range for ferritic-austenitic steels (22% and 25% Cr) is between 80 to 100°C and 90 to 110°C, respectively[11].

Atmosphere

The atmosphere plays a very important role in both creating and maintaining CUI. Its main role is to provide external water (either in liquid form or vapour form); this is the water that later when accumulated /condensed under the insulation, will provide the necessary electrolyte to maintain electrochemical corrosion. . The sources of external water can be the followings:

a) Natural (Rainfall, seawater spray, groundwater)
b) Industrial (drifts from the cooling towers, condensate falling from cold service equipment, condensation on cold surfaces after vapour barrier damage, process liquid spillage)

However, the effect of atmosphere is not limited to water. The corrosive species (chlorides and sulphates) are also to be considered in this category: if the plant is near marine or coastal environments, the salt spray from the sea will bring with it the chlorides necessary to cause corrosion later on in the accumulated water. The same is also true with sulphates that can easily found in the industrial atmospheres, especially in refineries and chemical plants. It is then obvious what will happen if the plant is build near the sea-this is a common practice for almost all industrial plants as all of them will require water: this will bring about a mixed atmosphere where main corrosive pollutants (chlorides and sulphates) are extremely high in concentration.

Because the corrosive species are to enter from outside into the accumulated water under the insulation, we may consider these species already existing in the insulation. These species will be leached out into the water and therefore will make it corrosive. *Suresh Kumar et al.*[12] describes a case of the failure of a stainless steel pipeline due to chloride stress corrosion cracking caused by leaching out of chlorides from the glass wool thermal insulation.

Design

This factor is so important that one may come to this conclusion after inspection of several cases of CUI that the importance of design is equal to that of the previous four factors, if not more. What we mean by "design" is not only the design of the equipment but also that of the plant, in other words, the layout of the plant. An example of equipment design resulting in CUI is seen in Figure 2.

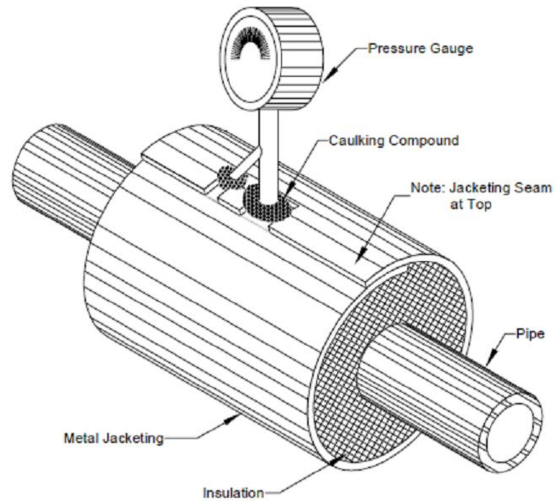


Figure 2: A schematic example of an attachment (pressure gauge) to the main body of the equipment where water bypass is possible. © National Corrosion Association (NACE)[2]

As it can be seen in Figure 2, the "discontinuity" dictated by the attachment lay-out on the main body of the equipment has been a significant factor in inducing CUI. In Figure 2, there is another important aspect of design that must be noted: to isolate the pipe against CUI, the design relies only on the caulking material around the gauge. The caulking compound will not be able to function properly after being exposed to moisture and/or harsh environment. A real life example of such can be seen in Figure 3 where due to water ingress, CUI has resulted in enhanced corrosion of the equipment.

Figure 3: CUI as induced on inorganic zinc coating after working for 8 years in a coastal industrial atmosphere: Note the steam inlet nozzle and the effect of water ingress around it. © National Corrosion Association (NACE)[10]

Figure 4 shows an example of insulation damage due to falling condensate from cold overhead surfaces.

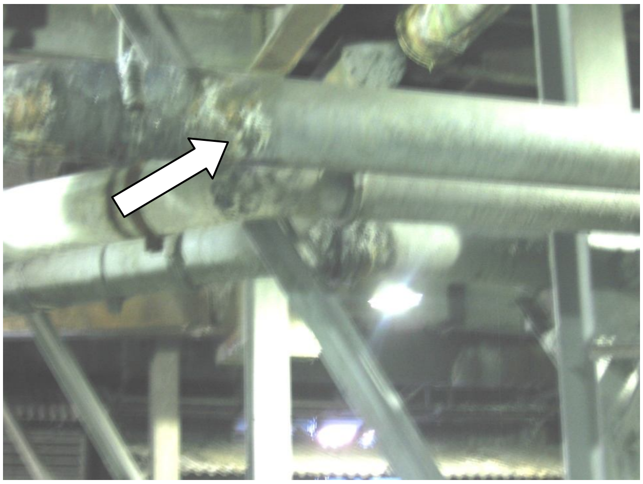


Figure 4: An example of CUI due to condensates falling from cold overhead equipment and installations (Courtesy of Reza Javaherdashti)

There are three essential steps involved in any CUI phenomenon:

1. Ingress of water , either in liquid form (e.g. rain) or vapour,
2. Water accumulation under the insulation, more technically in the space between the insulation and coating,
3. Dissolution of corrosive species, either from the insulation material or from the surrounding

If, therefore, any of these steps are omitted somehow, CUI will not happen. We can essentially think of three possibilities:

a) The equipment has no insulation
b) The equipment has insulation layer only.

The equipment has an insulation layer on the outside and under beneath it there is a layer of coating.

Possibility a) will be a common practice if the followings are valid:

- The equipment is not working at high temperatures
- Risk of exposure to high temperatures by the personnel is not an issue
- The heat loss is not exceeding the thermodynamical threshold so that except for what is considered as "normal" heat loss, there is no issue related to fuel economy management.

If any of the above becomes an issue, then application of insulation will be required. In this case, the equipment will be protected by only one line of defence which is the insulation itself. The problem, however, is that if for any reason the insulation losses its integrity and starts to develop cracks and pores, then through these entrances, either water in liquid form (such as rain) or in gaseous form (vapour) will start to penetrate through the insulation material. Figure 5 shows this schematically.

Figure 6 shows one case belonging to a refinery tower stiffener ring that apparently has corroded in accordance with what has schematically been shown in Figure 5.

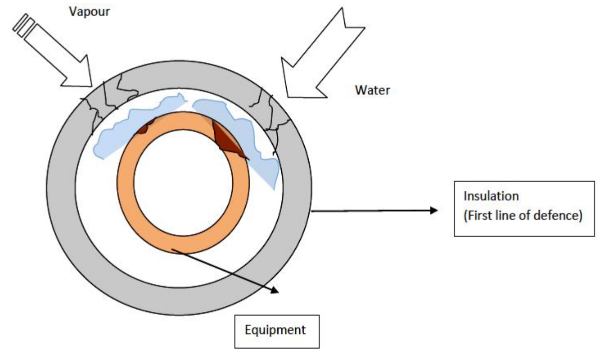


Figure 5. Due to cracks developed in the insulation material, water in either liquid form or vapour form can penetrate through the insulation. Under the insulation, this water will remain and will form an electrolyte.

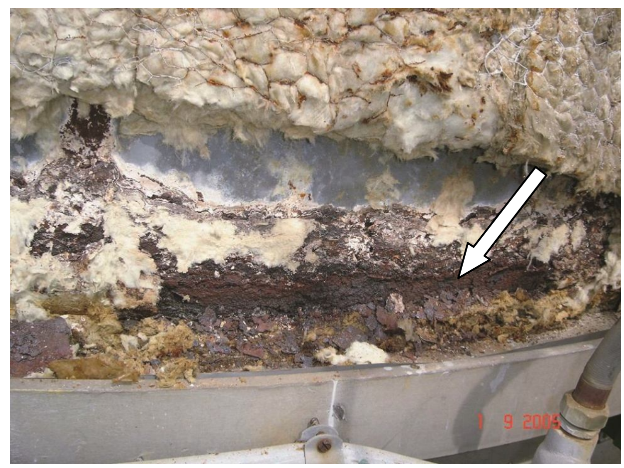


Figure 6: Advanced CUI as observed at a refinery tower stiffener ring ("Copyright Sulzer Technical Review, Sulzer Management Ltd, Winterthur, Switzerland". Used with permission)

In practice, however, it is not always the structural defects in the insulation that can give rise to water (or vapour) ingress. Misapplication of insulation (Figure 7a) is also a very important factor that can give rise to CUI.

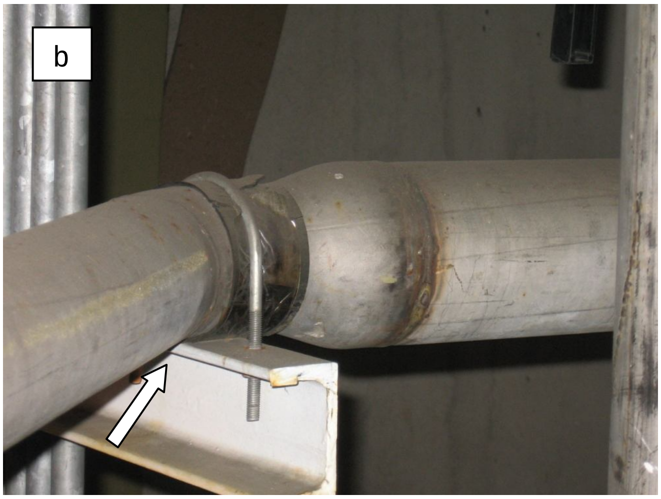


Figure 7: (a) An example of wrong application of insulation so that the wrapping is not applied completely and without openings around the equipment(b) the pipe supports can cause serious damage to the insulation material over time (Photos: Courtesy of Reza Javaherdashti).

As seen in Figure 7a, the wrapping of the insulation martial has not been applied properly, leaving an open exposure to the surrounding environment. This will allow moisture to get under the insulation. When the plant is not working and thus the equipment is sitting idle, the temperature falls down and this cyclic temperature impact, also assists in creating water under the insulation through, for example, condensation. Any external factor that will cause physical damage to the insulation (such as the pressure exerted on the insulation materials –which are generally "soft" material- via pipe supports, for instance, Figure 7b can actually facilitate water (vapour) ingress.

However, as mentioned earlier, there is also a third possibility that there are two lines of defence prepared for the equipment against CUI: in this approach, a dense coating on the skin of the equipment formed the second line of defence when compared to the first line of defence which is basically the insulation material itself, Figure 8:

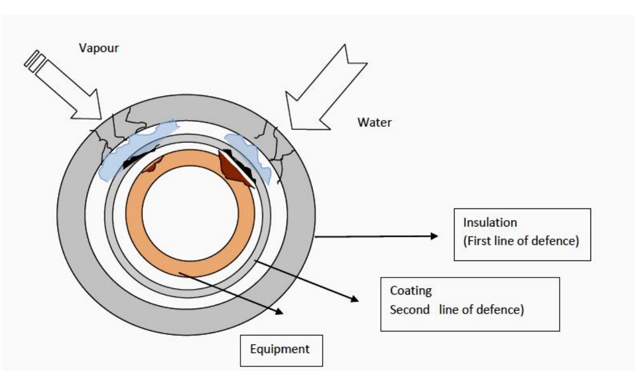


Figure 8: Two lines of defence prepared for the equipment against CUI

When there is coating in addition to the insulation, as long as the coating is durable against corrosion, one can consider the equipment safe. The problems start when not only the weakened insulation allows the water (vapour) ingress, but also this water is accumulated in the space between the insulation and the coating. If the coating is damaged, the water that now has become corrosive (by dissolving corrosive species either from the insulation materials itself or the outside), localised corrosion can start on the material of the equipment.

When a situation like that shown in Figure 5 or Figure 8 exists, that is to say, the corrosive water starts to actually induce corrosion to the equipment, then two more factors will have to be considered as well: the temperature range (that is, the metal skin temperature range) and the material. These issues were already discussed earlier.

Coating

As mentioned above, the recommended practice has always been use of a coating between the equipment and the insulation. There are several options for coatings. Currently there are at least seven such methods that can be applied with reasonably good results. Based on the substrate metal type of the equipment (carbon steel or stainless steel), NACE standard SP0198-2010 uses a code for the coating: SS-1 to SS-7 for both duplex stainless and austenitic stainless steels and CS-1 to CS-10 for carbon steel equipment. Because of issues such as liquid metal corrosion (LMC) for austenitic and austenitic-ferritic steels and possible galvanic reversal at temperatures above $60^{o}C$ for carbon steel, the metallic coatings should not contain zinc. In these situations, it is better not to use inorganic zinc coatings (IOZ) alone. In fact, while in some industries such as petrochemical and refining industries use of shop-applied IOZ is not a surprise due to its low cost and that it dries quickly, it is recommended to both topcoat it to extend its service life and that in temperatures up to 177 ^{o}C, IOZ must not be used on its own for long-term or temperature-cyclic environments[13]. Perhaps the most heard of these methods is Thermal Spray Aluminum (TSA). We will briefly explain this method below. As the main equipment materials are ferrous alloys, it is not surprising that this method is applied on these alloys (carbon steel, low alloy steel and stainless steel).In a variation of this method, aluminium as a wire with high purity (normally above 99%) is fed into a nozzle where it is mixed with air and then atomised as a spray onto the target metal surface. Figure 9 schematically shows the process.

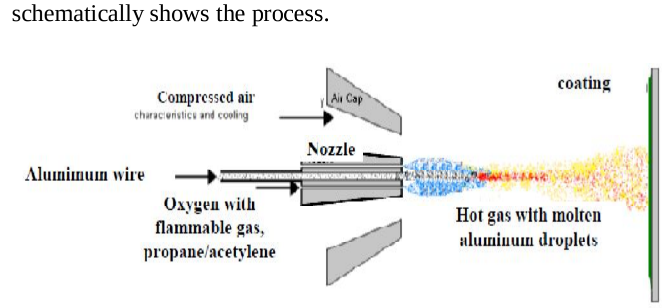


Figure 9: schematic of TSA Flame spray Tool, as the wire is fed into the nozzle, due to reaction with the flammable gas in the presence of oxygen and with the aid of compressed air, the molten aluminium droplets jet exit the nozzle and is spread over the substrate metallic equipment
© National Corrosion Association (NACE)[10]

In the galvanic couple Al-Fe* *, the steel will be protected cathodically by the aluminium. This will extend the life of the substrate so that service life spans of up to 40 years can be well

* **Unfortunately, there are still corrosionists that use the common yet wrong terminology of "dissimilar metal corrosion" instead of correct form of "galvanic corrosion": by joining a new pipe segment to an old pipe segment (both of the same materials), if the necessary cautions are not taken, one will end up in galvanic corrosion of the new pipe as the old pipe will become the cathode. Here, there are no dissimilar metals but still galvanic corrosion exists.*

expected. In addition to benefits such as prolonged service life, excellent applicability in various atmospheric conditions (from marine to tropical and coastal), TSA are also known for their ease of application on hard-to reach layouts of equipment and also complex shapes of equipment, Figure 10:

Figure 10: TSE are capable of being applied on different shapes and sizes of equipment with very good adhesion and reliability ("Copyright Sulzer Technical Review, Sulzer Management Ltd, Winterthur, Switzerland". Used with permission)

Some of the advantages of TSA coatings over conventional pain systems may be summarised as follow[13]:

- Longer service life expectancy (25-30 years) compared to that of conventional paints (5-13 years)
- Lower inspection and maintenance costs
- Larger temperature application range (-100 ^{o}C to +500 ^{o}C)

Capability of acting as a (sacrificial anode) cathodic protection barrier against pitting corrosion and chloride induced SCC when the coating is damaged. Although some laboratory studies show[14] corrosion rates of the substrate steel with damaged TSA could be about 10 times more than that of a non-defected TSA.

Inspection

With no doubt, inspection is a key element in early recognition and treatment of CUI. There are more than 10 methods and techniques that can be applied in this category and each has its own advantages and disadvantages[15]. All these methods can be classified into two subcategories:

1. Destructive inspection
2. Non-destructive inspection

Visual inspection of completely stripped off insulation is the best but at the same time the least valuable destructive inspections: it is the best because, the inspector can see directly through the insulation areas where CUI has started or has been enhanced. Therefore based on the severity of the situation, he can take the necessary measures. It is the least valuable method because it is both costly and time consuming. Even partial removal of the insulation will take time and will cost. In addition, it is always possible that in practice, applying new insulations may induce with it conditions to make the equipment prone to CUI.

For Non-destructive methods and techniques, as the name indicates, there is no need to remove the insulation material to see what is going on under the insulation. These methods normally use indirect measures to obtain data about CUI.

While there are many such methods and technologies (such as, but not limited to, Pulsed Eddy Current Non-destructive testing technology[16] or microwaves for water detection under the insulation[17]) we will explain only one of such NDT inspection technique that can easily be applied in inspection of CUI on the equipment. In addition to being relatively easy, this technique is also new. This method is called "Neutron Backscatter". The theory is relatively simple and is actually know from the very early days of developing nuclear physics: it is known that water, better to say, hydrogen atoms can slow down high-speed neutrons that are leaving a radioactive source. Water being one of the main requirements for CUI to happen will have the same effect. Therefore, if the intensity of incoming and outgoing neutrons can be measured, the pattern can show if water exists under the insulation and thus CUI can be expected, Figure 11: Neutron scattering has many advantages, including that it is a quick and accurate method for identification of areas potentially suspected to CUI. In addition, without any need for scaffolding, the probe can reach both overhead equipment .Also, congested areas are also reachable for inspection by this method. It must be noted that this method can only be used to register areas where water has been accumulated under the insulation and thus susceptible to CUI Neutron backscattering does not measure corrosion rates or detect corrosion[18].

Figure 11: Neutron Backscattering as an easy Non-destructive method to locate CUI "hot spots" (PetroChem Inspection Services Inc., used with permission)

Some important "practical" guidelines:

Corrosion under insulation is a hidden phenomenon. Due to practical reasons, it may not always be possible to apply the best insulation-coating combination or use the most feasible inspection methods. There is, then, one important factor that like all other cases of corrosion has a very significant role in the management of corrosion to lower its risk: design-lay out factor.

If the equipment is located near cooling towers and thus exposed to water spray, no matter the insulation-coating type, the equipment is at CUI risk: some years ago this author was involved in a plant inspection where insulation had been highly defected. The problem was hard to eliminate even if the insulation was being changed almost every two years. The reason was that the vapour containing corrosive species droplets in it was affecting this structure immediately nearby. During certain times due to strong wind direction, the corrosive vapour spray was moving towards the structure and thus affecting the insulation. By some modifications, the problem was solved.

However, there are still other points that may help in identification of CUI. Some of these points, in addition to what mentioned earlier are:

a) Identification of spots/venues for water collection by gravity is favoured. These spots may include penetrations to the insulation or where due to the attachments water intake is possible. This means that mechanical strength of the insulation is a very important factor, even more important than its hydrophobicity: if a highly hydrophobe insulation material has a poor mechanical strength so that its mechanical damage is easy, no matter how good the hydrophobe insulation is, CUI will happen.
b) Isometric lay-out: on horizontal pipes, the damage normally occurs at 6 o'clock position where as on vertical pipes, it happens at the bottom.
c) CUI for carbon and low alloy steel substrate metal usually is identified with wet scale large areas whereas for austenitic stainless steels, welds and non-stress relieved bends are vulnerable to chloride-induced SCC.
d) The risky combination of material and service temperature/conditions for CUI is as follows:
   i. For carbon steel: cycling wet/dry temperature around the ambient temperature of working temperatures below the dew point,
   ii. For Austenitic steels: when the skin temperature is about 93^o C (200^OF). With regards to austenitic steels in addition to temperature, chloride levels are also very important. Stainless steels 304, 316 and the like (known as 18-8 grade) are extremely susceptible to SCC.
e) Design of steam vents, dead legs, cyclic thermal operation, poor jacketing, periods of service-no service, too many attachments are all contributing to increasing the likelihood of CUI.
f) Absence of evidence is not the evidence of absence: While doing inspection, if in doubt about anything related to CUI, record it such that it will give a negative impression to the reader! If, for example, the question is whether the condition of coating is satisfactory and you are not sure, record it as "No". Remember that it is prudent to overestimate a possible risk than underestimate it.
g) Determine the environment to define the atmosphere. Table 2 can assist in determining and specifying the atmosphere. In addition to the factors given here, determination of average annual rainfall can also assist in classification of atmospheres. Knowing the atmosphere and its characters will help in defining one of the most important factors for atmospheric corrosion.
h) The impact of vibration: if due to vibration of the equipment, insulation's (or jackets) mechanical integrity can become at risk, then that equipment must be considered a "hot-spot". Due to mechanical damage, the insulation/jacket can be damaged and thus water ingress can be facilitated.

Table 2: Table 2: Determination of the atmospheric conditions based on Atmospheric gases[19] (**ISO 9223-ISO 9224**)

Atmosphere	SO_2 ($mg.dm^{-2}.d^{-1}$)	CO_2 ($mg.dm^{-2}.d^{-1}$)
Rural	< 0.25	< 0.3
Urban	0.25< <1.25	<0.3
Industrial	>1.25	<0.3
Coastal	<0.25	0.3 < <30
Marine	<0,25	>30

i) One of most vulnerable points to CUI in equipment will be spots where insulation plugs or ports have been removed to allow thickness measurement and not replaced/resealed again. Figure 12 shows an example of such conditions:

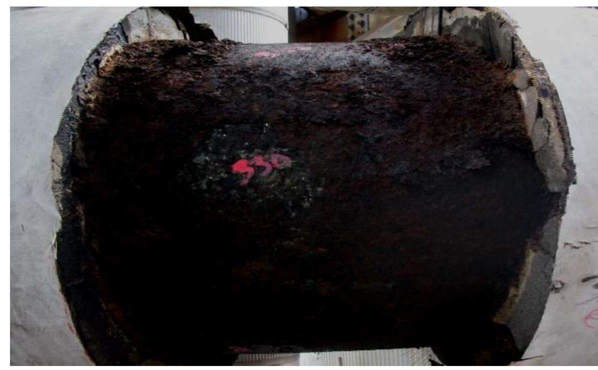


Figure 12: CUI becomes a significant issue when insulation plugs are removed but not replaces and resealed again (PetroChem Inspection Services Inc, used with permission)

j) While CUI may be regarded by some professionals as a high temperature problem, it can actually occur also on "cold" equipment that are experiencing a temperature cycle above and below 0^oC[20].

Conclusions

1. CUI is an electrochemical corrosion that like all other types of corrosion is manageable,
2. Essentially there can be two approaches towards prevention of CUI: use of "one line of defence approach "which is essentially use of insulation on the equipment and "two lines of defence) which is application of a coating under the insulation. Having a coating under the insulation can be regarded the best strategy to control CUI given that coating is selected and applied correctly,
3. One of most frequently used coating options is use of aluminmum (TSA). This way, aluminium not only protects the underlying substrate metal but also will act as a sacrificial anode to protect it furthermore,
4. There are many factors that can contribute to either increasing or decreasing the likelihood of CUI. Perhaps the most important of these factors is the design-layout factor: if the equipment is exposed to potentially aggressive environments or its shape and attachments allow for complications in applying insulation material this will definitely increase the possibility of CUI.

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