Low thermal conductivity CUI coatings

The benefits to industry of insulating tanks, process equipment and pipework to reduce energy usage and the risk of personal injury by burns cannot be overstated. An unfortunate downside, however, is that if corrosion of the underlying steelwork is initiated it often proceeds un-noticed until dangerous loss of wall thickness results or, even worse, catastrophic failure occurs leading to loss of containment. Corrosion under insulation (CUI) is, therefore a major concern to facility maintenance engineers.

Steel will corrode when it is in contact with water and oxygen and so if water can penetrate the insulation there is a likelihood that corrosion will result. Examples of possible causes are:

1. Poor choice of insulation – material such as mineral wool, fibreglass and calcium silicate can absorb water from rain, deluge systems or leaks in the system. In addition, certain insulation materials contain chlorides which will accentuate galvanic corrosion and can also induce stress corrosion cracking of austenitic stainless steel.
2. Poor design or installation of the insulation especially at problem areas such as cut outs for nozzles, valves and flanges, etc.
3. Mechanical damage to insulation as part of plant operation or maintenance activities.
4. Insulation not being correctly replaced after inspection or maintenance activity.
5. Degradation of sealants by natural weathering, thermal oxidation or UV degradation.
6. Water condensation, particularly on refrigerated or chilled water systems but also on hot surfaces when there is temperature cycling.
7. Absorption of airborne moisture in factories where steam is predominantly the heating medium


Picture caption to come

In addition, there are other factors which might influence the likelihood of corrosion such as contamination from salts in the atmosphere, particularly in marine environments, or leakage of process fluids and especially acids.

Fortunately, there are many coating systems on the market which can help to prevent CUI by providing an effective barrier against corrosion or chemical attack. Thermally sprayed aluminium (TSA) or polymeric coatings are commonly used and can be highly effective but it has to be remembered that product selection to meet specific process conditions is extremely important.

In the case of polymeric coatings, epoxies and epoxy novolacs are the most commonly used as they offer the greatest formulation flexibility. By the appropriate choice of resins, hardeners and fillers, coating materials can be created to cater for a wide range of design criteria, such as, the ability to be applied onto poorly prepared or damp surfaces, high temperature resistance, low temperature flexibility, chemical resistance, etc., while at the same time protecting the steel substrate against corrosion. Epoxies and epoxy novolacs are widely recognised as providing excellent adhesion and can typically be used at temperatures down to -20°C and, in the case of novolac's, are thermally stable and, when properly formulated, can retain a high percentage of their performance properties up to around 230°C. Most commonly they are formulated as two component systems but single pack heat activated latent hardener systems are also available.

In addition, recent developments have seen the introduction of novel low thermal conductivity coatings which not only reduce surface temperature and heat loss but also provide protection against CUI. Depending upon performance and design requirements, these materials can be used at thinner coating thicknesses as a CUI coating which will enhance the performance of conventional insulating systems or can be used a higher thicknesses as a standalone system to reduce heat loss and surface temperature.

Typically a 4-5 mm layer of such a material has the ability to reduce the surface temperature of a steel substrate from 180°C to ca 120°C but most importantly from the stand-point of safety, the dramatic reduction in heat transfer through the coating means that even at temperatures significantly in excess of those normally regarded as contactable without burning, the surface can be safe to touch for enough time for operatives accidentally coming into contact with the surface to realise it is hot before burning themselves. This difference between measured temperature and touch temperature is the subject of independent studies which are documented in the literature. As a result, in many cases the use of such coatings can eliminate the need for insulation or safety caging if safety is the only consideration.

With the ever increasing cost of energy and associated environmental considerations, however, reducing heat loss is another important consideration to industry and is a key driver for equipment to be insulated in such a way without the risk of CUI. By utilising such materials the savings in energy can generally be seen to pay for the cost of installation of the system many times over the lifetime of the equipment.

Utilising Finite Element Analysis (FEA), the potential energy savings as a result of using a thermally insulating barrier coating system has been quantified. This study also compared temperature and heat losses with those of a more conventional insulating material, Rockwool.

An 8 inch shed 40 stainless steel (304) pipe was used in this example. To compare the insulated and non-insulated pipe, three individual pipe models were designed and submitted to the same thermal constraints as follow:

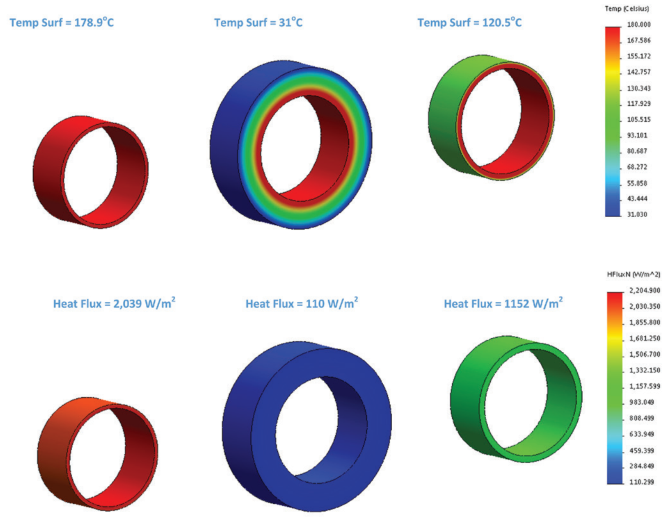
Heat load: 180˚C was applied to the inner surface of each three pipes.

Convective losses: 7 W/m².K at an ambient of 20°C was applied to the external surfaces of the three pipes.

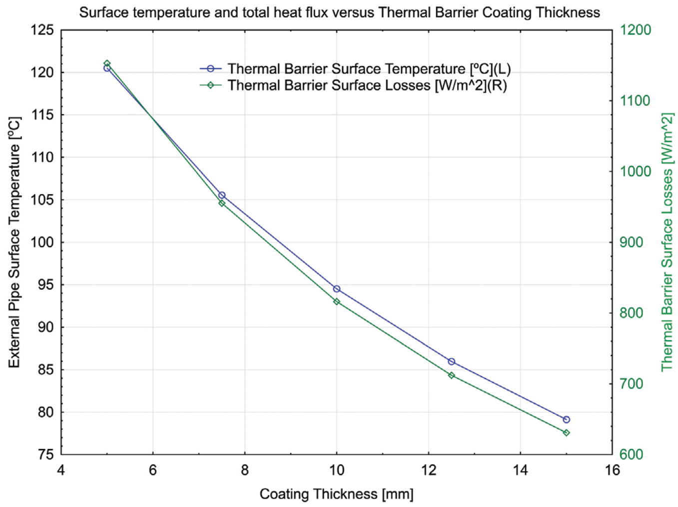
Radiative losses: it was assumed that all the three pipes were of the same external surface emissivity (0.95) with a surrounding temperature of 20°C.

The illustration below shows the three pipe system and the FEA mesh representation. Each pipe is discretised into sub-elements which are used for each calculation point.

The following picture illustrates the results of this analysis. With 5mm of the thermally insulating barrier coating the surface temperature is reduced by 58.4°C and the total heat loss is almost halved. As expected, the surface temperature and heat losses are much



Picture caption to come



Picture caption to come

lower when using 10 times the thickness of Rockwool but the thin layer of the thermal barrier coating still almost halves the heat loss from the pipe while providing corrosion protection and eliminating the risk of CUI

Furthermore, by increasing the thickness of the thermally insulating barrier coating from 5mm to 15mm, both the surface temperature and heat flux can be further reduced by respectively 34.3% and 45.3%.

A further consideration is that it is well known that Rockwool can soak up moisture from the environment leading to it becoming more thermally conductive and become more likely to promote CUI problems. A number of studies in the literature show that the thermal conductivity of 'wet' Rockwool can increase up to 0.125 W/m².K.

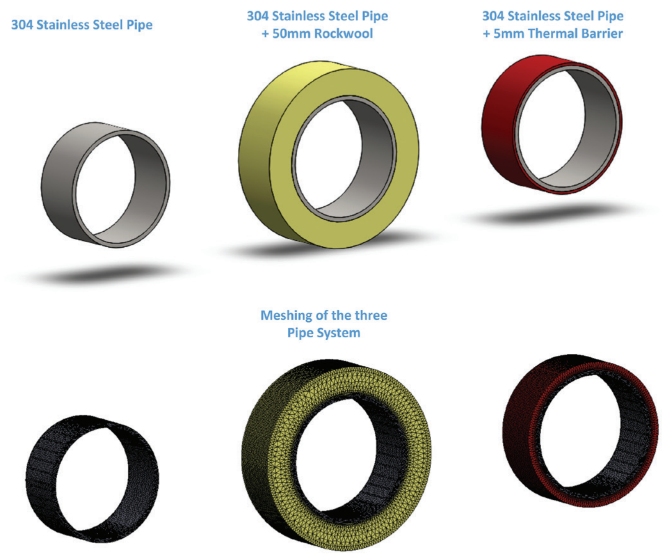
The graph below shows the result of a study where the thermal conductivity of Rockwool was increased from dry (0.044 W/m².K) to wet (0.125W/m².K).

Here it can be seen that there is a significant increase in heat loss and surface temperature as the degree of moisture in the Rockwool increases while clearly the non-porous epoxy-based thermal barrier coating does not suffer this disadvantage.

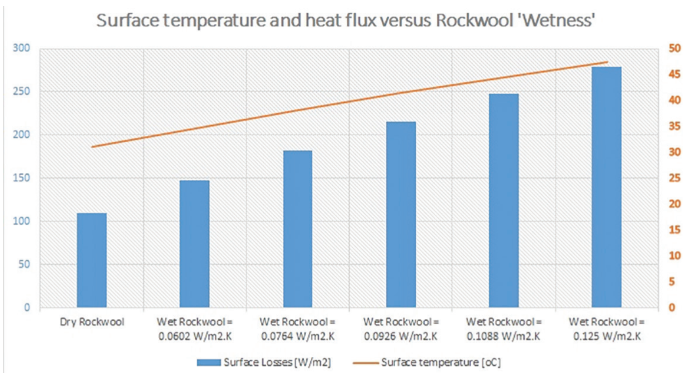
In conclusion, epoxy based coatings provide an effective way of protecting steel structures against corrosion under insulation. Additionally the advent of low thermal conductivity barrier coatings mean that the need for additional insulation can in some cases be eliminated or where it is required its performance is enhanced and the substrate protected against CUI problems. The formulation flexibility of epoxy based coatings means that such materials can be tailored to meet a wide variety of application and service conditions and ongoing developments are targeted at providing further enhancements to thermal barrier protection.

For more information:

This article was written by Dr. Paul Battey, Resimac Ltd and Dr Francois Pierrel, Enertherm



Picture caption to come



Picture caption to come