Daikin Blueprint: Conquering Corrosion

Overcoming corrosion requires a comprehensive strategy from the very beginning of equipment design.

By Paul Crisman – Daikin Chiller Applications Engineer, Daikin Applied Americas.

Corrosion mitigation is a leading concern in chiller operation and maintenance. Over time, corrosion can cause irreparable damage to equipment and significantly impact operating performance. Overcoming this costly problem requires a comprehensive strategy from the very beginning of equipment design. This article presents the Outstanding Anti-Corrosion Methods implemented at Daikin Applied.

All metal corrodes when exposed to moisture. The rate of decay is affected by several factors including: water purity, metal nobility, oxidation, temperature and material stress. To combat this complex and challenging issue, Daikin Applied utilizes a comprehensive strategy which includes coatings and material selection.

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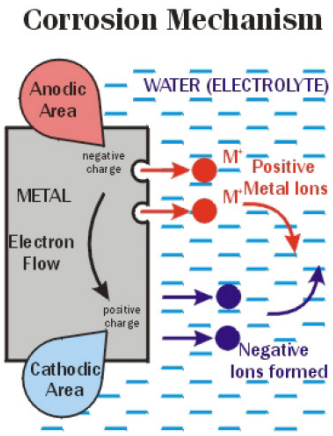
1 How Corrosion Occurs

Corrosion begins when metal atoms dissolve into liquid. These atoms become positively charged ions, as they give up and leave behind electrons at the surface of the metal. A build-up of electrons generates a negative charge, forming an electric potential (voltage) with other metallic surfaces with fewer electrons (positive charge). These surfaces are referred to as anode and cathode. If the liquid surrounding them has enough electrolytes contained in it to allow electric current to flow, an electro-chemical circuit is formed as is shown in the image to the right. Oxygen and water are consumed at the surface of the cathode and converted into negatively charged ions called hydroxyl (OH-). These hydroxyl ions combine with the metallic ions, leaving the anode, to form a metallic byproduct. For iron-based metals such as steel, ferrous hydroxide is formed, which is commonly referred to as rust. In this system, decay will continue until all of the material is consumed.

Figure 1: Corrosion eletro-chemical circuit



Because corrosion occurs at the metal surface, the typical means of mitigating it is through surface coatings. **Daikin Applied employs only the most reliable coatings, such includes Enecon ceramic coating for tube sheets and Defcon epoxy coating for the interior of vessel heads, as shown below.**

Figure 1.2: Defcon epoxy coating

Source Images – Performance Metal Products

Of all the things that accelerate corrosion, water purity will impact it the most. If a high level of electrolytes are present, as in saltwater, a higher electrical conductivity of the water will cause corrosion to accelerate. Similarly, If there is a high pH value, such as in ground water, the elevated acidity will increase the rate of dissolving metal atoms into the liquid, thus increasing corrosion. Also, biological and mineral composition in water can foster material growth along heat transfer surfaces. This is referred to as fouling. If unchecked, fouling can result in significant energy losses resulting from heat transfer degradation. It is always recommended to test water quality in order to fully understand the protection and preventative maintenance requirements for each application. To prevent the effects of fouling, it is also recommended to institute a regular tube maintenance protocol to ensure continued optimal performance. **Daikin Applied offers solutions that allow for easy access to vessel tubes for maintenance, including Marine Water Boxes and Water Box hinges.**

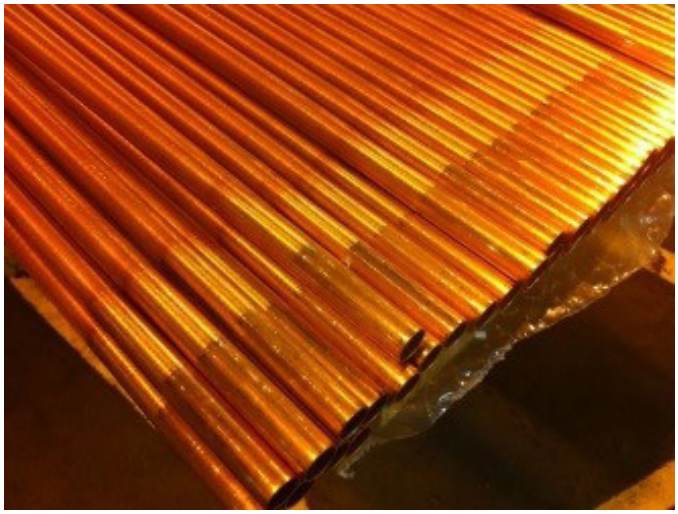
A metals nobility can also significantly impact corrosion. Nobility is related to the metals electrode potential, which in turn is an indication of its tenancy to dissolve into liquid. Essentially, the more noble the metal, the less tendency it has to dissolve and so the more resistant to corrosion. The table below shows a list of common metals and alloys, and their associated electrode potential. Note that Zinc and Magnesium have the lowest potential, and so are the most susceptible to corrosion, whereas gold and silver have the highest and so are the least.

Metal	Electrode Potential
Gold	+0.42
Silver	+0.19
Stainless Steel (Passive)	+0.09
Copper	+0.02
Tin	-0.26
Stainless Steel (Active)	-0.29
Lead	-0.31
Steel	-0.46
Cadmium	-0.49
Aluminium	-0.51
Galvanized Steel	-0.81
Zinc	-0.86
Magnesium	-1.36

Also, there is a type of corrosion that can be beneficial to equipment up keep. This is referred to as oxidation, or tarnishing. Tarnishing occurs because some types of metal ions react with oxygen ions in the water (oxidation), that then collect at the surface area. This forms a thin layer that acts as a protective coating against further corrosion due to the high impenetrability of the oxide. Copper and titanium are more resistant to corrosion than steel due to their oxide layer and higher electrode potential. However, if steel is mixed with chromium and nickel, both of which have a higher resistance to corrosion, the result is a stainless steel alloy which takes on the anti-corrosion qualities of its constituents.

Daikin Applied has over 65 years experience in chiller design, ensuring that only the most effective and reliable materials are selected to mitigate corrosion. Evaporator and condenser vessels are designed with high performance copper tubes as standard.

Figure 1.3: High performance copper tubes

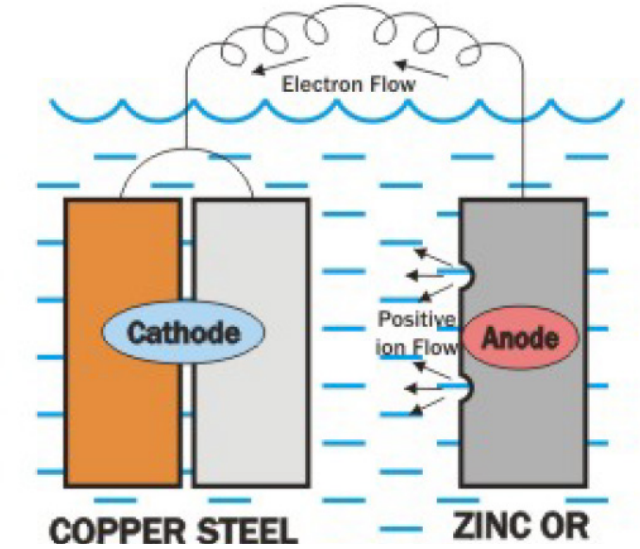


This provides optimal heat transfer while maintaining a high resistance to corrosion. For applications which have higher levels of water impurities, more advanced materials such as cupronickel, stainless steel, and titanium tubes are available. Also, tube sheet cladding is available in stainless steel, monel, and titanium.

2 Galvanic Corrosion and Sacrificial Anode

When two different metals are immersed in a liquid together they form an electrochemical circuit, with the lower potential metal acting as an anode, and the other acting as a cathode. This is referred to as galvanic corrosion. If not designed properly, critical equipment components can corrode rapidly and fail due to galvanic corrosion. However, if designed properly, galvanic corrosion can be used as a means of mitigating corrosion. For example, if a steel and copper plate are connected and submerged in a liquid, a circuit will form. Because the steel has a much lower electrode potential, and minimal oxidation, the copper plate will act as the cathode and the steel as the anode. Over time the steel will corrode and rust. However, if a zinc or aluminum plate is then connected in parallel to the other two and submerged in the liquid, it will act as the anode with the steel/copper combination acting as the cathode. This is because zinc and aluminum have a lower electric potential. This significantly reduces corrosion of the steel and copper. In this system, the zinc plate is referred to as a "sacrificial anode". This is illustrated in the image below. **At Daikin we offer the most advanced materially engineered sacrificial anodes as a competitive solution to corrosion.**

Figure 2: Cathodes and anodes



Mitigating corrosion is one of the most difficult challenges in chiller operation and maintenance. **At Daikin, we have over 65 years of design experience to meet this challenge with a comprehensive corrosion mitigation plan which includes: superior coatings, effective material selection in design, and sacrificial anodes.**

Source Images – Performance Metal Products