CORROSION
SOME BASICS ON CORROSION

Aluminum is actually a very active metal, in the sense that it oxidizes very quickly. This feature, while a weakness for most metals, is actually the key to its ability to resist corrosion. When oxygen is present (in the air, soil, or water), aluminum instantly reacts to form aluminum oxide. This aluminum oxide layer is chemically bound to the surface, and it seals the core aluminum from any further reaction. This is quite different from oxidation (corrosion) in steel or other metals, where rust puffs up and flakes off, constantly exposing new metal to corrosion. Aluminum’s oxide film is tenacious, hard, and instantly self-renewing.

Therefore, as long as this oxide layer is not damaged, aluminum will remain resistant to corrosion. What factors can affect this oxide layer? Basically, extreme pH levels. Very high or very basic environments can destroy this protective layer and it might not renew itself as fast as needed to keep protecting the aluminum core. Normally, aluminum’s protective oxide layer is generally stable in the pH range of 4.5 to 8.5.

Salt water DOES NOT corrode aluminum!
There is a traditional fear in the AC industry about heat exchangers exposed to marine conditions. For sure, aluminum does not corrode in lakes and pools. But, what about seawater? Well, surprising as it may be, seawater does not corrode aluminum, simply because of its neutral pH. Then, why traditional copper coils made of copper and aluminum corrode so much near the ocean, up to the point where the aluminum fins disappear? Will not this happen even more likely to aluminum coils being aluminum a softer metal than copper?
The reason is a more complex kind of corrosion called galvanic corrosion and saltwater can be a major facilitator for this.

What is galvanic corrosion?
Galvanic corrosion (or dissimilar metal reaction) is the basic principal behind the way batteries and fuel cells work. Galvanic corrosion is an electromechanical process in which one metal corrodes preferentially to another when both metals are in electrical contact and immersed in an electrolyte. It can be synthesized in the schema below:
When two dissimilar metals are immersed in an electrolyte solution, a battery is created. If the two metals get in contact through a conductor or simply by physical proximity (like the copper tubes and the aluminum fins of a heat exchanger) the electrical loop is closed and the current is created. The metal with the highest potential will be the cathode and the one with the lowest potential will be the anode. Electrons start flowing from one metal to the other. The anode will start losing ions and the cathode gains them. This process is actually transferring mass from the anode to the cathode, making the anode weaker and the cathode more resistant.

Which metal will be the anode and which one the cathode?
Metals are ordered in what it is known as the galvanic series. Just “google” it and you will find several sources for this. Galvanic series are different for every electrolyte. The further the metals are in the series, the higher the potential difference and, therefore, the higher their galvanic corrosion. The metal closer to the noble end will be the cathode and the one closer to the active end will be the anode. In the case of traditional copper aluminum coils, copper will be the cathode and aluminum will be the anode.

What is pitting corrosion?
Pitting corrosion is a localized type of galvanic corrosion. When a metal surface is not homogenous and there is a dissimilar metal impurity on it, a localized galvanic process can start in the presence of an electrolyte, thus resulting in the development of cavities.

Some conclusions.
CLIMETAL microchannel coils are more corrosion resistant than traditional copper and aluminum coils because:

1. Aluminum is a very stable, low corrosion material due to its natural protective oxide layer.
2. This protective oxide layer is very stable as long as you keep the pH around between 4,5 and 8,5.
3. The most frequent cause of corrosion in aluminum is due to galvanic corrosion.
4. The good news is that if you properly understand how galvanic corrosion works, it is very easy to avoid or at least, minimize.
5. Galvanic corrosion takes place when:
   a. We have two metals in contact
   b. They are immersed or surrounded (totally or partially) by an electrolyte (in AC applications the most common would be humidity and salt).
6. We also know:
   a. The further these metals are in the galvanic series, the stronger the reaction
   b. The anode will be the sacrifice material whereas the cathode will get stronger.
CORROSION PROTECTION

As we have learned in the previous introduction the corrosion resistance of an aluminum heat exchanger depends on:

1. **Environmental factors:**
   a. Extreme acidic or basic environments
   b. Acid or basic pollutants deposited on the surface
   c. Presence of an electrolyte (most often, humidity and salt)

2. **The microstructure of the core material:**
   a. Non homogeneous alloys
   b. Presence of impurities in the aluminum alloys due to bad manufacturing process

3. **Electrochemical interaction among the different aluminum alloys:**
   Aluminum heat exchangers are made of headers, microchannel tubes and fins. Although all these elements are basically made of aluminum the alloys used for each of them are slightly different. And as we learned, when we have dissimilar metals, a galvanic process can begin when in presence of an electrolyte. Therefore, the right alloy combination is a key factor for corrosion prevention.

**Alloy combination design.**
Microchannel heat exchangers are made of headers, tubes and fins. These three are basically aluminum but because each of them is manufactured with a different process (lamination and extrusion) they require different alloys suited for each of them. Again, because of dissimilar aluminum alloys, we encounter –although very limited compared to traditional copper and aluminum coils - a potential risk of galvanic corrosion.
At Climetal we did a careful selection of our alloys in order to control and minimize the risk of corrosion. The key elements we took into consideration were the following:

1. **Material compatibility for correct temperature homogeneity during brazing.** If brazing temperatures of the different alloys are too different it can complicate the brazing process causing diffusion in some of the alloys and eventually leading to pitting corrosion.

2. **Refrigerant must not leak from the heat exchanger**, therefore corrosion has to be kept away from the microchannel tubes, which have extremely thin walls and contain the refrigerant at high pressure.

3. **Corrosion attack must be directed to the least important element** of the heat exchanger.

Ideally the corrosion attack should follow this sequence:

1. **Fin:** The fin should be the first component to corrode as it does not contain any refrigerant.

2. **Header:** The header walls are normally very thick (1,2mm-1,5mm), so very unlikely to corrode to a critical level that might cause a leak.

3. **Microchannel tubes (MP tubes):** MP tube wall thickness can be as thin as 0,3mm and working pressure inside can be as high as 45bars, so this is the most critical element to protect.

As we know, in a galvanic process the anode or sacrificial element is the one with the lower galvanic (electric) potential. Therefore as shown on the following experiment the galvanic potential order of each element should be as follows –from lower to higher potential: fin, brazed joint (fillet), header and microchannel tube. Schematically:

\[
\text{Ucorr fin} \leq \text{Ucorr fillet} \leq \text{Ucorr header} \leq \text{Ucorr MP tube}
\]

<table>
<thead>
<tr>
<th>Days in SWAAT</th>
<th>10 Days</th>
<th>30 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube surface</td>
<td>Tube</td>
<td>Fin</td>
</tr>
</tbody>
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**Corrosion Design**

- Poor Galvanic Situation
- Good Galvanic Situation
**Zinc protection against pitting corrosion.**

Zinc has a much lower galvanic potential than aluminum. Therefore, introducing this variable correctly into the equation can give us even more control on the galvanic process. For example, CLIMETAL’s MPE tubes have a zinc coating that reduces pitting corrosion. Basically, as the zinc acts as a sacrificial material, in the case of an eventual corrosion attack on the MP tube it will spread it over the surface rather than create a cavity.

**Coil coatings.**

We now understand the basic principles of corrosion and why CLIMETAL’s microchannel coils are more resistant to corrosion than other manufacturers’. However, as mentioned before, you might need the coils to work in an aggressive environment or you might just want an extra protection. In this case, microchannel coils can be coated with the same type of coating methods used for traditional copper aluminum coils (Blygold, e-coating, cataphoresis, epoxy...). One of the methods we normally recommend for its excellent results and quality price ratio is epoxy coating. The epoxy powder is sprayed and electrostatically fixed to the coil. After drying and curing in a furnace, the results is a uniform and durable coating that provides our heat exchangers with an enhanced protection.
**Copper aluminum joints.**

In the HVACR industry, most coils need to be delivered with copper connections in order to integrate them easily into the units. As we know, the risk of this joint is significant due to copper’s high galvanic potential. As in every galvanic process, the intensity of the process depends basically on the dissimilarity of the metals and the presence of an electrolyte. In this case we act on the later by putting an effective barrier between the Cu-Al joint and the environment, avoiding any trace of humidity getting into the joint.

CLIMETAL has enhanced the standard protection of the Cu/Al connections in order to avoid galvanic corrosion. Experience shows that over time, moisture could get under the shrink sleeve into the Al/Cu joint, creating a favorable environment for corrosion.

CLIMETAL’s improved solution involves the following process:

1. Remove all flux remaining from the Cu/Al joint (to get a better adhesion of the sleeve).

2. Use an adhesive sleeve instead of a non-adhesive sleeve, providing better and more resistant adhesion.

3. Apply UV resistant high adhesive polyurethane around the inlet and the outlet of the sleeve. With this extra protection we ensure that the sleeve does not get loosened due to the thermal dilatations of the joint, permanently sealing the joint from any kind of external humidity which would act as an electrolyte.
What other measures should be taken into account to reduce corrosion.

As we have seen, the extraordinary alloy combination design and manufacturing process of CLIMETAL’s coils assure a very low risk of corrosion. However, you should also think of your HVAC unit as a whole. Once we understand the nature of aluminum and how galvanic corrosion works there are some simple rules you should take into account to make your coils last for years:

1. Avoid extreme pH environments.

2. Avoid contact between aluminum and other metals by using some plastic, rubber or polymer washers. Be aware that there are some materials that have a high metal content like pressure treated wood (plywood) and concrete.

3. Avoid grounding electrical circuits to aluminum coils. Make sure your AC systems are completely ground isolated and that there is no electrical derivation going through the coil.

4. Cleaning: Pollutants with extreme pH levels can attack the aluminum oxide layer. Therefore, the more often you clean your coils from any kind of deposits, debris or any other type of residues or dirt, the less likely the oxide layer will be attacked. Cleaning a microchannel coils is a very simple procedure:
   
   a. You can use high pressure air or water, up to 120 bars (hot or cold).
   b. You can also use a soft brush to remove debris or persistent dirt.
   c. You can use some NEUTRAL soap or detergent. VERY IMPORTANT: it has to be neutral. Extreme pH chemicals can affect the natural protective aluminum oxide layer.

Despite these easy and simple recommendations, we at CLIMETAL are always ready to help. Send us your questions and doubts and we will be happy to give you our best advice.