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# Effectively reducing the effects of corrosion on air coolers

*Even an optimally designed heat exchanger will be useless in the long run if the materials of which it is made have not been carefully selected to suit its surrounding atmosphere. In the worst case scenario, this can even result in a unit or parts of a unit corroding in next to no time and needing to be replaced prematurely. This text provides an overview of corrosion and its effects on heat exchangers, explains various different potential hazards and demonstrates ways of effectively combating corrosion of air coolers.*

The very fact that no useful metals are abundantly available in pure form in nature demonstrates that even intrinsically corrosion-resistant metals, such as copper and aluminium, are eventually attacked over time by environmental influences, i.e. corrode. To put it simply, with this type of corrosion, the chemical reactions produced in the manufacturing process are undone and therefore the metals and alloys are converted back to the ores from which they were once originally extracted, for example aluminium oxide and copper sulphide.

Of course, generally speaking, this as an extremely slow process and is hardly noticeable (take copper roofs and aluminium façades, for example) but with air coolers, corrosion, caused on account of operating conditions and the wrong choice of materials, can advance at such a speed that users are faced with capacity losses and even leaks in next to no time.

Let's have a quick look at the chemistry behind all this. At microscopic level, the surface of a metal is not static but subject to constant change. Whilst the atoms inside are surrounded on all sides by other metal atoms and can therefore saturate all their electrons, the atoms on the surface in some cases don't have the necessary partners. However, they manage by bonding molecules from their surroundings to the solid surface. As such, the surface atoms form new bonds with these molecules in some cases and hence abandon their metallic characteristics.

This means that a thin non-metallic layer forms on the bare metal surface of all useful metals extremely quickly when they are exposed to air or placed under water. As to whether this constitutes the first stages of a corrosive attack will depend on various different factors. Depending on the type of metal and the surrounding environment, this layer can actually significantly slow down any further corrosion (e.g. aluminium) or have hardly any noticeable effect on the speed of the chemical reactions taking place on the metal surface (e.g. non-alloy steel).

## Not all corrosion is the same

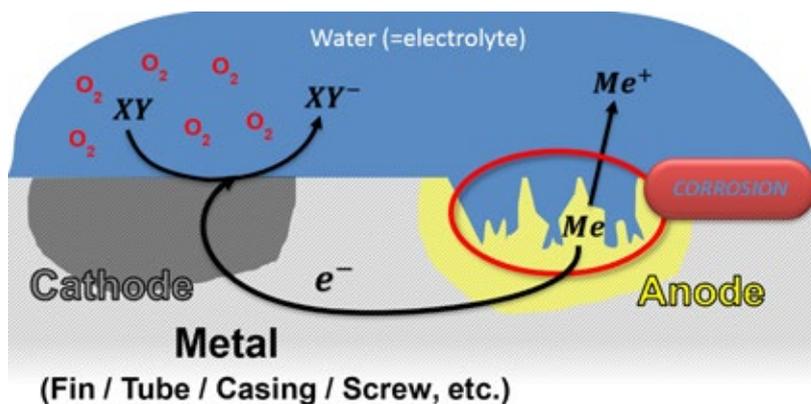
Five of the 56 types of corrosion described in DIN EN ISO 8044 in particular affect heat exchangers:

1. Uniform surface corrosion
  2. Pitting corrosion (localised corrosion)
  3. Shallow-pit corrosion
  4. Crevice corrosion
  5. Contact corrosion (= bimetallic corrosion or galvanic corrosion)
- (See Figures)

These types of corrosion are all caused by the same basic principle, i.e. the mechanism of electrochemical corrosion, whereby two partial reactions always take place on the surface of a metal. Firstly, the metal releases electrons in the anode area which are absorbed by other reactants in the cathode area. The reactant in most cases is oxygen.



Water plays an important role in this process as it dissolves salts and can conduct ions and therefore acts as an electrolyte.



**Picture 1:**  
General mechanism of electro-chemical corrosion

Water is always present around a heat exchanger, whether as a condensate, rain or humidity. The longer and more frequently moisture acts on a surface, the faster the corrosion processes will work. The same can be said of temperature. The higher it is, the faster the corrosion will advance. This means that air coolers in normal and positive temperature refrigeration rooms need greater protection from corrosion attacks than comparable units used in deep-freeze environments.

As to whether a metallic workpiece corrodes or builds up a protective layer ultimately depends on what happens with the metal atoms which have released electrons. Only some of these positively charged metal ions dissolve in the water. The rest react with negatively charged ions present in electrolytes to produce metal salts and form surface layers in the anode area. If these are only loosely attached and rather porous in nature, oxygen and water can continue to act on the metal virtually unhindered and increasingly dissolve it. Examples of this are the typical

### Definition of “corrosion” as per DIN EN ISO 8044:

“Corrosion is the physicochemical interaction between a metal and its environment that results in changes in the properties of the metal, and which may lead to significant impairment of the function of the metal, the environment, or the technical system, of which these form a part.”

rusty brown coloured areas which build up on components made from non-alloy steel and in some cases even flake off of their own accord or verdigris, which is formed when acetic acid acts on copper and is very soluble in water.

However, if the surface layer is firmly attached and so thick that the electrolyte can hardly penetrate through it to the metal surface, further corrosion processes will be significantly slowed down. A well-known example of such a protective surface layer is copper patina, which consists of basic copper salts which (unlike verdigris) are hardly soluble in water .



**Picture 2:**  
Copper fin with already clearly visible green patina, which forms a firmly attached protective surface layer.

## Passive layer

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Passive layers, which work in a very similar way to copper patina but are much thinner, build up on bare aluminium and chrome-containing high-grade steel (usually referred to as „stainless steel“) for example extremely quickly. This oxide layer, sometimes only a few nanometres thick, provides extremely effective corrosion protection. However, it generally has two limitations. Firstly, oxide layers are not stable in all pH value ranges, which is why, for example, aluminium is only recommended for use where pH values are between 4.5 and 8.5.

Secondly, just like the metal surface, the oxide layer is a very active boundary layer which is always changing and trying to incorporate ions present in the electrolyte. Therefore, if chlorides, in particular, find their way into the oxide layer, it will also become permeable over time and the underlying pure metal will start to dissolve. The ion lattice is usually broken up in isolated, localised areas. This phenomenon then becomes noticeable at an advanced stage as pitting corrosion.

The localised concentration of individual species has a huge influence on the speed of the corrosion process. In crevices, corners and under adhesive contaminants, the concentrations of individual substances can greatly differ from the concentrations in the remainder of the electrolyte.

As such, completely different conductivity and a very different pH value can develop at these locations. A corrosive environment then develops locally, although the actual composition of the electrolyte can in no way be valued as being corrosive.



**Picture 3:**  
The pitting corrosion, which is hardly noticeable on the exterior, makes pinprick-like holes deep in the material.

## Contact corrosion

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If two metals come into contact in a workpiece, for example an aluminium fin and a copper tube, the anode and cathode are defined solely by means of the respective electrochemical potentials of both metals. Copper, for example, at pH 7.5 (neutral range) has a potential of +0.1 V and aluminium has a potential of approx. -0.7 V. In this set-up, copper acts as the cathode and the more base aluminium acts as the anode.

If the cathode (to which the electrons migrate) also has a particularly large surface area, the anode will preferably release electrons and the attack on the metal (corrosion) in the anode area will be correspondingly high. The cathode/anode surface area ratio is therefore an important factor in terms of the speed of the corrosion.



**Picture 4:**

In the case of contact corrosion, the anode and cathode are formed of different metals/alloys with different electrochemical potentials. They are connected with each other through conduction. The partner with the lower potential dissolves – sacrifices itself, so to say.

## Adverse environmental conditions

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As explained at the beginning, every useful metal is subject to environmental changes. How quickly these take place largely depends on the environmental parameters, i.e. temperature, moisture, and impactful chemicals, etc.

The semi-precious metal copper in particular becomes so “non-precious” in the presence of sulphates, acetates, chlorides, ammonia, amines, nitrogen oxides, sodium hydroxide solution, hypochlorites, and formates, etc. that it corrodes and dissolves if oxygen is also present.

Particular care therefore needs to be taken with heat exchangers if a suitable material is sought for applications involving tobacco products, pickled products, fish, cheese, wastewater, fermentation processes and aggressive cleaning agents.

As already explained above, aluminium can tolerate neither high nor low pH values, nor the presence of large amounts of chlorides. As such, without any specific corrosion protection, it is essentially not suitable for use in areas in which acidic foods (e.g. dressings and fruit) and fish are processed. Marine climates also have a negative effect on service life. Aluminium should also not be allowed to come into contact with strong alkaline or strong acidic cleaning agents.

The high corrosion resistance of stainless chromium-nickel steel is primarily due to the formation of a passive chromium oxide layer, which is itself very resistant to concentrated lyes and acids.

However, high concentrations of halides, such as fluoride, chloride and bromide ions, hamper the formation of this passive layer and make these steels prone to localised corrosion, such as pitting or crevice corrosion.

Such high concentrations can, for example, be reached very quickly when chloride-containing cleaning agents (hypochlorite, active chlorine, etc.) are used. Even stainless steel coolers therefore need to be rinsed with plenty of fresh water after cleaning as otherwise, over time, chloride will find its way into crevices and other hard-to-reach parts and the critical concentration point at which corrosion processes start will quickly be exceeded.

## Corrosion protection measures

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Unfavourable environmental conditions which, for corrosion reasons, rule out the use of standard air coolers with copper tubes, aluminium fins and galvanised steel casings, require the implementation of appropriate protection measures. Options include:

1. *Increasing the thickness of materials*
2. *Using corrosion-resistant materials (AlMg or stainless steel) or combinations of materials (copper tube with copper fin)*
3. *Coating individual components or the entire heat exchanger*

Güntner's Research and Development Laboratory has conducted extensive series of experiments in order to test the resistance of various different materials and combinations of materials. This, and our decades of practical experience, ensure that our products are constantly and iteratively improved. It has been proven that doubling the thickness of materials disproportionately extends the service life but this also of course has a corresponding effect on price and weight.

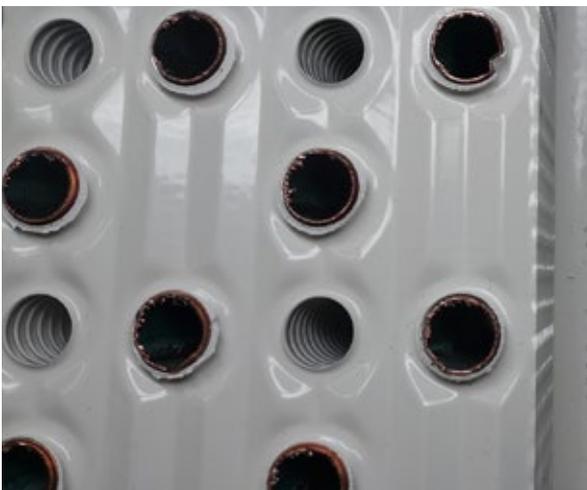
Using stainless steel instead of copper for the core tube also automatically improves the corrosion resistance, and the service life can be more than three times that of a standard unit. However, this solution involves an equally significant price increase, not least due to the fact that approx. 40 % more surface area is required for the same capacity.

## Güntner Coil Defender

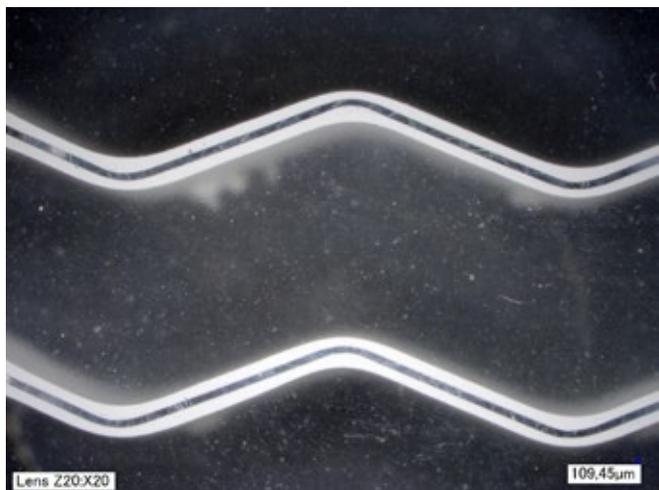
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Where corrosion protection is provided using coatings, at Güntner firstly the individual casing parts of air coolers are powder-coated and secondly pre-coated aluminium strips are used to produce epoxy resin-coated fins. In accordance with DIN EN ISO 12944, the powder coating (depending on the thickness of the layer) even meets the requirements of the highest corrosion protection categories C5 M (very high) and C5 I (very high). And even the coating layer of epoxy resin-coated fins, which is only a few micrometres thick, easily survives 500 hours in a standardised corrosion test, the neutral salt spray test in accordance with DIN EN ISO 9227.

The new Güntner Coil Defender is also a powder coating, which is applied all-over afterwards and wraps core tubes as well as fins and front plates with a protective layer which is on average 200  $\mu\text{m}$  (0.2 mm) thick. This high-quality coating means that the copper-aluminium heat exchanger coil of a standard air cooler can be given a corrosion resistance similar to that of a comparable unit with a stainless steel tube. The quality of the coating at every point in the depth of the coil (even in the narrowest of gaps) is guaranteed by the production technolo-



**Picture 5:**  
A cross section of a Coil Defender heat exchanger. The coating is applied uniformly over the entire surface area and envelops the core tube as well as the fin and tube sheet.



**Picture 6:**  
A microscopic image of a fin cross section shows the approx. 200  $\mu\text{m}$  thick and uniformly applied corrosion protection powder coating of the Güntner Coil Defender.

gy developed by Güntner. The Güntner Coil Defender is also approved for production environments in the highly sensitive food sector as the powder coating has already been certified by TÜV Süd as “HACCP-ready” (HACCP = Hazard Analysis and Critical Control Points).

## Conclusion

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There are as many ways of effectively combating corrosion as there are factors that promote the development of corrosion in the food processing industry. The latter is firstly due to the different items of food that are stored and/or processed (e.g. salt-water fish, meat, cheese, fruit, vinegar, curing salt) and secondly due to the cleaning agents used which often contain aggressive, highly acidic or alkaline ingredients. The prevailing humidity and room temperature also have a significant influence on corrosive processes.

As such, in the quest to find a durable and long-lasting air cooler, high product quality is essential, but a solution that is tailored specifically to the operator can only be devised if there is constructive dialogue between the partners involved. The unit's requirements will therefore, as a whole, depend on the industry, specific application and user in question.

More information on this topic is available in the Güntner brochure entitled “Material Recommendations” and in the corresponding Güntner app, which can be downloaded from the Güntner homepage.