



Understanding

Heat

Exchanger

Corrosion

Modine's HVAC Products

Modine Manufacturing Company has been leading the way in thermal management since 1916. We design, manufacture, and test heat transfer products for a wide variety of applications and markets. We're at work in practically every corner of the world, delivering the solutions our customer's need, where they need them. Modine is a full service provider of custom-designed heat exchangers for the residential, industrial, and commercial air conditioning, heating, ventilation, and refrigeration markets. Our ability to offer microchannel, heat recovery, and round tube plate fin (RTPF) coils allows us to select the optimum heat exchanger for the customer's application.

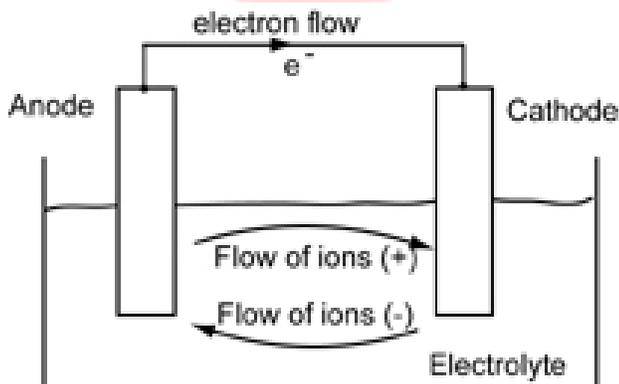


Modine invented microchannel parallel flow (PF™) coils more than 25 years ago (U.S. Patent 4,998,580). Today, this technology offers OEMs a number of advantages. These all-aluminum coils are now available up to 1,200mm (48") X 2,540mm (100"), offering solutions for residential and commercial HVAC&R systems. Modine also provides the counter flow, CF™, evaporator; its new 2-row microchannel coil designed for ease of application, energy efficiency and durability. The CF™ microchannel evaporator provides customers with a state-of-the-art solution for their residential and commercial indoor coil needs.

Our copper tube/aluminum fin heat exchangers are used in a wide range of applications to transfer heat between air and a fluid (refrigerant, water-glycol, or oil). Tailored to specific end-product requirements, these coils set the standard for cost-effective heat-transfer.

Corrosion Basics

The primary material in Modine's HVAC heat exchangers is aluminum. Aluminum is a very reactive metal, which is easily oxidized on its surface. As long as this hard aluminum oxide layer remains intact, the base aluminum will remain resistant to corrosion. For most materials, like steels, the oxide layer spalls from the surface, allowing for continued attack of the base metal.



Extreme environments, however, can damage the oxide layer which may not regenerate quickly enough to provide sufficient protection for the product. These harsh environments are typified by very high or very low pH levels. Normally, aluminum's protective oxide layer is generally stable in the pH range of 4.5 to 8.5. The reason why precaution has to be taken with aluminum fin and copper tube (RTPF) heat exchanger in marine environments is galvanic corrosion.

Galvanic corrosion occurs when dissimilar metals are immersed in an electrolyte. Due to an electrochemical reaction, one of the metals will be stripped of electrons (oxidized), while the other will gain electrons (reduced). The role of each metal is determined by their galvanic potential, typically summarized by the galvanic series for a given electrolyte and temperature. The metal with the lower galvanic potential will be oxidized (consumed), while the metal with the higher potential will be reduced, becoming more resistant. In the case of aluminum and copper (in the presence of salt water, for example), the aluminum will be sacrificial to the copper. Modine always tailors their material chemistry and selection to insure that the first component to corrode is a fin structure. The refrigerant-carrying round or microchannel tube is the most protected heat exchanger component, since perforation would result in a refrigerant leak.

Pitting corrosion is localized corrosion. Many times, surface treatments, such as zinc flame spray (with a low galvanic potential), are used to preferentially create general corrosion acting laterally across the part surface as opposed to downward via a pit to avoid perforation.

Formicary, or ant's nest, corrosion is a corrosion phenomenon which gets its name from the similarity of the morphology to an ant's nest. This type of corrosion only appears in copper and is caused by a chemical reaction with an organic acid breaking down to acetic and formic acids.

Causes of Corrosion

The following factors can influence the rate of corrosion:

Humidity: A galvanic corrosion cell requires an electrolyte or current carrying media, to reach a dynamic state. The electrolyte can be water or any water-soluble substance with good conducting properties. Moisture in the air is one such electrolyte. Humid air contaminated with corrosive gasses further accelerates the corrosion rate as the air's current carrying potential increases.

Temperature: Chemical reactions in general are temperature dependent, with increased temperature normally resulting in a faster reaction rates.

Corrosive Gases: Not all gases cause corrosion. Specifically, we are concerned with three types of gases:

1. Acidic gases, such as hydrogen sulfide, sulfur oxides, chlorides, hydrogen fluoride (HF) and nitrogen oxides;
2. Caustic gases;
3. Oxidizing gases, such as ozone

Of the gases that can cause corrosion, the acidic gases are typically the most harmful.

Chloride Salts: The presence of chlorides, in seawater for example, significantly enhances the conditions for pitting corrosion of most metals.

Corrosive Environments

Potentially corrosive outdoor environments include areas adjacent to the seacoast, industrial sites, heavily populated urban areas, some rural locations, or combinations of any of these environments. Factors including but not limited to the presence of flue gas, sewage vents or open sewage systems, and diesel exhaust can all have a detrimental effect on HVAC coils.



Coastal/Marine: Coastal or marine environments are characterized by the abundance of sodium chloride (salt) which is carried by sea spray, mist, or fog. Most importantly, this salt water can be carried more than several miles by ocean breeze. It is not uncommon to experience salt-water contamination as far away as 10 km (6.2 miles) from the coast. As a result, protection of HVAC equipment from ocean-borne electrolytes in inland areas may be necessary.



Industrial: Industrial applications are associated with a host of diverse conditions with the potential to produce various atmospheric emissions. Sulfur and nitrogen oxide contaminants are most often linked to industrial and high-density urban environments. Combustion of coal and fuel oils releases sulfur oxides (SO_2 , SO_3) and nitrogen oxides (NO_x) into the atmosphere. These gases accumulate in the atmosphere and return to the ground in the form of acid rain or low pH dew.

Not only are industrial emissions potentially corrosive, many industrial dust particles can be laden with harmful metal oxides, chlorides, sulfates, sulfuric acid, carbon, and carbon compounds. These particles, in the presence of oxygen, water, or high humidity environments can be highly corrosive and may lead to many forms of corrosion including general corrosion and localized corrosion such as pitting and formicary corrosion.

Combination Marine/Industrial: Salt-laden seawater mist, combined with the harmful emissions of an industrial environment, poses a severe threat. The combined effects of salt mist and industrial emissions will accelerate corrosion. Internally in manufacturing plants, corrosive gases may be the result of process chemicals or the typical industrial processes employed in manufacturing activities. Open sewage systems, vents, diesel exhaust, emissions from dense traffic, landfills, aircraft and ocean vessel exhaust, industrial manufacturing, chemical treatment facilities (cooling tower proximity), and fossil fuel burning power plants are potential contributors to consider.



Urban: Highly populated areas generally have high levels of automobile emissions and increased rates of building heating fuel combustion. Both conditions elevate sulfur oxide (SO_x) and nitrogen oxide (NO_x) concentrations. Within a building, gases can be produced by cleaning agents, cigarette smoke, process operations, and data center printers. Some indoor environments such as swimming pool areas and water treatment facilities can also produce corrosive atmospheres.

Corrosion severity in this environment is a function of the pollution levels, which in turn depend on several factors including population density for the area. Any HVAC equipment installed immediately adjacent to diesel exhaust, incinerator discharge stacks, fuel burning boiler stacks, or areas exposed to fossil fuel combustion emissions should be considered an industrial application.



Rural: Rural environments may contain high levels of ammonia and nitrogen contamination from animal excrement, fertilizers, and high concentrations of diesel exhaust. These environments should be handled much like industrial applications.

The local weather conditions play a major role in concentrating or dispersing external gaseous contaminants. Temperature inversions can trap pollutants, producing a serious air pollution problem.

Electrocoating Process

To extend heat exchanger life in corrosive environments, Modine's products can be electrocoated with a durable and flexible epoxy coating. The process is often referred to as "E-coat". The coating is applied uniformly over the heat exchanger surface. Modine uses a cathodic electrode position of epoxy material that provides the highest corrosion resistance when compared to other electrocoating processing options.

Electrocoating is a multi-step process. The heat exchanger is washed to remove contamination and ensure all surfaces are clean. The fundamental principle behind electrocoating is that the coating material has an opposite charge from the part to be coated. An electrocoating system applies a DC charge to the heat exchanger while immersed in a bath of oppositely charged molecules. The molecules are drawn to the metal, forming an even, continuous film over the entire surface. At a certain thickness, the coating insulates the metal, slowing the attraction, and the process becomes self-limiting. An oven

bake cross-links the coating uniformly to ensure optimal properties on the heat exchanger surface. Finally, a UV protective topcoat can be applied to shield the finish from ultraviolet degradation and ensure coating durability and long life.



This coating process creates a smooth, consistent, and flexible coating that penetrates deep into all cavities and covers the entire heat exchanger including the fin edges, without bridging between adjacent fins. E-coat provides superior protection in the most severe environments.

Recommendations

Although each of the corrosive environments discussed above can be detrimental to the life of a heat exchanger, many additional factors should also be considered before making a final design selection. The local climate around the application site may be subject to:

- Sea salt
- Wind
- Dust
- Road salts
- Swimming pools
- Diesel exhaust / traffic
- Localized fog
- Household cleaning agents
- Sewer vents
- And many other discrete contaminants

Even being within 3-5 km (1.9-3.1 miles) of these special local climates may reclassify a normally mild environment into one that requires additional preventative measures for corrosion. When these factors are part of the immediate direct environment, their influence is further exacerbated.

Modine suggests the following guideline to be followed in applying our products to corrosive environments.

Application	Recommendation
Severe Environment	e-coated PF™ or RTPF with top-coat for UV protection
Mild Environment	uncoated PF™, CF™, or RTPF

This application guide is meant to provide general information on corrosion mechanisms and corrosive environments. Although recommendations are given, details about the real world application of our products cannot be fully anticipated in this document. The service lifetime requirements of a potential product are also unknown. For these reasons, Modine prefers to work closely with our customers to thoroughly understand their design requirements and operating environments. With this information, our application engineering team can create a final design that meets all customer expectations. We also assume no liability for the completeness and correctness of the information contained in this document.