Formicary corrosion in a coil

HVAC in Corrosive Environment

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Part 2

Introduction

In Part 1 of this article, published in the September-October 2016 issue of AC&R SIM, we learnt about corrosion and its general effect on HVAC equipment. In Part 2 of the article, we shall study how corrosion affects modern HVAC units.

External coil corrosion appears to be on the rise. While coil corrosion can stem from poorly manufactured copper, chemical residue from coil manufacturing and other such causes that initiate the corrosion process long before the coils arrive on a job site, the majority of problems occur when environmental acids corrode coils from the outside in. HVAC units exposed to corrosive environments lose their body, fins, brazing joints of copper tubes like headers, U-bends and internal pipeline, testing instruments and control panels/PCBs completely or partially. Condenser units get affected by moisture much faster than cooling units. Units located near an open sewer, effluent treatment plant, saline exposure and chemical-industrial zones are affected faster than units located in residential areas.

About the Author

Mahesh Mehta entered HVAC industry accidentally, being a Textile Engineer. He started by marketing eco-friendly non-toxic imported chemicals in Western India in 1999, conforming to standards like RoHS and MIL. He then began executing turnkey orders for coil cleaning in industrial AC plants with specialized equipment, using a combination of mechanical and chemical cleaning. He has worked with multinationals and Indian companies in pharmaceutical, food, hotel and IT industries for deep coil cleaning, descaling, fin coating, environmental corrosion control, power saving, etc. He likes to work at challenging sites.

Improvements in Coil Design

Almost all manufacturers of HVAC&R equipment have made significant strides in an effort to achieve higher star ratings on their equipment. Equipment operating today saves the user operating costs. Finned tube heat exchangers are not manufactured the same way as they were 10 years ago. Simply stated, equipment today is much more efficient in operation than equipment manufactured 10 years ago. In the development of higher efficiency equipment, typical changes include increasing the fins per inch (fpi), increasing the square foot face area and adding configured or enhanced fin areas to increase air flow through the coil for better heat transfer. Most manufacturers have opted for coil design changes rather than mechanical changes to improve equipment efficiency. Coil changes were the quickest and easiest to make: changing the fin die was all that was required. Some OEMs

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are now offering pre-coated fin stock in the construction of coils as corrosion protection. This option is effective inland for condenser coils, but not for coastal or industrial applications. These coils also do not go through testing, unlike post-coatings. Another drawback is un-coated fins at cut edges.

Enhanced Fins

A common method of providing higher heat transfer is by punching patterned slits in fin surfaces. In addition to weakening the structural integrity of the fins, these slits entrap contaminated particulates that accelerate the corrosive process. Enhanced fins are not easily cleaned and often the leading fin edges are compromised during corrosion attack. Since there are increases in the fins per inch count, it means fin stock is much thinner and, with added enhancements, much quicker to deteriorate.

Recycled Aluminum

Much of today's aluminum is recycled. Aluminum products, including fin material, may also be manufactured with recycled aluminum. Recycled aluminum is not as corrosion resistant, since it is not as pure as virgin aluminum from bauxite. Recycled aluminum contains impurities from the re-manufacturing process. In addition to white rust (aluminum oxidation), it is not uncommon to see specks of red rust on aluminum fins when subjected to a corrosive environment.

Rifled Tubing

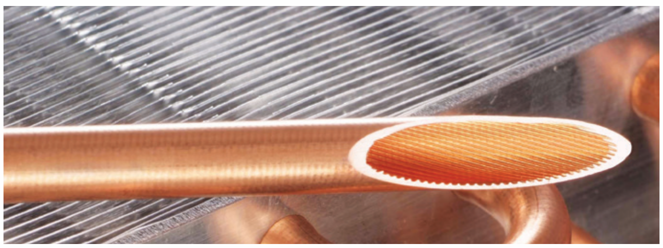

Figure 1: Rifled tube

Tube rifling is a method used to increase refrigerant velocity through coils. The quicker refrigerants move, the faster the cooling/heating cycle. Quicker cooling means less energy consumption and a better star rating. Unfortunately, the walls of rifled tubing are very thin. In acidic and alkaline environments, when cooper is attacked, these thin walls allow failure at quicker rates. This occurrence is most common in environments containing sulfuric acid, sulfur, and/or hydrogen sulfide. A common occurrence is leaking refrigerant. Such incidence is also known as the ant's nest due to its structure. *Figure 2* shows a typical ant's nest corrosion.

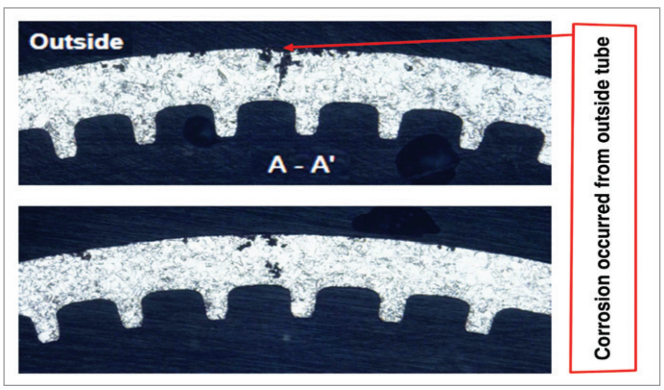

Figure 2: Transverse cross section of tube at leak area showing ant nest kind of corrosion

Figure 3 shows corrosion in a cooling coil occurring below the fins, which is very difficult to repair. Dip coating prior to installation is the only answer, if coating of tubes has not been done at the time of production.

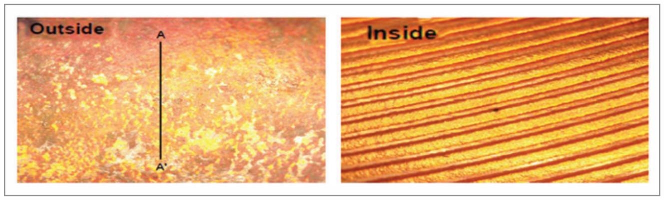

Figure 3: Magnified picture of the outside and inside of a tube surface at corrosion area

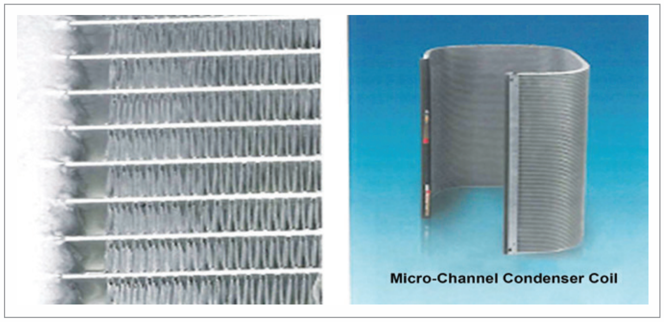

Figure 4: Micro-channel coils

Micro-channel Coils

These coils are constructed from seprately extruded components, which are then factory-assembled and brazed to construct a coil. Delicate tubes run horizontally into a manifold tube. Once the tube is damaged, it is hard to repair. Repairing and brazing aluminium is more difficult than copper. New technology makes it difficult to find comptetent repairers.

Figure 5 shows how dirt contamination gets trapped in a clean section, which is difficult to remove. Inside-out cleaning operation in large units is even more difficult, leading to reduction in heat exchange. When moisture mixes with corrosive deosits, corrosion follows rapidly, ending in coil destruction. Special accessories are needed to clean such large units.

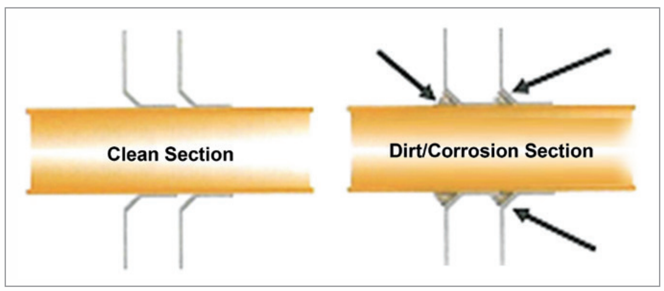

Figure 5: Dirt getting trapped in a micro-channel heat exchanger

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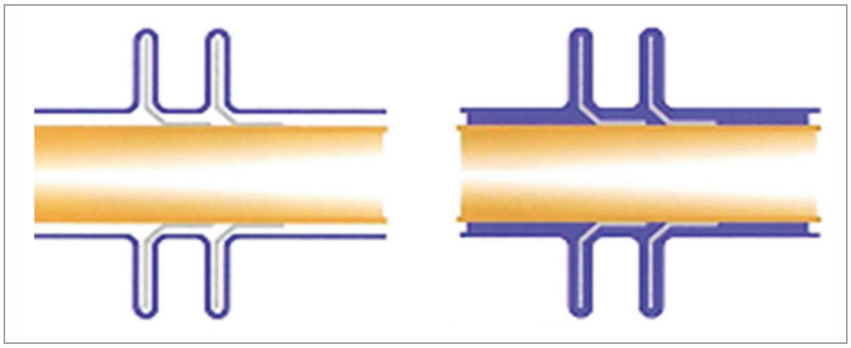

Figure 6: Coating heat exchanger to seal off dirt traps

Figure 6 shows how coated units protect the heat exchanger from contamination, as dirt traps are sealed off. It would be wise to confirm from the coater that such coating does not affect ΔT, which should not reduce by more than 1% as a general thumb rule, especially for fin area.

Types of Corrosion

There are many types of corrosion. The most common types of corrosion associated with coating protection of structures and equipment are galvanic and general corrosion. These types of corrosion can lead to equipment failure.

Galvanic corrosion results from the current caused by a galvanic cell, which is a cell consisting of two dissimilar metals in contact with each other and with a common electrolyte. An electrolyte is an ion conductor, usually an aqueous solution.

General attack corrosion is corrosion that happens in a uniform manner.

Economic reasons as well as formability and heat transfer ability make copper tube aluminum fin coils the most popular material for HVAC&R applications. Corrosive environment, such as salt air, prevalent in certain industries affects copper and aluminum in HVAC units. When aluminum and copper alloys in a coil are placed in a corrosive environment, they are highly susceptible to galvanic and general attack corrosion. They corrode and deteriorate quickly if not protected by a corrosion resistant coating.

While corrosion can take one or more forms, the mechanism of attack in aqueous solutions involves some aspects of electrochemistry. There will be a flow of electricity from some areas of the metal surface to other areas through a solution capable of conducting electricity, such as water, hard water or even condensed moisture containing soluble gases or salts. The term anode is used to describe the portion of the metal surface that is corroded and from which current leaves the metal to enter the solution. The term cathode is used to describe the metal surface from which current leaves the solution and returns to the metal.

Galvanic corrosion is more commonly seen in cooper tube aluminum finned coils. It causes fin corrosion and ultimately coil destruction. The efficiency of the unit declines fast. Units located in environmental/ industrial corrosive areas retain good fin strength, but their heat exchange property is considerably depleted (see *Figure 7* and *8*). Such slow coil destruction is difficult to notice over a period of time.

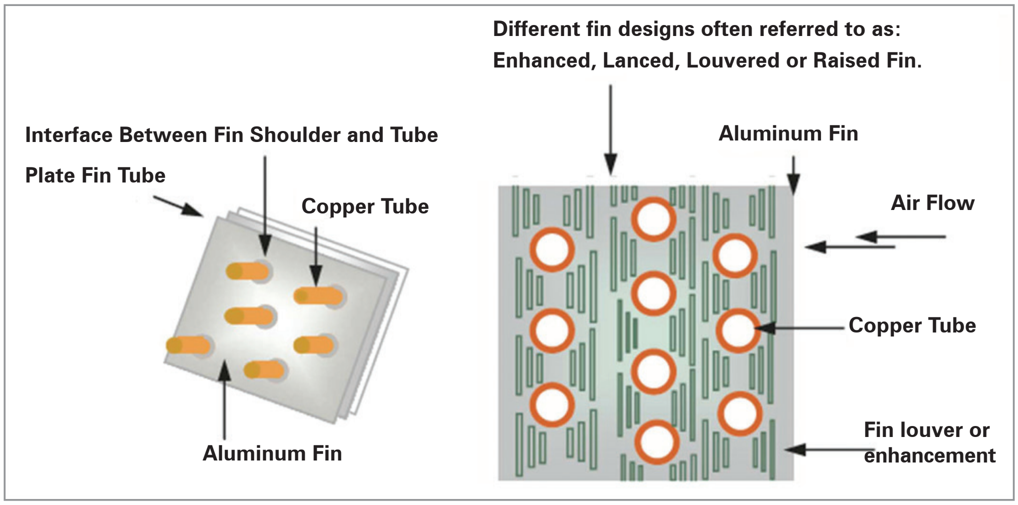

Figure 7: Basic coil construction – non-louvered and louvered fins

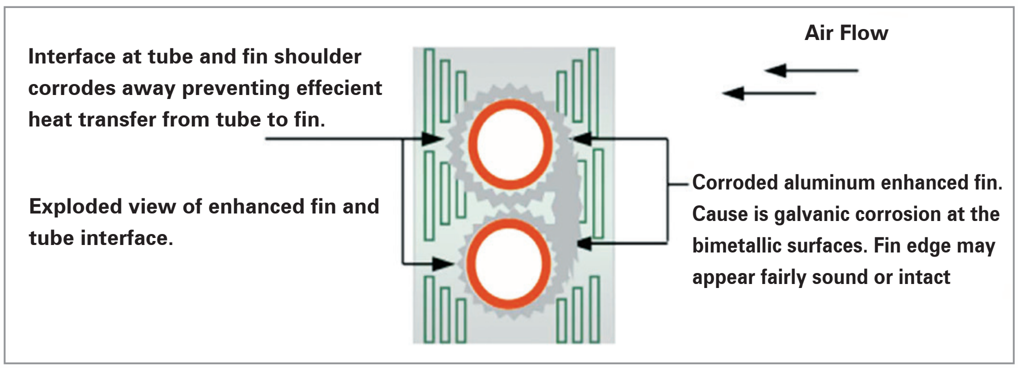

Figure 8: Galvanic corrosion begins at interface of aluminium fin and copper tube

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Galvanic corrosion starts at the interface of the tube and fin. An uncoated fin deteriorates faster; the lost metal creates gaps between the tube and fin shoulder, degrading coil efficiency and reducing its performance. Visual destruction of the coil from corrosion is evident. It is not possible to repair it by coating, since there is no way to bridge the gap at the fin-tube interface; corrosion deteriorates the joint or the fins are embrittled.

The effect of corrosion can be felt in a few weeks to as long as a few years, during which period the unit's working and efficiency degrade slowly, or within a few weeks it may start leaking from the brazing joints . The result varies from low fin corrosion to rapid degradation of brazing joints causing leaks. It ultimately leads to premature unit failure.

Coil Corrosion Examples

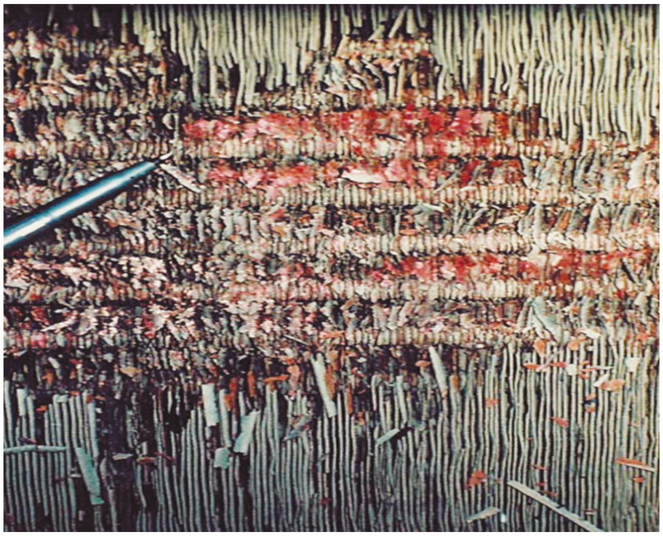

Figure 9: Copper coil exposed to salt air and burning of sugar fields, located 2 km from sea shore, for 18 months showing loss of fins and built-up oxides

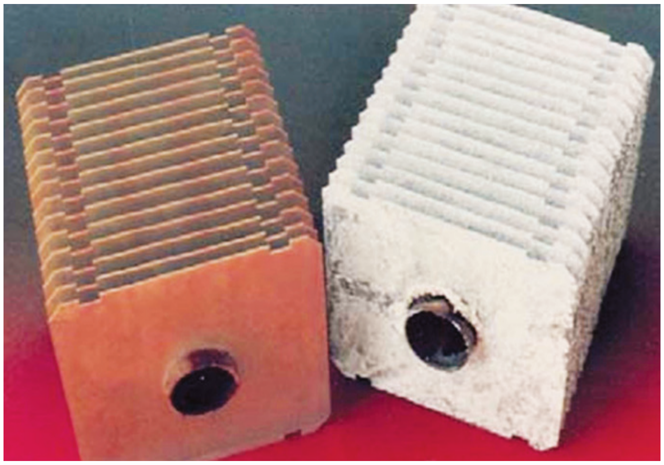

Figure 10: Coils exposed to Salt Spray Test as per ASTM B117.85 for 360 hours; corrosion on the untreated coil would shorten equipment

Figure 11: Old header with paint and rust oxides

Figure 12: Chemically cleaned and coated header

Figure 13: Old coil with dirt and corrosion

Figure 14: Restored coil after fin cleaning and nano coating

Case Study

In a recent assignment, the author has revived an old unit on the verge of being junked, by repairing the header and U-bend, deep coil cleaning and fin coating. (Note increase in fin sharpness in the final photo). Old copper tubes with multiple coating were also chemically cleaned and re-coated.

Conclusion

Today's coils are more susceptible to corrosion and abrasion attack, which often leads to accelerated coil failure, increased operating costs, increased head pressures and unit failure. It is more important than ever that contractors, engineers, consultants, and owners should consider protecting their equipment with a high quality professional protective coating process. It is also important to establish a proactive preventative maintenance program, which should include cleaning coils with a product that is not harsh and abrasive. A clean coil is an efficient coil. Efficient equipment helps building owners save on the bottom line. The responsibility for maintaining a healthy coil lies with the owner.