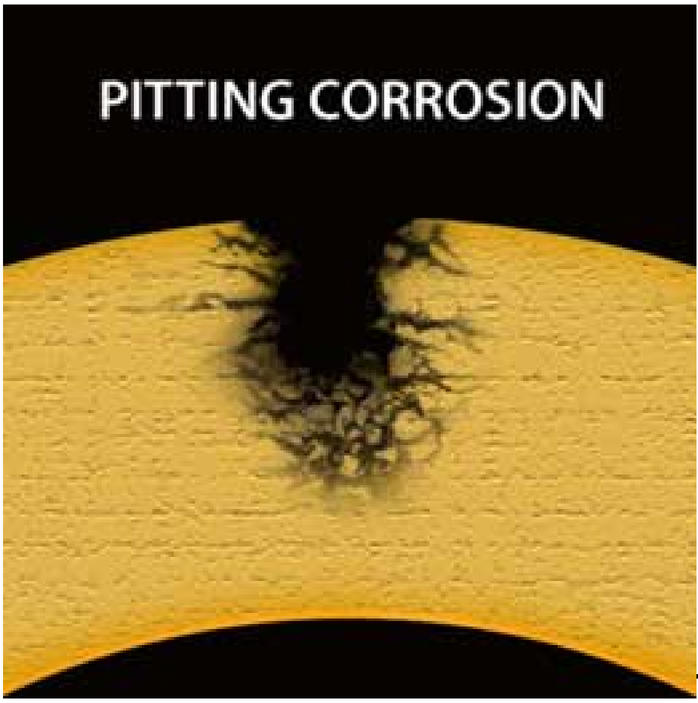
Strategies for Combatting Coil Corrosion

Many HVAC manufacturers, distributors, and contractors may not realize that hundreds of thousands of coil failures have occurred during the last decade from corrosion. The cause is most typically environmental pollutants, which range anywhere from salt-air, to household cleaning agents, pesticides, formaldehydes, building materials, and even off-gassing of food. Each of these contaminant sources can initiate corrosion in coil tubing in a year or less when the conditions are right.

For example, refrigeration coils were continually failing in a South American fruit processing plant’s banana room that used fruit ripening ethylene gas generators. Gaseous byproducts from the catalytic generator combined with the moisture in the ripening area formed a weak acid that resulted in pinhole leaks in the coil tubing after a year or less.

Aside from fruit processing plants, most coastal area HVAC equipment—whether it’s commercial or residential—is also bombarded with corrosion from ocean salt.

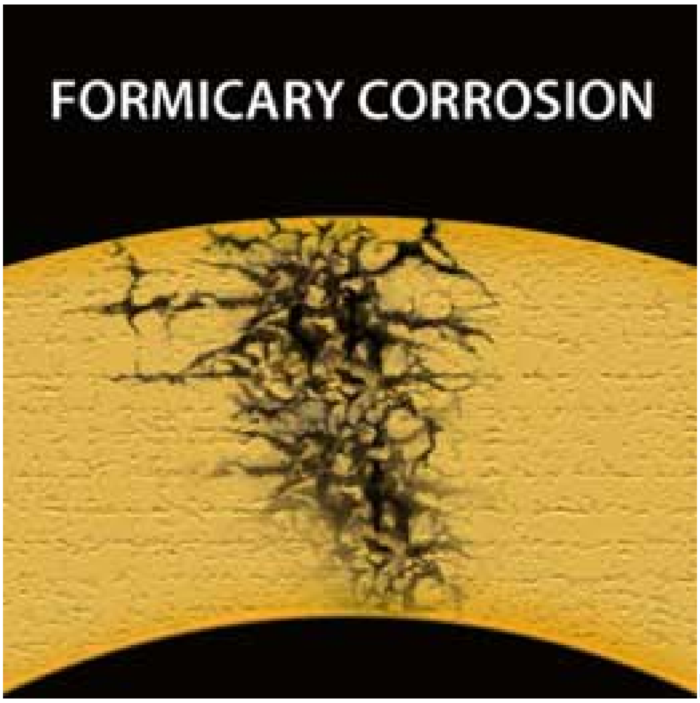


Two Common Types of Coil Corrosion

The two most common forms of coil corrosion are pitting and formicary. These two corrosive processes can occur in as little as a few weeks after installation. More typically, corrosion will begin appearing within a one- to four-year period. The ability to distinguish pitting from formicary corrosion might help detect and eliminate the cause.

Pitting corrosion is typically caused by the presence of chlorides or fluorides.

Chlorides are found in numerous items such as snow-melting crystals, toilet bowl/tile cleaners, dishwasher detergents, fabric softeners, vinyl fabrics, carpeting, paint strippers, etc. Fluorides are used in many municipal water treatment plants. Unlike formicary corrosion, pitting is usually visible on the exterior of the copper tube with the naked eye. Pitting is caused by an aggressive attack of negatively-charged chloride/fluoride ions carried to the metal surface by condensate. The negative ions attack the oxide film the metal usually uses to protect itself, essentially forming a corrosion driven battery that consumes the copper. After pits have formed in the copper, they will progress through the thickness of the copper tube until a pinhole is formed causing the coil to leak refrigerant.



Formicary corrosion is caused by organic acids such as acetic and formic acids. Acetic acids are abundant in numerous household products such as adhesives, paneling, particle board, silicone caulking, cleaning solvents, vinegar, foam insulation and dozens of other commonly found products in the home or commercial/industrial workplace. Formic acid can be found in cosmetics, disinfectants, tobacco and wood smoke, latex paints, plywood, and dozens of other materials. The corrosion caused by these substances is usually not visible to the naked eye, although black or blue-gray deposits can sometimes be seen on the surface. Formicary corrosion can form a sub-surface network of microscopic corroded tunnels within the tubing wall resembling ant nest-type structures that are substantially larger than the surface pinholes above them. Eventually one or more of these tunnels will progress to the surface of the copper and form a pinhole which quickly results in coil leakage.

Choosing the Right Coating For the Job

The first step a contractor must take when confronted with coil corrosion is to determine if it will happen repeatedly when coils are replaced. It’s a difficult diagnosis to determine if the coil corrosion is a one-time phenomenon or a continuing problem in that particular location. In the case of the banana processing plant or a coastal area unit, coils most likely will continually corrode, and their replacement units should have a protective coating. In less corrosive environments, owners should attempt to eliminate in-home corrosive elements such as cleaning solvents from the return airstream by storing them in areas that are not near a return duct. These actions might eliminate the expense and need to coat a replacement unit.

Choosing the most appropriate coil coating for the application could save the project thousands of dollars and eliminate repeat treatments. Choosing the wrong coil coating could reduce heat transfer capabilities and lead to higher energy bills.

Heat transfer is a major issue to consider when coating a coil with any substance, especially in a retrofit application because the coil may no longer perform at its manufactured specification. The thinner the coating, the better the heat transfer, while thick coatings can lead to significantly diminished heat transfer. Another issue is a coating's hydrophobicity, or how well it drains condensation off the coil, to create optimum heat transfer capabilities. Ideally, water would drain quickly off of the coil to avoid reductions in efficiency.

Water accumulation is also detrimental because it can lead to the growth of mold and mildew. Most coatings do not actively resist biological growth, but their hydrophobicity can passively deter such growth.

Four basic coating types are prominent in the HVAC industry:

- Polyurethanes
- Epoxies
- Fluoropolymers
- Silanes

All four types of coatings offer differing degrees of advantages in terms of corrosion resistance, scratch resistance, flexibility, weight, thickness, hydrophobicity, and heat transfer capabilities.

Polyurethane (PU), invented in the 1940s, is used in a variety of applications. It can be manufactured as hard as fiberglass, bouncy as rubber, sticky as glue, and soft as upholstery foam. Many of the off-the-shelf PU-based coil coatings available to the HVAC trade can be applied in the field. PU formulations are fairly inexpensive, less viscous, more flexible, and thinner (typically 25-50 microns) than most coatings. The disadvantage is they are not as resilient or long-lasting as other coatings.

Epoxy, or phenolic-based, coatings are generally the cheapest of available coatings. Epoxies, developed in the late 1920s, are known for their excellent chemical and heat resistance, and are well known for coating floors and other surfaces. The high viscosity of epoxy-based systems leads to thicker coatings (approximately 50 to 100 microns) with poor flexibility and adherence characteristics. An epoxy coating is difficult to apply in the field. Therefore, the coil is typically disconnected and then shipped to a factory setting for a professional treatment. Because they are thicker, epoxy coatings will reduce heat transfer from the air to the refrigerant in the coil, and thus cause a decrease in system efficiency and capacity. Epoxy coatings might best suit new installations where heat transfer losses are accounted for in the system design specifications.

Fluoropolymers, first developed in 1938 by DuPont under the trade name Teflon®, are now available in many different forms under a variety of trade names. Fluoropolymers are known for their high resistance to acids, solvents, and bases. They are most effectively applied to metal through electrostatic powder coating or a thermal sintering process, as is done during the manufacturing of cookware and other non-stick products. Additionally, many field-use fluoropolymer sprays are available to contractors. The field-use sprays generally have very poor adhesion and their effectiveness will diminish significantly in a very short period of time. The cost of fluoropolymer-based field-use coatings is typically less than the more advanced epoxy and PU based coating system but their lifetime and effectiveness is very limited. Fluoropolymer coatings applied in the correct manner, through thermal sintering or electro-static powder coating, have not gained traction in the HVAC industry due to the expense of such processes and their inability to be performed in the field.

Silanes are well known as excellent coupling agents where two dissimilar materials such as paint (an organic) and glass (an inorganic material) can be bonded together. A variety of silane chemistries are available, many of which are tailored to have particular characteristics such as flexibility, hydrophobicity, and scratch resistance. Thus, the proper formulation of a silane coating can provide a flexible, resilient glass-like coating with good corrosion resistance and water draining capability, that bonds extremely well to aluminum and copper (an inorganic). Silanes form an extremely thin coating when cured (less than 10 microns) that has very little, if any, adverse effects on heat transfer. They are very resilient against cracking and corrosion, are hydrophobic, and reduce airflow friction. Silanes can be quite difficult to apply properly in the field unless a trained applicator is hired to do so. The coil surfaces must be cleaned thoroughly and prepared properly for a successful application and therefore, it is best if the coating is applied at an off-site application center. Although silane coatings are typically somewhat more expensive that the other coatings described, they also exhibit the best heat transfer properties and typically have a much greater lifetime as well.

To conclude, our research indicates that a silane-based coating provides the best protection from the environment, and has minimal impact on heat transfer while remaining a long-lasting barrier that protects a HVAC coil against corrosion for an extended period of time (typically 5 years or more).

Each of the coating technologies described carry different levels of toxicity. Service technicians planning to apply any of these coatings in the field should be outfitted with proper OSHA equipment and the appropriate breathing apparatus.

Sole and Brothers led an R&D team in developing a ductwork coating for the U.S. Navy that reduces duct airstream friction and improves corrosion resistance, resulting in improved duct lifetime and HVAC system efficiency. Mainstream (www.mainstream-engr.com [1]) is a Rockledge, Fla.-based research and

*development company with more than 70 patents and 30 current R&D projects with the U.S. Military and NASA. Mainstream's HVAC division markets a variety of service products under the Qwik Products brand (*www.qwik.com *[2]) which are available through traditional HVAC distributors.*

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