Detecting and Eliminating Causes of Coil Corrosion

By Alan H. Brothers, Ph.D.

External coil corrosion appears to be on the rise. While the possible causes of coil corrosion can stem from poorly manufactured copper, chemical residue from coil manufacturing, and other problems that initiate the corrosion process long before the coils arrive on a jobsite, the majority of problems occur when environmental acids corrode coils from the outside in.

A case in point is an American fruit processor that has replaced dozens of coils in the past year at a South American facility. The maintenance engineer had used Mainstream Engineering's internal acid detector, QwikChek®, and acid eliminator, QwikShot®, which is injected into the refrigeration system to vaporize moisture/acids and send them to the filter/drier to fix his corrosion problem because he erroneously believed the corrosion was happening from the inside out. Although the QwikCheck acid test indicated no acid, coil corrosion continued at the same alarming rate. Mistakenly convinced acid was corroding the coil from the inside, the plant engineers lodged complaints about the accuracy of the acid test method and efficacy of the acid eliminator. Mainstream Engineering, a research & development company that provides both the U.S. military and NASA with solutions to HVAC problems, sought to answer the fruit processor's problem and discovered the coils were corroding from the outside in, not vice-versa.

While no particular environmental chemical has yet been pinpointed at the South American plant, the problem could arise from a number of issues. For example, most fruit processors use ethylene gas generators to ripen fruits such as bananas. Combustion byproducts from the catalytic generator combined with moisture, prevalent in humid, equatorial regions, form a weak acid that eats pinhole leaks into the coil tubing in a year or less. The mixture of ethylene gas, high humidity, and a myriad of cleaning chemicals used to ensure sanitation at the facility will inevitably form a volatile mix of coil-corroding gaseous contaminants.

Few U.S. service technicians will find themselves in a South American fruit plant, but similar circumstances that result in the rapid corrosion of coils can be found at sites ranging from residential systems or commercial rooftop units to industrial refrigeration applications. Only the composition of the environmental contaminants and/or chemicals may vary. For example, a rooftop unit in a coastal area could be corroded from ocean salt. Household bleaches, aerosol sprays, high humidity, and other prevalent factors found in every home can damage an indoor residential unit coil. An abundance of fertilizers, industrial plant processes, pollution, or acid rain can corrode outdoor condensing coils.

The following list illustrates sources of coil corrosion that could be overlooked by service technicians:

- fermenting yeast (lactic acid from milk) in a bakery walk-in cooler
- chlorine from an indoor swimming pool or aquatic process
- urine (ammonia) from dead animals in meat processing plant coolers
- sulfur from well water used in cleaning coils or rooms with coils
- fertilizer (ammonia) in agricultural building evaporative coolers

Two Types of Environmental 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 between pitting and formicary corrosion might help detect and eliminate the cause. For example, pitting 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. Pitting, which appears on the exterior of the copper tube, is usually visible to the naked eye. It is caused by an aggressive attack of an anion, which is a negative-charged chemical species. The anions search for positive-charged species called cations, which are abundant in copper. Pitting will eventually break through to the inside of the tubing and create a leaking condition.

Formicary corrosion is associated with pinholes in the copper tube walls. Although this type of pinhole corrosion is not usually visible to the naked eye, some black or blue-gray deposits often can be seen on the surface. Formicary corrosion also exhibits a subsurface network of microscopic corroded tunnels within the tubing wall that resemble ant nest-type structures, immensely larger than the surface pinholes above them. Formicary corrosion is caused by organic acids such as acetic and formic acids. Acetic acids or the derivative acetate 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.

Given these common products containing organic acids attack copper, it is not surprising that coil corrosion occurs at alarming rates. The rise in corrosion the last 20 years might also be aggravated by the trend in tighter building construction methods, which allows less outside air induction to dilute or clear away these corrosive, indoor buildups. Even so, both pitting and formicary corrosions need two additional ingredients—oxygen and water. While oxygen is nearly unavoidable, limiting moisture might help the service technician fight or decelerate the problem.

Galvanic Corrosion

When two dissimilar metals, such as copper tubing and aluminum fins, are in contact with each other, a "galvanic couple" is formed, and the phenomenon of galvanic corrosion occurs. In this galvanic couple, the metal that corrodes and the metal that is protected depend on their relative positions in the galvanic series. Moisture is again a key factor in this corrosive process because it acts as the electrolyte needed in the reaction. Sea water accelerates the galvanic reaction because of its higher conductivity than fresh water and because salts can destroy the protective barriers on metal surfaces. The potential for galvanic corrosion is always present between two dissimilar metals. But how quickly galvanic corrosion results in system damage depends on variables like the electrolyte conductivity, the amount of oxygen present, and relative surface areas of each metal.

Keeping Coils Clean to Fight Corrosion

Outdoor condensing coils can best fight corrosion with periodic cleaning. Water is suitable, but existing corrosion and buildup typically are removed more completely with a coil cleaner. Numerous acid-based and alkaline-based coil cleaners are available. However, proper rinsing is important to avoid the coil cleaner chemical residue that could initiate the corrosion process. Some alkaline cleaners tout the fact that they are "non-acid" to capitalize on the belief that acids cause corrosion. However, alkaline cleaners also need to be rinsed thoroughly just like acid-based cleaners because alkaline residues can also corrode aluminum and other materials.

Outdoor coils located in areas where corrosives are prevalent, such as heavy industrial areas with acid rain or coastal areas where ocean salt is a factor, should have frequently scheduled, periodic cleanings. The fruit processing plant mentioned earlier would benefit from monthly coil cleanings to help offset environmental corrosion.

Corrosion from the Manufacturing Process

While no available statistics reveal the extent of environmental corrosion, it may cause the majority of coil corrosion problems. However, the manufacturing process itself can also initiate coil corrosion prior to installation. Manufacturing problems can be related to anything from poorly constructed copper tubing or lubricants coil manufactures use at their plants.

Replacing coils corroded during the manufacturing process or using substandard copper may not alleviate corrosion because the problem may be inherent in the product. Contact the manufacturer and/or distributor to address these issues.

Coatings to Protect Coils from Corrosion

Protective coatings are an option for new coils that are destined for corrosive applications and for existing coils that have been repeatedly replaced due to corrosion. Numerous coatings exist. However, most coil coatings are composed of either silanes or polymers. The advantage of coatings is they make coils virtually corrosion-proof when properly applied and maintained. Reducing corrosion can improve long-term performance and reduce replacement costs. The disadvantage perceived by some industry members is a decrease of up to 10 percent in heat transfer, a significant disadvantage for existing coils in the field because it affects efficiency and capacity. New coils with coatings can be oversized to offset this heat transfer loss. Some coating manufacturers actually claim an increase in heat transfer, due to the way in which water condenses and drips off coated coils.

For existing coils, some coatings can be applied in the field by specialists who clean and then spray a coating on the coil. Other coatings can be applied by service technicians in the field. Whether a field application is possible depends mostly on the depth of the coil. Other coatings require sending the coil to the coating manufacturer or a specially-trained applicator. Probably the most difficult area to reach with a coating is the gap between the fin and tube. Coatings plug this gap, preventing water and contaminants from penetrating, but they interfere with heat transfer between them.

There are two common types of coil coatings, and both differ greatly in chemical make-up and performance:

1) Polymers—These coatings, which are typically thick epoxy or phenolic coatings, are generally inexpensive and easy to apply. But because they are thicker than silanes, they decrease heat transfer more. Many polymer coatings are also sensitive to ultraviolet (UV) degradation and can crack off the coil surfaces over time.
2) Silanes—Silane-based coatings are mainly composed of alcohol and water, thus they are applied in a thinner coat. The thinness makes them more difficult to see, thus harder to maintain. However, the thinness minimizes their effect on heat transfer. Because curing is sensitive to temperature and humidity, they are usually applied only by a licensed applicator. They are typically harder and more abrasion resistant than polymers. Silanes are quite durable because they are actually chemically bonded to the coil surfaces.

When preparing to make a service call concerning a corroded coil, identify the type of corrosion then search for environmental cause(s). If possible, eliminate the source of corrosion. For irretrievable sources, coatings might be the only answer.

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Bio: Dr. Alan H. Brothers is a senior materials engineer for Mainstream Engineering, Rockledge, Fla., a leading research & development company specializing in thermal control and heat pump development. Brothers has a Bachelor's Degree in Engineering and Applied Science from California Institute of Technology, and a doctorate in Materials Science and Engineering from Northwestern University. Brothers continued his doctoral research on the processing and properties of light metals under a Helmholtz Fellowship from the Hahn-Meitner Institute in Berlin. Additionally he has researched the corrosion of aluminum in organic liquids and the use of coatings to mitigate corrosion in aluminum and galvanized steel HVAC components. He is the author or co-author of twelve peer-reviewed technical publications and a number of conference presentations.