Indoor Coil Corrosion Industry Research Report

Identifying Common Sources

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Introduction

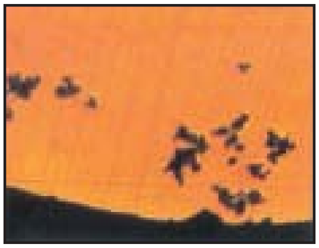
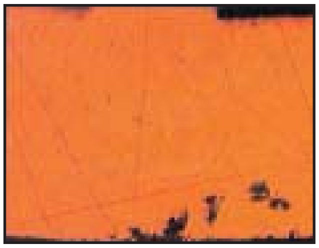
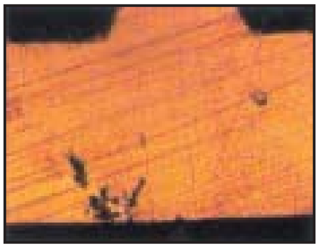
Indoor coil corrosion leading to coil failure is an issue that affects coils manufactured by the entire HVAC industry today. A leading cause of coil corrosion is formicary acid, an organic acid that can be formed in the home. Although the occurrence rate of these failures is low nationwide, some geographic areas have experienced higher incidence rates. For instance, some homes experience multiple corrosion-related failures while those around them have none. Failures are typically characterized by leaks that form in the fin pack area of the coil after one to four years of installation and use. ICP was the first to identify formicary corrosion and provide our dealers with an effective solution. With the aluminum coil, we are incorporating advanced manufacturing techniques to provide the next generation solution to formicary corrosion.

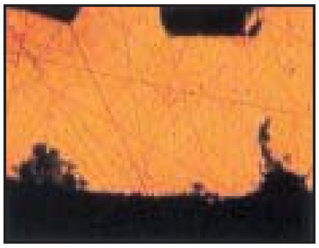
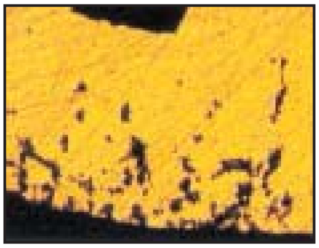
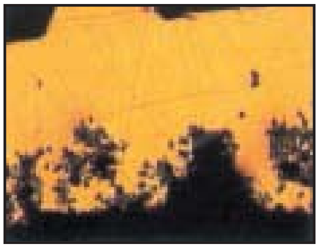
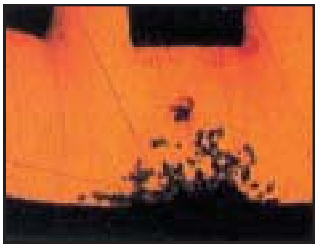
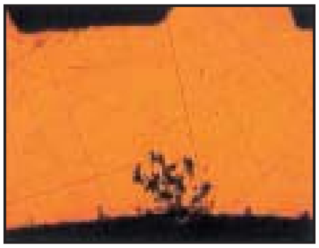
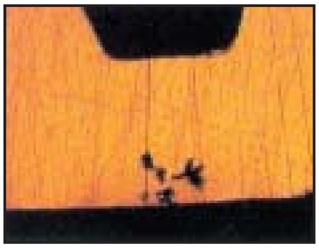
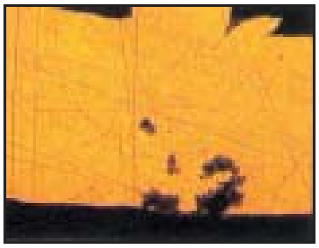
This formicary corrosion affects coils industry-wide. A competitive study has shown identical corrosion failure leaks in all coil brands investigated. The photos at right show magnified tubing cross-sections from failed coils. The progression of the corrosion is from the exterior of the tube inward, eating away at the copper, until penetration occurs and a leak results.[1] **Due to the corrosion process, some photos look better than others, but all corroded through the tube causing a leak at that point. All coils failed in the time period characteristic of such a failure.**

Manufacturers represented in photos:

- ADP
- Airpro (Coleman)
- American Standard
- Aspen
- Carrier
- Goodman
- ICP
- Janitrol
- Rheem
- Superior
- Trane
- York

Fin Pack Leaks – Formicary Corrosion

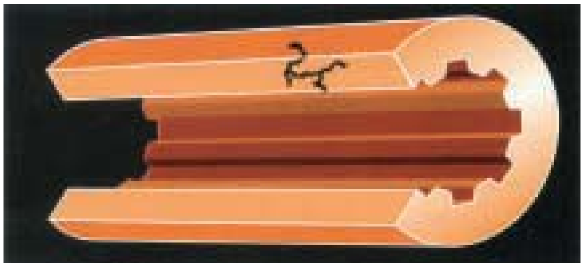









Corrosion Mechanisms

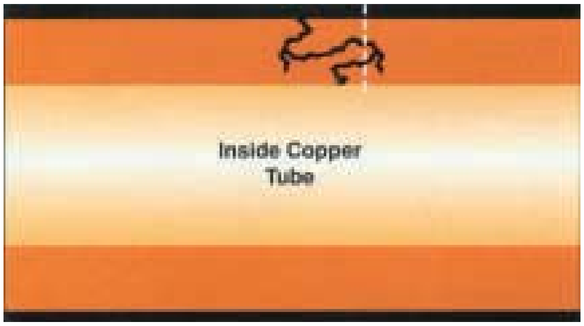
There are many potential causes of coil leaks in indoor coils, ranging from manufacturing or process-related defects to copper corrosion. Additionally, there are several different corrosion mechanisms that can affect copper tubing. The following discussion focuses on pitting corrosion failures of indoor coils.

There are two main forms of pitting corrosion found in indoor coils: (1) general pitting; and (2) formicary corrosion, sometimes called “ant’s nest” corrosion.

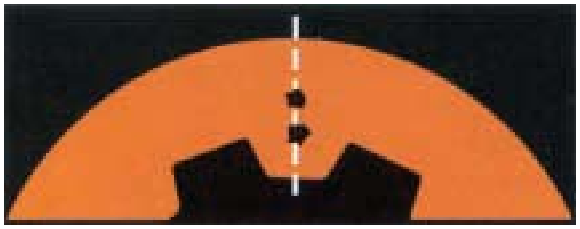
Illustration of Typical Corroded Tube



3-D representation of corrosion through tube



Side view of leak



Cross-section showing portion of corrosion (leak)

The illustrations above depict the characteristics of the corrosion process: at top, how a single leak might perforate the copper tube; center, where that tube might be cross-sectioned; and bottom, how the final cross-sectioned piece would look magnified.

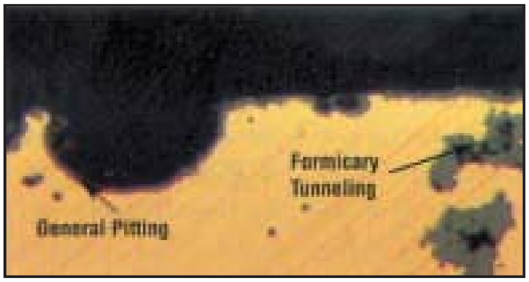


Fig. 1 General Pitting and Formicary Corrosion

General pitting corrosion is caused by aggressive anion attack on the copper tube. An anion is a negatively charged chemical species. Due to this negative charge, anions aggressively search for positively charged species called cations. Copper is an abundant source of cations. Large pits resembling bite marks characterize the footprint of general pitting. These pits can often be observed with the human eye. Chlorides are the most common source of the aggressive anions known to cause general pitting corrosion.

Common household substances that may contain chlorides include:[1-3]

- Aerosol sprays
- Carpeting
- Degreasing and detergent cleaners
- Dishwasher detergents
- Laundry bleach
- Fabric softeners
- Paint removers
- Tub and tile cleaners
- Vinyl fabrics
- Vinyl flooring
- Wallpaper

Formicary corrosion, on the other hand, appears as multiple tiny pinhole leaks at the surface of the copper tube that are not visible to the human eye. Upon microscopic examination, the formicary corrosion pits show networks of interconnecting tunnels through the copper wall, hence the association with ants’ nests. The agents of attack involved in this corrosion mechanism are organic acids.

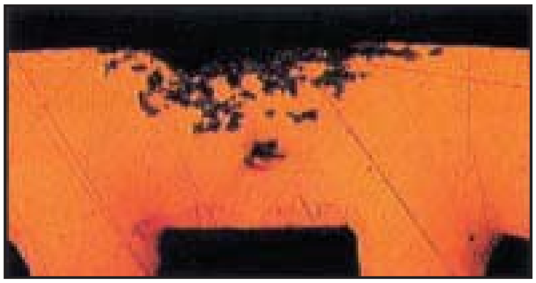


Fig. 2 Formicary Corrosion Tunneling

There are many possible sources of organic acids, which are volatile organic compounds (VOCs), in both the coil application (i.e. the home) and coil production environment. The most common organic acids are formic and acetic acids. Formaldehyde can be converted to formic acid and then to formate in moisture. Acetic acid is converted to acetate in water. All of these compounds are aggressive to copper, resulting in the ant's nest corrosion footprint.

Common household sources that may contain formic acid, formaldehyde, or formate include:[1-7]

- Building materials
  - Adhesives
  - Cabinets
  - Carpets
  - Countertops
  - Foam insulation
  - Laminates
  - Paints (latex and oil based)
  - Paneling
  - Particle boards
  - Plywood
- Cosmetics
- Disinfectants and deodorizers
- Tobacco and wood smoke

Typical household sources of acetic acid or acetate include:[1-7]

- Building materials
  - Adhesives
  - Cabinets
  - Carpets
  - Countertops
  - Foam insulation
  - Laminates
  - Paints (oil based)
  - Paneling
  - Particle boards
  - Plywood
  - Silicone caulking
  - Wallboard
  - Wallpaper
- Cleaning solvents
- Vinegar

There are three conditions required for formicary corrosion to occur:[7]

- The presence of oxygen
- The presence of a chemically corrosive agent (organic acid)
- The presence of moisture

If multiple corrosive agents are present, the result will be multiple corrosion footprints, as depicted in Fig. 1 (page 3), which shows both general pitting and formicary corrosion.

Research Findings

Environmental Factors

The fact that many manufacturers are experiencing identical failures shows that external environmental factors are playing a role. While each manufacturer has a different assembly process and multiple sources of raw materials, a chemical analysis of materials used can identify the presence of corrosive agents.

ICP has thoroughly inspected its manufacturing processes, materials and environment, including all oils and lubricants, to ensure corrosive agents are not present in the productions environment.

The evidence suggests the home environment is the primary contributor to coil corrosion. The trend in home construction is to improve energy efficiency by making homes "tighter." This decreased ventilation results in higher concentraion levels of indoor contaminants.

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Research Study

A year 2000 study was conducted to measure the volatile organic compound concentrations and emission rates in new manufactured and site-built houses.[8] The E.O. Lawrence Berkeley National Laboratory performed this research with the support of the U.S. Department of Energy.

This study shows that many materials used in the construction of new houses emit VOCs, including formaldehyde. Plywood, engineered wood products such as flooring and cabinetry, latex paint, and sheet vinyl flooring have been identified as major sources for these compounds. Measurements of acetic acid, formaldehyde, and acetaldehyde concentrations taken inside homes in this study were significantly higher than levels measured outside the homes. These elevated emission rates were seen to persist over a period of at least nine months while these homes were being studied. In fact, the measured levels of acetic acid increased during the study.

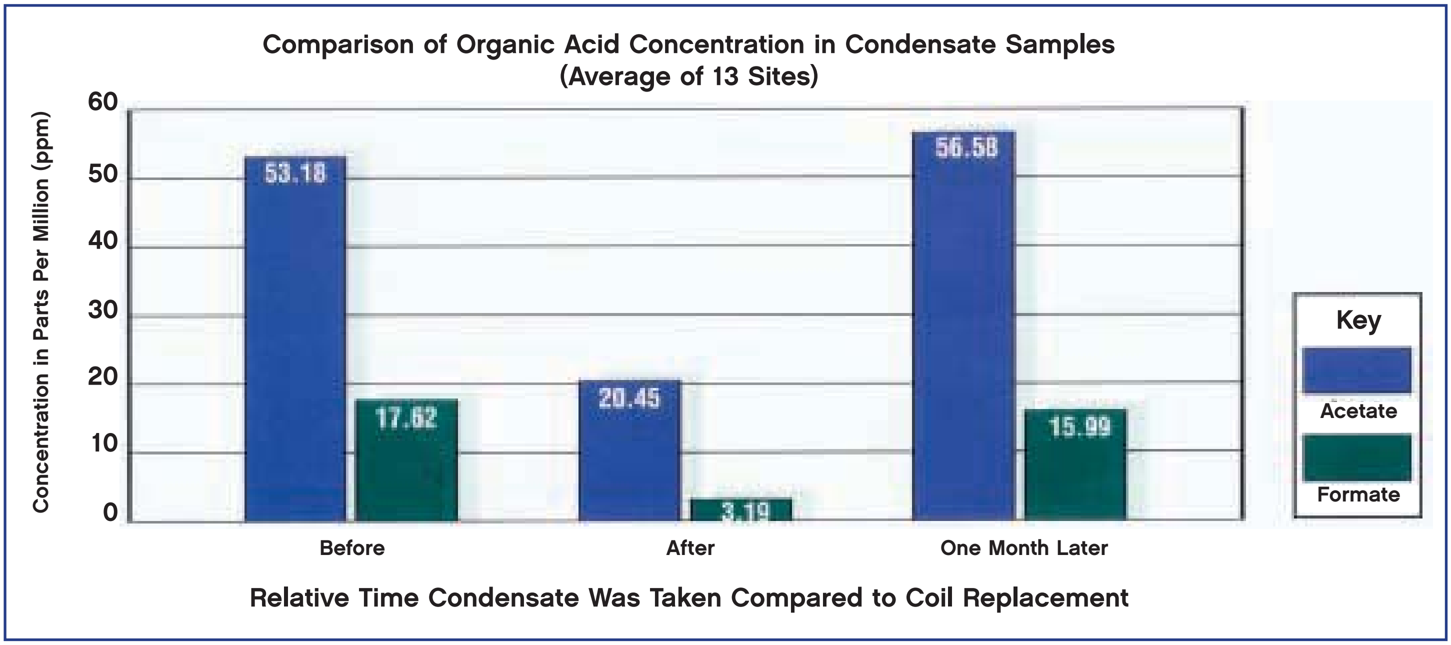
Another study specifically investigated the emission rates of wooden products in test chambers.[9] This testing supports the theory that wood is a source of organic acids, especially formic and acetic acids.

In addition, building materials, including woods and furniture, are generally the main sources of volatile organic compounds in the indoor environment.

Condensate Analysis

As part of ICP's efforts to research this problem, coil condensate sampling was performed at coil failure sites. The analysis of these samples confirmed the presence of significant levels of formate and acetate in the household environments. These samples were collected just prior to coil replacement and immediately after the coils were replaced. Additional samples were then taken at some sites during follow-up assessments a month later.

The following chart shows the average trend of acetate and formate levels from 13 sites located in the Houston, Mobile, St. Louis, Indianapolis and Memphis areas. The levels are elevated prior to coil replacement. When condensate is drawn immediately from the new coil, the levels decrease dramatically. Finally, after a short period of operation, the levels return to previously elevated levels. These measurements are also an indication that the corrosive agents are not tied to the new replacement coils because the condensate samples drawn directly off the new coils show decreased levels of acetate and formate. After the coil has been installed for a period of time, the levels of these agents once again reflect the operating environment of the coil.



Conclusions

There is increasing evidence linking the primary cause of indoor coil leak failures to agents present in the household environment. Significant levels of corrosive agents known to cause these failures have been quantified in indoor condensate sampling. The trend toward decreased home ventilation rates likely contributes to the elevated levels of indoor contaminants.

ICP has conducted extensive field and laboratory testing and research efforts to identify an effective method of preventing coil failures caused by agents in the household environment.

The ICP Solution

Today, International Comfort Products is proud to offer aluminum coils designed to resist the effects of formicary corrosion as well as many other forms of coil corrosion. As with virtually all of our products, these coils are backed with our 10-year parts limited warranty.
Our aluminum evaporator and fan coils are significantly more resistant than traditional copper and equal to tin-plated coils to corrosive agents found in the home and that cause formicary corrosion.

Aluminum coils provide enhanced durability and reliability:

- Testing to ensure durability and reliability: Running coils through more than 44,000 cooling cycles and over 2.5 years of accelerated corrosion testing
- Burst testing up to 2100 psi
- Each coil is leak checked in a helium leak chamber, allowing the detection of leaks as small as 0.1 ounces per year, prior to leaving the factory
- Aluminum to copper transitions are designed to resist corrosion attacks through the selection of specific alloys for fillers, joint geometry and location. Transition joints are also fatigue tested over 250,000 times with hydraulic fluids and jar tested in mixed acids as determined from 1,000 condensate samples from across the country to ensure their durability and reliability

Advantages of aluminum coils include:

- Aluminum protects against formicary as well as various other types of corrosion, preventing rusty tube sheets and pinhole leaks, while providing comfort and peace of mind to the homeowner
- The selection of tube enhancements matching current tube performance allows ICP to maintain dimensions and performance of current copper and tin-plated copper coils
- Aluminum to Copper transition of the suction and liquid lines means the installer will braze copper to copper in the filed using standard procedures
- Aluminum coil products are easier to handle and transport because they weigh less than copper coil products

References

1. G. Tetley, M. Heidenreich and K. Smith, "The Basics of Formicary Corrosion," *The Air Conditioning, Heating & Refrigeration News*, March 30, 1998, pp. 5-6.

2. T. Fairley and S. Gislason, M.D., "Handbook of Indoor Environments - Materials and Their Chemicals," http://www.nutramed.com/environment/handbook-materials.htm, pp. 1-8.

3. http://www.lifekind.com/glossary.htm#f

4. T. Notoya, "Localized Corrosion in Copper Tubes by Volatile Organic Substance," *Journal of University of Science and Technology Beijing*, Vol. 6 (1999), No. 2, p. 131.

5. R. S. Lenox and P. A. Hough, "Minimizing Corrosion of Copper Tubing Used in Refrigeration Systems," *ASHRAE Journal*, November 1995, pp. 52-56.

6. T. Notoya, "Ant Nest Corrosion in Copper Tubing," *Corrosion Engineering*, Volume 39, Number 6, p. 361.

7. P. Elliott and R. Corbett, "Ant Nest Corrosion—Exploring the Labyrinth," *Corrosion 99*, Paper No. 342, p. 2.

8. A. T. Hodgson, A. F. Rudd, D. Beal and S. Chandra, "Volatile Organic Compound Concentrations and Emission Rates in New Manufactured and Site-Built Houses," *Indoor Air 2000*, in press, ISSN 0905-6947.

9. S. Lange, O. Wilke, D. Broedner, and O. Jann, "Measuring the Emission Behavior of Organic Acids From Wooden Products in Test Chambers," *Indoor Air 99*; Volume 5.

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