Indoor Coil Corrosion Industry Research Report

Identifying Common Sources

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Introduction

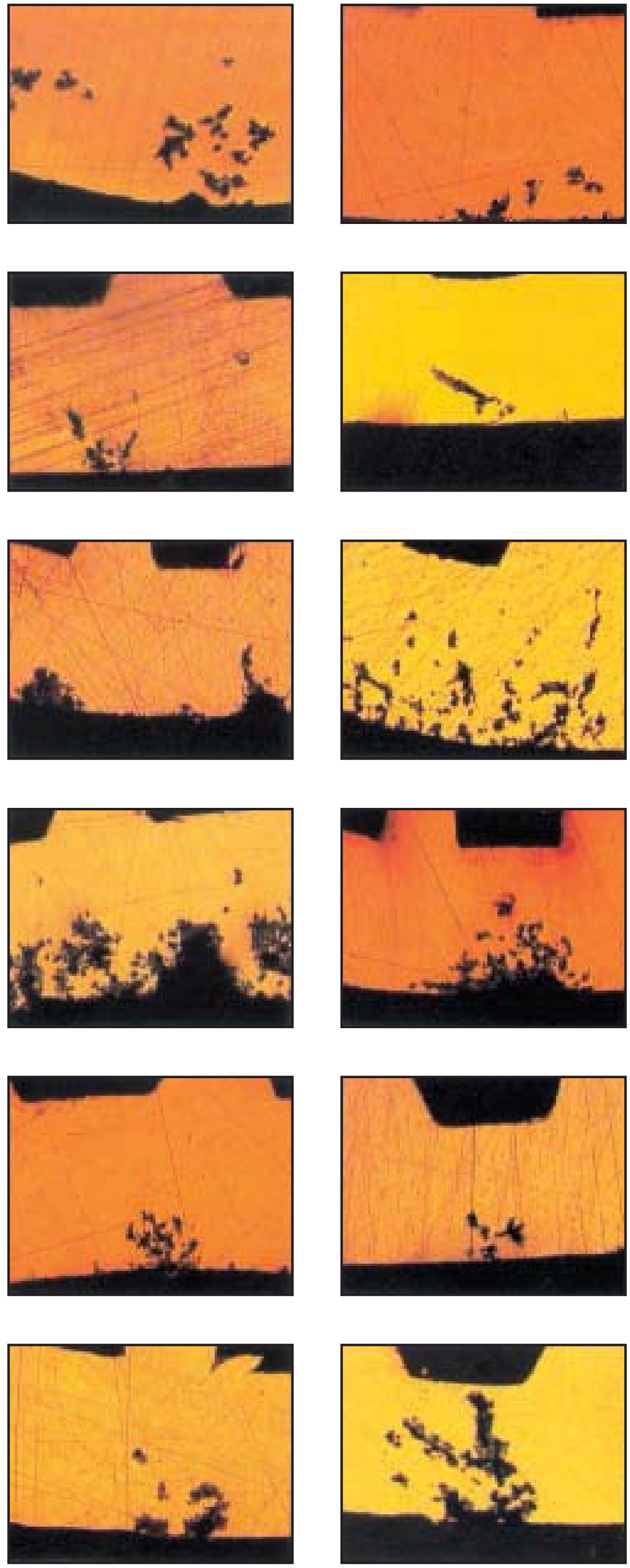
Indoor coil corrosion failures are an issue in the HVAC industry today. Although the occurrence rate of these failures is low nationwide, some geographic areas have experienced higher incidence rates. For instance, some homes experience multiple failures while those around them have none. Failures are typically characterized by leaks that form in the fin pack area of the coil after one to four years of installation and use.

This issue exists 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

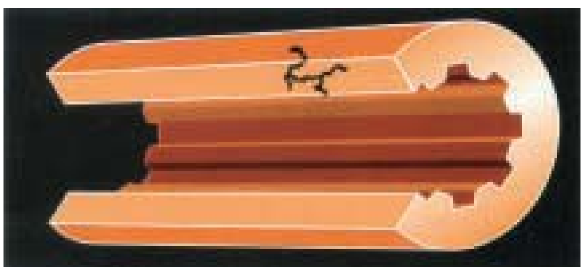


Corrosion Mechanisms

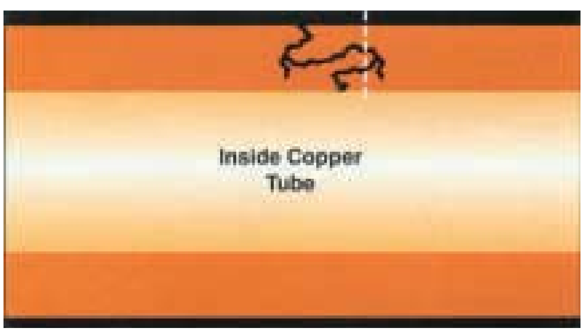
There are many potential causes of coil leaks in indoor coils, ranging from manufacturing or process-related defects to copper corrosion. Additionally, there are several different corrosion mechanisms that can affect copper tubing. The following discussion focuses on pitting corrosion failures of indoor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

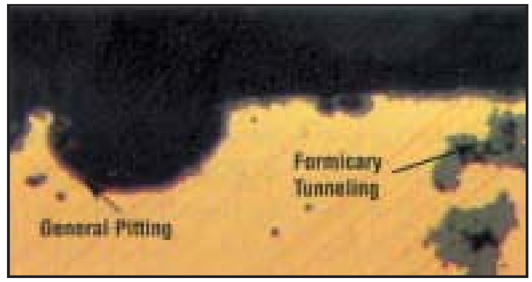


Fig. 1 General Pitting and Formicary Corrosion

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.

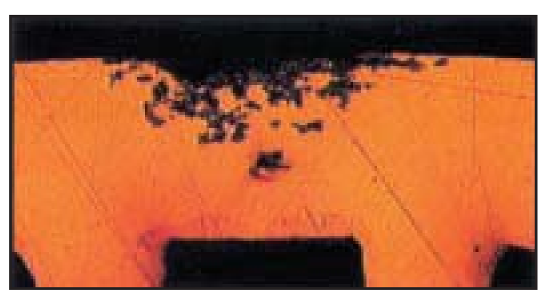


Fig. 2 Formicary Corrosion Tunneling

There are many possible sources of organic acids, which are volatile organic compounds (VOCs), in both the coil application 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 scrubbed its manufacturing processes, materials and environment, including all oils and lubricants, to ensure corrosive agents are not present in the production environment.

While the potential sources of agents that can cause pitting corrosion in indoor coils are numerous, there is increasing evidence showing the home environment to be a 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 concentration levels of indoor contaminants. In addition, environmental refrigerant mandates now heighten the awareness that all leaks be located and repaired.

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Research Study

A recent 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.

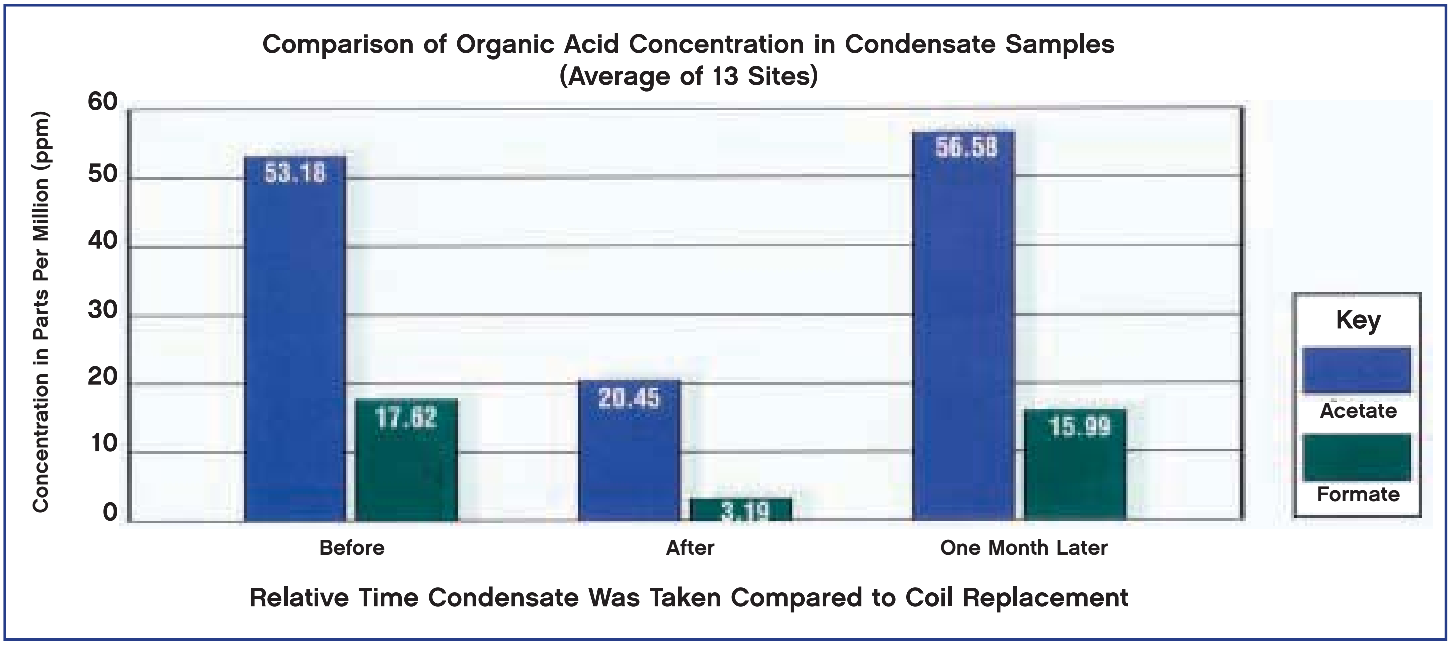
Another study specifically investigated the emission rates of wooden products in test chambers.[9] This testing supports the theory that wood is a source of organic acids, especially formic and acetic acids.

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. Identifying the sources of agents that cause these failures is certainly a step toward resolving this problem.



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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 during recent studies. The trend toward decreased home ventilation rates likely contributes to the elevated levels of indoor contaminants. In addition, increased environmental awareness to identify and fix refrigerant leaks will continue to focus attention on these indoor coil failures as an industry issue.

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 announce a product enhancement consisting of tin coating the copper hairpins in evaporator coils.

Because formicary corrosion is not a national phenomenon, these new coil products will be available under separate model numbers on a "build to order" basis.

Note that not only will there be a split system line of residential coils, but there will also be Tin-Plated Copper Coils available for the Small Package Product (SPP) offerings. FAST will also have Tin-Plated Copper coil - replacement coils for past SPP products now installed in the field.

References

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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.

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