M. E. Williams and Associates, Inc.

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12825 385th Avenue
Waseca, MN 56093

Formicary Corrosion in Copper Hairpin

By

Merlin E. Williams, P.E.

Subject

Examination of copper hairpin made from inner groove tubing to determine cause of leakage. The hairpin was from a copper tube/aluminum fin heat exchanger that had been in storage for two months. Prior to going into storage, the heat exchanger was back-filled with nitrogen. Pressure testing prior to installation showed leakage in the hairpin bends. A hairpin bend was examined by visual examination, scanning electron microscopic and EDX examination, and metallographic examination.

Visual Examination

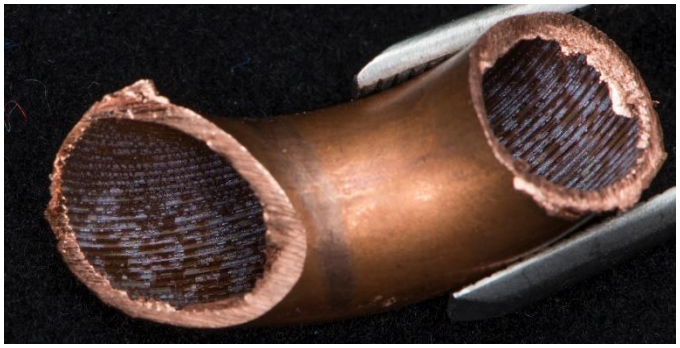

Figure 1 – Hairpin Sample

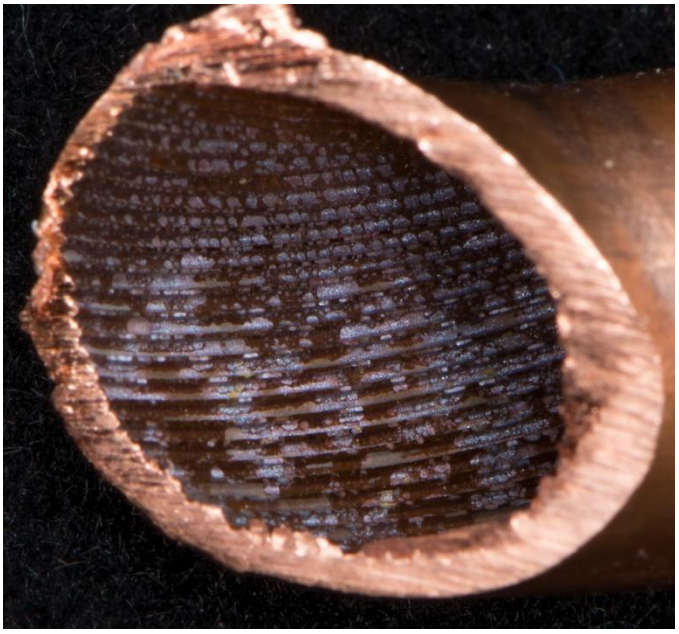

Figure 2 – Corrosion on I.D. of Hairpin

Phone (507) 835-2344 • FAX (507) 835-3412 • Twin Cities & Cell (612) 750-5578 • Toll Free (800) 854-6078

Email merlin@mewai.com – Web Site www.mewai.com

Figure 3 – Leak Location O.D. of Hairpin

Figure 1 shows the hairpin as received. Figure 2 shows corrosion on the inside diameter of the hairpin. Figure 3 shows the only location found on the outside diameter of the hairpin that appeared to be a leak.

Scanning Electron Microscope and EDX Examination

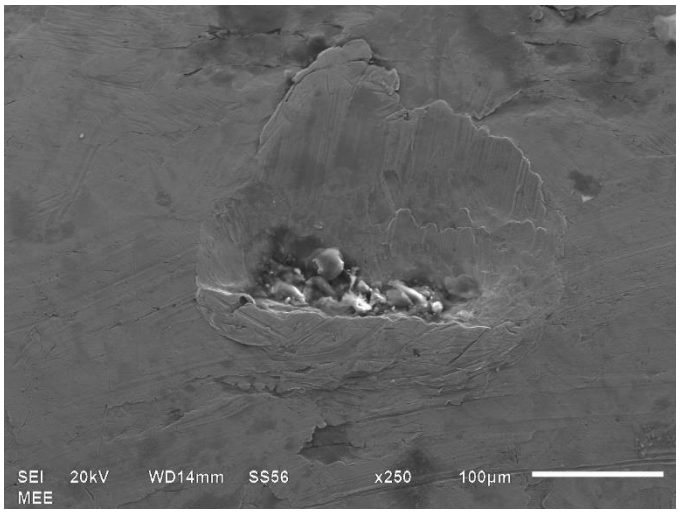

Figure 4 – 250X Leak Location O.D.


Figure 5 – 500X Corrosion Products on Hairpin I.D.

Figure 4 shows the only leak location on the outside diameter of the hairpin.

Figure 5 shows corrosion products on the inside diameter of the hairpin. The angular deposits are of copper oxide. The dark deposits are organic material.

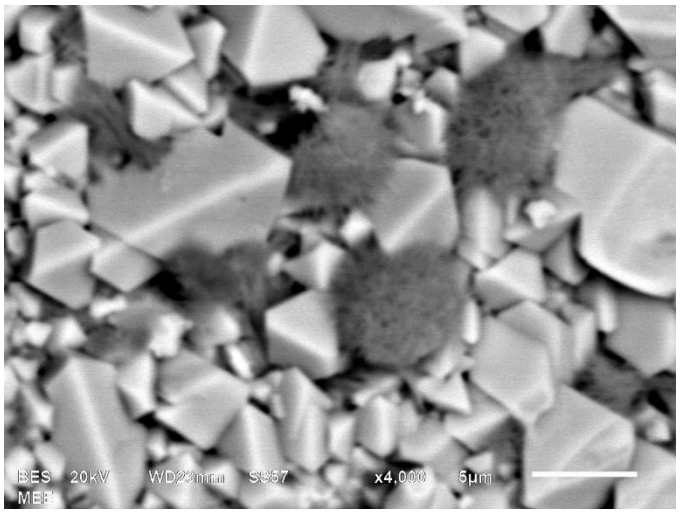

Figure 6 – 4000X Corrosion and Organic Material

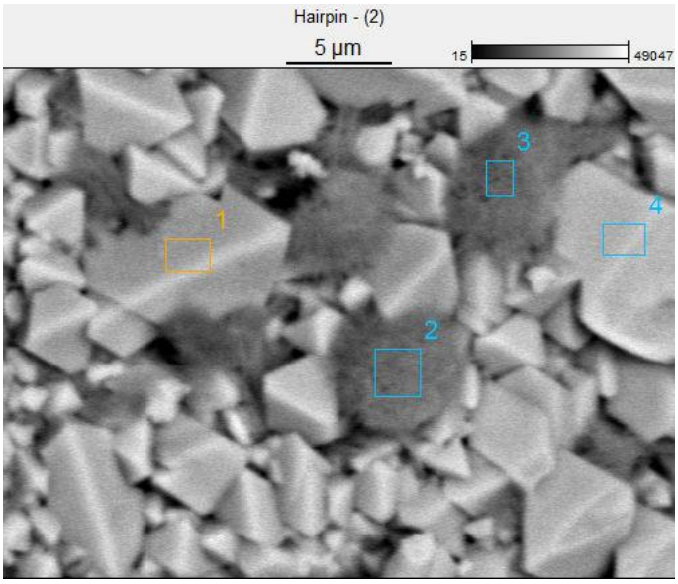

Figure 7 – 4000X Spectra Locations for Materials

Figures 6 and 7 are identical. They show the corrosion at a much higher magnification than Figure 5. The darker organic material has the characteristics of mold spores. Three conditions are needed for mold to grow: water, or humidity equal to 70%, organic material for food, and a temperature greater than 32 degrees F. The likely source of water was pressure testing of the heat exchanger. The water may have been introduced at some other time. The source of the organic material is unknown, but likely sources are lubricants use to draw the inner groove tubing or to form the hairpins. Molds can produce organic acids which cause formicary corrosion in copper tubing. The semi-quantitative analysis for the three locations shown in Figure 8 is given in Table 1 that follows, and the spectra are shown in Figures 8, 9, and 10.

Table 1
Corrosion Hairpin I.D.
(Percent by Weight)

Element/Location	Location 1	Location 2	Location 3
Carbon	1.15	3.67	4.59
Oxygen	12.42	31.14	33.40
Copper	86.43	65.19	62.00
Total	100.00	100.00	100.00

The carbon and oxygen levels for Locations 2 and 3 are somewhat high, indicating the material is organic. Because of the nature of the x-ray analysis, the levels of copper indicated are the result of the underlying copper oxide. The crystal at Location 1 is copper oxide.

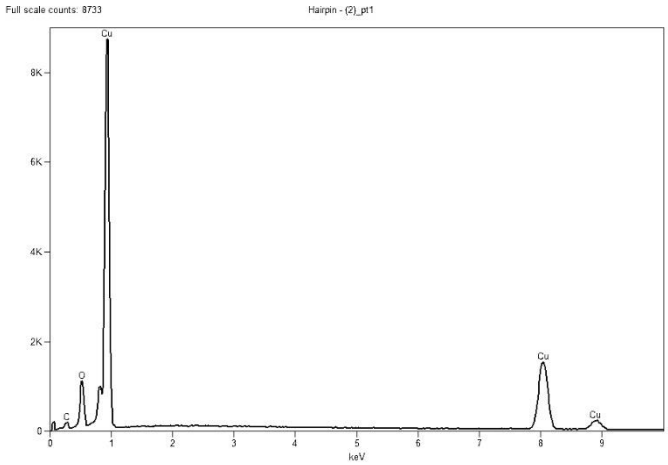

Figure 8 – Spectrum of Location 1

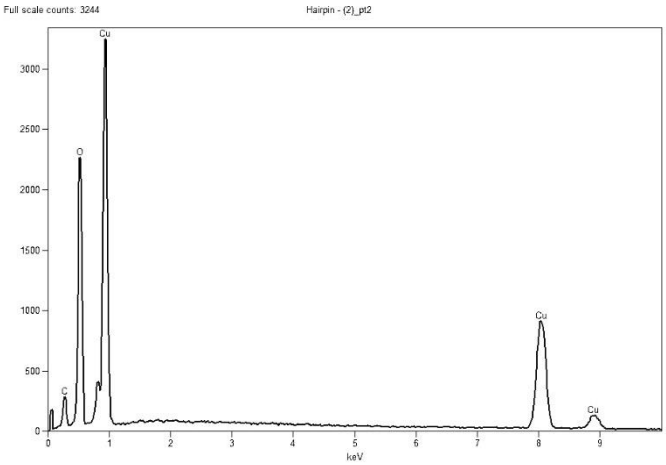

Figure 9 – Spectrum of Location 2

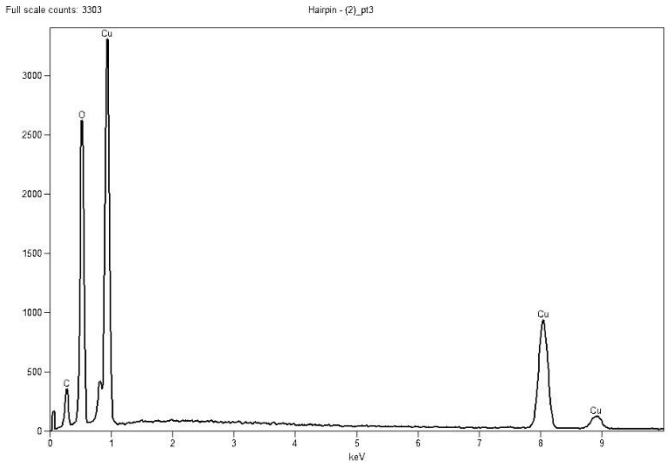

Figure 10 – Spectrum of Location 3

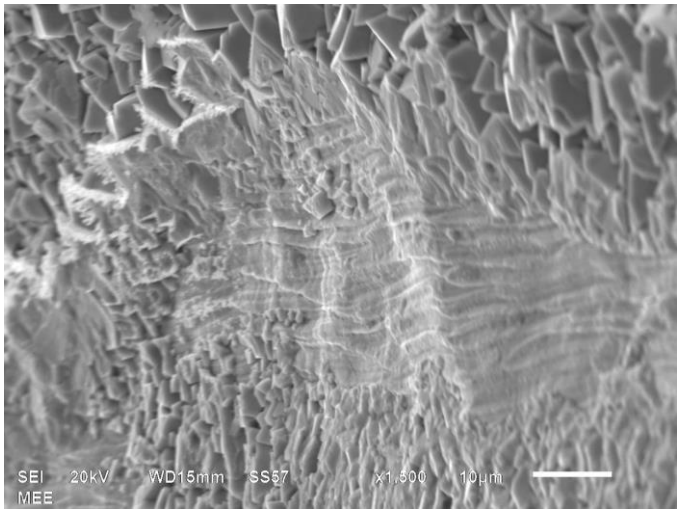

Figure 11 – 1500X Etched Copper in Tube I.D.

The inside diameter of the hairpin showed clear evidence of having been etched, Figure 11. The etching is a definite indication of the presence of acid and water.

Metallographic Examination

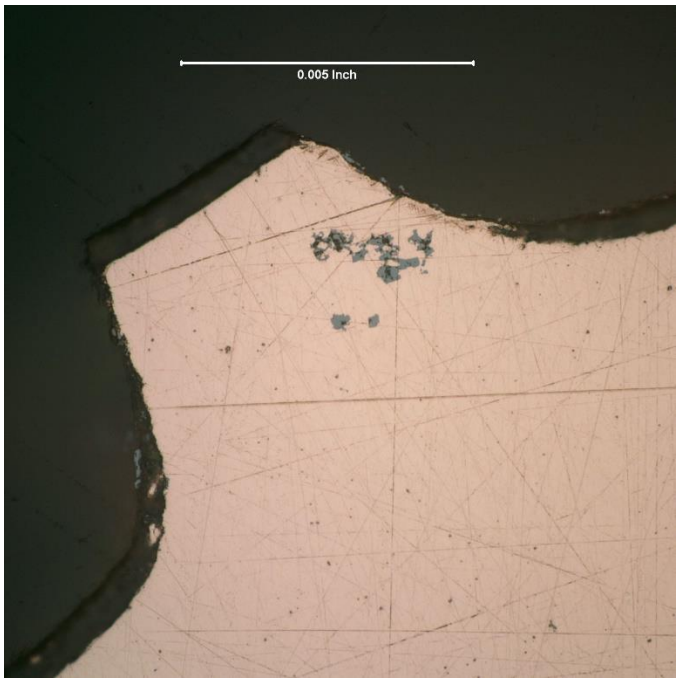

Figure 12 – 400X Indication of Formicary Corrosion in Tube I.D.

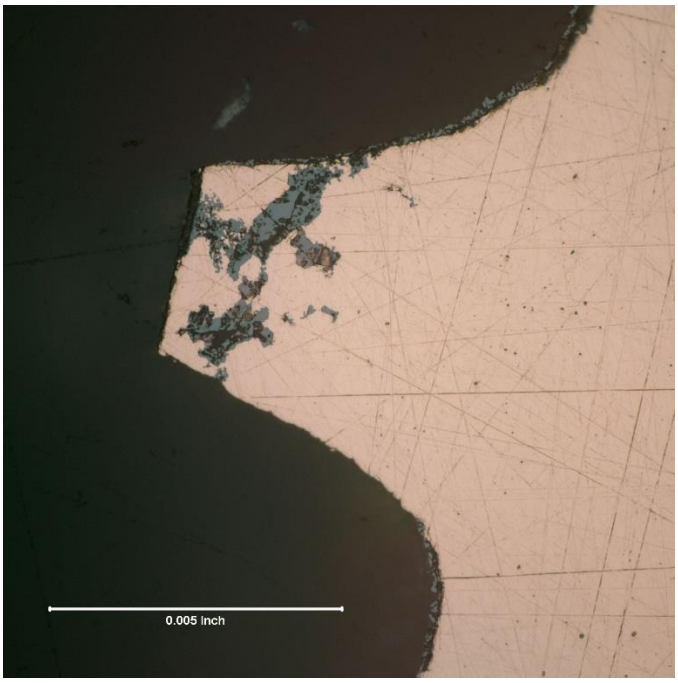

Figure 13 – 400X Indication of Formicary Corrosion in Tube I.D.

Figures 12 and 13 show a characteristic formicary corrosion pattern in two different fins on the inside diameter of the inner groove tubing. Formicary corrosion is caused by organic acids. Another characteristic of formicary corrosion is apparently disconnected corrosion deposits in the tube wall.

Conclusions

1. The leak was the result of corrosion starting on the inside diameter of the Hairpin.

2. Mold was associated with the corrosion on the inside diameter of the Hairpin

3. There was etching of the copper on the inside diameter of the Hairpin, indicating the presence of water.

4. Formicary corrosion was present, starting on the inside diameter of the Hairpin, indicating the presence of an organic acid. Mold can produce organic acids; however, the source of the organic acid may have been something else.