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Case Study: Corrosion Caused by Packaging Material

By

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Subject

Evaluation of copper tube - aluminum fin coil to determine the cause of white powder that had formed on the fins, where the powder was originating, and if the coil could be salvaged by coating the fins. The coil was examined by visual examination, energy dispersive x-ray analysis, and metallographic examination. A sample of the cardboard used as packing to protect the fins was examined by energy dispersive x-ray analysis.

Visual Examination

Figure 1 – Scale on Sheet Tube

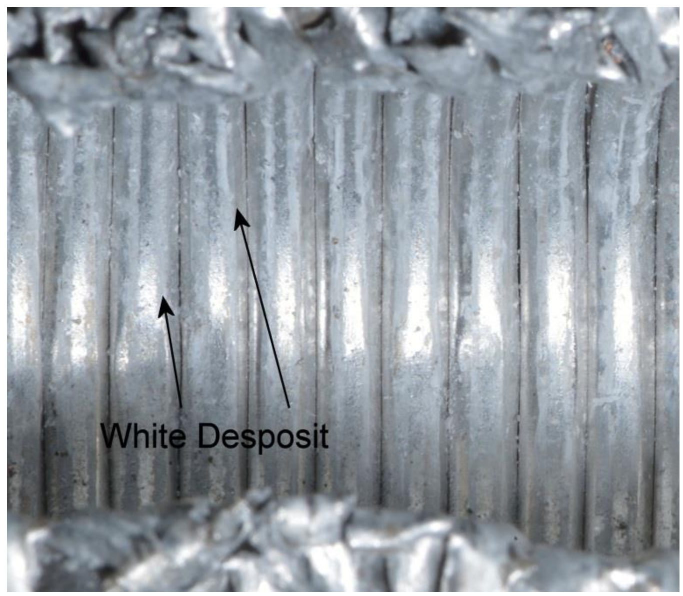

Figure 2 – Condition of Fin Associated with Tube

Figure 1 shows a white scale deposit on a sheet tube. There was evidence of white scale on the aluminum fins associated with this tube. The white scale was forming on the interface between the aluminum fins, Figure 1, and the copper tubing. The tube was wet when it was removed from the coil. This tube was used for energy dispersive x-ray analysis.

Figure 3 shows gray-white deposits on the edge of fins where they had been in contact with the galvanized drip pan. These deposits were used for the energy dispersive x-ray analysis. Figure 4 shows white crystalline material between the coil fins. This material was used for energy dispersive x-ray analysis.

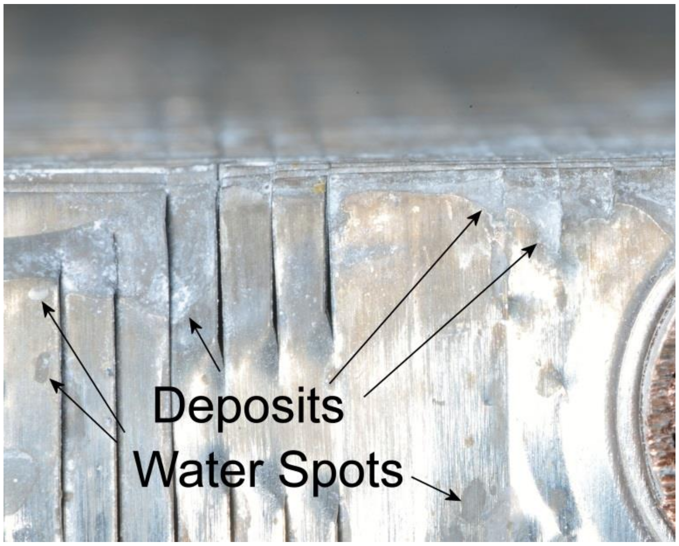

Figure 3 – Deposits and Water Spots on Aluminum Fin

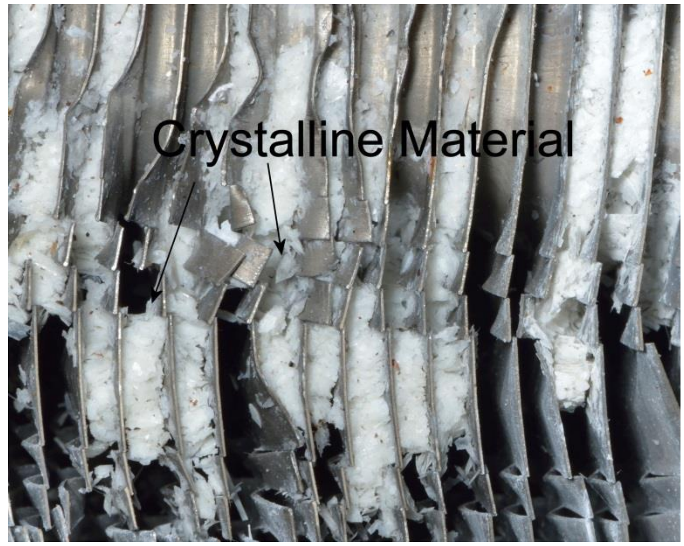

Figure 4 – White Crystalline Deposits between Fins

Energy Dispersive X-Ray Analysis

The unit used for the analysis was capable of detecting elements that are present in concentrations greater than 0.10 atomic percent, and that have an atomic weight of 12 or greater. The carbon percentage in the semi-quantitative analysis data is usually higher than the actual amount present. The results of the analysis of the various coil components are given in the following tables and figures.

Table 1
Chemical Analysis of Cardboard
(Percent by Weight)

Element/Sample	Cardboard
Carbon	35.9
Oxygen	60.2
Sodium	0.3
Magnesium	0.2
Aluminum	0.5
Silicon	1.2
Sulfur	0.2
Chlorine	0.1
Calcium	1.4
Location	Figure 5
Spectrum	Figure 6

The active elements found in the cardboard, Table 1, were sodium, sulfur, and chlorine. The sulfur and chlorine compounds used in the manufacturing of cardboard will form acids in the presence of water. Acid-sulfur compounds are corrosive to aluminum, copper, and zinc. Acid-chlorine compounds are corrosive to aluminum and zinc. Neutral salts of chlorine are soluble in water and are corrosive to aluminum. Soluble sodium, sulfur, and chlorine compounds are electrolytes, and will cause galvanic corrosion of dissimilar metals, such as aluminum, copper, and zinc. Wet cardboard and other paper products in contact with any active metal, such as aluminum, usually results in corrosion.

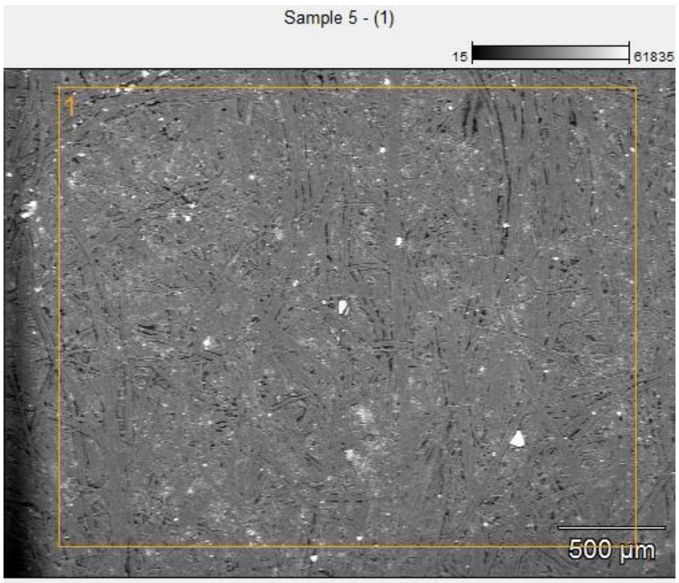

Figure 5 – Cardboard Surface that was Analyzed

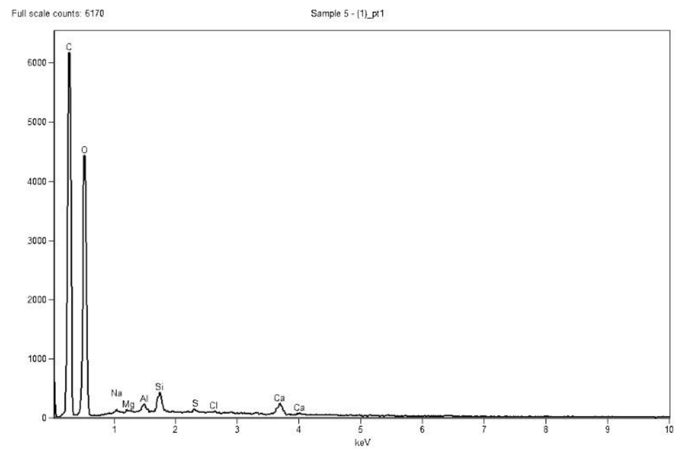

Figure 6 – Spectrum of Cardboard Surface

Table 2 **Chemical Analysis of Sheet Tube** **(Percent by Weight)**						
Element/Location	1	2	3	4	5	6
Carbon	2.2	3.0	3.3	3.0	2.8	3.0
Oxygen	7.4	40.6	52.6	52.6	47.5	50.4
Aluminum	4.0	50.6	35.6	34.0	40.7	32.3
Silicon			Trace			
Calcium			0.2	0.1		
Iron		0.4			0.3	
Copper	86.3	5.4	8.3	10.3	8.7	14.3
Spectra Locations	Figure 7					
Spectra	Figure 8	Figure 9	Figure 10	Figure 11	Figure 12	Figure 13

Table 2 gives the semi-quantitative analysis of the sheet tube. The tube was wet when it was removed from the coil. Any dissolved ions present would have made the water conductive, resulting in corrosion of the aluminum fin material by galvanic corrosion. The energy dispersive x-ray analysis did not indicate any chlorine or sulfur. The white material on the surface of the copper sheet tube was aluminum oxide. Location 1, shown in Figure 7, was a clean spot.

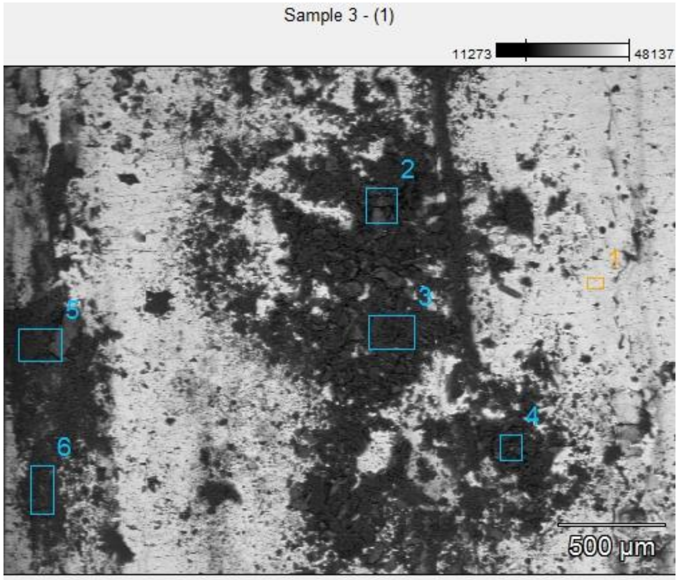

Figure 7 – Analysis Locations, Sheet Tube

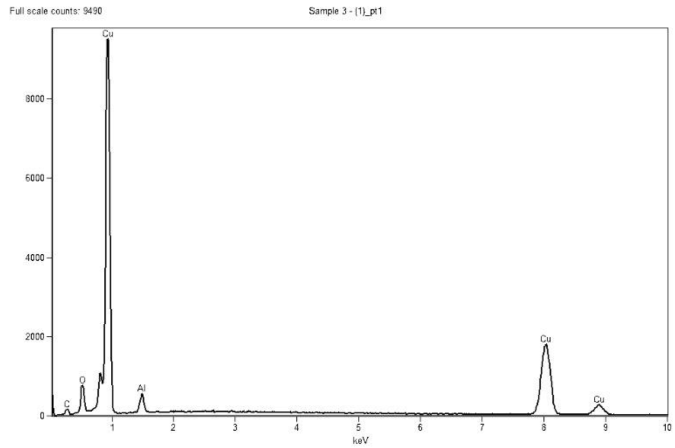

Figure 8 – Spectrum Location 1, Sheet Tube

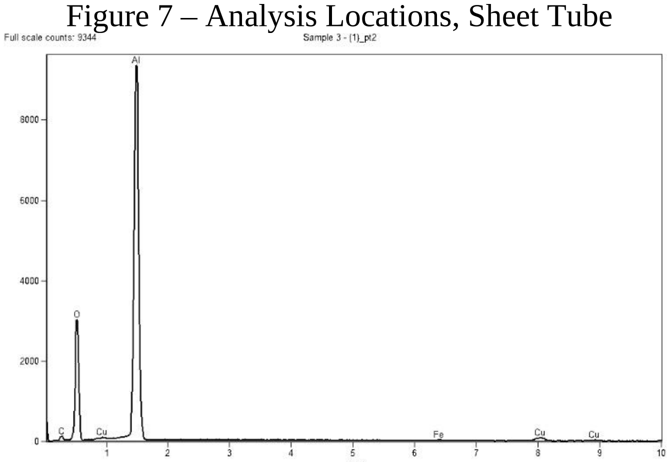

Figure 9 – Spectrum Location 2, Sheet Tube

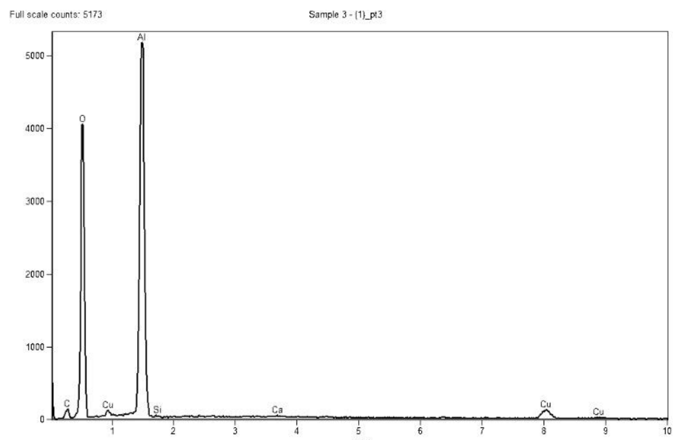

Figure 10 – Spectrum Location 3, Sheet Tube

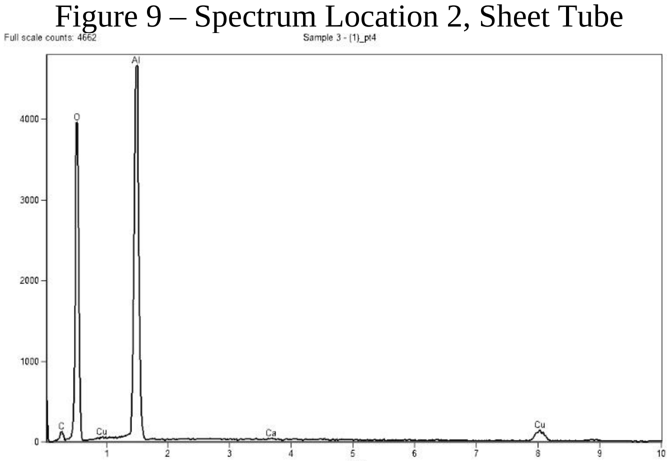

Figure 11 – Spectrum Location 4, Sheet Tube

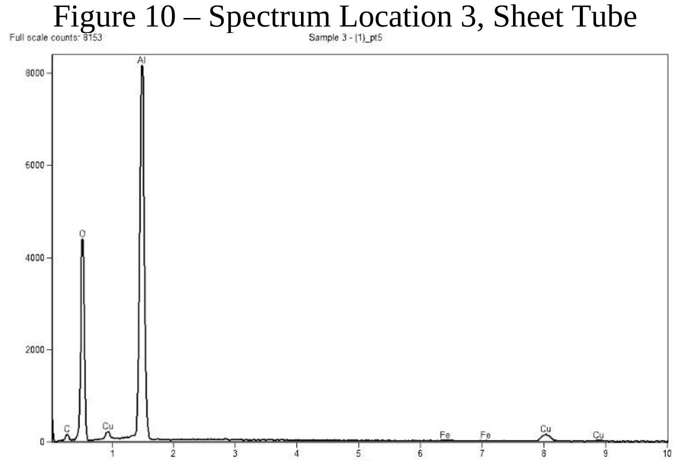

Figure 12 – Spectrum Location 5, Sheet Tube

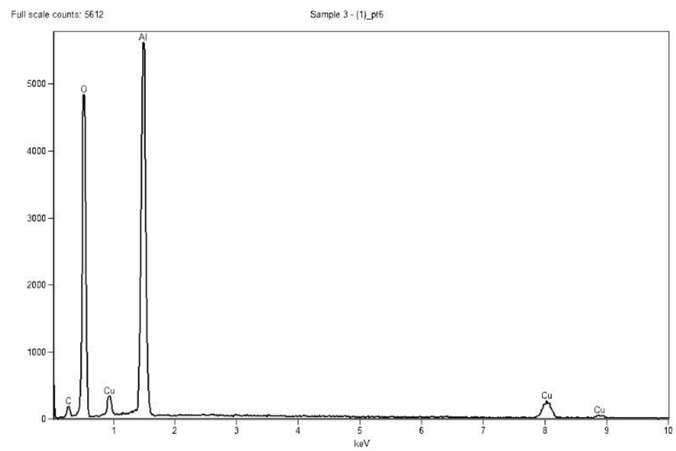

Figure 13 – Spectrum Location 6, Sheet Tube

Table 3 Chemical Analysis of Gray Area, Aluminum Fin (Percent by Weight)				
Element/Location	1	2	3	4
Carbon	6.0	3.4	4.1	4.9
Oxygen	48.5	45.1	45.9	43.5
Aluminum	20.1	13.7	22.0	35.1
Silicon	0.5			
Sulfur	1.0	0.2	0.6	0.4
Iron				0.4
Zinc	24.0	37.6	27.5	15.7
Spectra Locations	Figure 14			
Spectra	Figure 15	Figure 16	Figure 17	Figure 18

The semi-quantitative analysis of the gray deposits on the edge of the fin material, Figure 3, is given in Table 3. The gray deposit on the material was zinc from the galvanized drip pan or galvanized frame. The active element present was sulfur, and again, the likely source of the sulfur was cardboard packing material.

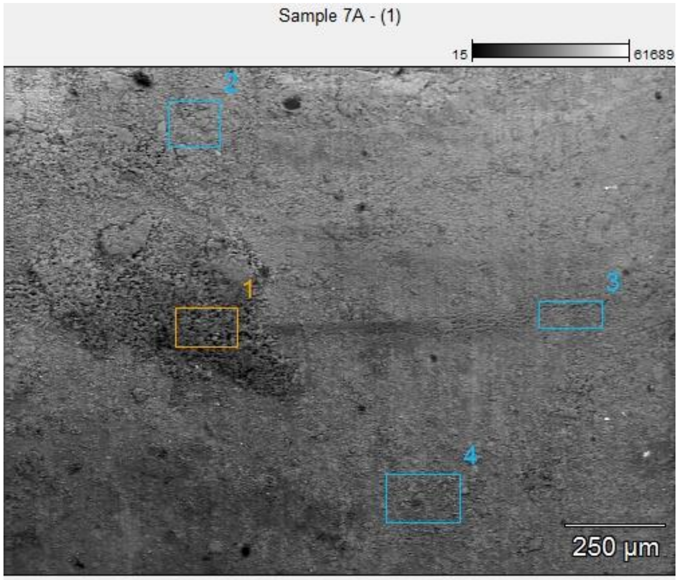

Figure 14 – Spectra Locations on Fin Material

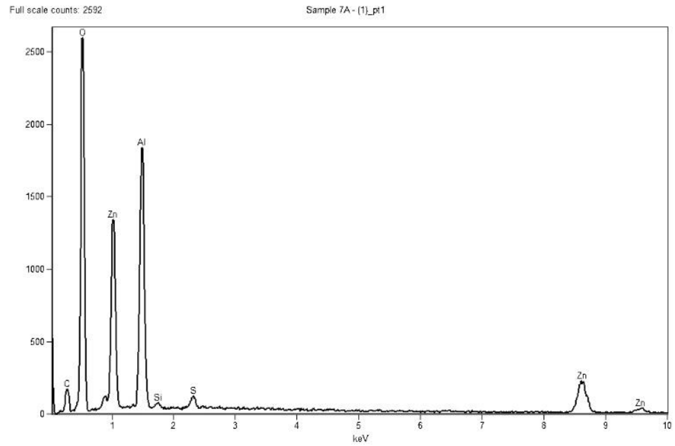

Figure 15 – Spectrum Location 1, Fin Material

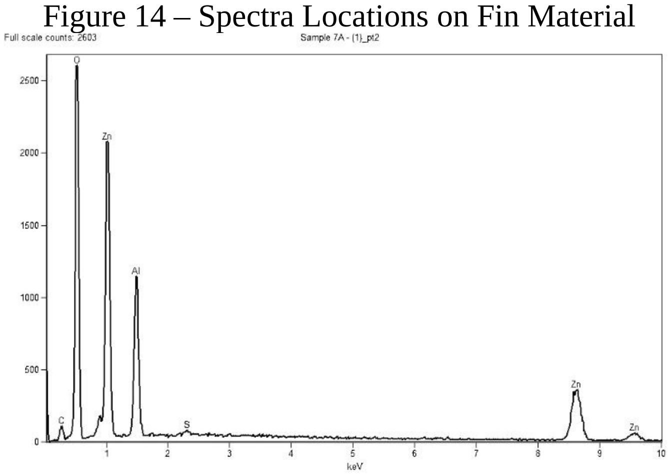

Figure 16 – Spectrum Location 2, Fin Material

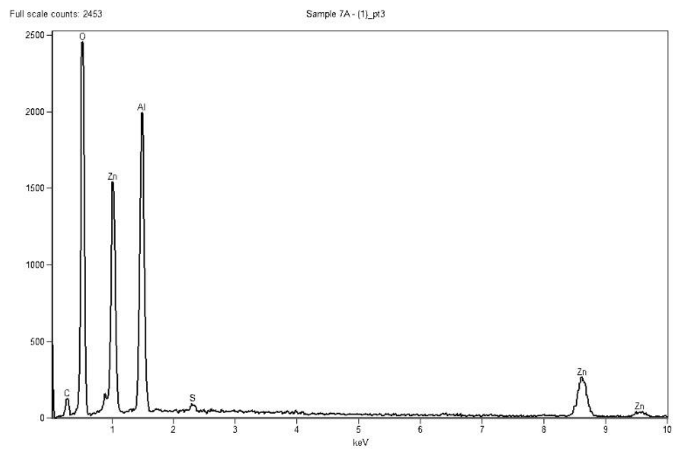

Figure 17 – Spectrum Location 3, Fin Material

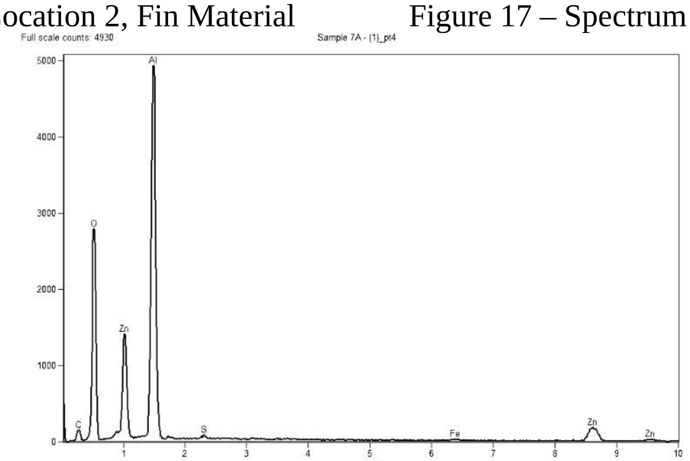

Figure 18 – Spectrum Location 4, Fin Material

Table 4 Chemical Analysis of White Powder Crystalline Material (Percent by Weight)					
Element/Location	1	2	3	4	5
Carbon	2.9	3.1	3.9	3.5	5.5
Oxygen	62.3	58.8	55.6	42.9	57.9
Aluminum	33.8	37.4	31.3	23.2	31.4
Silicon				0.2	
Sulfur		0.2	0.7	1.5	
Iron	0.3				
Zinc	0.8	0.5	8.5	28.6	5.2
Spectra Locations	Figure 19				
Spectra	Figure 20	Figure 21	Figure 22	Figure 23	Figure 24

The semi-quantitative analysis of the crystalline material, Table 4, indicates that the powder is a mixture of aluminum and zinc oxides, and that the corrosive agent was sulfur.

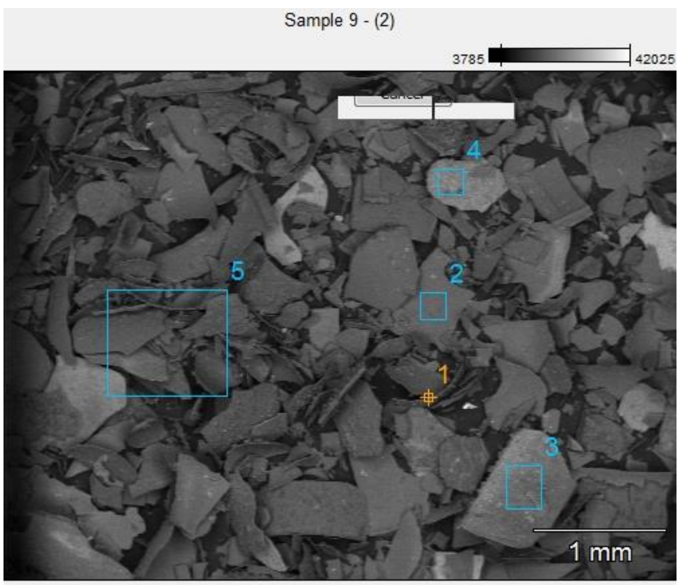

Figure 19 – Analysis Locations, Crystalline Material

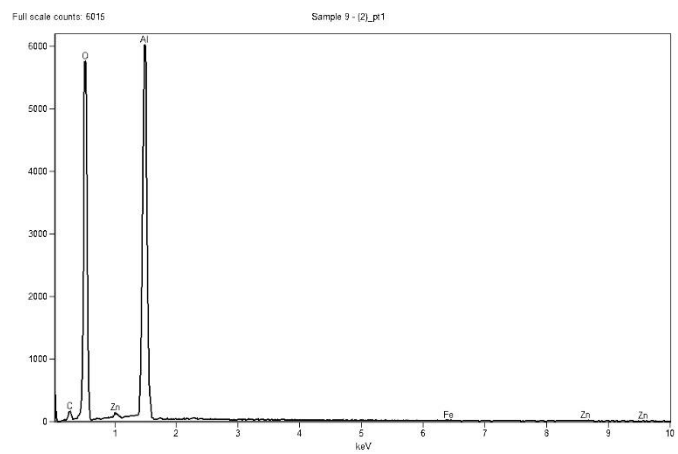

Figure 20 – Spectrum Location 1, Crystalline Material

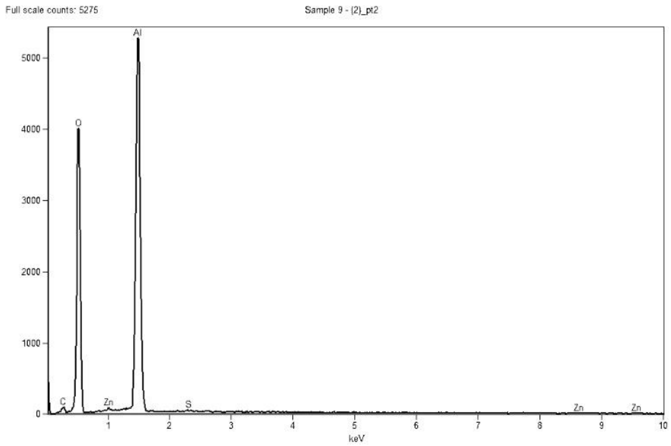

Figure 21 – Spectrum Location 2, Crystalline Material

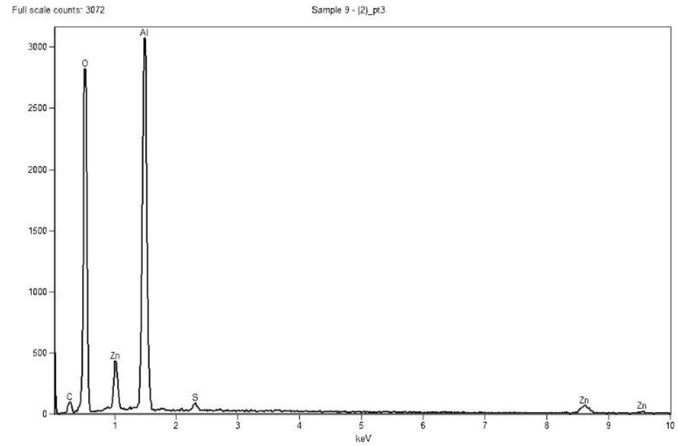

Figure 22 – Spectrum Location 3, Crystalline Material

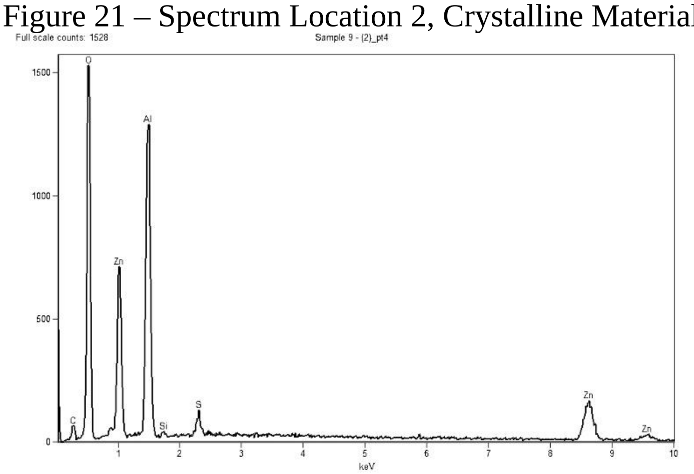

Figure 23 – Spectrum Location 4, Crystalline Material

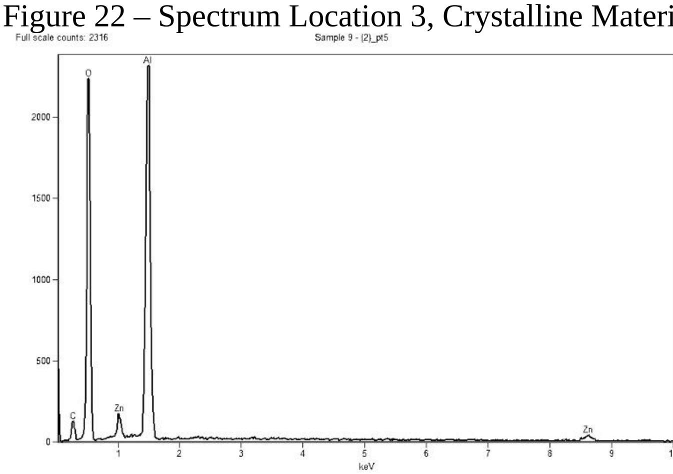

Figure 24 – Spectrum Location 5, Crystalline Material

The energy dispersive x-ray analysis showed that the white material coming from the coil was primarily aluminum oxide. Zinc oxide was also present in significant amounts. Sulfur and chlorine were the corrosive elements present. The absence of chlorine in the corrosion deposits is not unusual. Most chlorides are water soluble and may have been removed.

Metallographic Examination

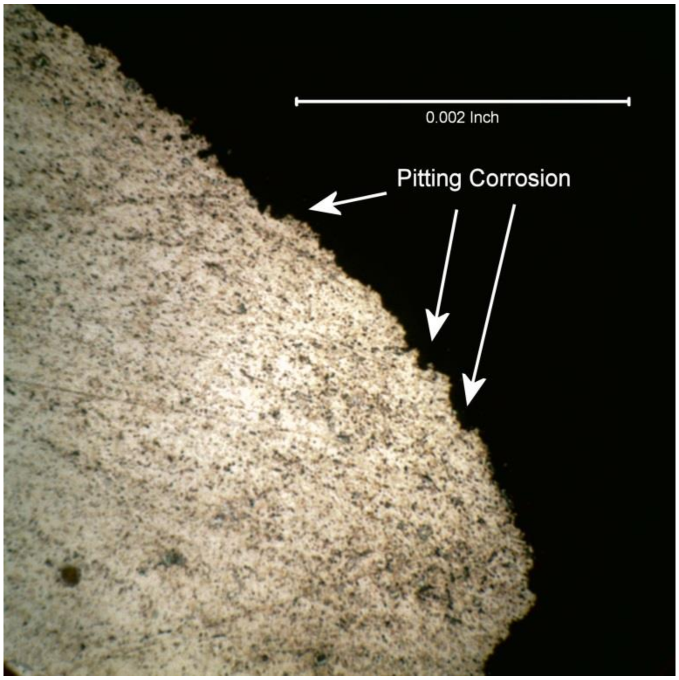

Figure 25 – 1500X Initiation of Pitting Corrosion

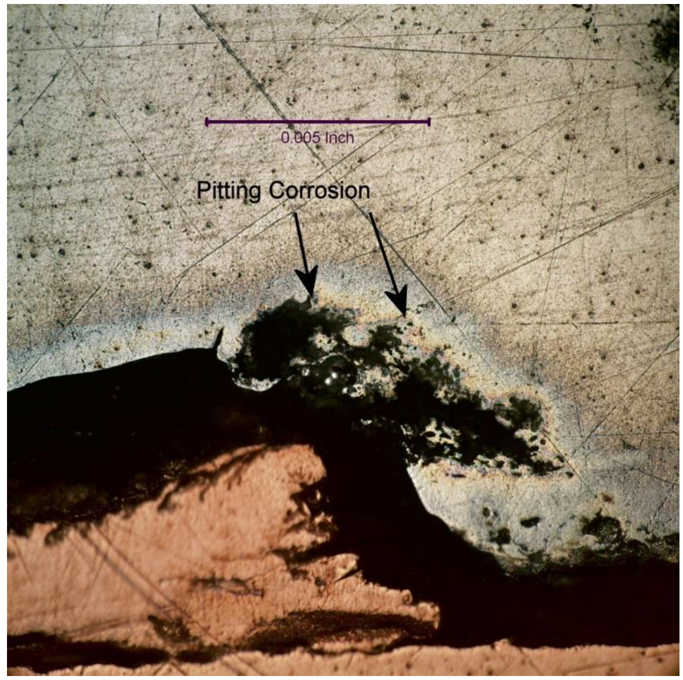

Figure 26 – 400X Initiation of Pitting Corrosion

Figure 25 shows the initiation of pitting corrosion on the fin material. The pitting corrosion was associated with the zinc oxide and sulfur compounds on the tips of the fins, Figure 3 and Table 3. The presence of small corrosion pits would make cleaning and coating similar coils very difficult. The corrosion products need to be completely removed to insure complete coating of the fin material.

The interface between the aluminum fins and a copper sheet tube are shown in Figure 26. At this location there is pitting corrosion of the fin material. The aluminum fin material is acting as an anode protecting the copper tubing from corrosion. Not every tube-fin interface had corrosion of the aluminum fin material. The apparent cause of most of the white powder is the anodic corrosion of the aluminum fin material. The white powder can be caused by the presence of chlorine, sulfur, and even tap water, under the right conditions.

Conclusions

1) The cardboard packing material was the source of the chlorine and sulfur, Table 1. Chlorine and sulfur materials are used in the production of paper products such as cardboard. The chlorine and sulfur compounds that are used in the production of paper products are acid, and the cardboard becomes corrosive in the presence of water.

2) The primary agents in the corrosion of the aluminum fins, copper tubing, and galvanized framing were chlorine and sulfur compounds.

3) The aluminum fin material was acting as an anode to protect the copper sheet tubes.

4) Cleaning and coating of the coils will not likely stop or eliminate further corrosion because of the degree of corrosion associated with the interface between the copper sheet tube and the aluminum fins.

5) The coils showing this type of corrosion needed to be replaced.

Summation

As a result of this thorough evaluation, this manufacturer made changes to the final inspection and packaging processes that prevented any further recurrence of fin corrosion in their product. The changes did not result in any significant production cost increase, but made a significant reduction in warranty claims.