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"Excellence in Metallurgical Engineering"

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Case Study: Steam Coil Return Bend Failure

By

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Subject

Evaluation of Steam Coil Return Bend to determine cause of leakage associated with the braze joints. The return bend was examined by visual examination, energy dispersive x-ray analysis, and metallographic examination. The copper return bend was brazed to the copper sheet tubes using BCuP-6 brazing alloy.

Metallographic Examination

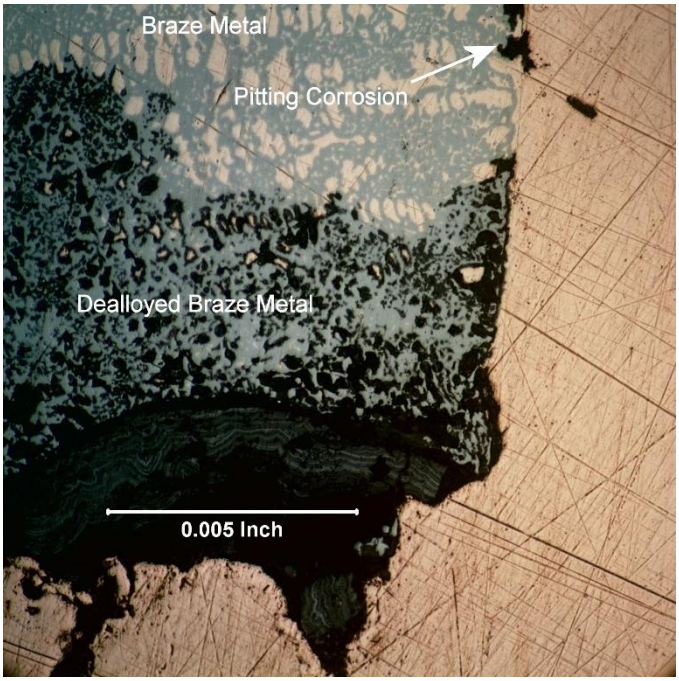

Figure 1 – 400X - Corrosion and De-Alloying of Braze Metal

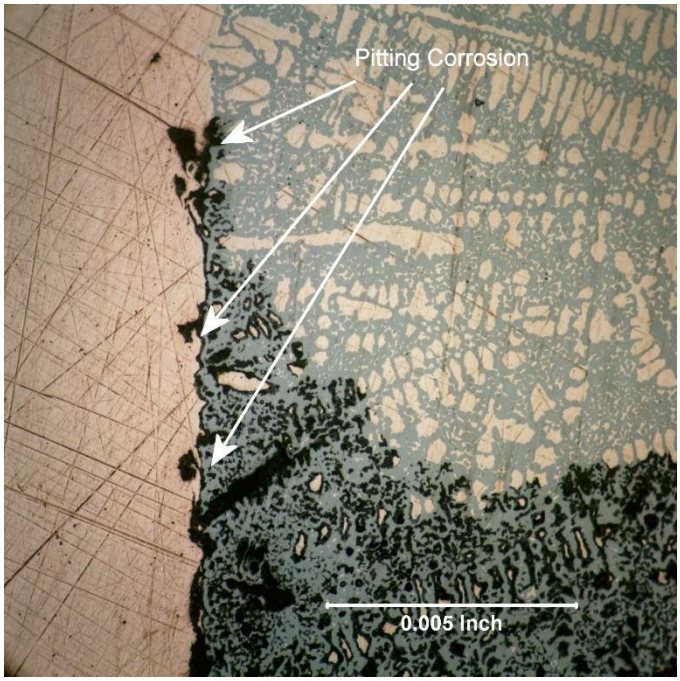

Figure 2 – 400X - Corrosion and De-Alloying of Braze Metal

Figure 1 shows corrosion in the braze joint of the bend. There was penetration of the corrosion into the braze joint. Dealloying of the braze metal was along the copper tube - braze metal interface, Figure 2.

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Visual Examination

Figure 3 – Scale on OD of Return Bend

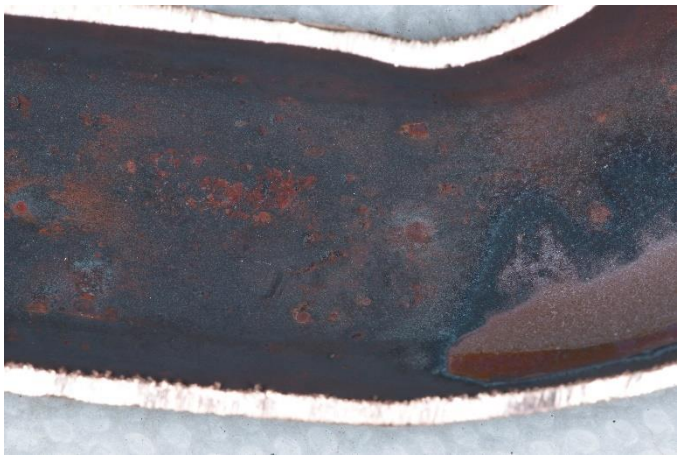

Figure 4 – Scale on ID of Return Bend

Figure 3 shows black scale on the outside diameter of the return bend. The black deposit appeared to be a buildup on the surface. Figure 4 shows the brown-to-black scale on the inside diameter of the return bend.

Scanning Electron Microscopic and EDS Analysis

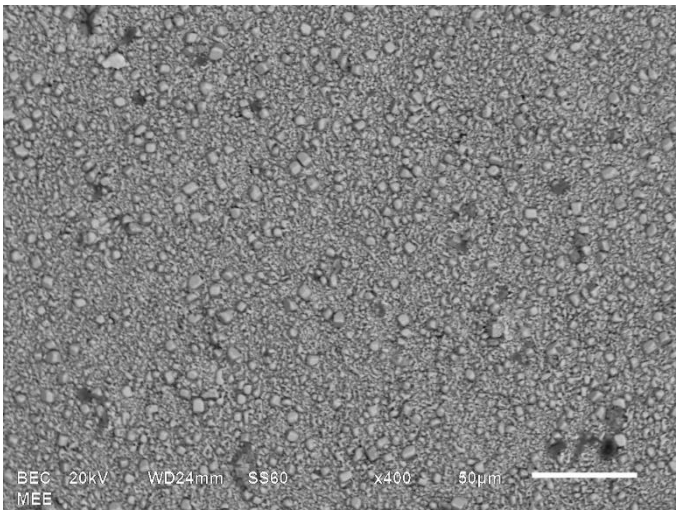

Figure 5 – 400X - Scale ID of Return Bend

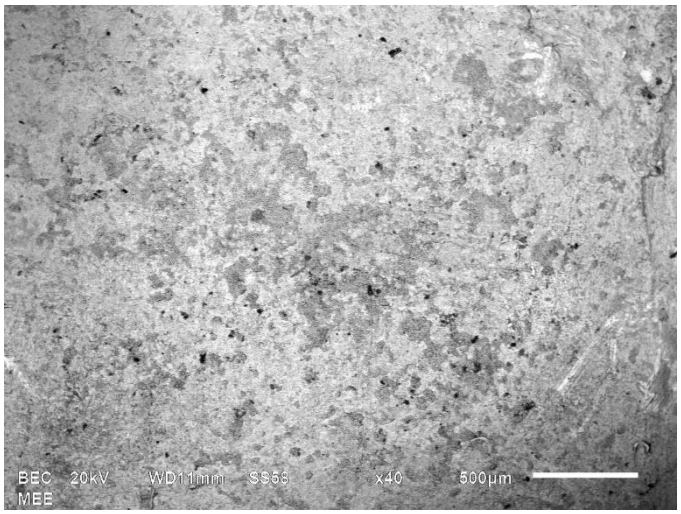

Figure 6 – 40X - Scale OD of Return Bend

Figure 5 shows the scale on the inside diameter of the return bend. The EDS analysis was done over the entire area shown. Figure 6 shows the scale on the outside diameter of the return bend. The Energy Dispersive X-ray, EDS, analysis was done on the entire area shown in Figure 6. Figure 7 shows a braze fillet on the return bend. EDS analysis was done on the two areas shown. The results of all the analyses are given in the table that follows.

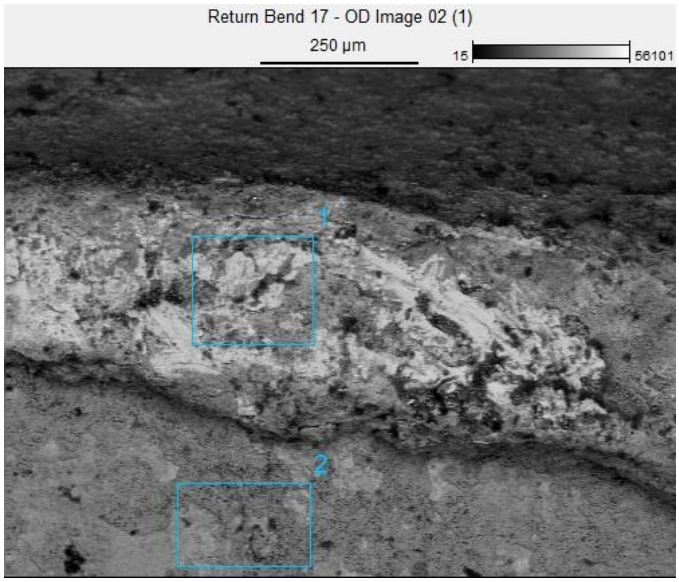

Figure 7 – 120X - Braze Fillet

Semi-Quantitative Analysis of Return Bend
(Percent by Weight)

Element/Location	ID	OD	Braze (1)	Tube (2)
Carbon	1.6	8.2	9.0	9.0
Oxygen	12.2	17.6	15.1	21.3
Magnesium			0.4	
Aluminum		0.2		
Silicon		0.5	0.4	0.4
Phosphorous		1.3	1.8	1.0
Sulfur		0.2	0.5	0.3
Chlorine		0.3	0.4	0.3
Potassium				0.2
Calcium		0.6	1.6	0.5
Iron		0.9	0.5	0.7
Copper	86.2	70.1	69.1	66.4
Silver			1.3	
Spectrum	Figure 8	Figure 9	Figure 10	Figure 11

The element that caused the de-alloying and corrosion of the braze metal and copper tubing used for the return bend was sulfur. Moist sulfur compounds will cause de-alloying of copper-phosphorous braze alloys. The sulfur came from the external environment and not from the steam boiler. There was nothing found on the inside diameter of the return bend but copper oxide.

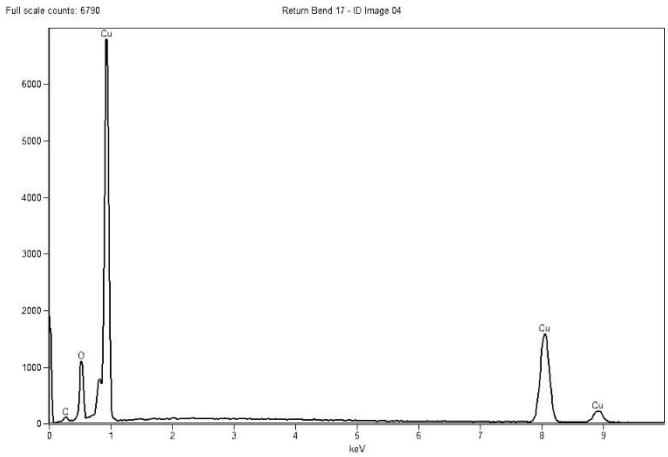

Figure 8 – Spectrum of Scale ID, Return Bend

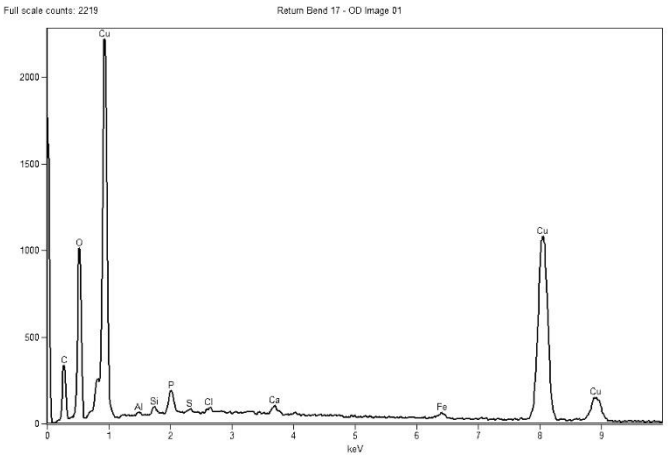

Figure 9 – Spectrum of Scale OD, Return Bend

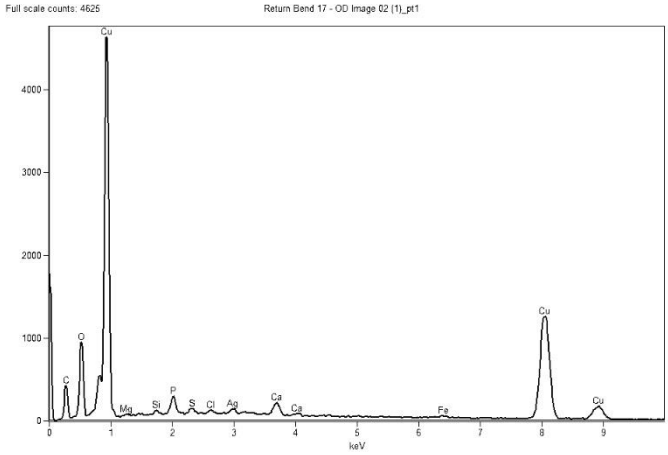

Figure 10 – Spectrum of Braze Fillet, Return Bend

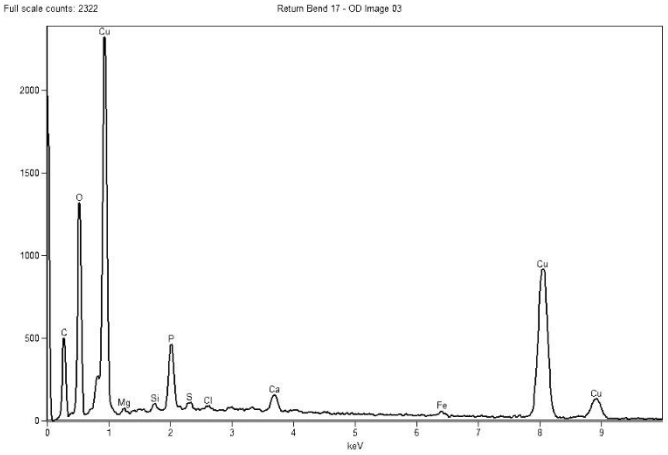

Figure 11 – Spectrum of Tube Next to Braze Fillet, Return Bend

There are two things that needed to be done to prevent future occurrences of leakage similar to what was found on this steam coil: (1) use a braze alloy that is free from phosphorous, such as Bag-7 and Bag-34, which contain copper, silver, zinc, and tin. These braze alloys work well in moist sulfur environments. (2) The return bends need to be enclosed to prevent buildup of debris around them. Pictures provided showed debris accumulation over the return bends. The debris was likely the source of the sulfur.

Conclusions

1) The leakage of the return bend braze joints was the result of de-alloying and corrosion of the copper-phosphorous braze metal by moist, sulfur rich compounds.

2) Corrosion is often the result of changing system environments, both internal and external. Metallurgical and materials engineering evaluations can identify sources of corrosion and how to eliminate or work around them. In this particular case, the corrosion of the braze metal was the result of a buildup of external debris on the return bends.