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Case Study – Brass Fitting Failure

By

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Introduction

The two brass fittings examined in this Case Study were from a production lot that had a 90% failure rate. The two fittings failed by different failure modes which had a common cause. These fittings are typical of brass fittings used in HVAC and plumping applications. The fittings were examined by visual examination, hardness testing, scanning electron microscopic examination, energy dispersive x-ray analysis, and metallographic examination.

Visual Examination

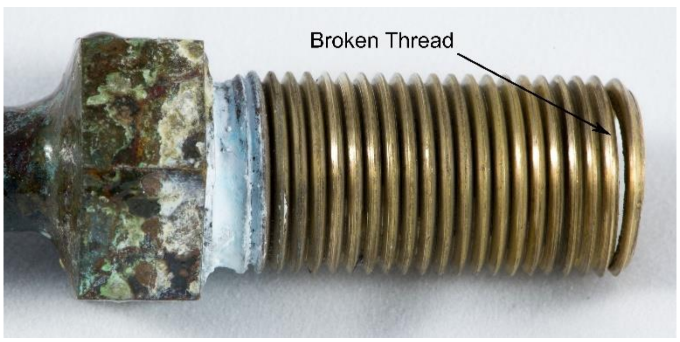

Figure 1 – Broken Fitting 1


Figure 2 – Fitting 1 after Sectioning

Broken Fitting 1 is shown in Figure 1. This fitting broke in the first thread. Figure 2 shows Fitting 1 after sectioning for metallographic examination. The thin sliver of material in the lower right was used for scanning electron microscopic examination and energy dispersive x-ray analysis.

Broken Fitting 2 is shown in Figure 3. The only tests done on Fitting 2 were scanning electron microscopic examination and energy dispersive x-ray analysis.

Visual examination showed that the fracture characteristics of the two fittings were different.

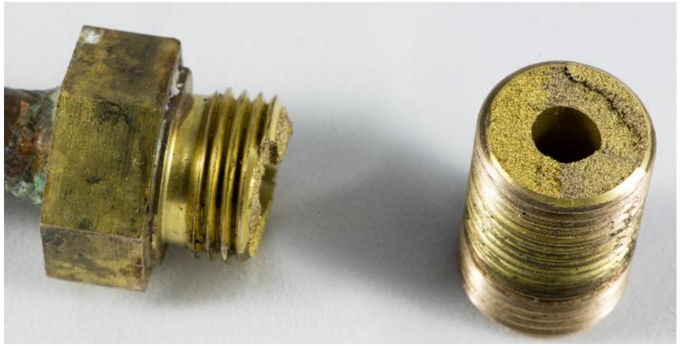

Figure 3 – Broken Fitting 2

Hardness Testing

The hardness testing was done according to ASTM E384, using a Vickers indenter and a 500 gram load. The results of the testing are given in the table that follows.

Hardness Test Data (Rockwell B Scale)					
Sample	Vickers	STD DEV	MAX VALUE	MIN VALUE	HARDNESS
Fitting 1	149.00	2.35	152.00	147.00	79.64

The hardness is within the expected range for a brass fitting.

Scanning Electron Microscopic Examination

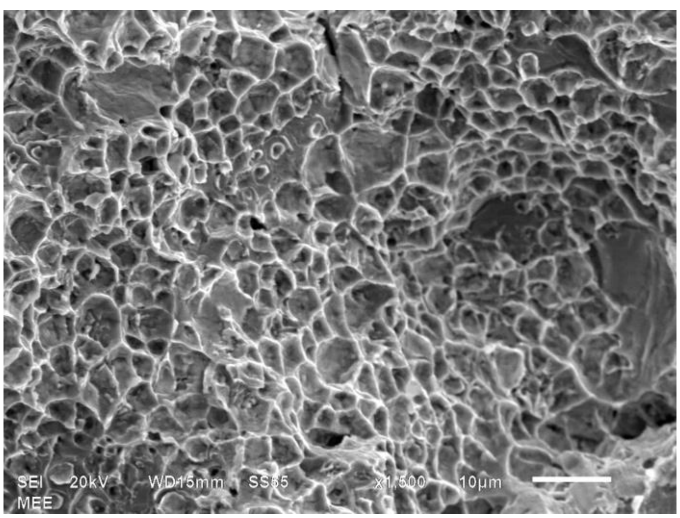

Figure 4 – 1500X Fracture Surface of Fitting 1

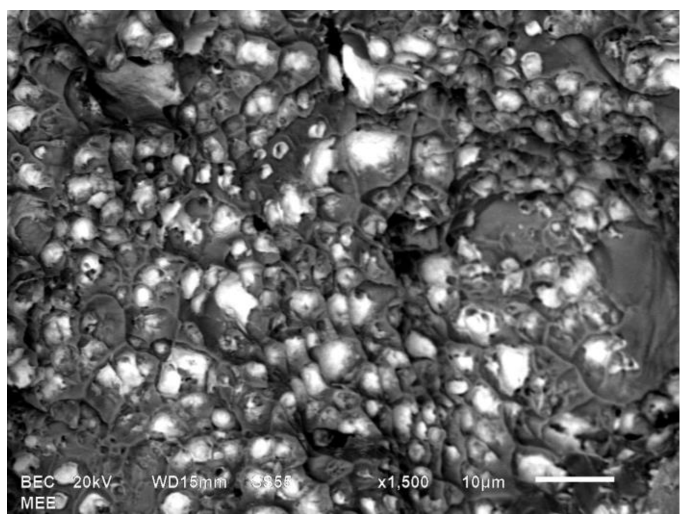

Figure 5 – 1500X Fracture Surface of Fitting 1 – Backscatter Mode

Figures 4 and 5 show the fracture surface of Fitting 1. The fracture mode is ductile rupture, which means the fitting failed in the ductile fracture mode at stress levels exceeding the tensile strength of the brass.

Figure 5 shows the same area as shown in Figure 4, but in backscatter mode. In backscatter mode the higher atomic number elements show up as white. All of the white areas were found to be lead in this case.

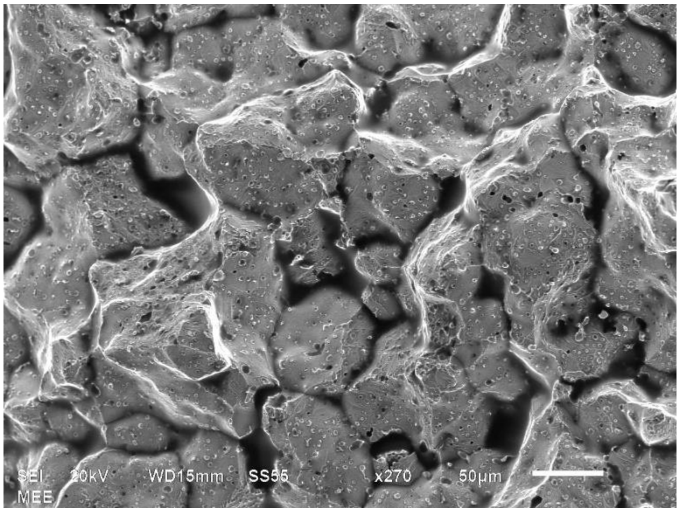

Figure 6 – 270X Fracture Surface Fitting 2

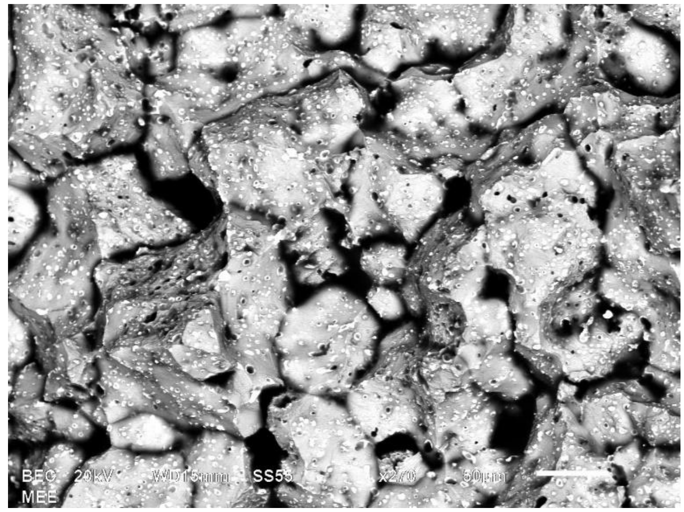

Figure 7 – 270X Fracture Surface Fitting 2 – Backscatter Mode

The fracture surface of Fitting 2, Figure 6, shows intergranular fracture. Intergranular fracture is a brittle fracture mode, meaning there was no ductility present. Intergranular fracture in a copper alloy is usually the result of exposure to nitrates or mercury. That does not appear to have happened in this case. The grain boundaries are covered with fine particles which are better seen in Figure 7. These particles were determined to be lead.

Energy Dispersive X-ray Analysis

The unit used for the energy dispersive x-ray analysis was capable of detecting elements that were present at 0.5 atomic percent or greater.

Semi-Quantitative Analysis of Fittings **(Percent by Weight)**		
Element	Fitting 1	Fitting 2
Aluminum	0.6	
Silicon	0.1	0.6
Iron	1.5	1.0
Copper	51.7	51.4
Zinc	32.2	34.3
Lead	13.8	12.7

The lead levels of approximately 13% are much too high for any standard wrought or cast brass alloys, and the amount of copper is too low. Lead is not soluble in copper. The maximum limit of lead in commercial brass alloys is around 4%. It appears that lead was substituted for some of the copper to keep the cost of production of these fittings down. These fittings should not be used for ROHS compliant equipment, and cannot be used in California, because of the high lead content.

Metallographic Examination

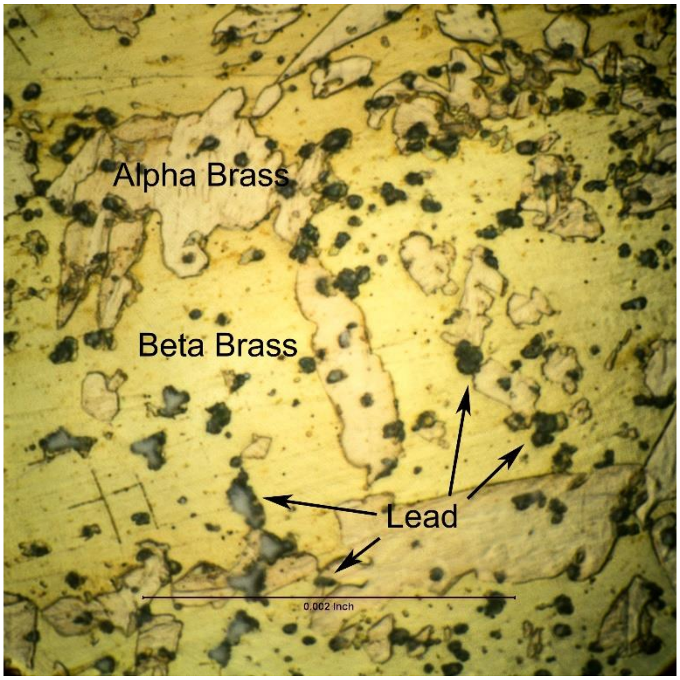

Figure 8 – 1500X Microstructure of Fitting 1

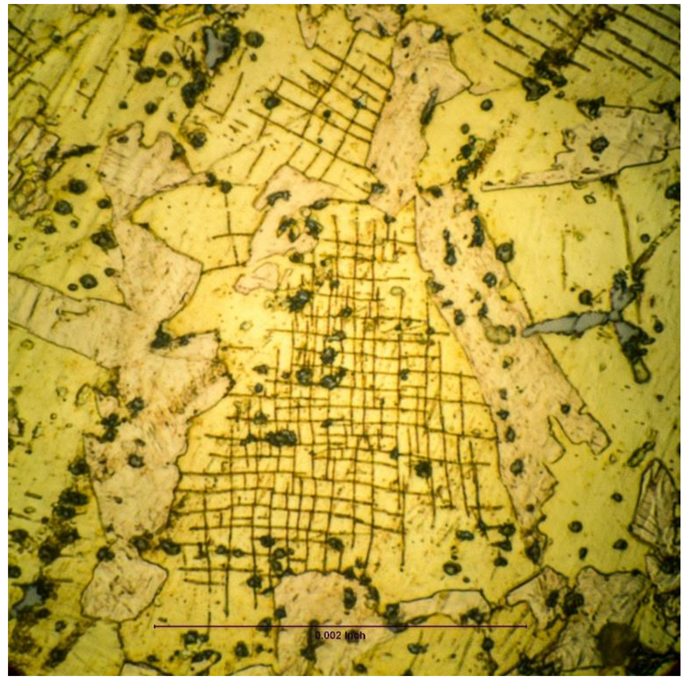
Figure 9 – 1500X Slip Plains in Beta Brass

Figure 8 shows the microstructure of Fitting 1. The microstructure consists of three phase: lead, and Alpha and Beta brass, with Beta brass as the predominant phase. Beta brass has a higher zinc content of typically 50%, than Alpha brass. The high levels of Beta brass indicate that overall copper levels in the fitting were too low.

Figure 9 shows slip plains in the Beta brass near the fracture surface. The presence of slip plains indicates that the Beta brass was stressed almost to the point of failure.

The microstructure shown in Figures 8 and 9 indicates that the fitting was a brass casting. Leaded cast brass alloys typically contain tin to provide for additional strength. These castings were free of tin. The maximum limit for lead in cast brass alloys is 5%. The copper levels are usually around 70%, tin up to 1.5%, and the balance is zinc. These castings were about 52% copper, 33% zinc, and 13% lead.

Conclusion

The cause of failure of these two fittings was the high lead and low copper content in the cast brass alloy used for the fittings. The alloy used is unknown and is not acceptable by International Standards, cannot be used on equipment being used in California or Europe, and is not ROHS compliant.