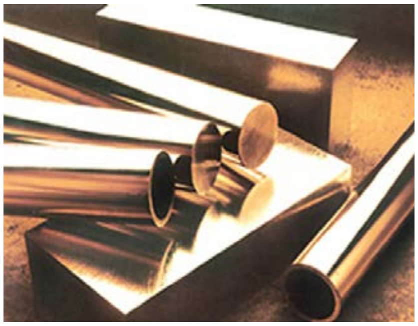
MATERION

CASE STUDY

OIL AND GAS VALVE FOR DRILL STEM TESTING

COMPETITIVE MATERIAL ANALYSIS



Alloy 25 provides the highest strength of any copper beryllium alloy, with conductivity considerably greater than other high-strength copper alloys.

CHALLENGE

An oil and gas company recently came to Materion with an annulus operated reversing valve (AORV) used for drill stem testing (DST). The component is hollow shaped and made from C17200 TF00 rod (subsequently referred to as just C17200), certified to ASTM B196 and customer minimum specifications. The company had originally specified Materion's Alloy 25 (certified to C17200) for use in this application, but a competing supplier was used instead. The component made from the competitor material cracked downhole, causing costly downtime for the oil and gas company. In an effort to determine the cause of failure, the company asked Materion to perform a failure analysis because the original supplier did not offer the technical support and failure analysis capabilities required for the job.

ANALYSIS

BACKGROUND

Initially, when the DST string is run down the hole, the AORV allows fluid flow between the annulus and tubing. When annulus pressure builds to a high enough pressure, a rupture disk will burst, moving the valve permanently into the open position.

After removal from the well, this AORV contained a crack roughly 15.5" long and showed signs of severe corrosion/erosion on the inside and near ports of liquid flow. This crack may have prevented the proper annulus pressure to build that was required to burst the rupture disk, causing the AORV not to perform. The environment in which the AORV was operating had temperatures up to 334°F and it was exposed to both hydrogen chloride and hydrogen sulfide. The part was downhole for a total of 48 days. To determine the severity of corrosion, the Materion team measured the reduction in thickness throughout the component, averaging about 0.026" of thickness lost throughout.

MECHANICAL PROPERTIES

The mechanical properties indicated by the certification from the customer's supplier are shown in the table below (**Table 1**), where they are compared to Materion's historical average for Alloy 25 of similar size and the customer specification minimums. Based on the certification, the competitor material narrowly met the customer's specification. However, it should be noted that property measurements can vary based on the location of the test sample and batch. These results were not validated by Materion, as the sample received was too small to conduct tensile tests.

TABLE 1: MECHANICAL PROPERTIES - COMPETITOR CERTIFICATION VS. MATERION AVERAGE VS. CUSTOMER SPECIFICATION

Property	Competitor Cert.	Materion Alloy 25 Avg.	Customer Spec. Min.
Tensile Strength, ksi	168.75	175.20	160.00
0.2% Yield Strength, ksi	140.80	149.40	140.00
Elongation, %	6.00	7.59	5.00

COMPOSITIONAL ANALYSIS

Compositional analysis was performed in Materion's lab for consistency of data comparison. Most notable was that the beryllium content of the competitor material was 0.05% lower than the customer's specification and UNS C17200 (Table 2, 3). Low beryllium content is especially alarming when taken into context of the overall microstructure seen in the samples of the competitor material. The material showed large beta phase stringers nearing 300 microns long (longitudinal), and beryllides over 50 microns long (longitudinal). Both phases are high in beryllium, meaning they take beryllium away from the primary alpha phase. This could indicate that the primary alpha phase was further depleted in beryllium. Depletion in beryllium could lead to a lower amount of the small, hard precipitate phases that give C17200 its uniform strength.

In addition, the material contained 0.068% lead, which was 0.048% higher than the customer specification, which allowed for 0.020% maximum **(Table 2,3)**. For comparison, there is only trace tramp amounts of lead in Materion's Alloy 25--historically less than 0.005%. This high amount of lead was apparent when looking in the microstructure shown in pictures below, appearing as small dark circles in the micrograph.

TABLE 2: COMPOSITION - UNS C17200 AND CUSTOMER SPECIFICATION

	UNS C17200		Customer Spec.	
Element	**Min**	**Max**	**Min**	**Max**
Be	1.80	2.00	1.80	2.00
Co + Ni	0.20	--	0.20	--
Co + Ni + Fe	--	0.60	--	0.60
Al	--	0.20	--	0.20
Si	--	0.20	--	0.20
Pb	Not Specified	Not specified	--	0.02
Cu	Remainder	Remainder	Remainder	Remainder

TABLE 3: COMPOSITION - COMPETITOR CERTIFICATION VS. MATERION ANALYSIS VS. MATERION AVERAGE

Element	Competitor Cert (%)	Materion Analysis (%)	Materion Avg Mat'l (%)
Be	1.908	1.750	1.845
Co	0.095	0.080	0.012
Ni	0.172	0.180	0.021
Fe	0.048	0.050	0.048
Al	0.02	0.030	0.008
Si	0.029	0.030	0.009
Pb	0.099	0.068	0.0027

MICROSTRUCTURE AND FRACTURE SURFACE

Observing the fracture with optical microscopy, it was determined that the part fractured from the inner diameter to the outer diameter. The fracture mode was from mechanical overloading, with some corrosion occurring after the fact as indicated by the combined transgranular and intergranular primary crack with limited and uniformly dispersed corrosion between grain boundaries (**Figure 1**). Along the fracture surface, there are many shallow "divots" (**Figure 2**) present from corrosion. These divots may have caused weak points in the component and could have become crack initiation points.

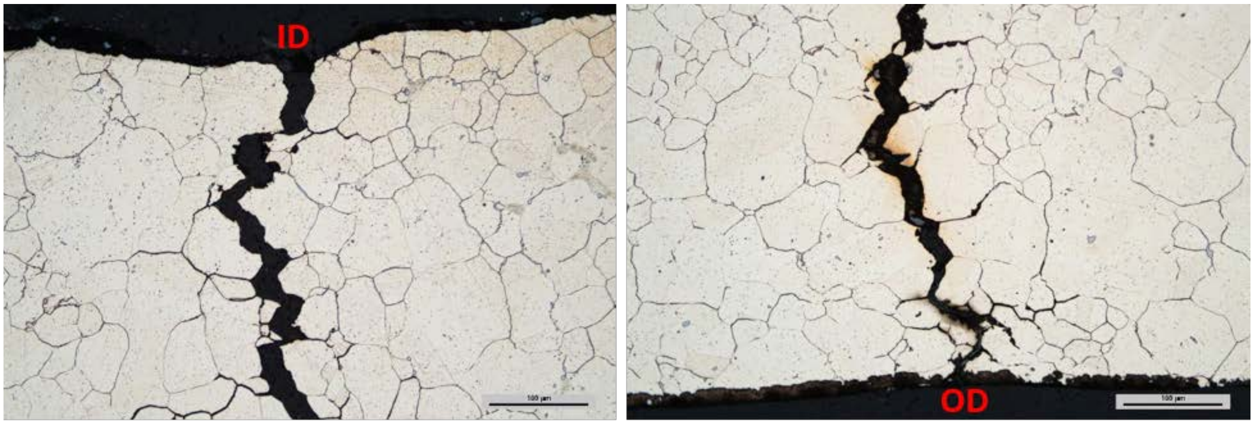


Figure 1: Micrographs of fracture from ID (left) to OD (right); scale bars are 100µ

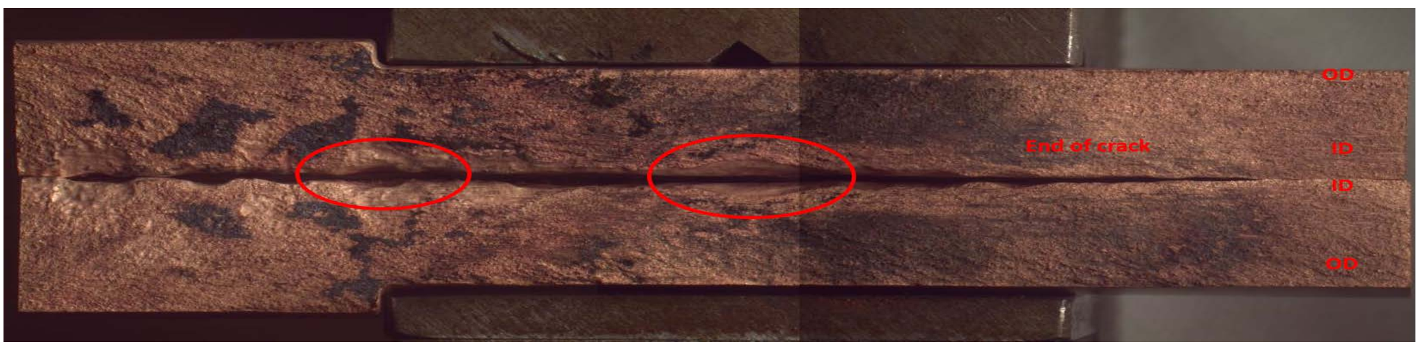


Figure 2: Fracture surface of the component, examples of divots circled in red

The overall microstructure (**Figure 3**) reveals—by Materion standards—abnormally large and elongated beta phase and beryllides. Beta phase is hard, brittle and undesirable in C17200. It often appears due to excessive casting temperature or improper quenching. The high lead content is also visible and manifests as the small dark circles.

Figure 4 shows the difference between Materion Alloy 25 and the competitor material. Notice that Alloy 25 has a uniform, homogenous grain structure with no obvious beryllides, lead or beta phase. The competitor material contains elongated grains in the longitudinal direction, large beta phase stringers, beryllide stringers and lead.

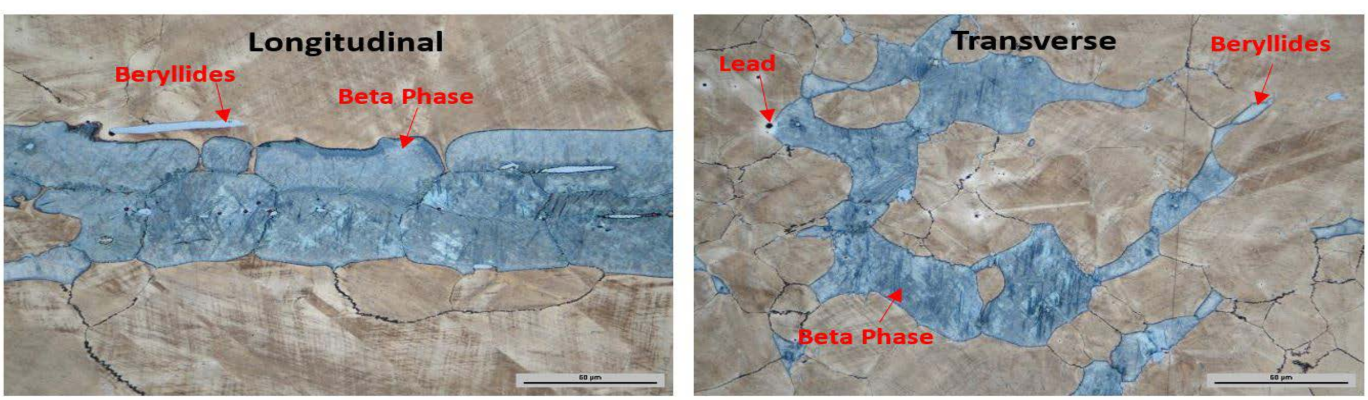


Figure 3: Competitor C17200 microstructure shows large beta phase stringers, beryllide stringers and lead; scale bars are 50µm

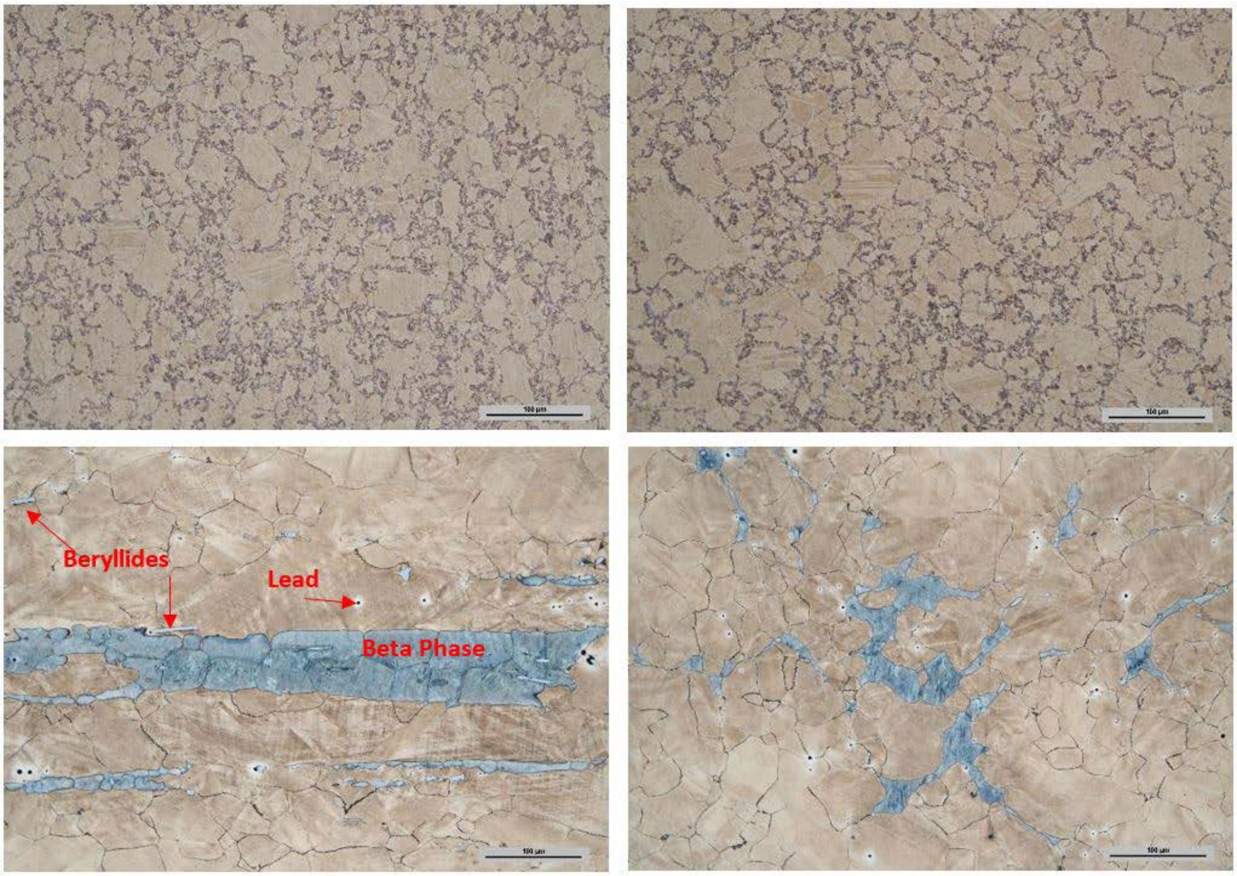


Figure 4: Materion Alloy 25 (top) vs. competitor C17200 (bottom). Notice the Materion microstructure displays uniform, homogenous grain structure, no obvious beryllides, no beta phase and no lead. The competitor micro structure displays elongated grains in the longitudinal direction, large beta phase stringers, large beryllides and lead clusters throughout. Scale bars are all 100µm.

CONCLUSION

Evidence of severe corrosion was found throughout the component that would be expected from the aggressive sour environment. The corrosion created weak points within the mandrel in the form of divots, which is where the fracture may have initiated.

The competitor C17200 material was 0.05% under the customer's beryllium specification and contained .048% more lead than the customer's specification. It also contained an undesirable microstructure with hard, brittle phases. Inhomogeneous microstructure can often lead to inconsistent properties. For example, if many of the hard, brittle phases were concentrated in an area with a corrosion divot, it could have resulted in premature fracture; a material with a more uniform microstructure (such as Materion's Alloy 25) would have had a higher chance of resisting fracture.

To learn more about Alloy 25, contact our engineers at 216.692.3108 or visit www.materion.com/oilandgas.

HEALTH AND SAFETY

Processing beryllium-containing alloys poses a health risk if safe practices are not followed. Inhalation of airborne beryllium can cause serious lung diseases in some individuals. Occupational safety and health regulatory agencies worldwide have set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Safety Data Sheet (SDS) before working with this material. The SDS and additional important beryllium health and safety information and guidance can be found at berylliumsafety.com, berylliumsafety.eu and Materion.com. For questions on safe practices for beryllium-containing alloys, contact the Materion Product Stewardship Group at +1.800.862.4118 or contact us by e mail at Materion-PS@Materion.com.