

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594



September 1, 2017

MATERIALS LABORATORY FACTUAL REPORT

Report No. 17-069

A. ACCIDENT INFORMATION

Place : Bethel, Alaska
Date : November 11, 2016
Vehicle : Piper PA-32R-301, N9084J
NTSB No. : ANC17LA006
Investigator : Noreen Price, AS-ANC

B. COMPONENTS EXAMINED

Engine oil cooler

C. DETAILS OF THE EXAMINATION

The engine oil cooler submitted for examination is shown in figure 1. The oil cooler was an Aero-Classic part number 8000074, serial number 1041902, manufactured in October, 2009. The oil cooler was cracked at a brazed seam in the manifold at the location indicated with arrows in figure 1. The remainder of the oil cooler was intact and was free of visible deformation or bulging.

A closer view of the crack is shown in figure 2. The crack intersected the exterior surface of the oil cooler at the area indicated with a bracket in figure 2. Local bulging deformation of the wall adjacent to the crack was observed.

Next, the oil cooler was cut at locations indicated with dashed lines in figure 1 to remove a section of the manifold containing the crack. The sectioned piece was then cleaned in acetone using an ultrasonic cleaner. A view of the interior surface of the cleaned manifold piece is shown in figure 3, and a closer view of the interior edge of the crack is shown in figure 4. A bracket in figure 3 indicates the location of the crack at the interior surface.

To facilitate opening the crack and to set aside a piece of the manifold for metallography, a section of the manifold piece including the through-pin was cut from the side within the rectangle in figure 3. The through-pin on the opposite side of the piece was cut within the cracked chamber to allow the cracked seam to be opened. The crack was then opened by forcing the adjacent walls of the cracked chamber apart by hand. Views of the piece and the crack surface as the lab fracture was produced are shown in figures 5 and 6. The lab fracture exposed the crack surfaces and fractured adjacent areas

of the seam. Walls of the manifold deformed during the lab fracture process, and in some areas, the wall fractured, leaving the seam intact (see figure 5).

A view of the exposed crack is shown in figure 6. The surface of the crack had a dark color compared to the lab-induced fracture surfaces. Dashed lines in figure 6 indicate the crack boundary. The overall shape of the crack was consistent with initiation from the interior of the manifold. The dark color associated with the crack appeared relatively uniform from the interior to exterior with no indication of crack arrest marks or progressive levels of staining of the surface.

A magnified optical image of the crack fracture surface in an area where the crack extended through the brazed joint is shown in figure 7. The fracture surface had areas with two different general characteristics. Some areas of the crack surface had a brownish gray appearance generally with rounded features in low areas on the fracture surface. Higher areas of the fracture surface had a more silver-gray color with rougher faceted features. The outer edge of the surface consisted entirely of the silver gray area, and the remainder of the surface was intermixed with the two characteristic areas. Overall, approximately half the crack surface was characterized by the features with the brownish gray color, and the remaining half was characterized by the features with the silver-gray color. Similar characteristics were observed on the lab fracture where the brownish gray and silver-gray areas from the crack had a shinier gold color and a lighter silver color, respectively, as shown in figure 8.

After an initial examination, the lab fracture of the seam was completed by peeling the pieces shown in figure 5 apart the rest of the way, producing both wall fractures and fractures along the seam. The smaller piece was then examined using a scanning electron microscope (SEM). SEM images of the crack surface are shown in figures 9 through 11. The areas that appeared brownish gray in optical images had rounded features with dendritic shapes on the surface, features consistent with a void. The silver—gray areas generally showed quasicleavage fracture features where tear ridges and isolated dimples were intermixed with cleavage fracture features. No evidence of crack arrest lines or striations were observed. Similar features consistent with voids and quasicleavage fracture were also observed in areas associated with the lab-induced fracture.

The area of the manifold within the rectangle in figure 3 was mounted in 2 separate metallographic mounts with 3 of the seams including the cracked seam contained in one of the 2-inch diameter mounts, and the remaining seam contained in the second mount. The two mounts were then polished for metallographic examination in the as-polished condition. The brazed seams showed limited voids in the polished plane.

The mount containing the 3 seams was examined using an SEM. An image of the seam interface in one of the seams is shown in figure 14 as viewed in the SEM using the

backscattered electron detector in composition mode.¹ The composition of the features of the interface were also analyzed and mapped using energy dispersive x-ray spectroscopy (EDS). The bulk of the area had a high peak of aluminum in the EDS spectrum. Small areas appearing nearly white scattered across the image in figure 14 were associated with concentrations of iron and manganese, consistent with a 3xxx-series aluminum alloy. The phases appearing a slightly lighter shade of gray relative to the background in a band across the middle of the image were associated with concentrations of silicon, consistent with a 4xxx-series aluminum alloy. Sheet consisting of 3xxx-series aluminum alloy clad with a 4xxx-series aluminum alloy is commonly used for vacuum brazing of heat transfer components.

According to an article in the Pacific Oil Cooler Service website,² new Aero-Classics oil coolers are vacuum brazed at 1,130°F to 1,135°F, and the finished parts are pressure tested to 400 psi. According to the Operator's Manual for Lycoming O-540 and IO-540 series engines,³ IO-540 series engines operate at a maximum oil pressure of 95 psi under normal operation and 115 psi during start and warmup.

Matthew R. Fox, Ph.D.
Senior Materials Engineer

¹ SEM images produced using a backscattered electron detector in composition mode have contrast that is associated with atomic weight of the elements in the image. Areas with elements having higher atomic weights appear as a relatively lighter shade of gray compared to areas having elements with lower atomic weights.

² <http://www.oilcoolers.com/articles.asp> accessed on August 31, 2017.

³ *Operator's Manual, Lycoming O-540, IO-540 Series*, 4th Edition, Lycoming Engines, Williamsport, Pennsylvania (2006).

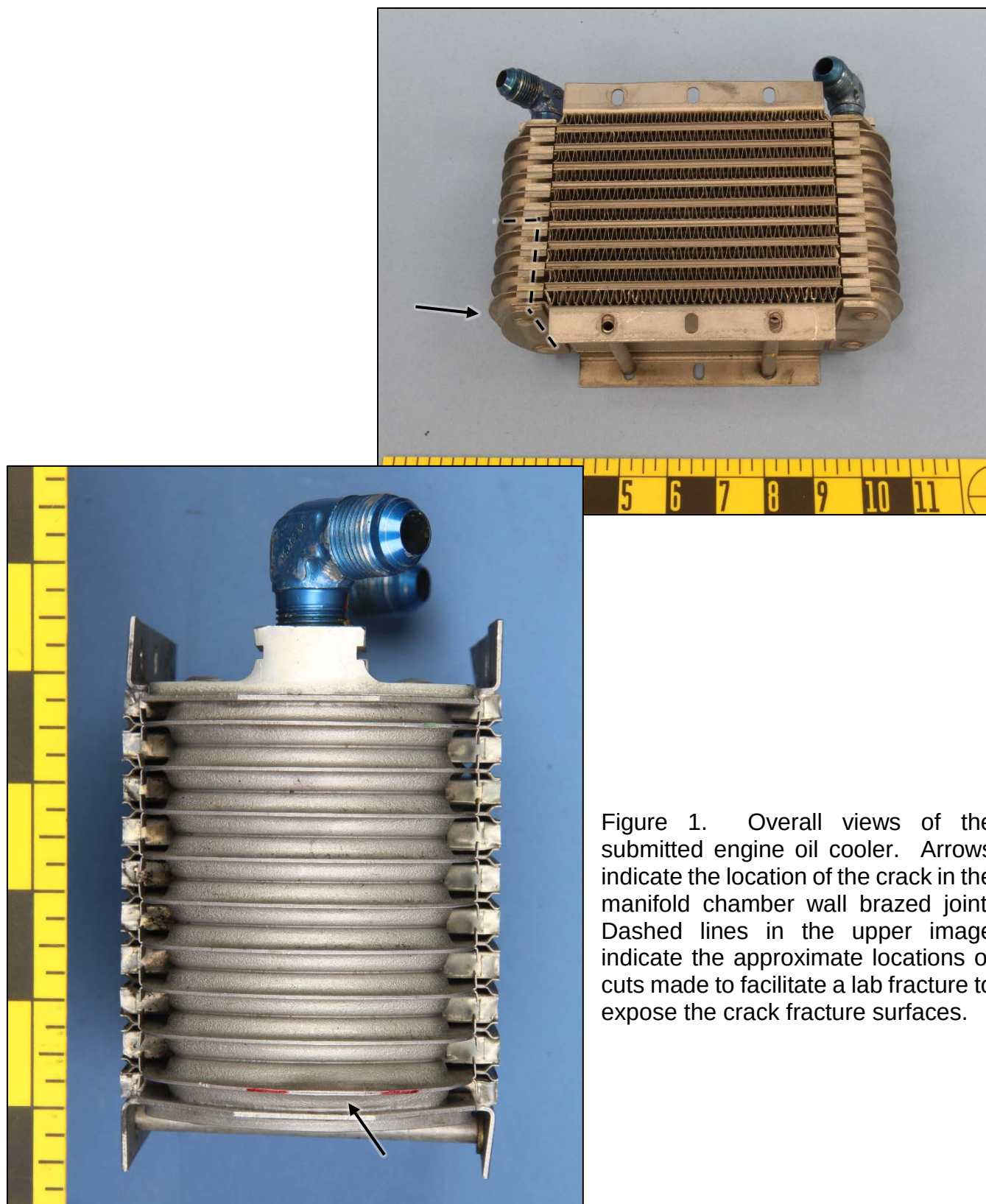


Figure 1. Overall views of the submitted engine oil cooler. Arrows indicate the location of the crack in the manifold chamber wall brazed joint. Dashed lines in the upper image indicate the approximate locations of cuts made to facilitate a lab fracture to expose the crack fracture surfaces.

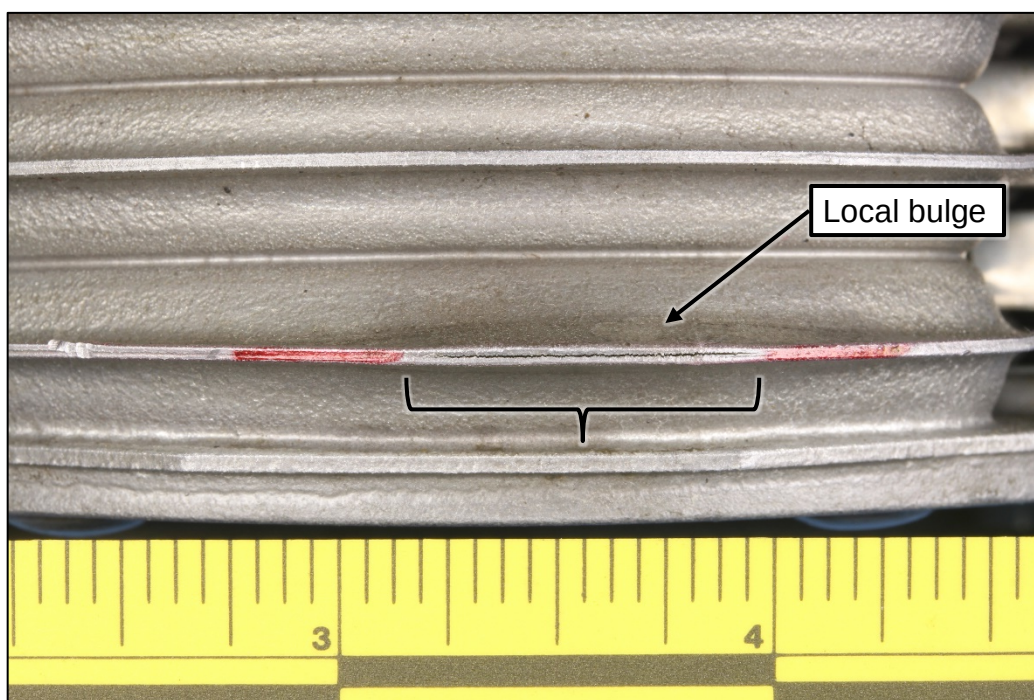


Figure 2. Closer view of the crack as indicated with a bracket.

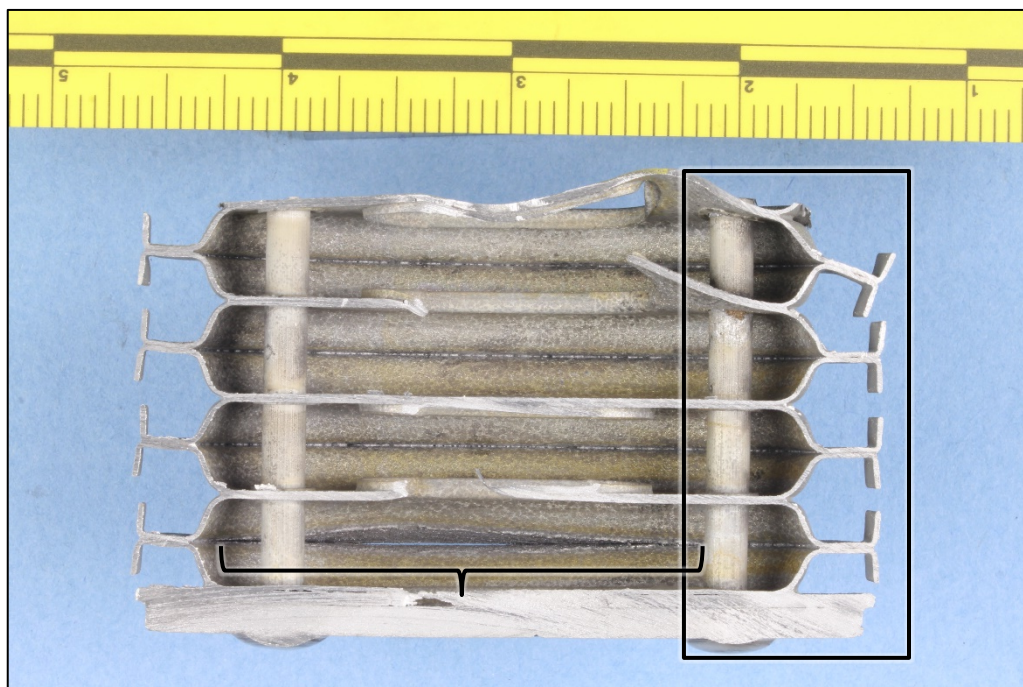


Figure 3. View of the manifold interior after sectioning and cleaning with acetone in an ultrasonic cleaner. The rectangle indicates the area of the cross-section prepared for metallographic examination, and a bracket indicates the crack location.

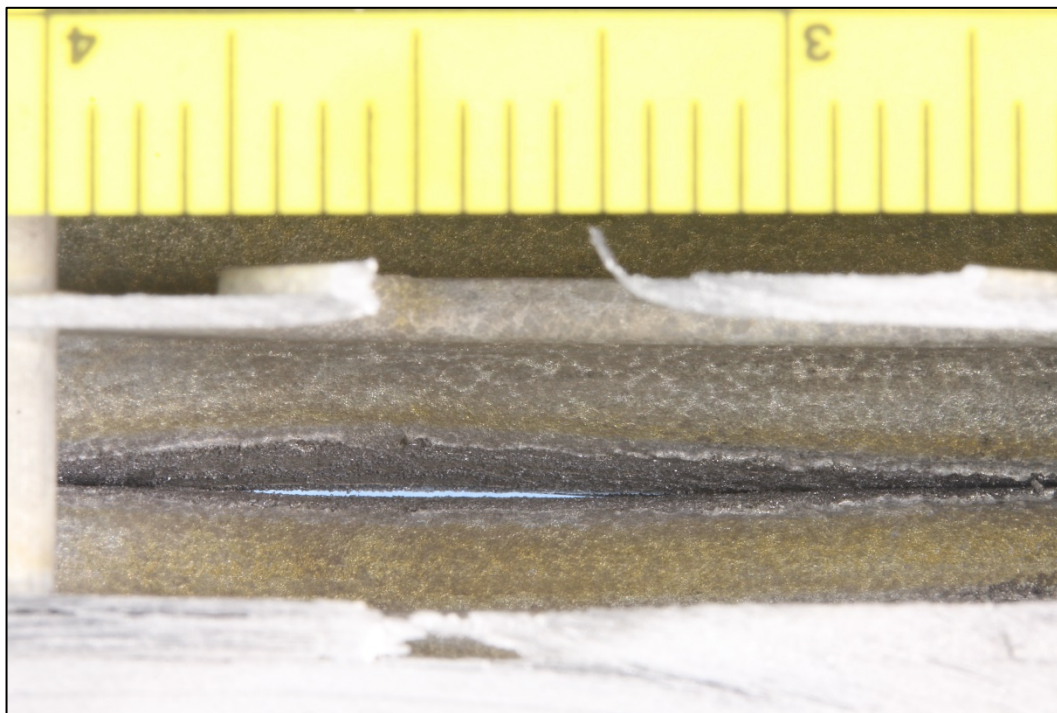


Figure 4. Closer view of the manifold interior at the crack location.

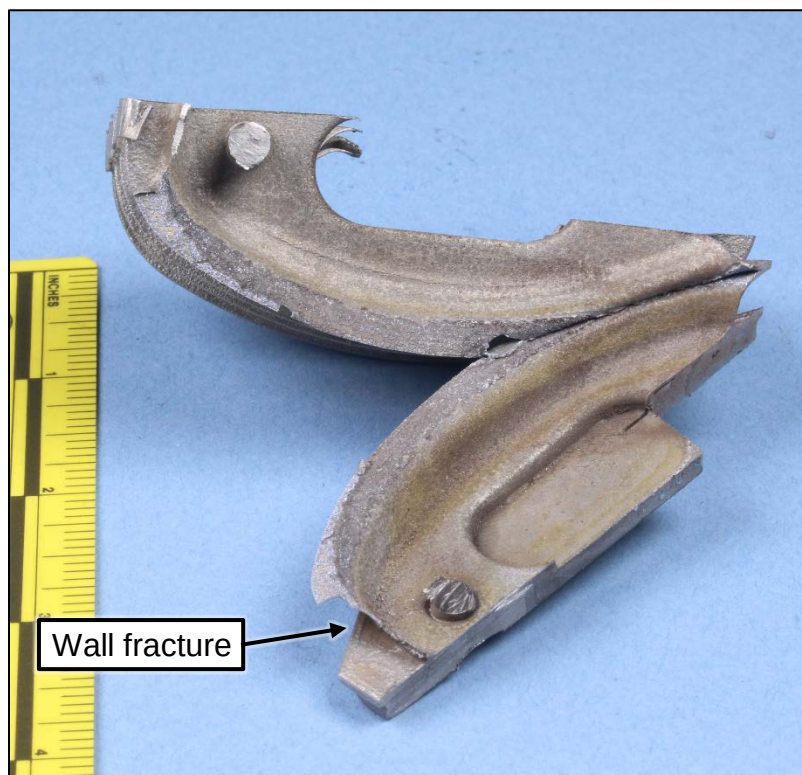


Figure 5. Lab fracture to open the crack.

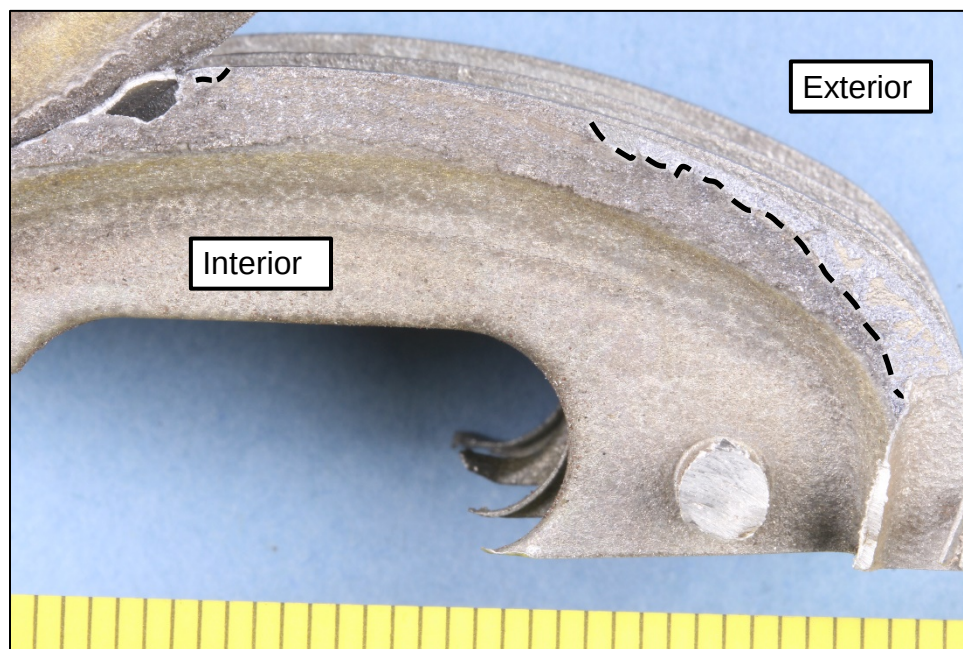


Figure 6. Photograph of the crack as exposed by lab fracture. Dashed lines indicate the crack boundary.



Figure 7. Magnified optical image of the crack fracture surface near the middle of the crack.

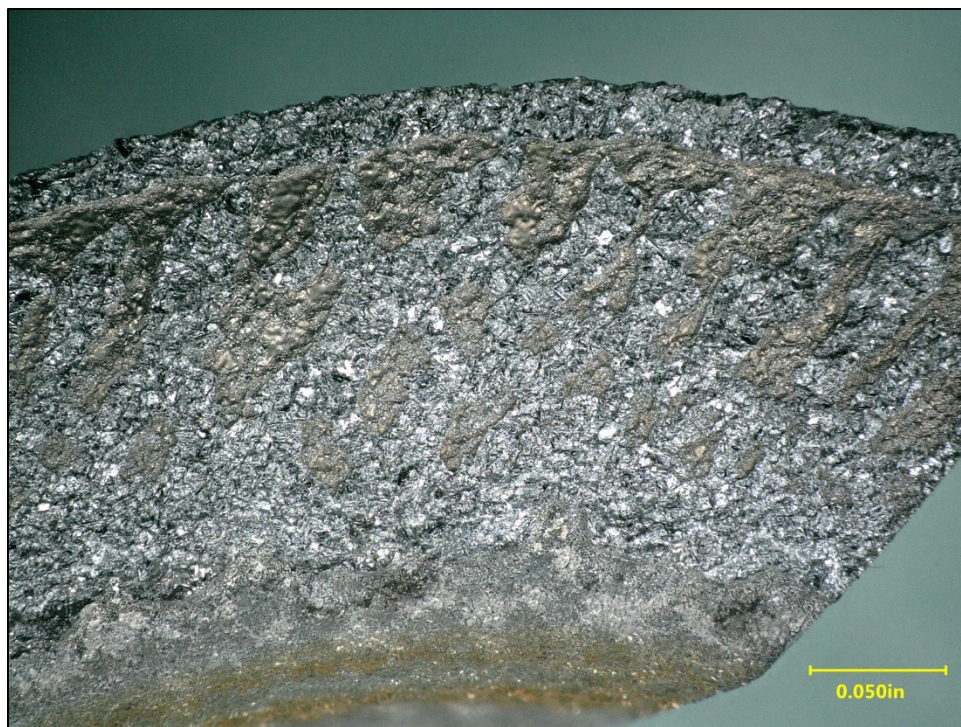


Figure 8. Magnified optical image of the lab-induced fracture surface beyond the crack boundary.

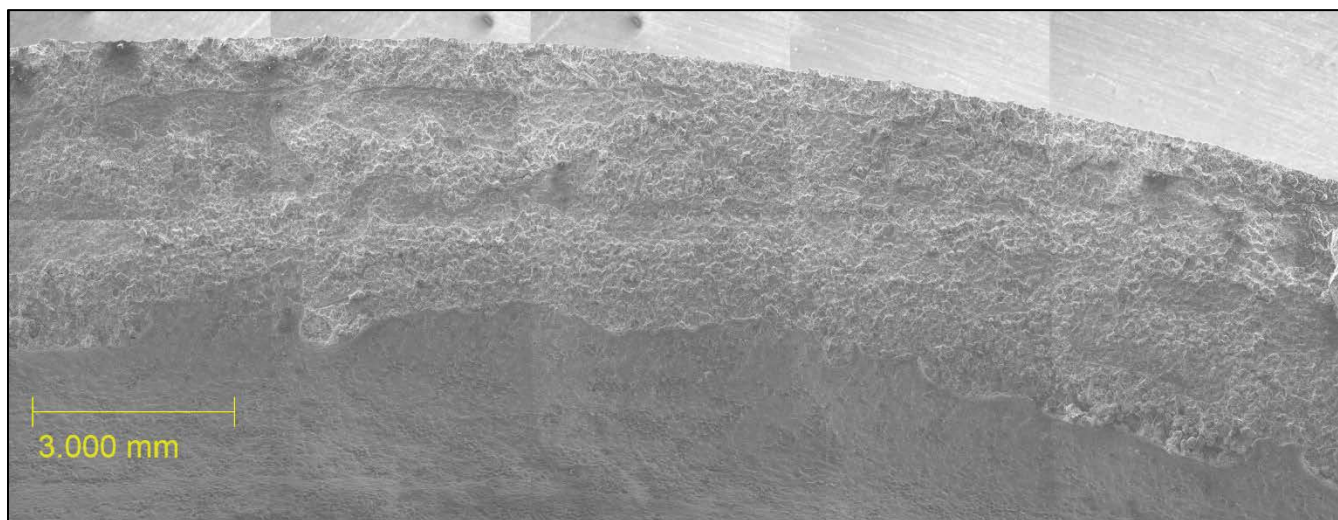


Figure 9. SEM images stitched together to show a portion of the crack fracture surface.

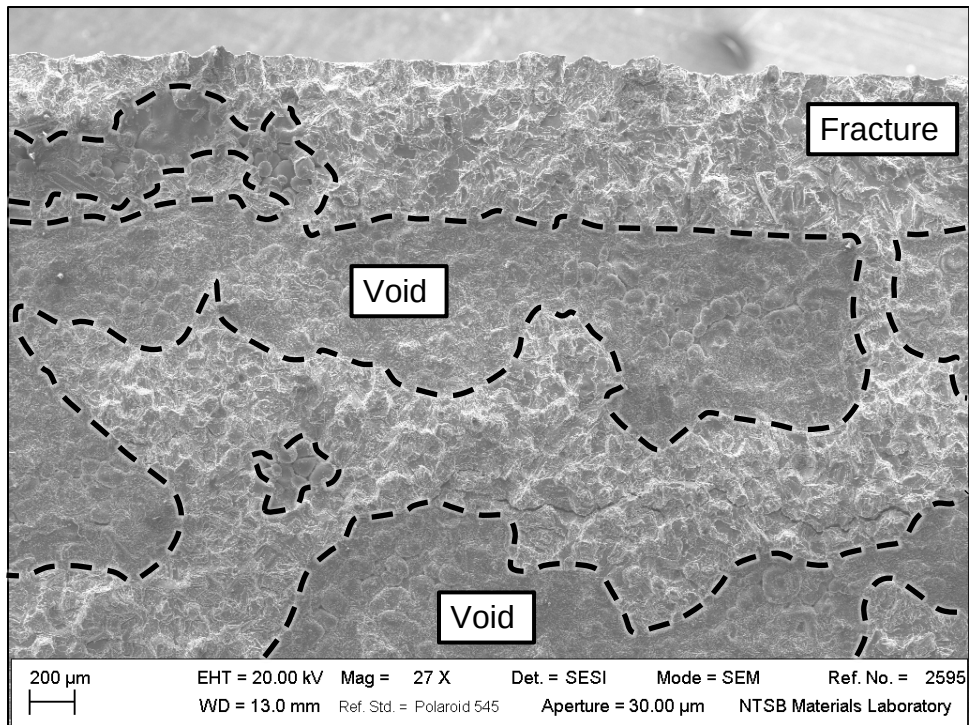


Figure 10. SEM image of an area of the crack fracture surface. Dashed lines indicate boundaries between voids and fractured surfaces.

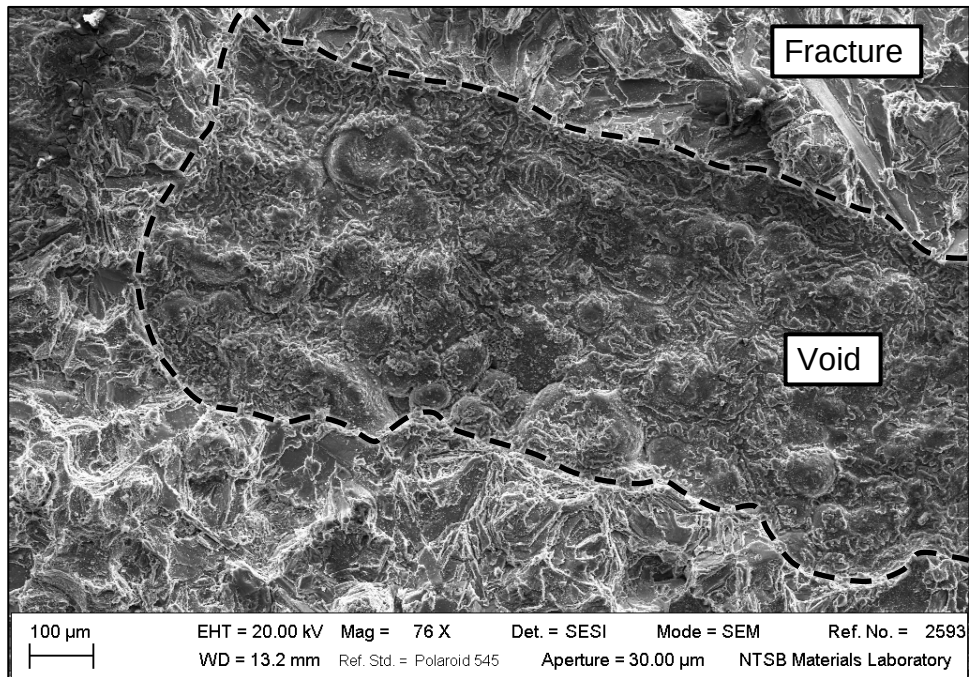


Figure 11. SEM image at higher magnification showing void and fracture surface features.

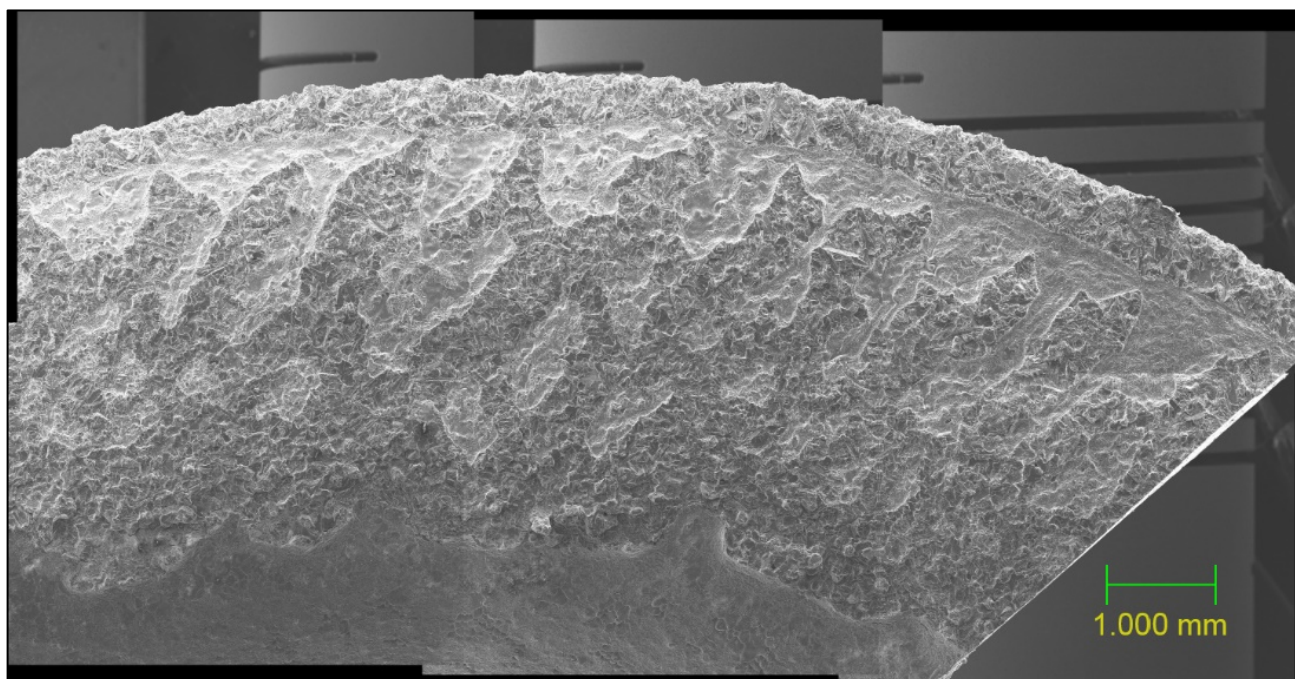


Figure 12. SEM images stitched together to show a portion of the lab-induced fracture surface features.

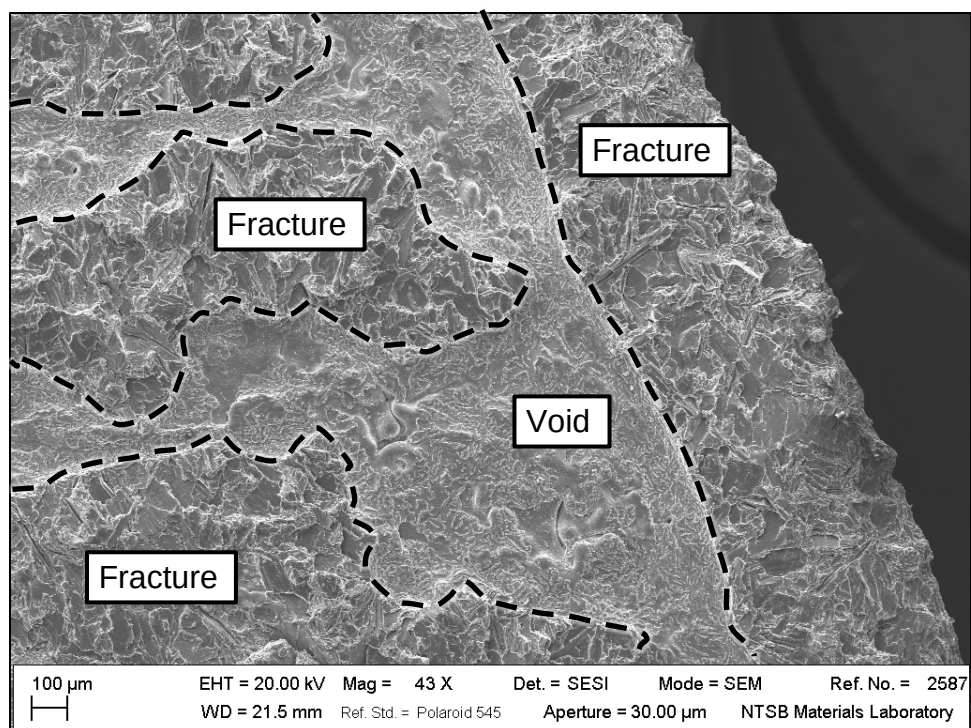


Figure 13. SEM image of lab fracture features where dashed lines indicate boundaries between voids and fractured surfaces.

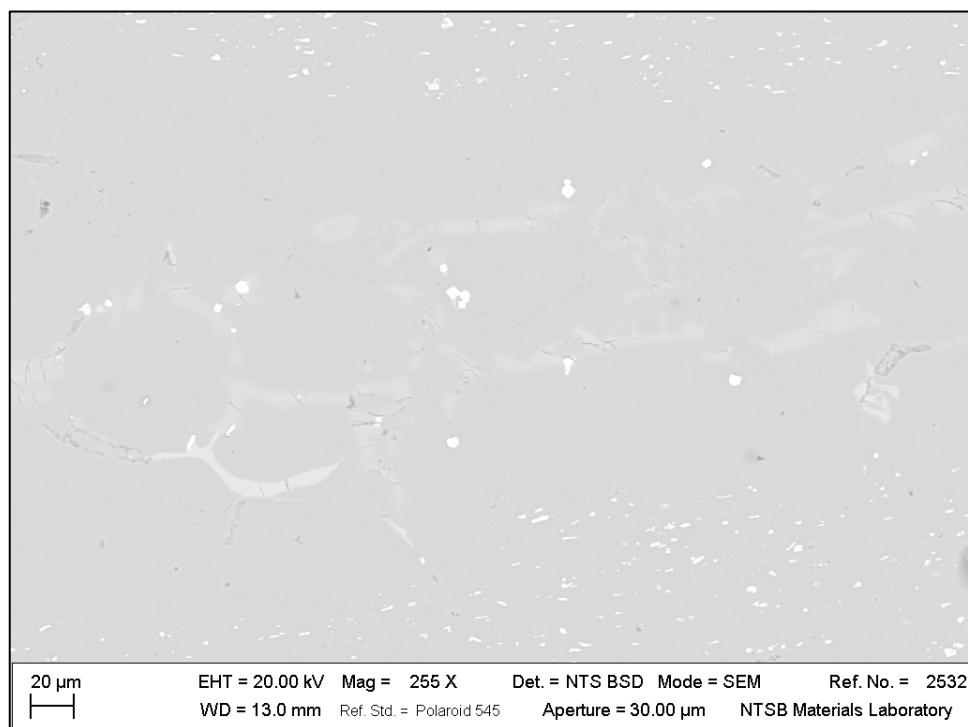


Figure 14. SEM image of a brazed seam in the metallurgical mount as viewed using a backscattered electron detector in composition mode. Phases containing higher concentrations of iron and manganese appear nearly white, and phases with a high concentration of silicon appear a slightly lighter shade of gray relative to the background.