

NATIONAL TRANSPORTATION SAFETY BOARD

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



May 20, 2022

MATERIALS LABORATORY FACTUAL REPORT

Report No. 22-033

A. ACCIDENT INFORMATION

Place : Buckingham, Pennsylvania
Date : June 15, 2021
Vehicle : Vans RV6A, N74MS
NTSB No. : ERA21FA253
Investigator : Todd Gunther, ASI – ERA

B. COMPONENTS EXAMINED

Pieces from a Lycoming O-360-A1A engine as follows:
Two pieces of the number 4 connecting rod.
Four pieces of the number 4 connecting rod end cap.
Two connecting rod bolt fragments.
Oil line and elbow fitting.
Additional contents of oil sump.

C. DETAILS OF THE EXAMINATION

Pieces of a Lycoming O-360-A1A engine were submitted to the NTSB Materials Laboratory for examination as listed above and shown below in figure 1. The number 4 connecting rod was fractured through the yoke and the end cap was fractured into multiple pieces. Both connecting rod bolts were fractured and multiple metal fragments had been retrieved from the oil sump. An oil line and elbow fitting were obstructed by an unidentified substance. The connecting rod pieces, associated bolts, and sump contents were examined first followed by the oil line components.

1. Connecting rod assembly and sump contents

The relative positions of the connecting rod, end cap and bolt fragments were determined by examining mating fracture faces and interlocking surfaces. The nominal configuration is shown in figure 2. The right side of the connecting rod, as oriented in figure 2, had fractured near the yoke to rod transition. The end cap fragment was oriented by matching a battered slot on the large cap fragment to a battered tab on the yoke fragment. A bolt fragment, entrapped in the end cap was matched to a fracture surface on one of the free-standing bolt pieces (see below). The other bolt fragment was then matched to the opposite side (left side of figure 2). Three metal fragments from the sump had a size and thickness that were consistent with fractured pieces of the cap and are also shown in figure 2. The fragments were battered, and their exact orientation could not

be determined. The rod and yoke exhibited bending deformation. The end cap had also deformed in bending, opening the cap and reducing its curvature.

The bearing saddle (backing surface for the bearing insert) on the connecting rod is shown in figure 3a and the yoke fracture faces are shown in figures 3b and 3c. A metal layer was smeared across part of the saddle that was consistent with remnants of the bearing insert. The insert, saddle, and surrounding material exhibited a dark, heat-tinted appearance, consistent with high-temperature exposure. The yoke fracture surfaces were examined with the aid of a stereomicroscope. Ratchet marks and striated features were observed originating from the inner diameter surface progressing radially outward. Striated features were also observed progressing radially inward from the outside of the yoke, but the origin areas were battered. Areas of final overstress separation were observed where the two cracks met. The direction of crack progression and the regions of final separation are indicated by yellow arrows and solid lines, respectively, in figure 3b. The features were consistent with a fracture in reverse bending fatigue.

The connecting rod bolts from the left and right sides of figure 2 were similarly examined with the stereomicroscope. Both bolt fragments exhibited a dark tint similar to the connecting rod, consistent with high-temperature exposure. The fracture surface on the left-side bolt fragment, shown in figure 4, exhibited striated features, consistent with fatigue, that originated from two locations on opposite sides of the bolt and met along a line near the center of the bolt. Two regions of overstress separation, indicated in figure 4, were observed along the edge of the bolt, approximately 90° around the circumference from either origin. The bolt cross section and overstress areas were measured on the image and the calculated fatigue fraction was 0.96. The features were consistent with a high-cycle fatigue fracture under reverse bending. The mating fracture surfaces from the right-side bolt are shown in figures 5a and 5b. The fracture was nominally coplanar with the plane of the end cap / yoke joint. Coarse striated features, consistent with fatigue, were observed that originated on the side closest to the end cap / yoke inner diameter. The striated features progressed partially across the bolt in a radially outward direction, then transitioned to an out of plane fracture with coarse features, consistent with a final separation in overstress. The fatigue fraction was approximately 0.45. A second fracture on the free-standing bolt fragment exhibited coarse fracture features on an inclined plane, consistent with a bending overstress fracture.

The metal chips from the sump were examined visually and were partitioned into three groups. Most of the chips were similar to that shown in figure 6a, exhibiting laminate separations and indications of thermal distress. The thicknesses of several chips were measured using a point micrometer and the thickness ranged from 0.0035 inch to 0.0089 inch. Two chips exhibited a silver-metallic appearance as shown in figure 6b. The chemical composition of one of the chips was examined in a scanning electron microscope (SEM) equipped with an energy dispersive X-ray spectrometer (EDS) as shown in figure 6c. The spectrum consisted primarily of aluminum (Al), silicon (Si), and oxygen (O).

Finally, one chip, shown in figure 6d, was thicker than the other chips, measuring between 0.0772 inch and 0.0845 inch according to the point micrometer. One edge of the chip was straight. The adjacent flat face was beveled and exhibited longitudinal machining lines. Elsewhere on the face of the chip, the surface exhibited mud cracking and a smeared silver-metallic residue. The fractured edges of the chip were examined and exhibited features consistent with either batter or overstress. The chip was examined in the SEM (shown in figure 7a) and by EDS. The spectra from two spots, indicated by the yellow dots in figure 7a, are shown in figures 7b and 7c, one at a location with the silver-metallic residue and a second in a region without the residue, respectively. The region with the residue, shown in figure 7b, exhibited primarily Al and Si, with an additional peak of iron (Fe). The region without the residue, shown in figure 7c, exhibited primarily iron (Fe) with additional peaks of Al and chromium (Cr).

2. Oil line and elbow fitting

The oil line and elbow fitting were examined by eye and with the aid of the stereomicroscope. A plug of material was observed at one end of the oil line, as shown in figure 8a. Using a fiber optic light, an obstruction was also observed within the passage of the elbow fitting. The obstruction, after mechanically dislodging it, is shown in figure 8b. The plug of material was extracted from the fitting as shown in figure 9a. A sample of the material was collected on a piece of carbon tape and examined by SEM/EDS, as shown in figure 9b. The spectrum consisted primarily of Si, Al, and O, with traces of sodium (Na), magnesium (Mg), chlorine (Cl), potassium (K), calcium (Ca), and Fe.

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Sr. Materials Engineer



Figure 1: Connecting rod assembly pieces, fragments from sump, oil line, and elbow fitting, as received.



Figure 2: Connecting rod assembly pieces placed in their relative positions using fracture and interlocking surface features. Three fragments found in the sump were battered and their position could not be identified.



Figure 3: a) Image of the bearing saddle and fractured yoke on the connecting rod fragment;
b) annotated view of the yoke fracture; and

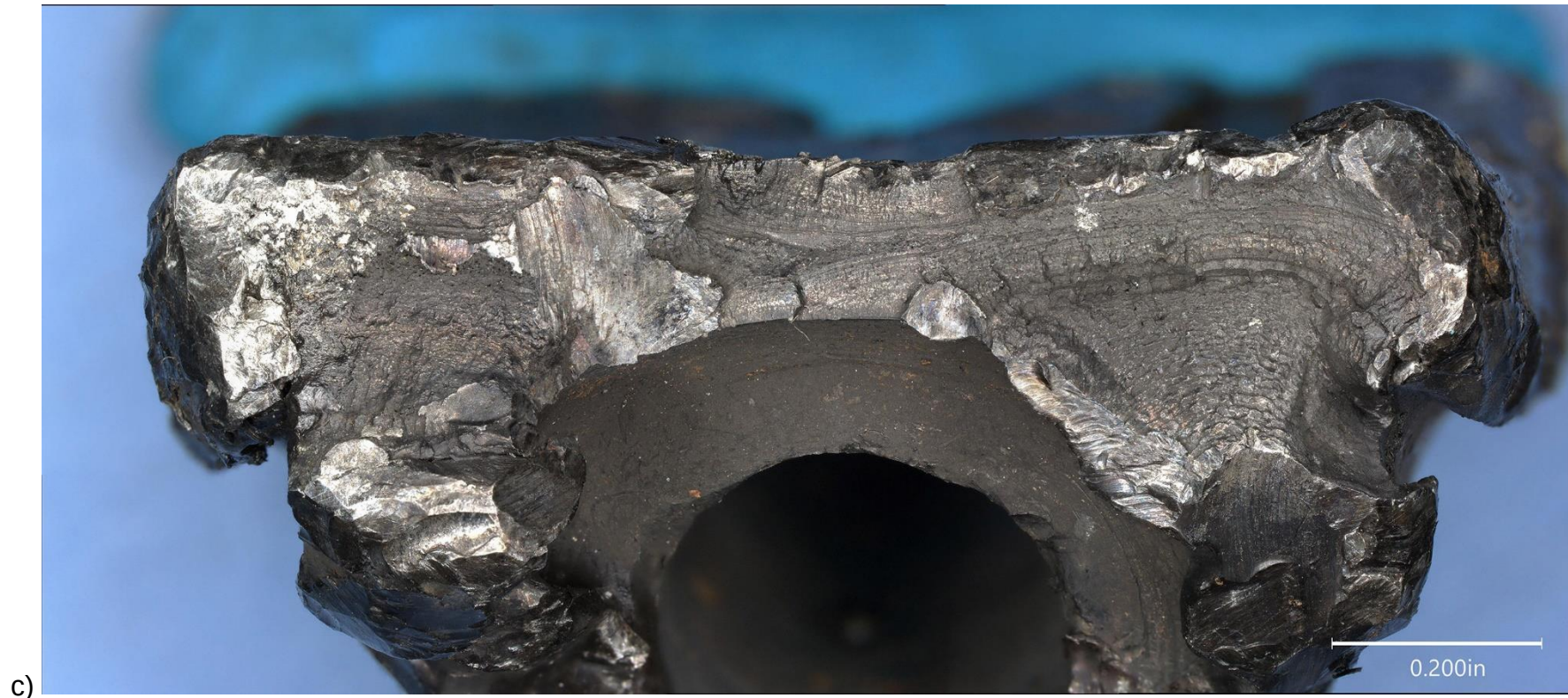


Figure 3 (cont.): c) the yoke's mating fracture face.

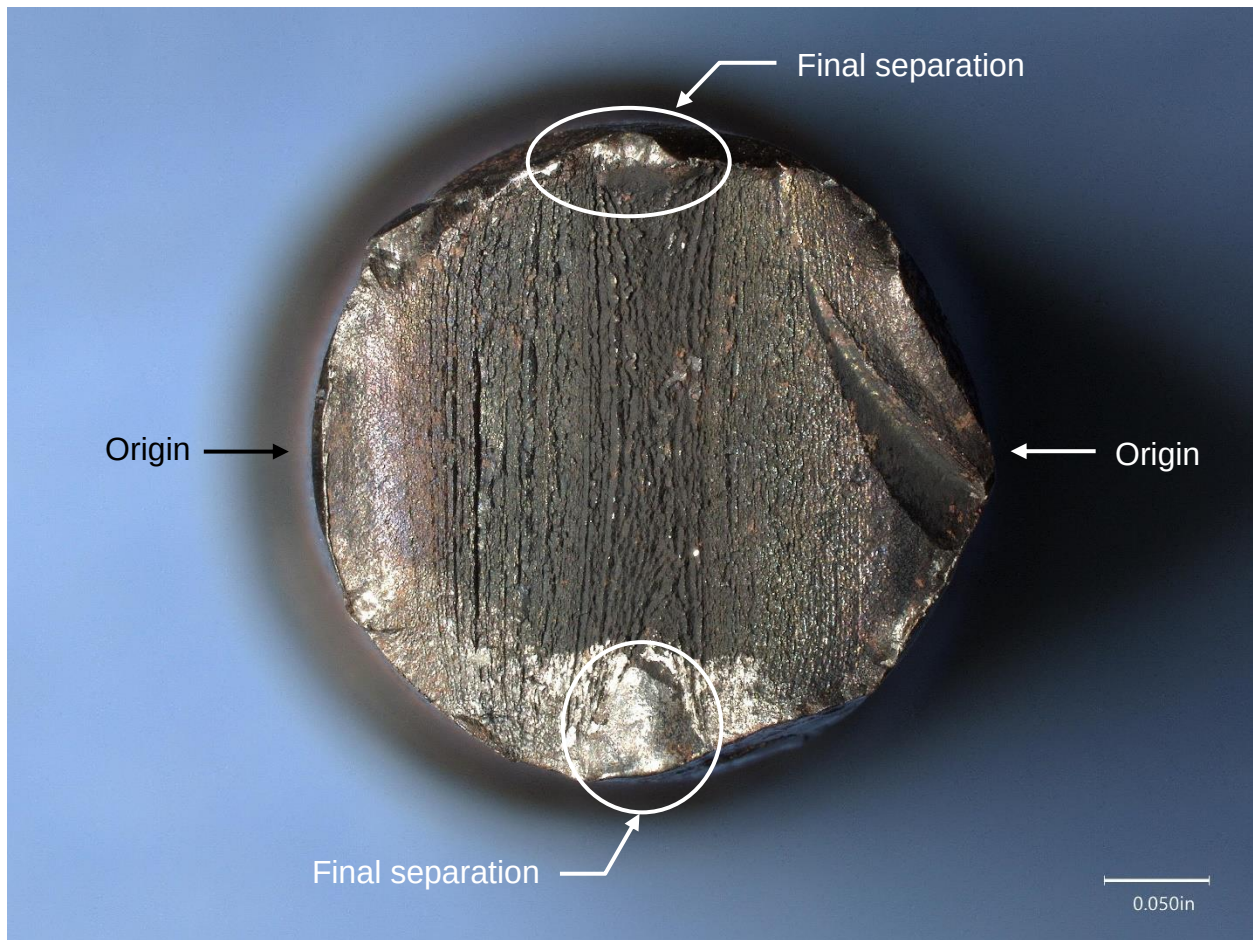


Figure 4: Image of fracture surface from the bolt fragment on the left side of the connecting rod in figure 2.



Figure 5: Images of mating fracture faces from the bolt on the right side of the connecting rod in figure 2: a) fracture face on a piece of bolt trapped in the end cap and b) mating fracture face on a free-standing bolt fragment.



Figure 6: a) Image of a typical chip from the sump; b) two silver-metallic chips found in sump;

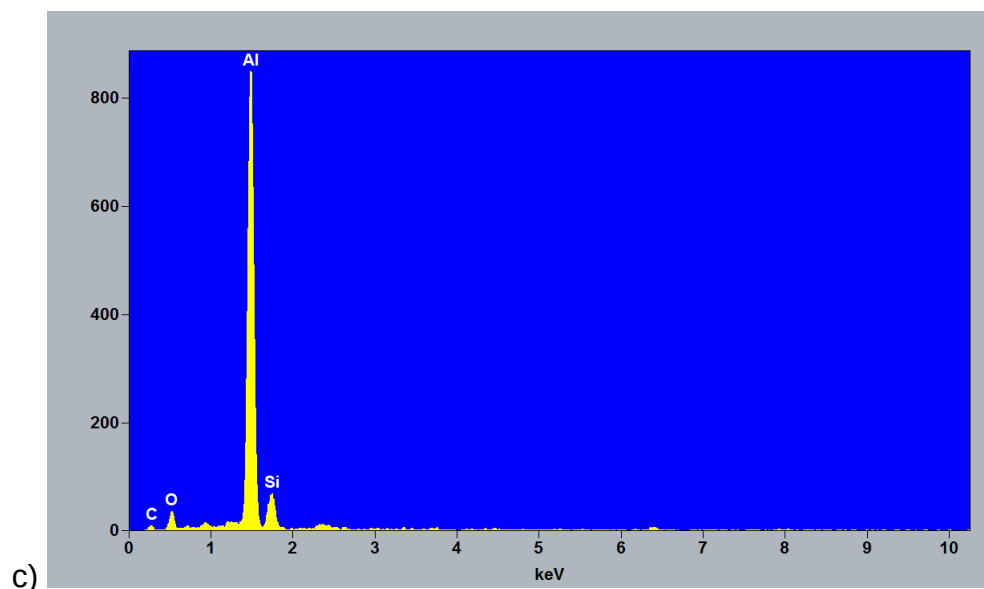


Figure 6 (cont.): c) EDS spectrum from one of the silver-metallic chips showing the presence of aluminum (Al) and silicon (Si); and d) thicker metal chip exhibiting mud cracking and smeared silver-metallic material.

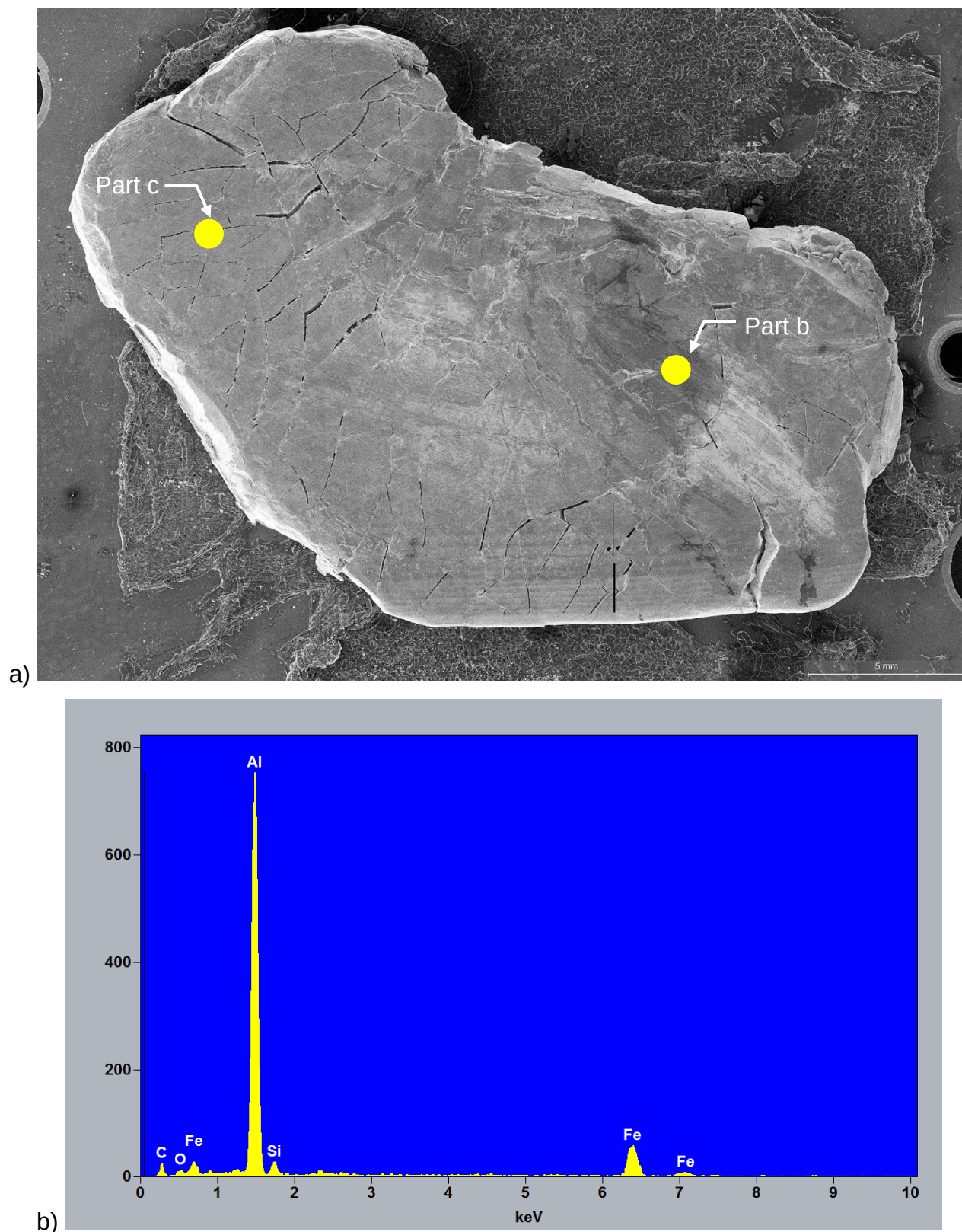


Figure 7: a) SEM image of the chip from figure 6d; b) EDS from a location with the silver-metallic region, exhibiting primarily Al and Si and an additional iron (Fe) peak; and

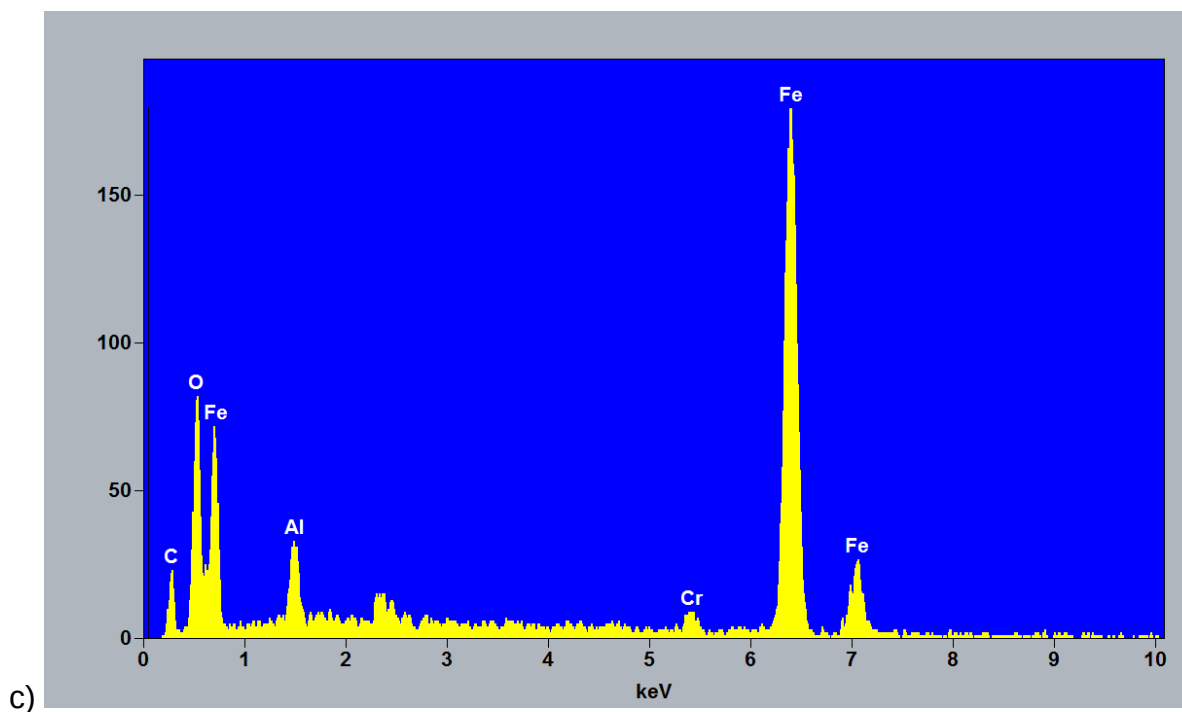


Figure 7 (cont.): c) EDS spectrum from a typical dark matte region exhibiting primarily Fe with additional peaks from Al and chromium (Cr).



Figure 8: a) One end of the oil line showing an obstruction and b) the elbow fitting showing a piece of the obstruction at the entrance to the internal passage after it had been dislodged.

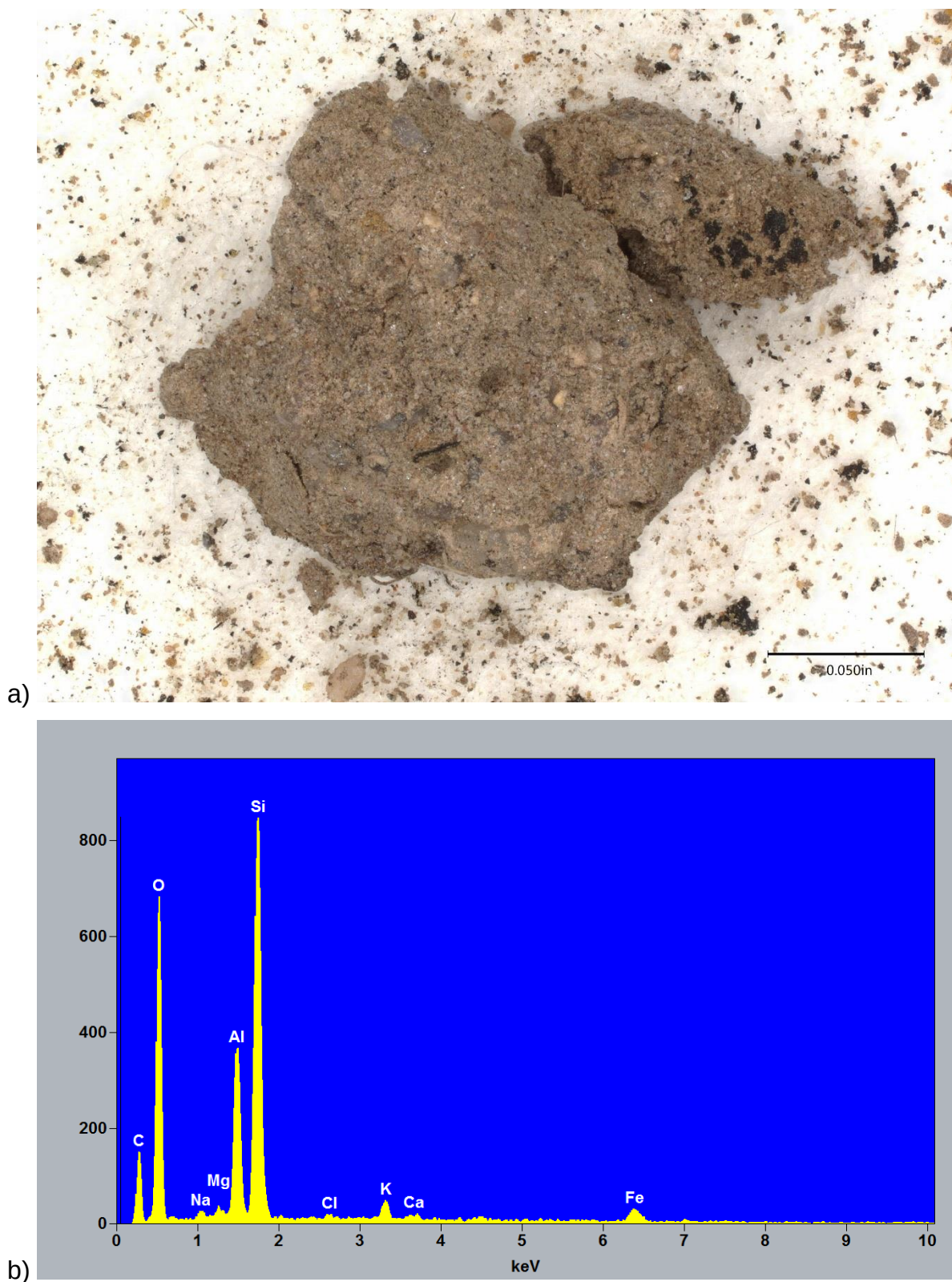


Figure 9: a) image of the obstructing material after extraction from the elbow fitting and b) EDS spectrum of the debris showing primarily Si, Al, and O, with additional peaks from Na, Mg, Cl, K, Ca, and Fe.