

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



WPR22FA188

MATERIALS LABORATORY

Specialist's Factual Report 22-090

December 8, 2022

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A. ACCIDENT INFORMATION

Location: Show Low, Arizona
Date: May 25, 2022
Time: 17:50 mountain standard time
00:50 coordinated universal time
Vehicle: Cessna 172F, N5532R
Investigator: Dan Baker, AS-WPR

B. COMPONENTS EXAMINED

No. 4 engine cylinder assembly
Exhaust and intake valves

C. EXAMINATION PARTICIPANTS

Specialist Erik Mueller, Ph.D., P.E.
Office of Research and Engineering – Materials Laboratory Division
NTSB

D. DETAILS OF THE EXAMINATION

On May 25, 2022, a Cessna 172F airplane was substantially damaged during an accident near Show Low, AZ. The pilot and passenger were fatally injured. While performing multiple takeoffs and landings, the airplane impacted a stream in an open field about 1 mile southwest of the airport. A postaccident examination of the airplane's engine revealed that the #4 cylinder exhaust valve had seized in the open position. Components from the #4 engine cylinder were sent to the NTSB Materials Laboratory for further examination.

Figure 1 shows the components from the #4 cylinder position as received. Most of the components had been disassembled from the cylinder assembly, and the spark plugs had not been included in the shipment.

Views of the cylinder surfaces are shown in Figures 2 through 4. The oil cover had been removed, with the valves, springs and other components in this area removed. The side with the exhaust valve stem bore (left in Figure 2) exhibited darker coloring and deposits, consistent with exposure to the hotter exhaust gasses than the intake side.

Figure 3 shows the pushrod side of the cylinder. The intake tube had been deformed inward, consistent with compressive forces such as crushing. The port connecting to the exhaust side (lower part of Figure 3) was not included. The opposite side

revealed soil compacted into the gaps between the cooling fins (Figure 4). There was no other noted damage on this side of the cylinder.

Figure 5 shows the interior of the cylinder, lit with a diffuse flash to reveal the interior features. On the left of the figure, the intake side displayed flattened, dull deposits, exhibiting a light yellowish-brown color. While these deposits were present throughout the cylinder crown interior, they were concentrated more around the intake valve seat. There were no indications of deformation or impact on the interior surfaces of the cylinder assembly.

Figure 6 shows the two push rods as received. Neither rod exhibited any visible gross deformation or impact damage.

Figure 7 shows the components that had been removed from the intake side of the cylinder prior to receipt by the Materials Laboratory. These components included the three springs, rocker arm, two keeps, two retainers, and the intake valve. None of the components had fractured or deformed. Figure 8 shows the contact surfaces between the rocker arm and the intake valve stem. The wear pattern exhibited a centrally located streak, with two comparably sized semicircles on either side. This pattern was consistent with the rocker arm contacting the valve tip along the center line. There were no noted wear marks on the valve stem consistent with off-center positioning.

Figure 9 shows the components from the exhaust side of the cylinder, which had been previously disassembled. The components included three springs, rocker arm, two keeps, two retainers, and the exhaust valve. None of the components had fractured or deformed. Figure 10 shows the contact surfaces between the rocking arm and the intake valve stem. The wear pattern exhibited a centrally located streak, thinner in width than the intake valve, with two larger semicircles on opposite sides. These features were also consistent with centerline contact by the adjacent rocker arm.

Figure 11 shows the side views of the stem near the valve seat and the valve head, shown rotated 90° from each other. The 0.6 to 0.7 inches along the stem from the seat exhibited deposits, with the deposits in the nearest 0.5 inches from the seat exhibiting a dark brown color with a dull luster. The farther 0.1 to 0.2 inches of deposits exhibited a more reflective black color. These dark brown and orangish-yellow deposits were present over the exhaust valve head, as illustrated in Figure 12a.

A closer view of these deposits along the exhaust valve stem is shown in Figure 13 and Figure 14. The deposits exhibited a flaky layered morphology, showing an increase in the overall diameter of the stem. The amount of additional thickness is annotated in Figure 13. The valve stem diameter was measured using vernier calipers

and was 0.4320 inches away from the deposits. The maximum diameter of the stem with the deposits was 0.4505 inches, indicating a deposit thickness of 0.0092 inches.

The deposits were examined using energy dispersive x-ray spectroscopy (EDS) in a field emission scanning electron microscope (SEM). Figure 14 illustrates a typical spectrum of the deposits on the exhaust valve. This spectrum exhibited prominent peaks of lead (Pb), with peaks of oxygen (O) and bromine (Br). These elements were consistent with lead-oxide combustion products from the brominated tetraethyl lead additive in avgas aviation fuel. The spectrum also shows iron, manganese, and chromium, consistent with the elements of the valve alloy steel.

The deposits were also examined with Fourier transform infrared spectroscopy (FTIR). The exhaust valve exhibited some indications of chlorine and siloxane. The other deposits were consistent with lead-oxide based deposits typical of avgas additives.

The intake valve is illustrated in Figure 16. Like the exhaust valve, there were deposits along the stem up to 0.7 inches from the seat. There were also dull yellowish-brown deposits along the head of the intake valve facing the cylinder interior, as shown in Figure 17a. However, unlike the exhaust valve, the deposits along the stem near the intake valve seat exhibited a reflective black appearance. These deposits were also along the seat surface, shown in Figure 17b.

Figure 18 shows a closer view of these deposits, with a glare removal filter applied to illustrate the deposit texture. The deposits were layered but also protruding rather than flat and plate-like. The deposits were rounded but also exhibited definitive peaks and valleys (Figure 19). The buildup was not uniform, as shown by the opposite divots or depressions in the black deposits to the right in Figure 18. The deposit thicknesses were annotated in Figure 18. The intake valve stem diameter was measured as 0.3415 inches. The maximum diameter in the deposits was 0.3830, indicating a deposit thickness of 0.021 inches in that area.

The deposits were examined using EDS, and Figure 20 shows a typical spectrum from the extracted material. This spectrum contained a high Pb peak and high Br and carbon (C) peaks, with a lower oxygen peak than the exhaust valve. The FTIR examination of the intake valve stem deposits showed indications of a single-chained polymerlike organic compound, consistent with deposits of unburnt fuel.

Submitted by:

Erik M. Mueller
Materials Research Engineer



Figure 1. Components from the #4 engine position, as received.

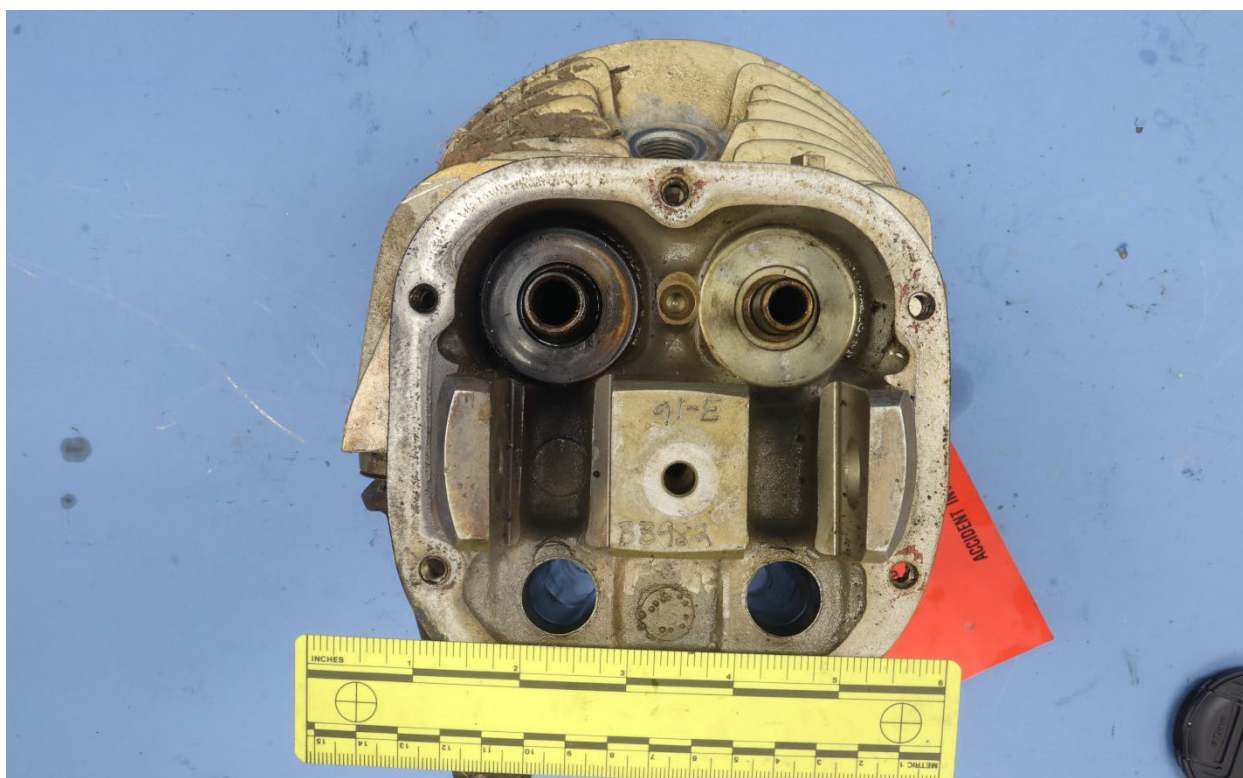


Figure 2. Top view of the cylinder assembly, as received, partially disassembled prior to receipt.

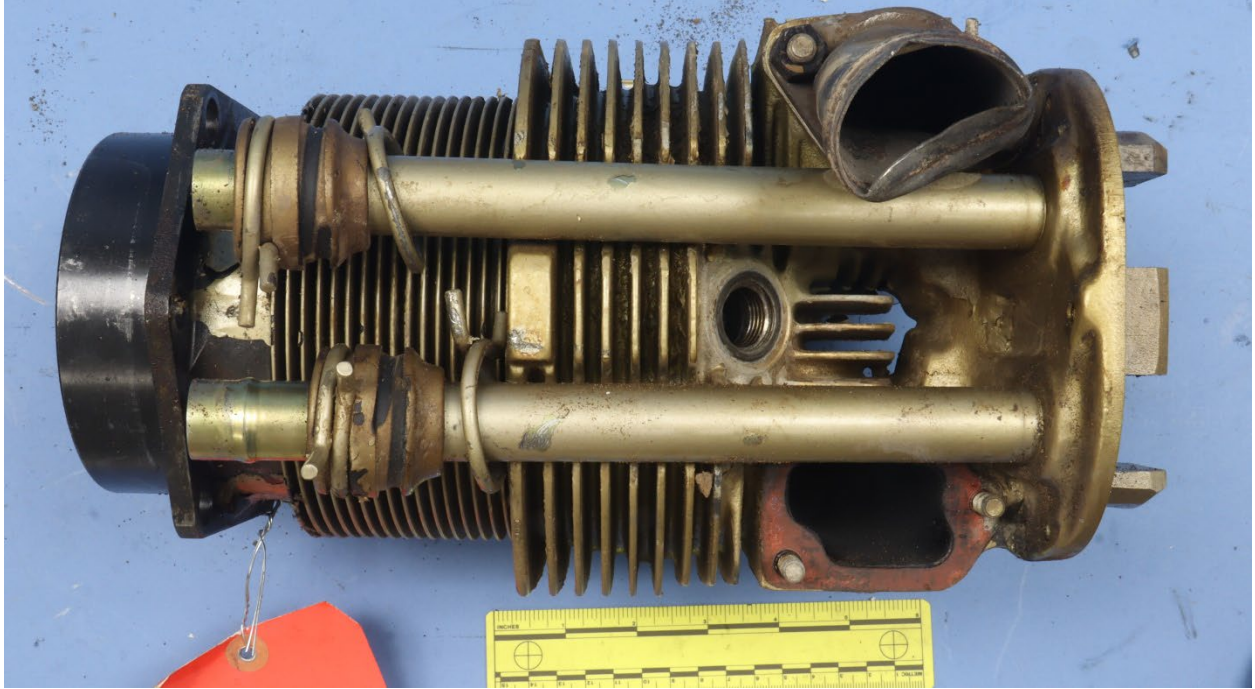


Figure 3. Side view of the #4 cylinder assembly, as received.

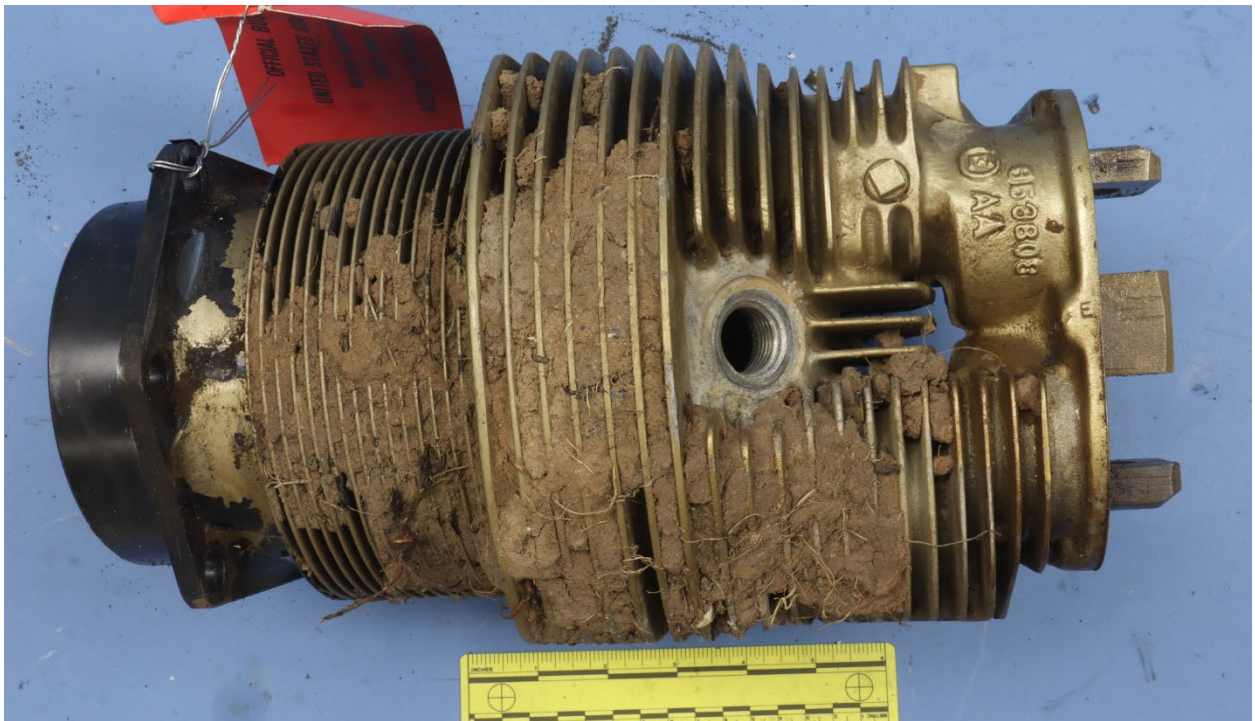


Figure 4. Opposite side view from **Figure 3** of the #4 cylinder assembly, showing caked soil between multiple cooling fins.

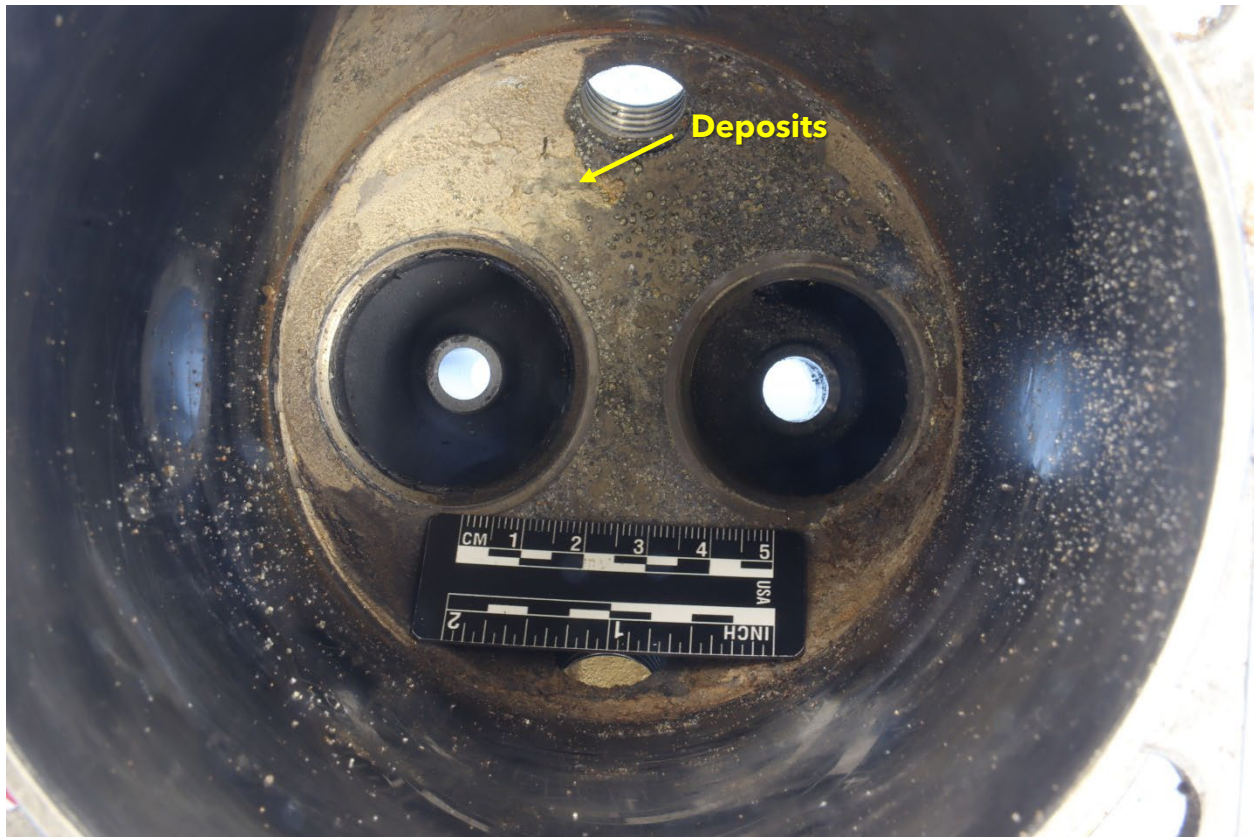


Figure 5. View of the interior of the cylinder, showing combustion deposits accumulating, particularly on the intake side (left).



Figure 6. The pushrods from the #4 cylinder, as received.



Figure 7. Components from the intake side of the #4 cylinder.



Figure 8. View of the contact surfaces of the rocker arm and intake valve stem.



Figure 9. Components from the exhaust side of the #4 cylinder.



Figure 10. View of the contact surfaces of the rocker arm and exhaust valve stem.



Figure 11. Side views of the stem near the head of the exhaust valve, rotated 90°.

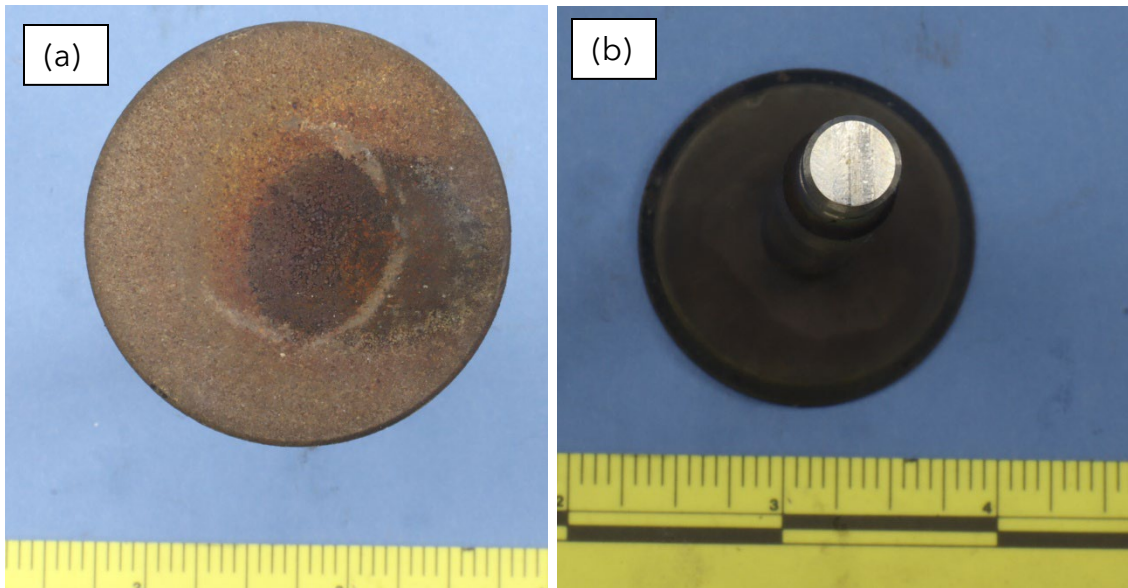


Figure 12. The exhaust valve (a) head and (b) stem tip, as received.

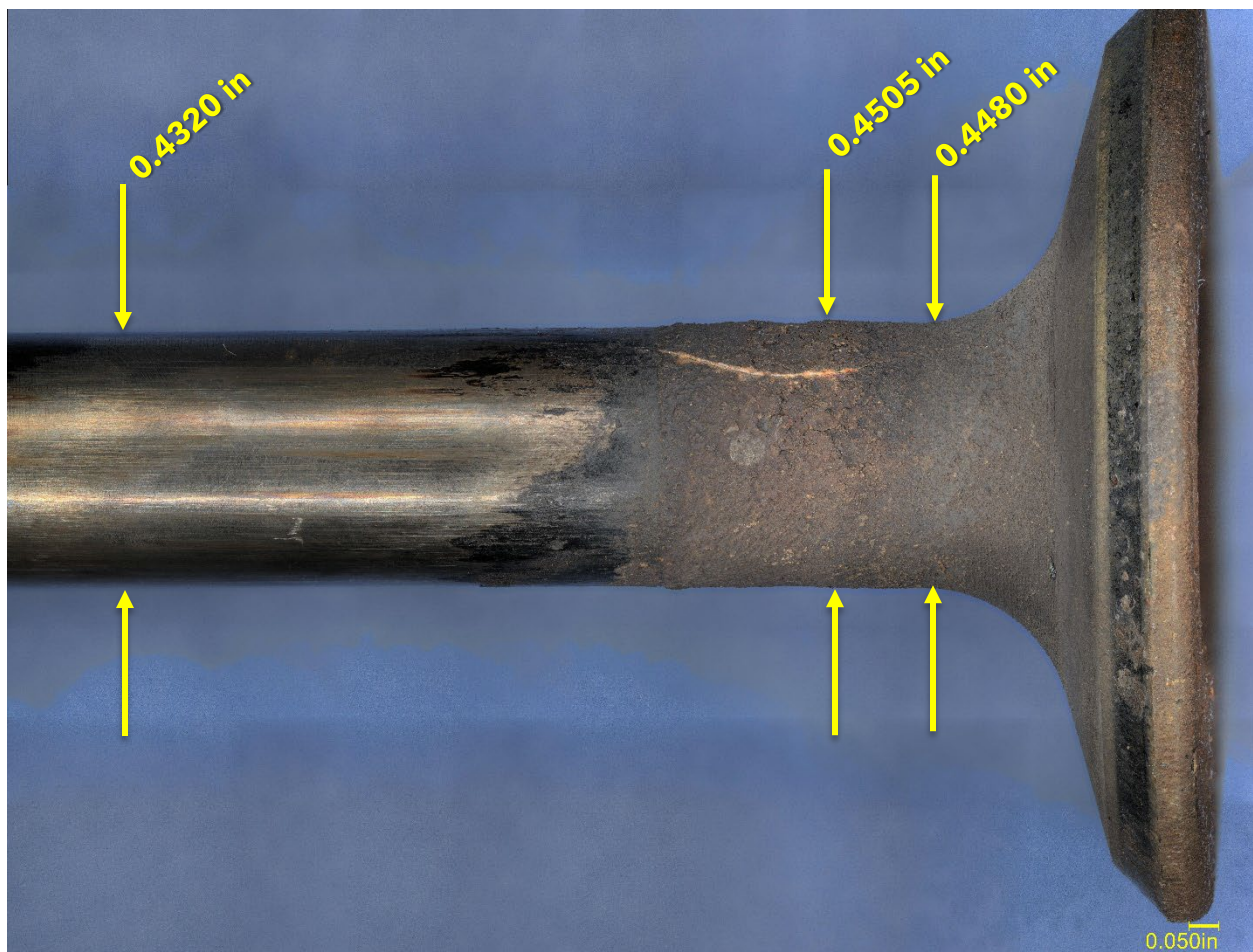


Figure 13. Closer view of buildup on the seat of the exhaust valve.



Figure 14. Closer view of the buildup on the stem in **Figure 13**.

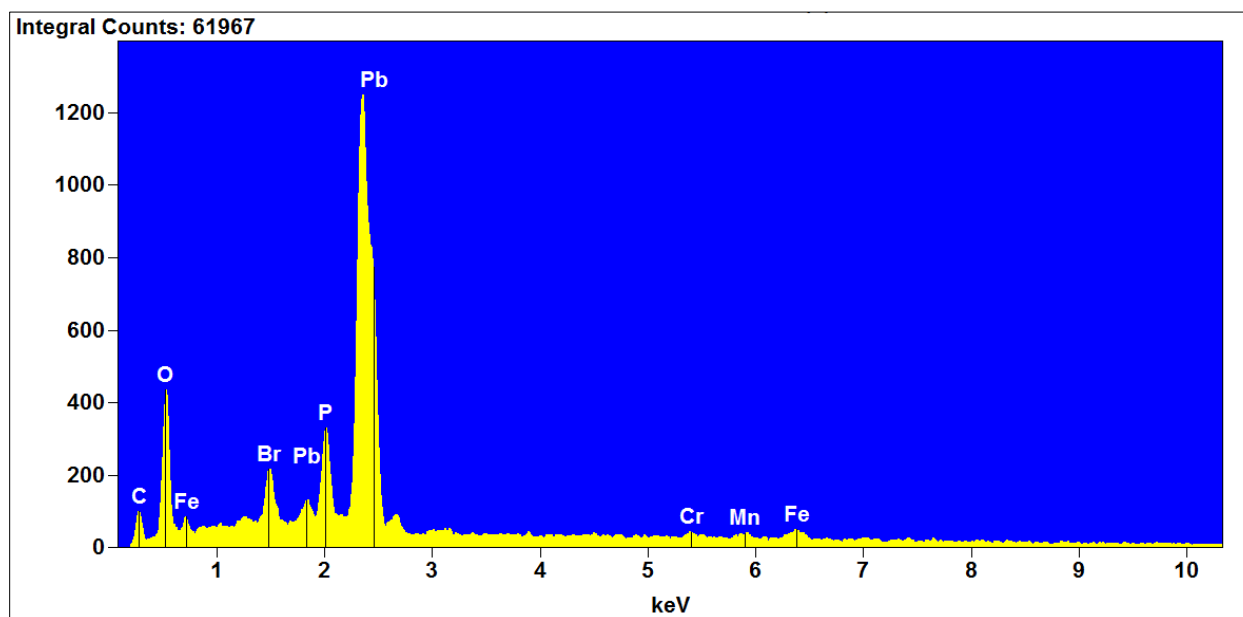


Figure 15. EDS spectrum from material extracted from the exhaust valve stem.



Figure 16. Side views of the stem near the head of the intake valve, rotated 90°.

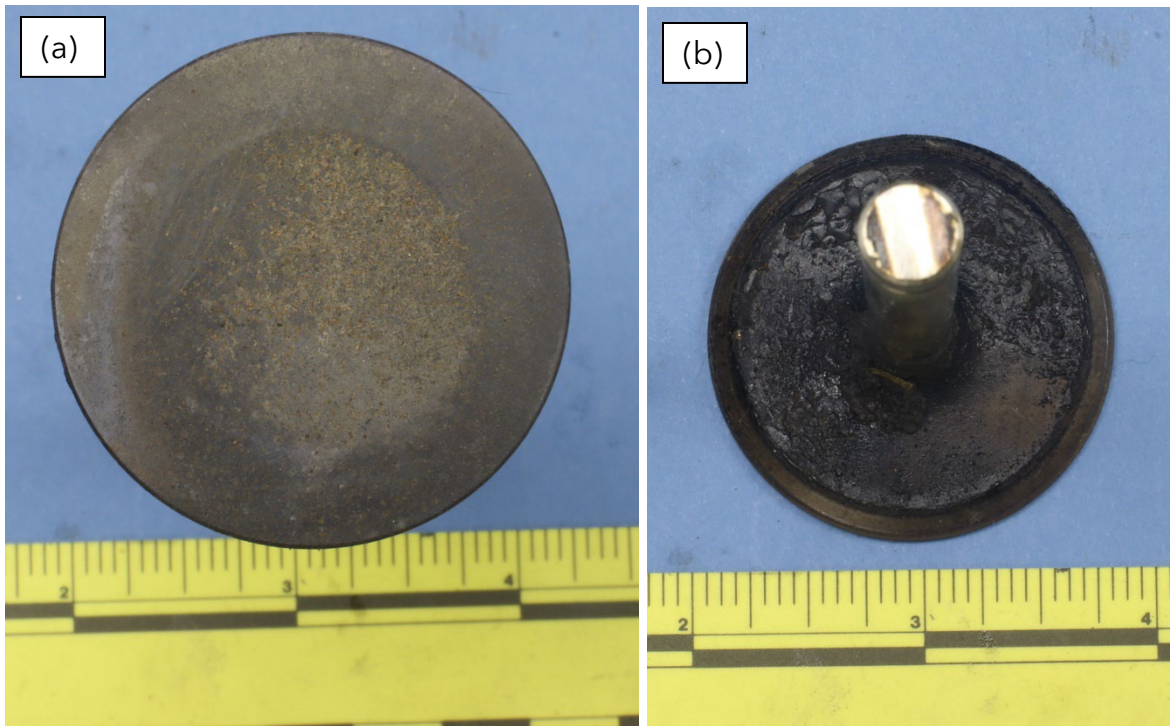


Figure 17. The intake valve (a) head and (b) stem tip, as received.

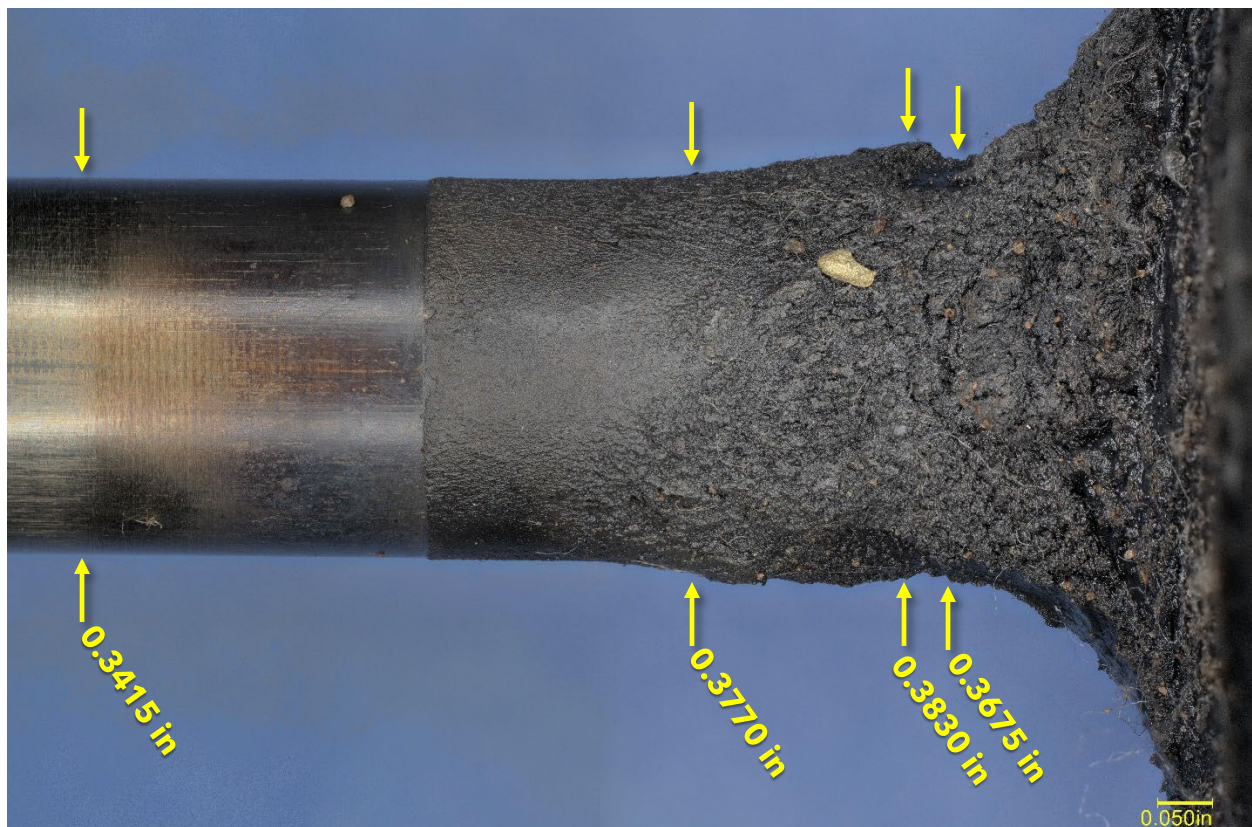


Figure 18. Closer view of buildup on the seat of the intake valve.



Figure 19. Closer view of the buildup on the stem in Figure 18.

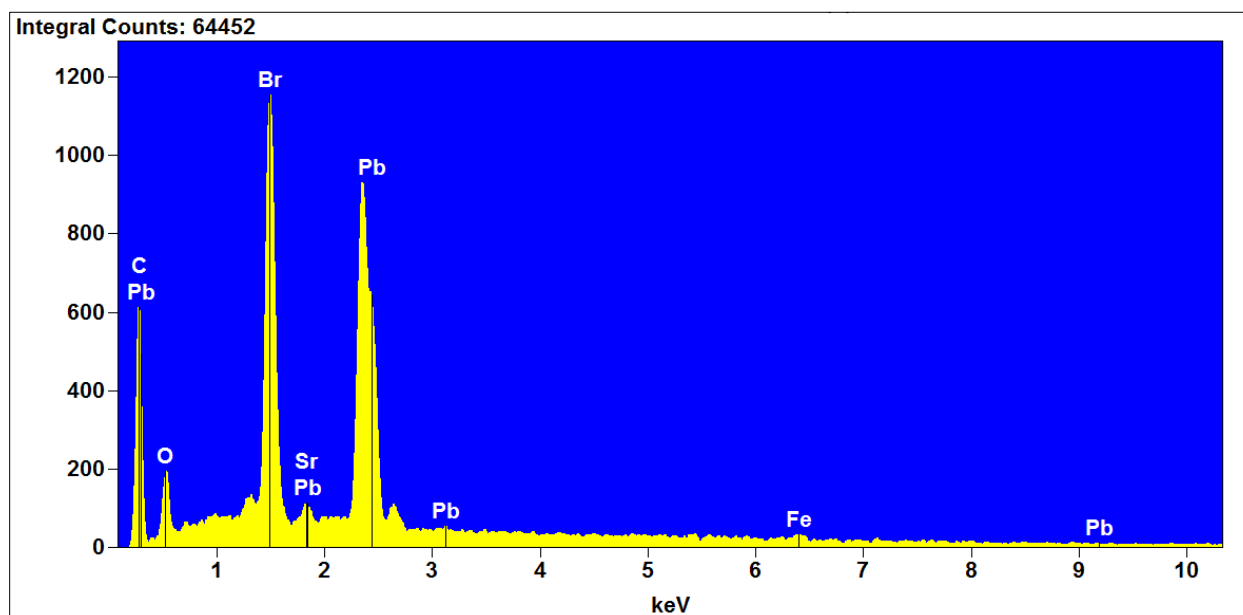


Figure 20. EDS spectrum from material extracted from the intake valve stem.