

NATIONAL TRANSPORTATION SAFETY BOARD

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



August 31, 2021

MATERIALS LABORATORY FACTUAL REPORT

Report No. 21-063

A. ACCIDENT INFORMATION

Place : San Diego, California
Date : December 13, 2020
Vehicle : Cessna 172N, N5098E
NTSB No. : WPR21LA069
Investigator : Eric Gutierrez, AS-WPR

B. COMPONENTS EXAMINED

Number 3 cylinder assembly with a broken exhaust rocker arm attachment stud, spark plugs, piston assembly, intake and exhaust valves with corresponding valve train components including rocker arms, valve springs, valve spring seats, push rods, and hydraulic lifters from a Lycoming O-320-H2AD engine.

C. DETAILS OF THE EXAMINATION

Overall views of the submitted components are shown in figures 1 and 2. The intake and exhaust valves, not visible in figure 1, were retained in the valve guides and were held in place for shipment with tape. The piston skirt had dark scoring damage on one side as shown in figure 1 consistent with piston skirt scuffing, and corresponding scoring damage was observed on the upper side of the piston barrel. The rocker attachment stud for the exhaust rocker arm was fractured, and the outboard end with the nut is shown in figure 2. The intake pushrod and corresponding shroud tube were bent, and the intake and exhaust hydraulic lifters were spalled.

A view of the cylinder interior is shown in figure 3, and views of the rocker box are shown in figure 4. The interior surface of the cylinder head was covered with mostly dark deposits, and the exhaust valve had an oxidation pattern with circular symmetry. Cracks were observed in the cylinder head at the lower spark plug port. Dark deposits consistent with coked oil were observed in the rocker box around the exhaust valve guide. The inboard end of the fractured exhaust rocker attachment stud was retained in the cylinder head, and the fracture surface is shown in the close view in figure 4. A portion of the fracture surface was in a flat plane with curving crack arrest lines, features consistent with fatigue. The fatigue features emanated from a broad origin area at the forward side of the stud as indicated in figure 4.

The mating side of the exhaust rocker arm attachment stud and attached nut (see figure 2) were submerged in a bath of acetone and cleaned using an ultrasonic cleaner.

An optical image of the cleaned fracture surface is shown in figure 5. Ratchet marks were observed on the forward side of the fracture surface consistent with multiple fatigue origins in the area indicated with a bracket in figure 5. The fatigue region extended across approximately 90 percent of the cross-sectional area to the boundary delineated with a dashed line in figure 5. An unlabeled arrow in figure 5 indicates the general direction of fatigue crack growth. The fracture surface of the cleaned stud was further examined using a scanning electron microscope (SEM), and the fatigue region showed features consistent with fatigue crack growth in steel (see figure 6).

Next, the stud was placed in a rubber-faced vice, and a wrench was used to remove the nut from the exhaust rocker arm attachment stud (the nut did not move by hand). Then two parallel transverse cuts were made through the stud piece using a water-cooled abrasive saw, and one of the surfaces was ground to a 600-grit finish. Hardness tests were then completed on the prepared transverse cross-section. The measured hardness (average of 5 indents) was 32 HRC (52.3 HR30N).

An oblique view of the cylinder rocker box at the exhaust valve guide is shown in figure 7 after the tape holding the valves in place was removed. Note remnants of tape adhesive are visible on the valve tip when photographed. Circumferential gouges were observed on the side of the exhaust valve near the valve tip corresponding to contact with the edge of the valve guide. Next, the tape residue was wiped from the intake and exhaust valve tips, and the valves were removed from the cylinder as shown in figure 8. Thick black deposits were observed on the back side of the intake valve head, and tan deposits were observed on the back side of the exhaust valve head. Further up the exhaust valve stem, raised black deposits were observed as indicated in figure 9. Multiple circumferential gouges on the side of the stem near the tip are also shown.

A close view of the hydraulic lifters is shown in figure 10. The camshaft contact faces were rough and pitted consistent with substantial spalling damage.

According to engine maintenance logs, the engine was last overhauled on January 23, 2015. The log entry for the overhaul indicated eight "16812 cam followers" were installed. At the last oil change approximately 1 month before the accident, the engine had 615.5 hours time in service since overhaul.

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

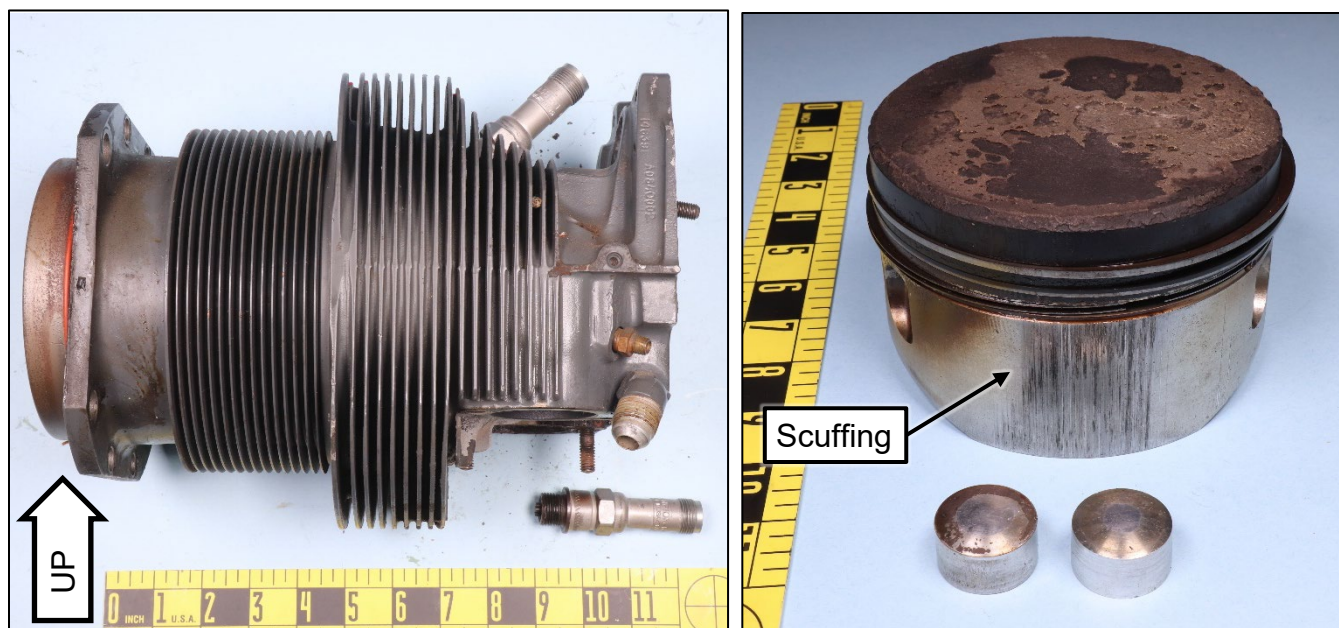


Figure 1. Overall views of the cylinder assembly with the disassembled lower spark plug (left) and the piston assembly with piston pin plugs (right) as received.

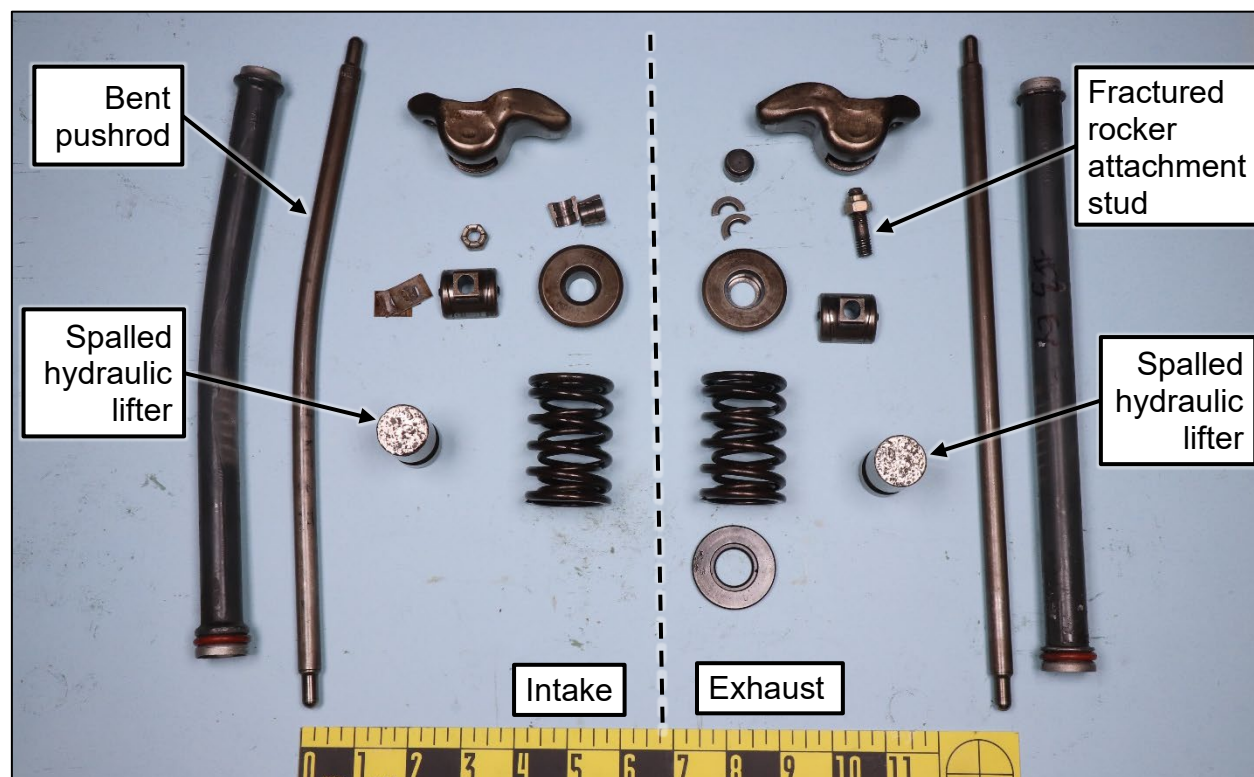


Figure 2. Overall view of the broken exhaust rocker attachment stud and disassembled valve train components as received.

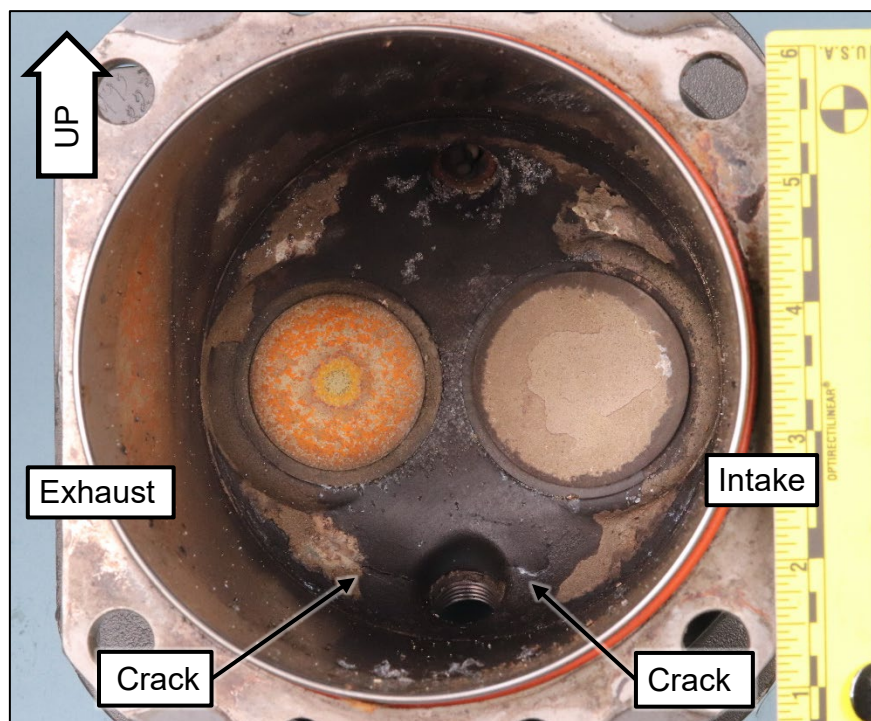


Figure 3. Interior of the cylinder.

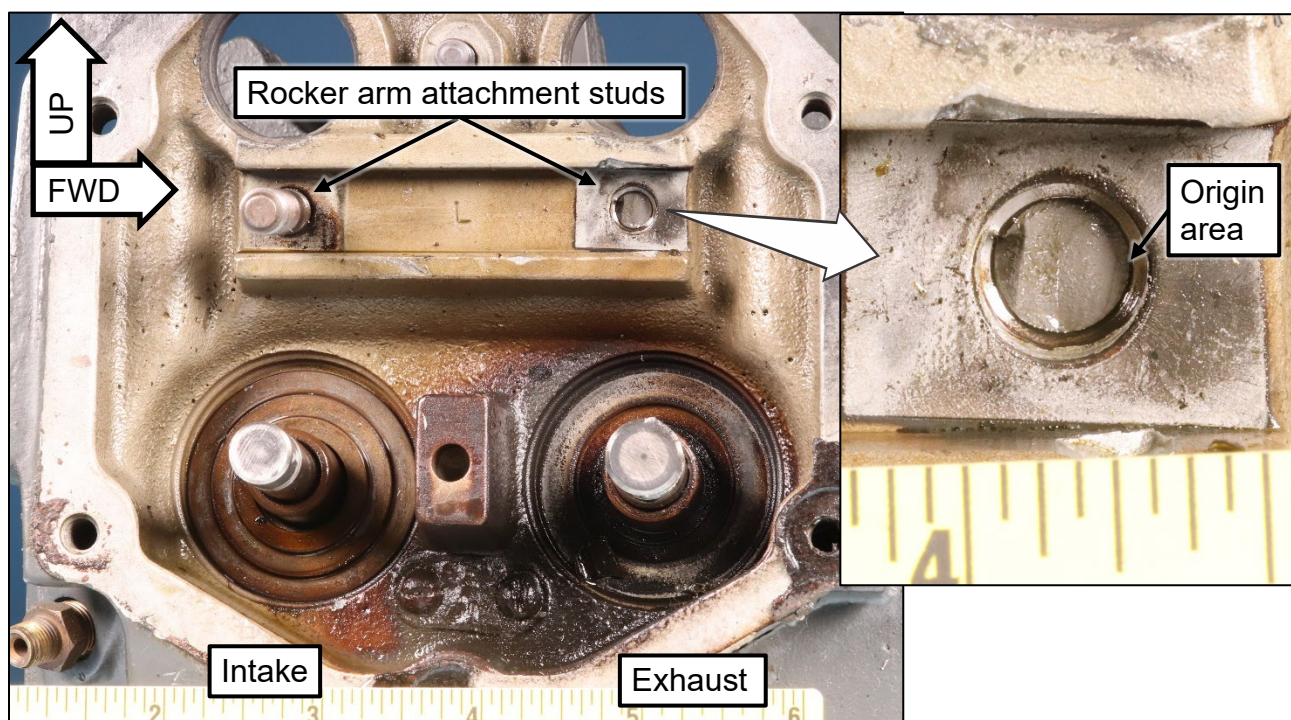


Figure 4. Overall view of the rocker box showing coked oil deposits around the exhaust valve and a closer view of the fractured exhaust rocker arm attachment stud.

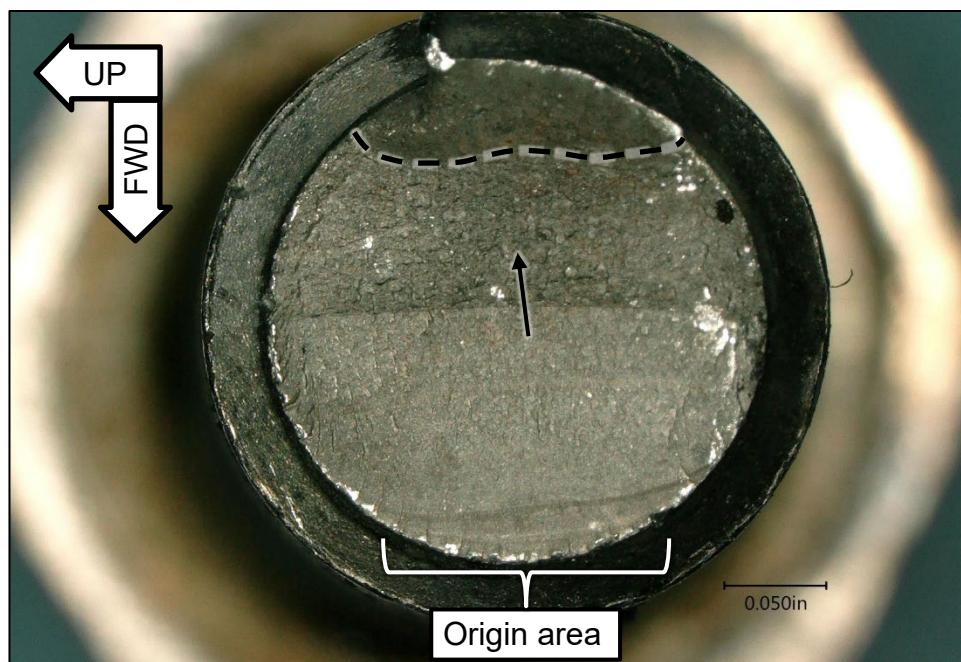


Figure 5. Optical image of the fracture surface on the exhaust rocker arm attachment stud piece shown in figure 2 after cleaning with an ultrasonic cleaner while submerged in acetone. An unlabeled arrow indicates the fatigue crack growth direction, and a dashed line indicates the fatigue boundary.

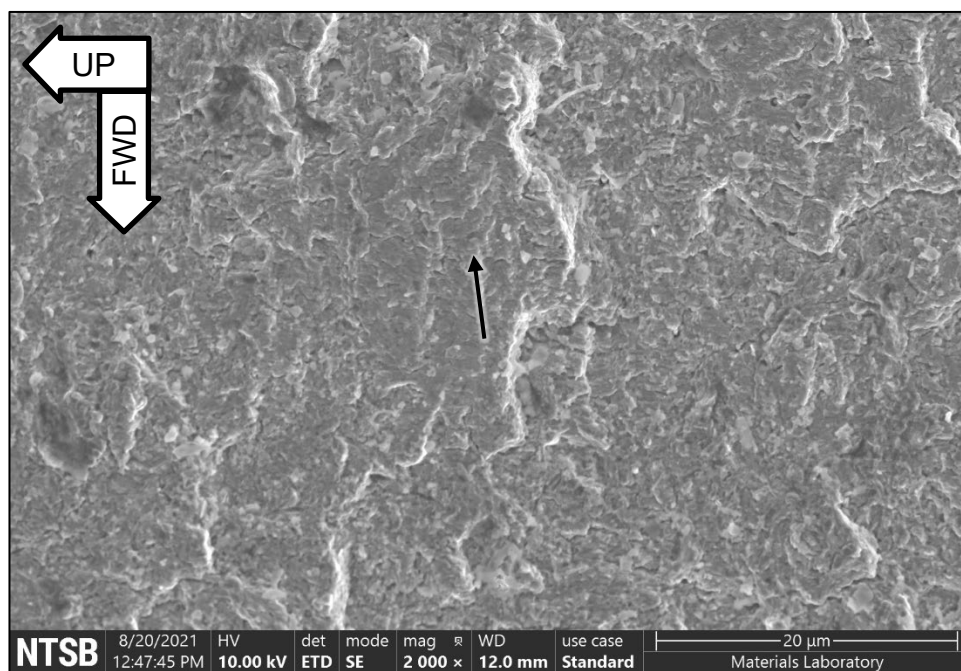


Figure 6. SEM image of fatigue features on the cleaned exhaust rocker attachment stud piece. An unlabeled arrow indicates the fatigue crack growth direction.

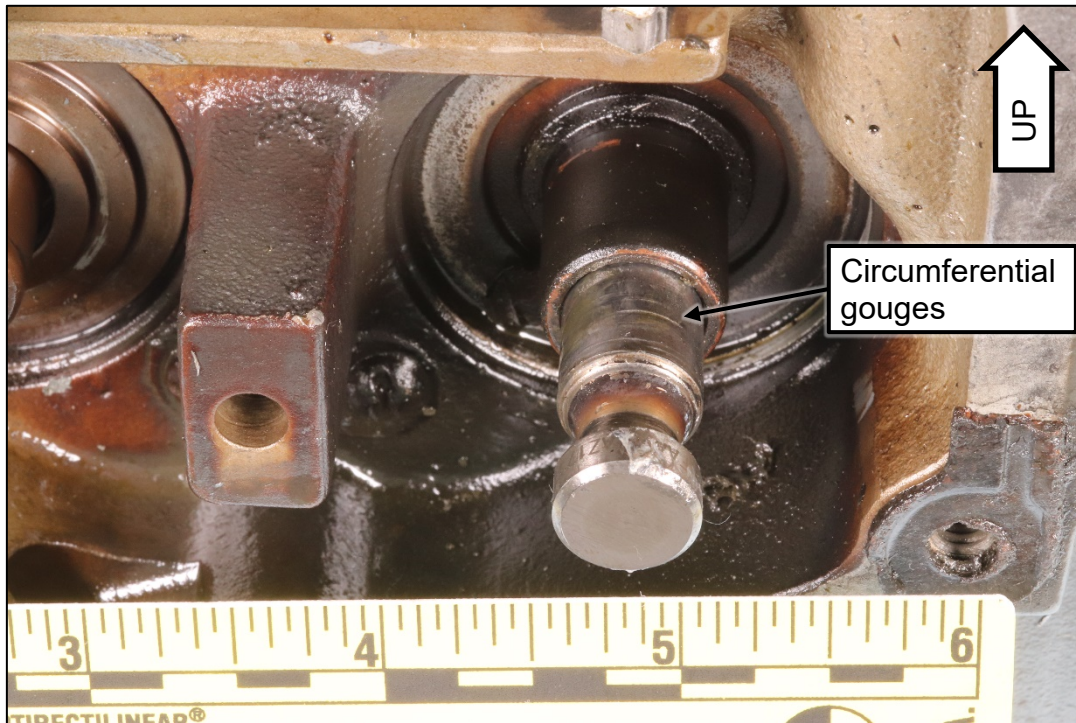


Figure 7. Exhaust valve tip before removal from the cylinder assembly.



Figure 8. Intake and exhaust valves after removal from the cylinder assembly.

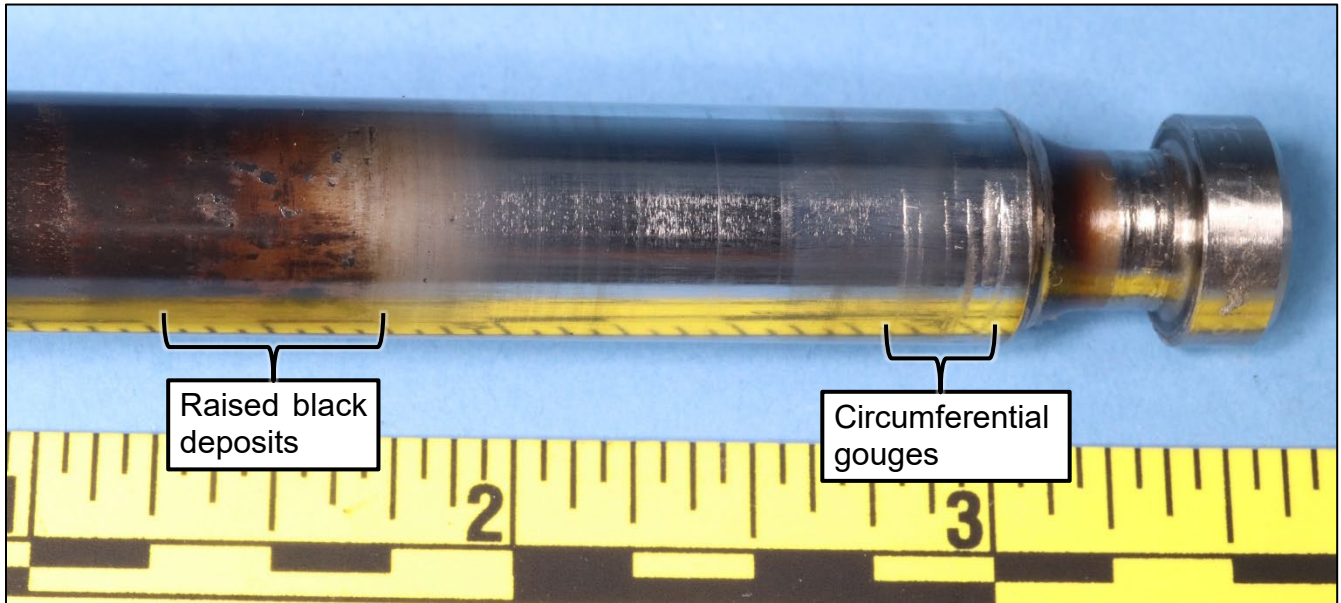


Figure 9. Close view of the exhaust valve stem.

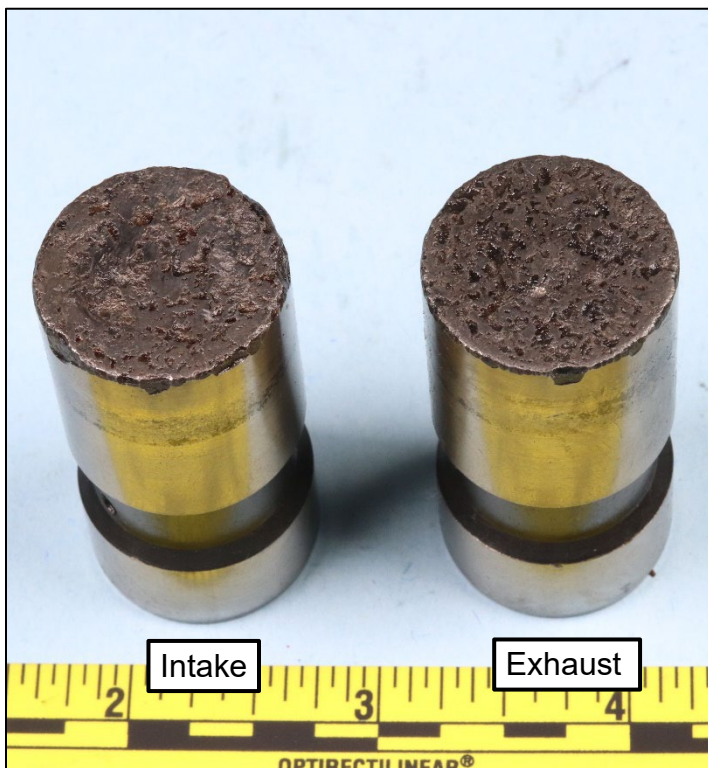


Figure 10. Spalled surfaces on the intake and exhaust hydraulic lifters.