

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



CEN24LA121

MATERIALS LABORATORY

Factual Report 24-086

December 17, 2024

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A. ACCIDENT INFORMATION

Location: Watertown, South Dakota
Date: February 25, 2024
Vehicle: Piper PA-28-181, N38696
Investigator: Andrew Finne, AS-CEN

B. COMPONENTS EXAMINED

Number 2 cylinder and piston assemblies with rocker arms, valves, valve springs and seats, valve keepers and tip cap, pushrods, and the exhaust lifter plunger assembly from a Lycoming O-360-A4M engine.

C. EXAMINATION PARTICIPANTS

Specialist Matthew R. Fox, Ph.D.
NTSB
Washington, DC

D. DETAILS OF THE EXAMINATION

An overall view of the submitted components from a Lycoming O-360-A4M engine installed on the accident airplane is shown as received in figure 1. The submitted components included the number 2 cylinder and piston assemblies and associated components from the intake and exhaust valve trains consisting of valves, valve springs and seats, keepers and tip cap, and the exhaust lifter plunger assembly. In figure 1, the exhaust components are shown at the left of the image, and the intake components are shown at the right.

According to engine maintenance records, the engine had been factory overhauled on March 3, 2023. At the time of the last oil and filter change, completed on February 23, 2024, the engine had 646.6 hours time in service since the overhaul.

A closer view of the piston assembly is shown in figure 2. Relatively thick tan deposits covered most of the piston crown. Scuffing marks were observed at the outside edge between the piston crown and the outboard oil ring.

The interior of the cylinder assembly is shown in figure 3. Tan deposits were observed on the cylinder dome surfaces mostly around the outside diameter. Relatively thicker tan deposits were also observed in the exhaust port shown in the right image in figure 3.

Dark deposits were observed on the interior surface of the exhaust valve guide as shown in figure 4. The deposits remained in place after a paper shop towel was

fed through the valve guide to remove any loose debris that might have been present.

Views of the intake valve are shown in figure 5. Gray and black deposits with varying thicknesses were observed on the stem side of the valve head. On the intake valve tip face, a rectangular rocker contact patch was observed as shown in the right image in figure 5, a contact pattern consistent with a valve that was not rotating.

According to the examination summary from the engine examination conducted after the accident, the number 2 cylinder exhaust valve was found stuck in a partially open position and had been removed from the cylinder assembly with the use of penetrating oil and a mallet. The exhaust valve is shown as received for examination in figure 6. The neck area and adjacent surfaces on the head were covered with reddish brown deposits. Gray-colored raised deposits were observed on the side of the stem as shown in the right image in figure 6.

Samples of deposits on the intake and exhaust valves were collected for analysis using energy dispersive x-ray spectroscopy (EDS). A scalpel was used to collect a piece of the gray and black deposit from the intake valve head surface next to the neck, and the sample was transferred to a carbon tape-coated aluminum stub. A sample of the reddish-brown deposits on the neck area of the exhaust valve was also collected and transferred to a similarly prepared aluminum stub. The resulting typical EDS spectra for the two samples exposed to a 20 kV electron beam are shown in figure 7. The sample from the intake valve showed high peaks of lead and carbon with an overlapping high peak of bromine and aluminum. The sample from the exhaust valve showed a high peak of lead with relatively smaller peaks of bromine and carbon.

The inside diameters of the valve guides were measured using a T-gauge and micrometer, and the micrometer was also used to measure the outside diameters of the valve stems. The intake valve stem outside diameter measured 0.4026 inch at the inboard and outboard ends of the stem. The exhaust valve stem outside diameter measured 0.4939 inch at the outboard end and 0.4937 inch at the inboard end. Results of the valve guide measurements and associated clearance between the valve guide and the valve stem are listed in table 1. For each guide, the inside diameter was measured parallel and perpendicular to the rocker arm spine at 3 locations along the length of the guide for a total of 6 measurements as listed in table 1.

Manufacturing and service limits for the valve guides, valve stems, and clearances for the engine are listed in the Lycoming *Service Table of Limits and Torque Value Recommendations*, SSP-1776-5.¹ According to service limits for the accident engine as listed in Lycoming SSP-1776-5, the intake valve stem-to-guide

¹ SSP-1776-5, *Service Table of Limits and Torque Value Recommendations*, Lycoming Engines, Williamsport, Pennsylvania (2020).

clearance should have a maximum value of 0.006 inch, and the exhaust valve stem-to-guide clearance should be between 0.0040 inch and 0.0060 inch. All intake stem-to-guide clearance values for the examined cylinder (fifth column in table 1) conformed to the limit as listed in Lycoming SSP-1776-5. On the exhaust side (last column in table 1), stem-to-guide clearances at the outboard end of the guide conformed to the specified service limits, but the exhaust stem-to-guide clearances measured at the middle and inboard ends of the guide, highlighted in red text, were less than specified. While each outside diameter measurement for the exhaust valve stem and the two inside diameter measurements at the outboard end of the exhaust valve guide were within the as-manufactured allowable limits, the four inside diameter measurements of the valve guide at the middle and inboard end were less 0.4985 inch, which is the as-manufactured minimum value for the exhaust valve guide listed in SSP-1776-5.

Submitted by:

Matthew R. Fox, Ph.D.
Chief Technical Advisor, Materials Laboratory

Table 1. Valve Guide Inside Diameter and Guide-to-Stem Clearance Measurements

Lengthwise Position	Orientation to Rocker Arm Spine	Intake Inside Diameter (inch)	Exhaust Inside Diameter (inch)	Intake Clearance (inch)	Exhaust Clearance (inch)
Outboard	Perpendicular	0.4037	0.4991	0.0011	0.0052
Outboard	Parallel	0.4040	0.4986	0.0014	0.0047
Middle	Perpendicular	0.4034	0.4947	0.0008	0.0009
Middle	Parallel	0.4041	0.4945	0.0015	0.0007
Inboard	Perpendicular	0.4040	0.4966	0.0014	0.0029
Inboard	Parallel	0.4041	0.4948	0.0015	0.0011



Figure 1. Overall view of the submitted components associated with the number 2 cylinder.

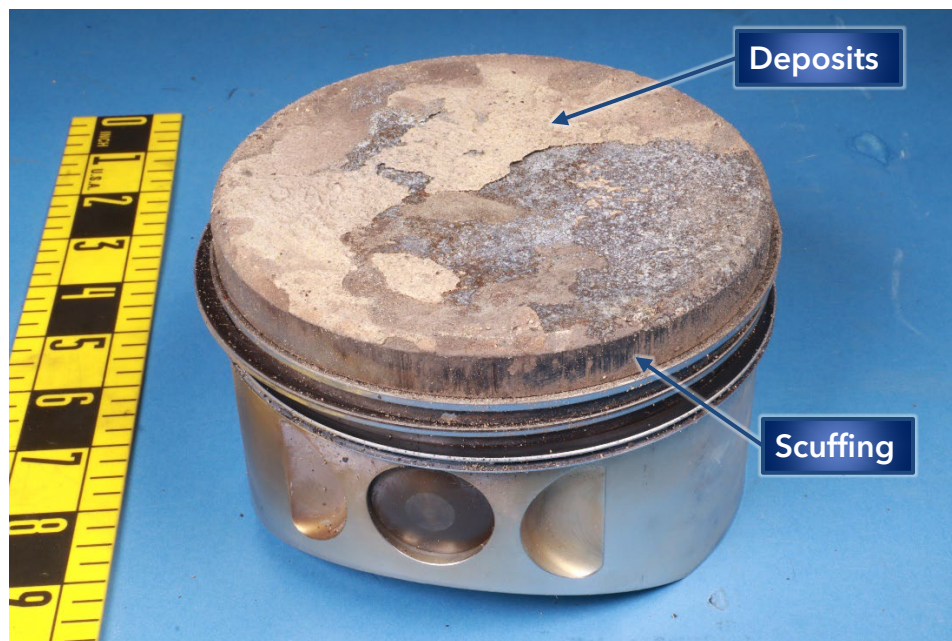


Figure 2. Piston assembly showing tan deposits on the crown and scuffing at the outside edge between the crown and the outboard oil ring.

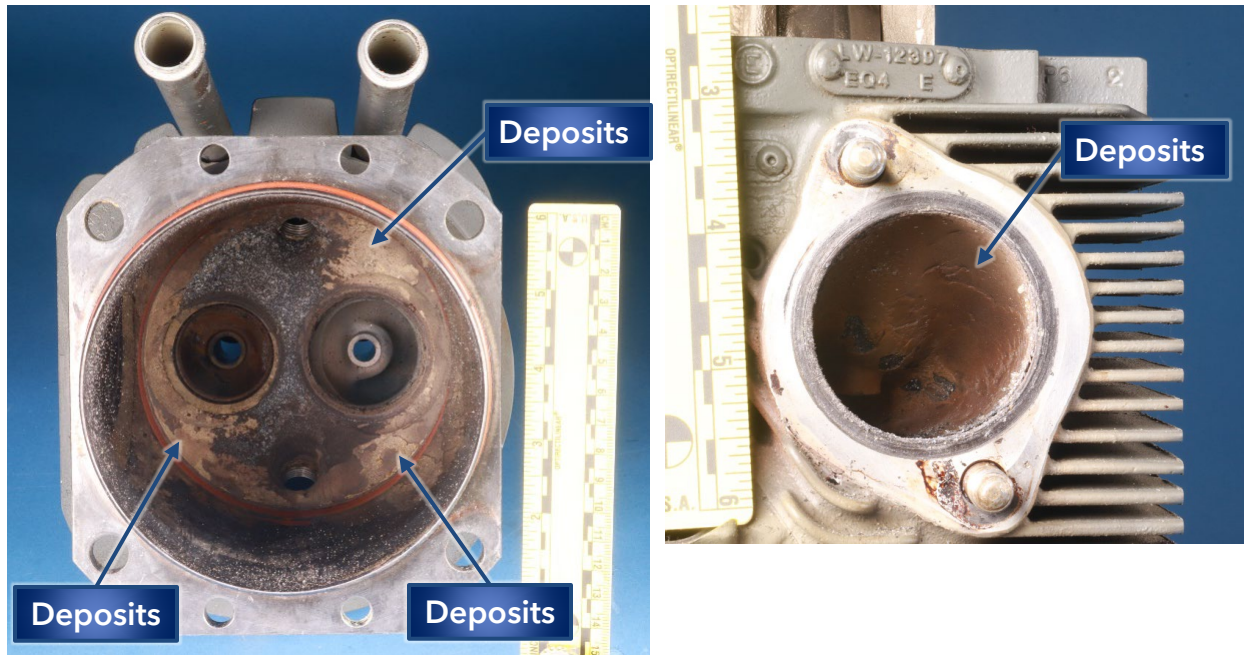


Figure 3. Views of the cylinder interior (left image) and exhaust port (right image) showing tan deposits on the dome surface and thicker tan deposits in the exhaust port.

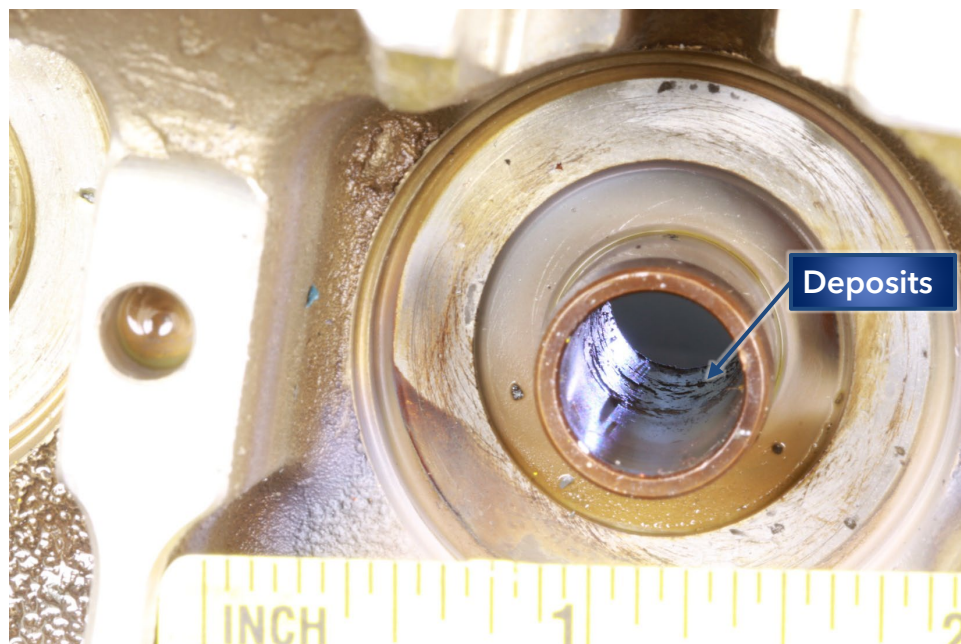


Figure 4. Exhaust valve guide showing deposits on the interior surface in the inboard half of the guide.

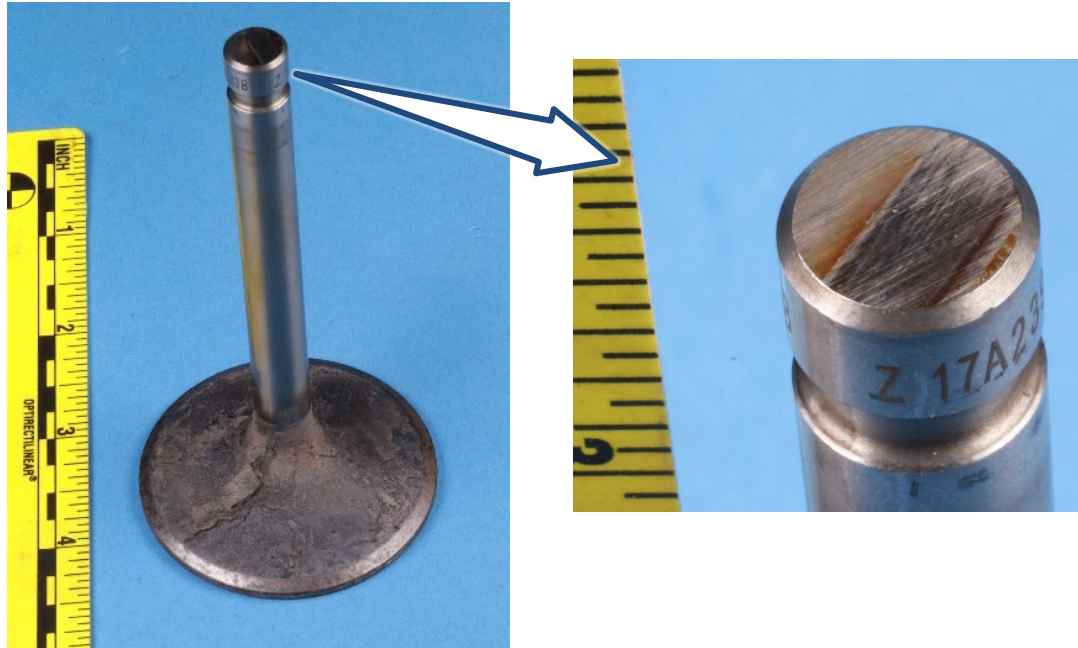


Figure 5. Intake valve showing black and gray deposits on the stem side of the head (left image) and a closer view of the rocker contact pattern on the tip face (right image).



Figure 6. Exhaust valve showing raised deposits of smeared gray material (circled area) on the stem.

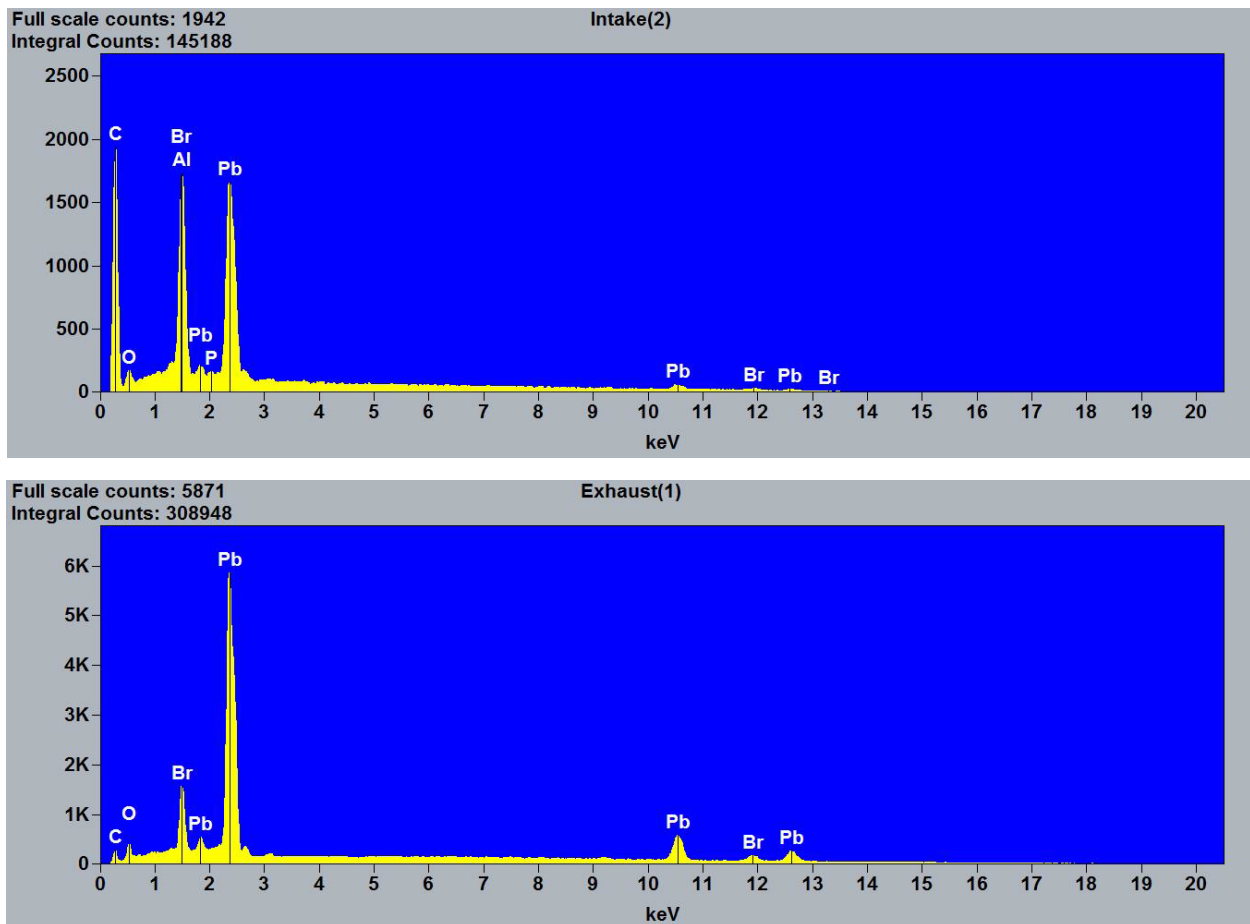


Figure 7. EDS spectra of deposits collected from the stem side of the intake valve head (upper spectrum) and from the neck area on the exhaust valve (lower spectrum).