

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



CEN24LA011

MATERIALS LABORATORY

Factual Report 24-038

July 5, 2024

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A. ACCIDENT INFORMATION

Location: Red Oak, Iowa
Date: October 15, 2023
Vehicle: Cirrus SR22T, N6JA
Investigator: Andrew Finne, ASI-CEN

B. COMPONENTS EXAMINED

Components from a Continental Motor TSIO-550-K1B engine; Time since last inspection: 161 h; Time since overhaul: 1860 h.
Number 4 exhaust valve - fractured; P/N: 655771 E.
Number 6 exhaust valve; P/N: 655771 E.
Numbers 4 and 6 cylinder assemblies (multiple pieces); P/N: 658178 A.

C. EXAMINATION PARTICIPANTS

Specialist Donald Kramer, Ph.D.
National Transportation Safety Board
Washington, DC

D. DETAILS OF THE EXAMINATION

The numbers 4 and 6 cylinder assemblies from a Continental Motors TSIO-550-K1B aircraft engine were submitted to the NTSB Materials Laboratory for examination, as shown in figures 1a and 1b. The exhaust valves had been removed from the cylinders and the intake and exhaust valve train components up to but not including the tappets were also included. The number 4 exhaust valve head was fractured, and the number 6 exhaust valve had an asymmetric color pattern on its combustion face. The valve train components were examined and contained no notable features unless noted otherwise.

1.0 Number 4 exhaust valve

The number 4 exhaust valve head was fractured (figure 2a). The combustion face was covered with combustion products and some regions exhibited a red/purple tint (figure 2b). The fracture had initiated in the fillet on the downstream-facing side of the valve head and progressed through the head to the combustion face (figure 3a). The fracture was approximately 1.5 inch wide by 0.25 inch through the thickness of the head. Closer examination revealed a thumbnail-shaped fatigue crack at the origin that was 0.212 inch wide and 0.054 inch deep (figure 3b). The origin sustained some post-fracture impact damage, but there were no apparent pre-existing anomalies at the crack origin. The valve head's seat face was worn (figure 3a) and the valve head was dished/mushroomed. The valve stem displayed a buildup of combustion products below the region that engaged the valve guide (figure 4).

Combustion products were also observed on the inner surface of the valve guide (figures 5a - c).

The number 4 exhaust rotocoil was worn. The rotocoil (figure 6a) was disassembled using a rotary cutting tool and the top and bottom halves were separated (figure 6b). The lower half contained a flat washer that served as a flat race for the spring to ride against. The race was covered in cooked oil except for a 0.080-inch wide annular track that the spring contacted (figure 6c). The spring was worn flat on the side that contacted the washer (figure 6d).

2.0 Number 6 exhaust valve

The number 6 exhaust valve is shown in figure 7a. The valve head combustion face exhibited an asymmetric burn pattern (figure 7b). As shown in the figure, the 12 and 6 o'clock positions had a slight green tint while the center, 9 o'clock, and 3 o'clock positions had a red color. The combustion face was covered with exhaust deposits except at the 12 o'clock position. At the same clock position, the valve head's margin showed signs of incipient erosion (figure 7c). Just as with the number 4 exhaust valve, the valve head's seat face was worn (figure 7c) and the head was dished/mushroomed (figure 7d). The valve stem displayed a buildup of combustion products below the region that engaged the valve guide (figure 8). Combustion products were also observed on the inner surface of the valve guide (figures 9a - c).

The number 6 exhaust rotocoil was worn, similar to the number 4 rotocoil. The rotocoil was disassembled using the same method (figure 10a). The spring exhibited a similar wear pattern as with the number 4 rotocoil. The flat race also exhibited an annular track but, in contrast with the number 4 rotocoil, impressions of the spring were visible in portions of the track (figure 10b).

3.0 Exhaust valve and exhaust valve guide measurements

Exhaust valve stem diameters and valve-in-guide diametrical clearances were measured for the numbers 4 and 6 exhaust valves and compared to the service limits listed in section 10-8.4.1 of Publication M-18: Continental Aircraft Engine - Permold Series Engine Maintenance and Overhaul Manual for TSIO-550 engines. The stem diameters were measured using a micrometer starting 1.5 inch above the valve head and continuing toward the stem tip in 0.5-inch increments. Valve guide inner diameters were measured at the lower opening (exhaust manifold-adjacent), middle, and upper opening (rocker box adjacent) using a split ball gage and micrometer. The gage was rotated in the guide to find the largest diameter. The measurements are shown in tables 1 and 2 for the valve stems and valve guides, respectively.

Table 1. Exhaust valve stem diameters for numbers 4 and 6 cylinder assemblies. The minimum service limit according to the Maintenance and Overhaul Manual is 0.433 inch.

Distance above valve head, inch	Number 4 diameter, inch	Number 6 diameter, inch
1.5	0.4329	0.4325
2.0	0.4305	0.4281
2.5	0.4325	0.4320
3.0	0.4327	0.4327
3.5	0.4334	0.4334
4.0	0.4341	0.4338

Table 2. Valve guide inner diameters for numbers 4 and 6 cylinder assemblies.

Valve guide location	Number 4 inner diameter, inch	Number 6 inner diameter, inch
Middle	0.4494	0.4471
Upper opening	0.4382	0.4377

Neither valve met the minimum service limits for stem diameter or diametrical clearance. The stem diameters on both exhaust valves were below the minimum service limit of 0.4330 inch between 1.5 inch and 3.0 inch above the valve head. The valve-in-guide diametrical clearance for the number 4 exhaust valve ranged from a high of 0.0189 inch in the middle third to a low of 0.0041 inch at the upper opening. For the number 6 exhaust valve, the values for the same locations ranged from 0.0190 inch to 0.0039 inch. The valve-in-guide service limit was 0.0062 inch.

Submitted by:

Donald Kramer, Ph.D.
Sr. Materials Engineer



Figure 1. Exhaust valves and cylinder assemblies with intake and exhaust valve train components: a) number 4 and b) number 6.



Figure 2. Number 4 exhaust valve: a) stem and fractured valve head and



Figure 2 (cont.). b) Image of combustion face.

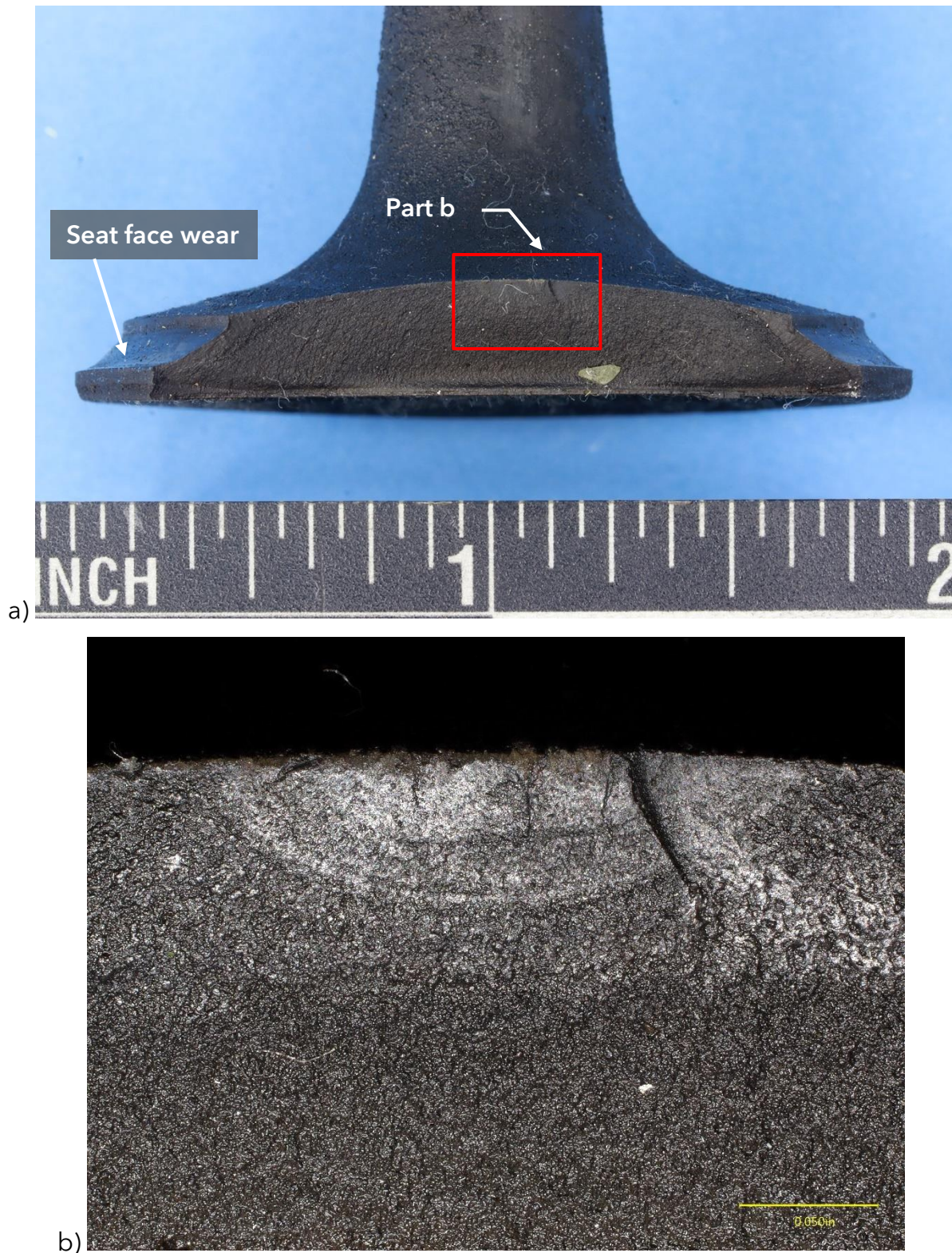
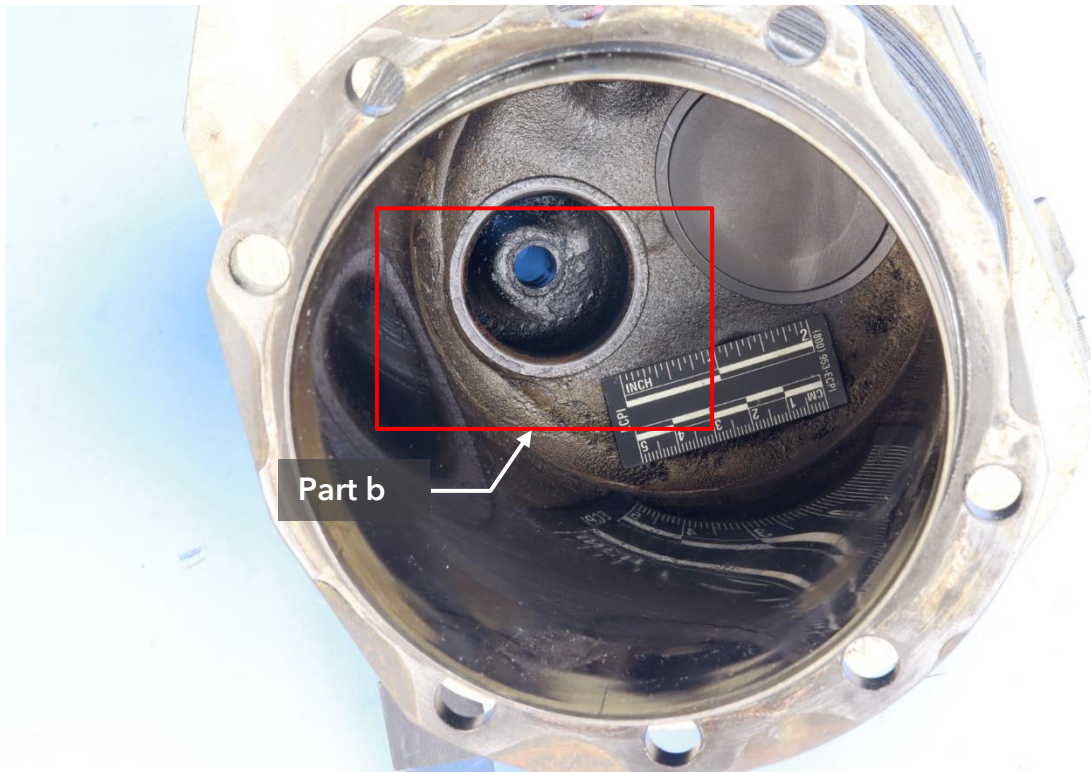


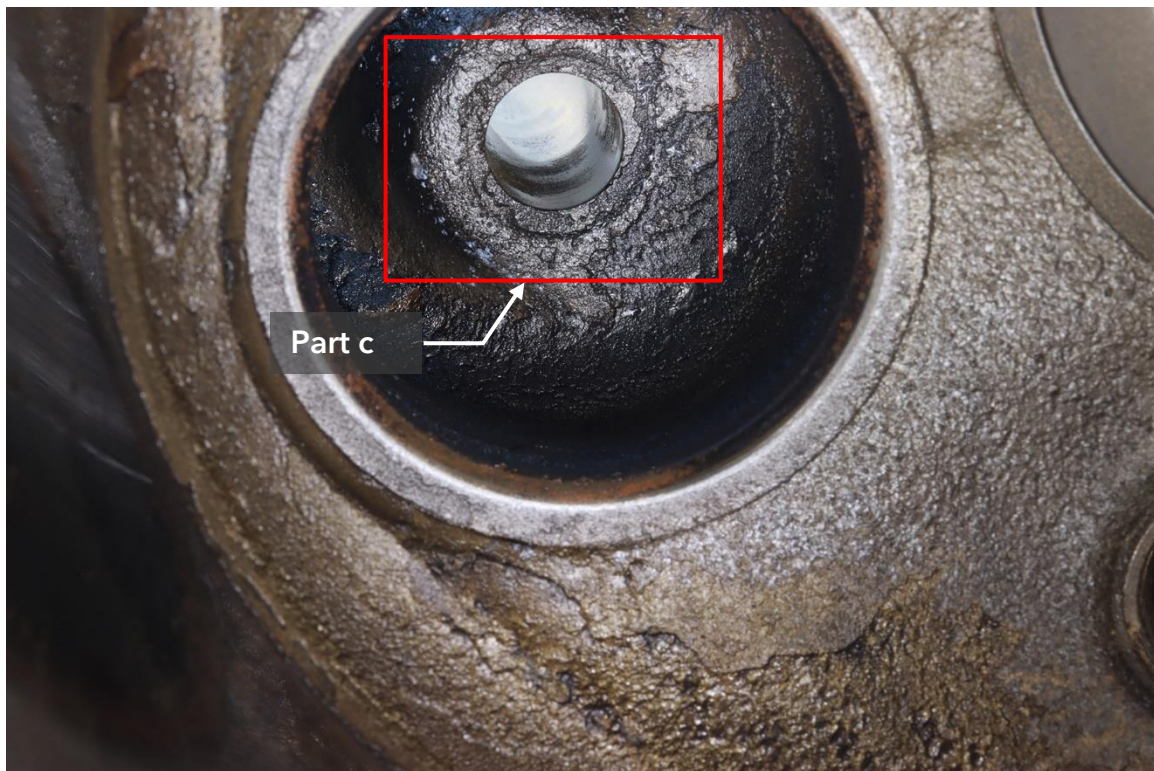
Figure 3. Images of number 4 valve fracture: a) fractured valve head with origin on fillet-side of head and valve seat wear and b) thumbnail-shaped fatigue crack near the transition radius between the stem and the head. The crack was 0.212 inch wide and 0.054 inch deep.



Figure 4. Buildup of combustion products on the number 4 exhaust valve stem outside the area that engaged the valve guide.



a)



b)

Figure 5. Number 4 cylinder combustion chamber showing condition of valve guide: a) image of chamber with region indicated for part b; b) closer image of valve seat and valve guide with region indicated for part c; and

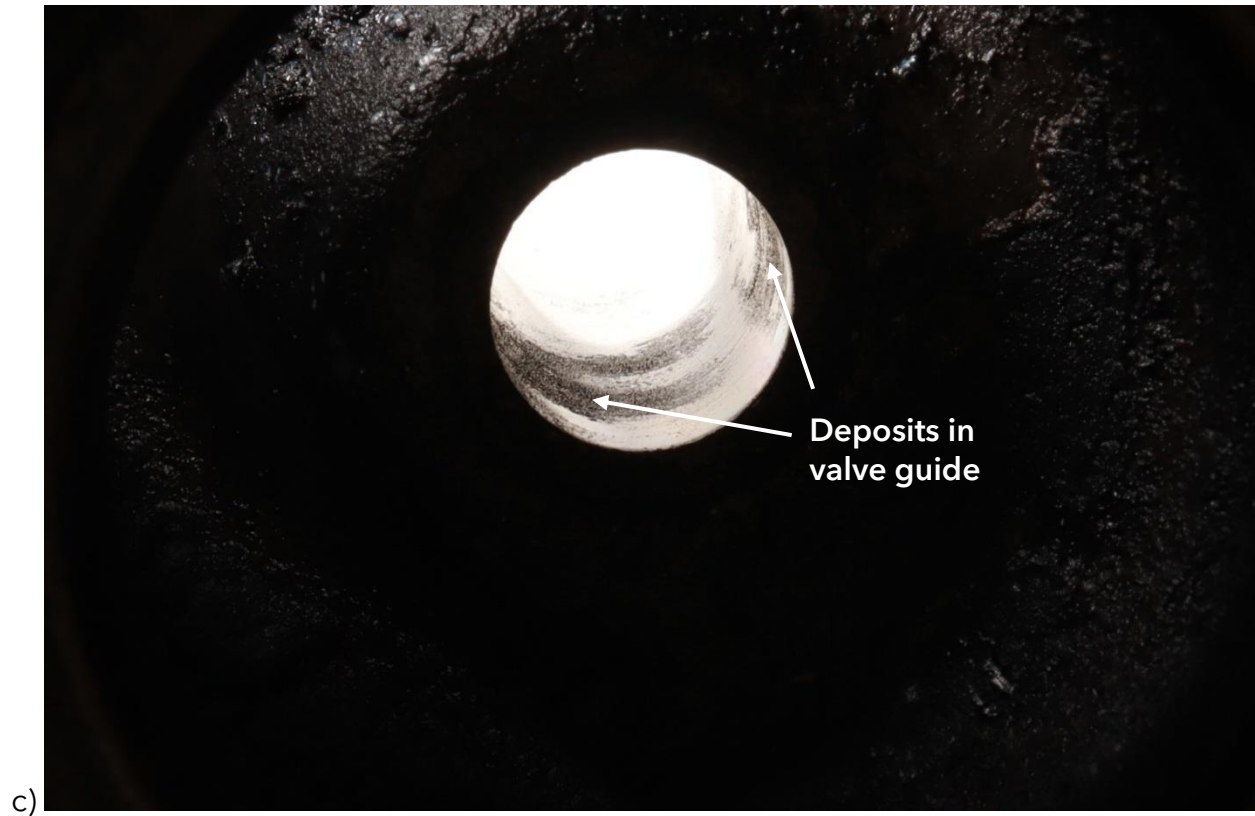


Figure 5 (cont.). c) backlit image of exhaust valve guide. Arrows indicate the locations of deposits on the barrel of the guide.



Figure 6. Number 4 exhaust valve rotocoil: a) As received before disassembly; b) post disassembly;

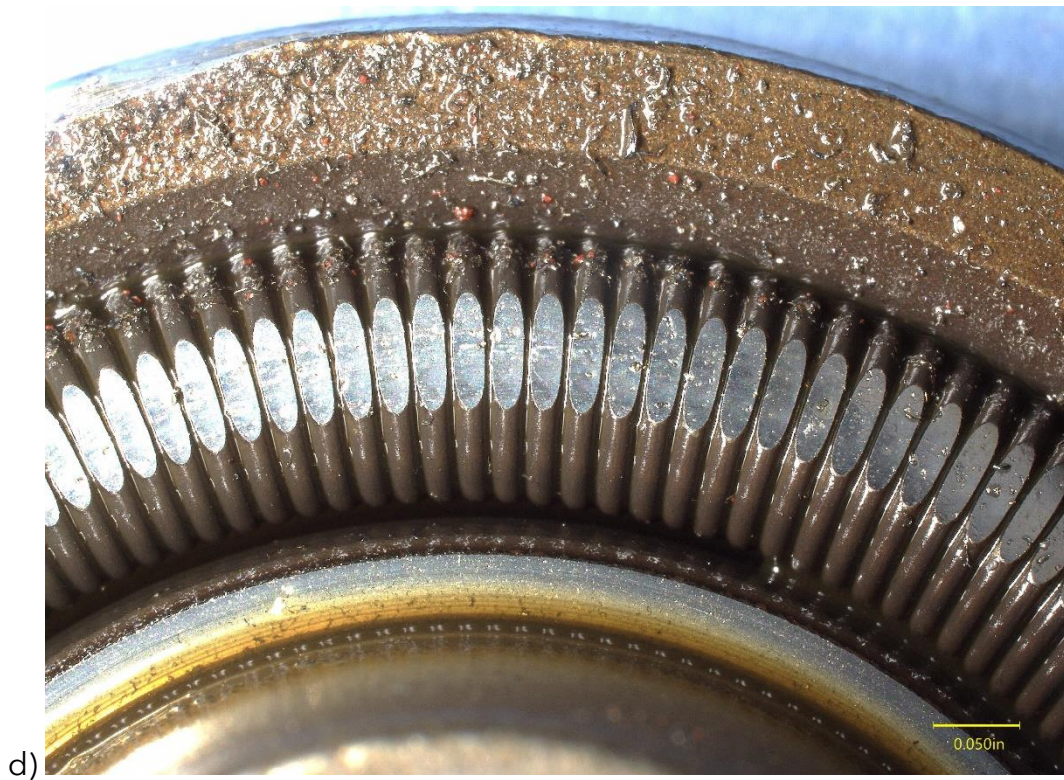


Figure 6 (cont.). c) spring washer showing the spring's flat race; and d) spring sitting in annular channel showing wear of the spring surface that was in contact with the flat washer.



Figure 7. Images of number 6 exhaust valve: a) overall image;

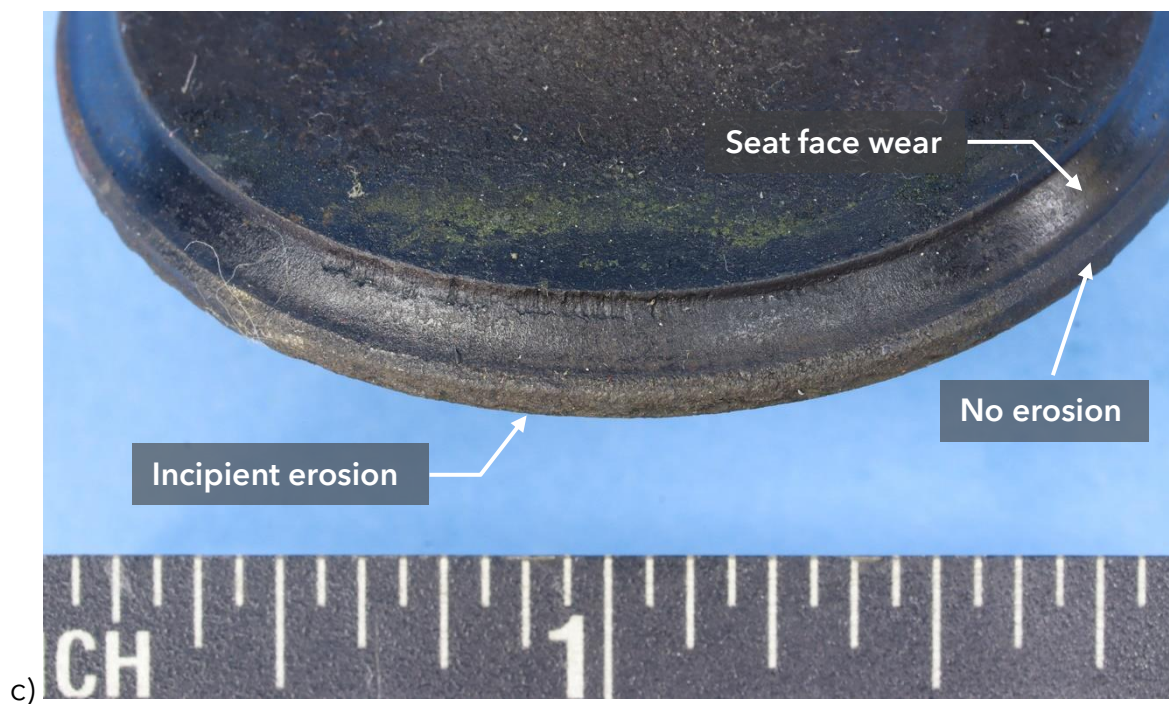
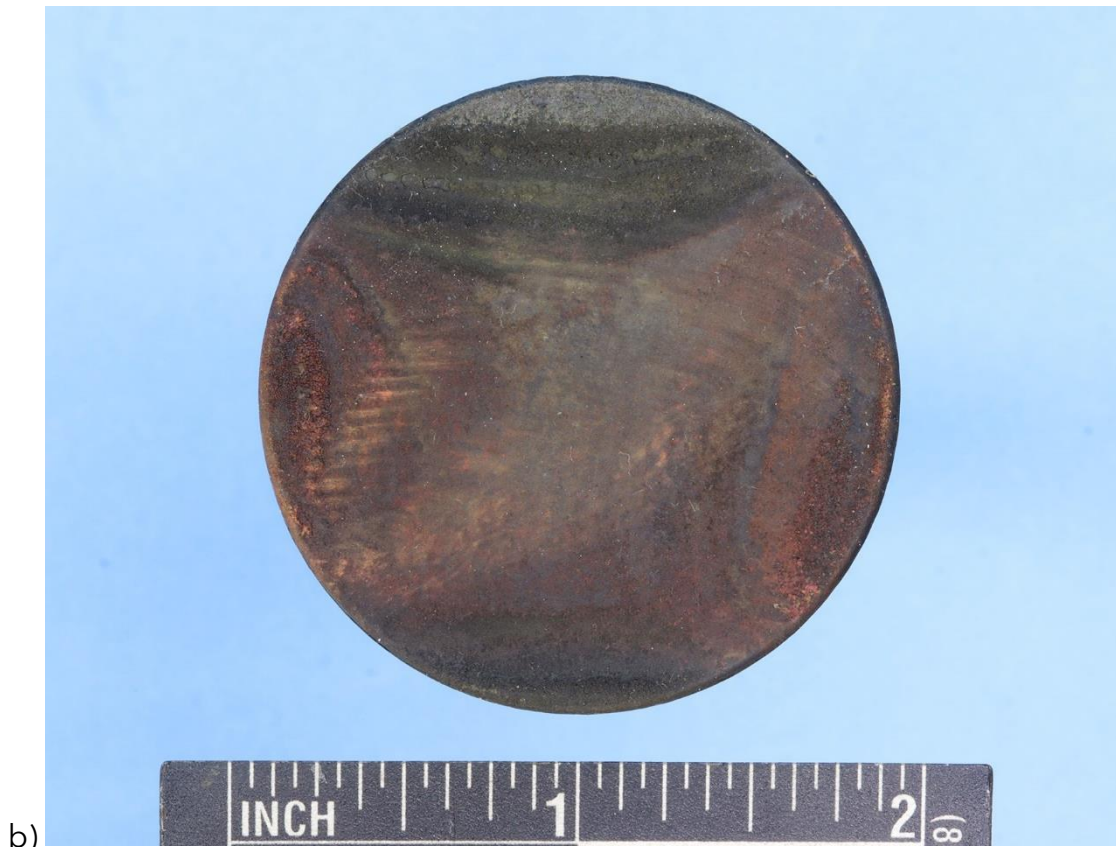
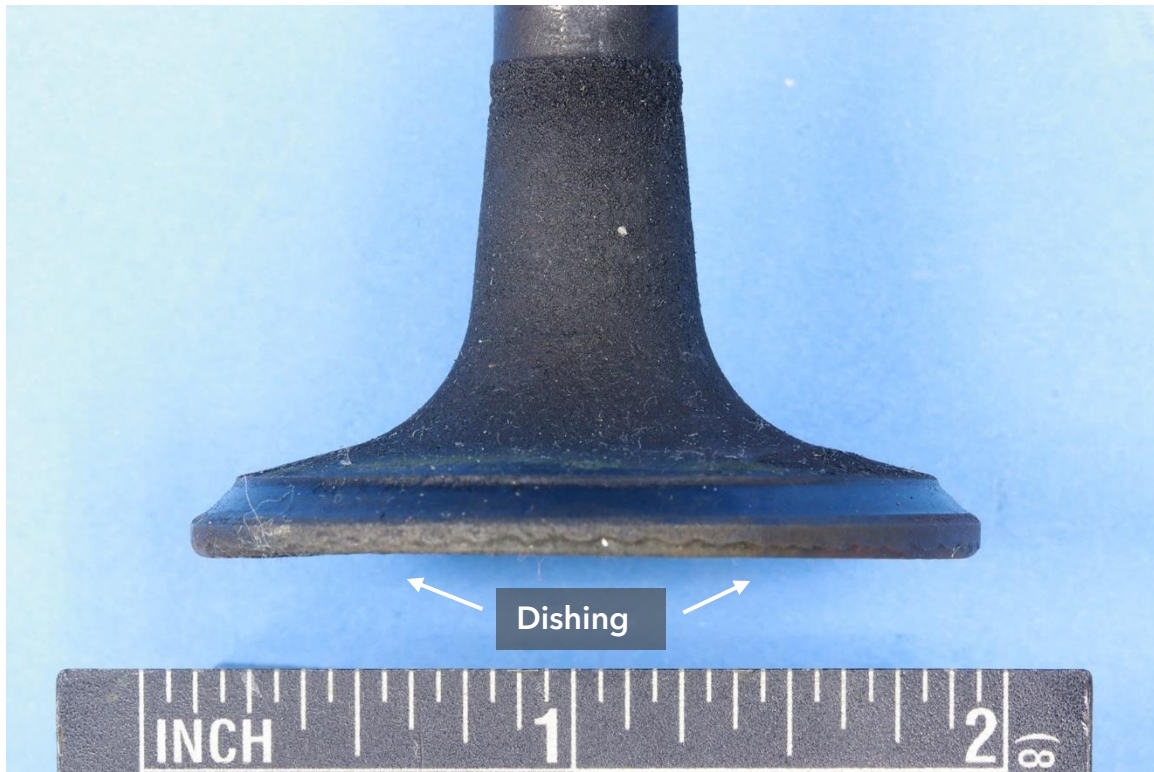


Figure 7 (cont.). b) valve combustion face showing asymmetric heat pattern; and c) seat face showing seat wear and incipient erosion along the margin.

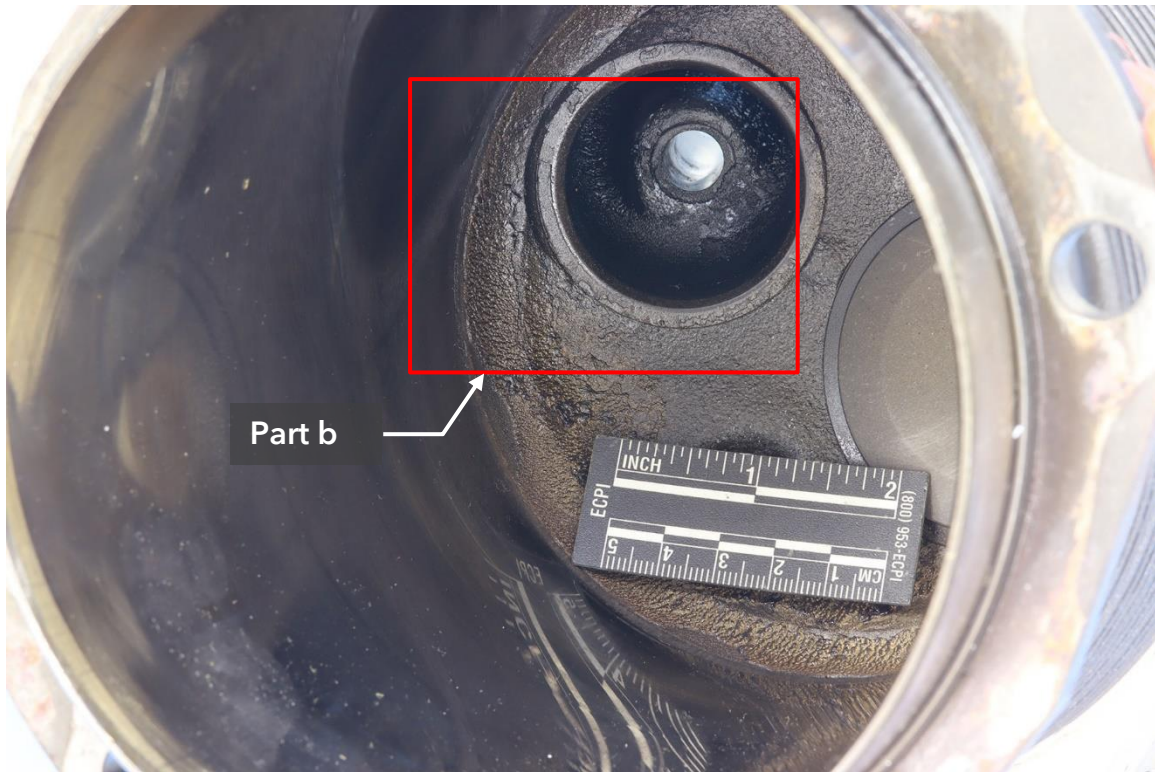


d)

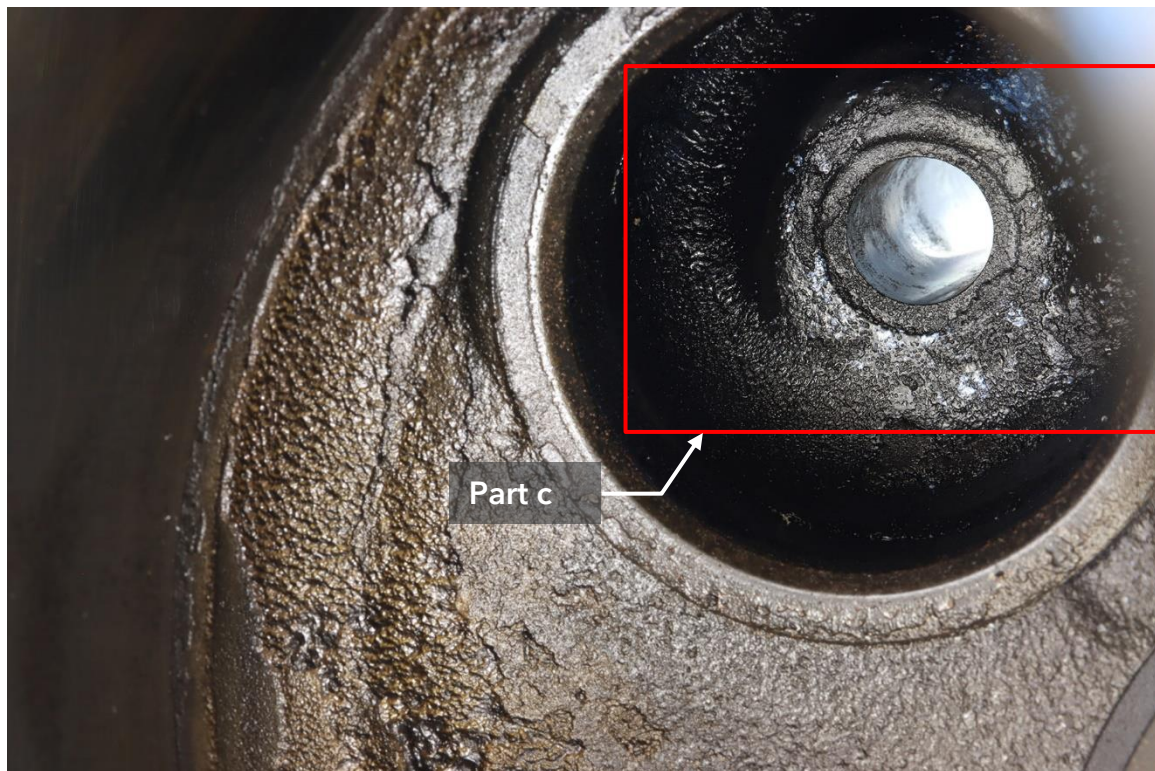
Figure 7 (cont.). d) side view of valve head with signs of dishing indicated.



Figure 8. Number 6 valve stem showing buildup of combustion products outside the area that engaged the valve guide.



a)



b)

Figure 9. Number 6 cylinder combustion chamber showing condition of exhaust valve guide: a) image of chamber with region indicated for part b; b) closer image of valve seat and valve guide with region indicated for part c; and

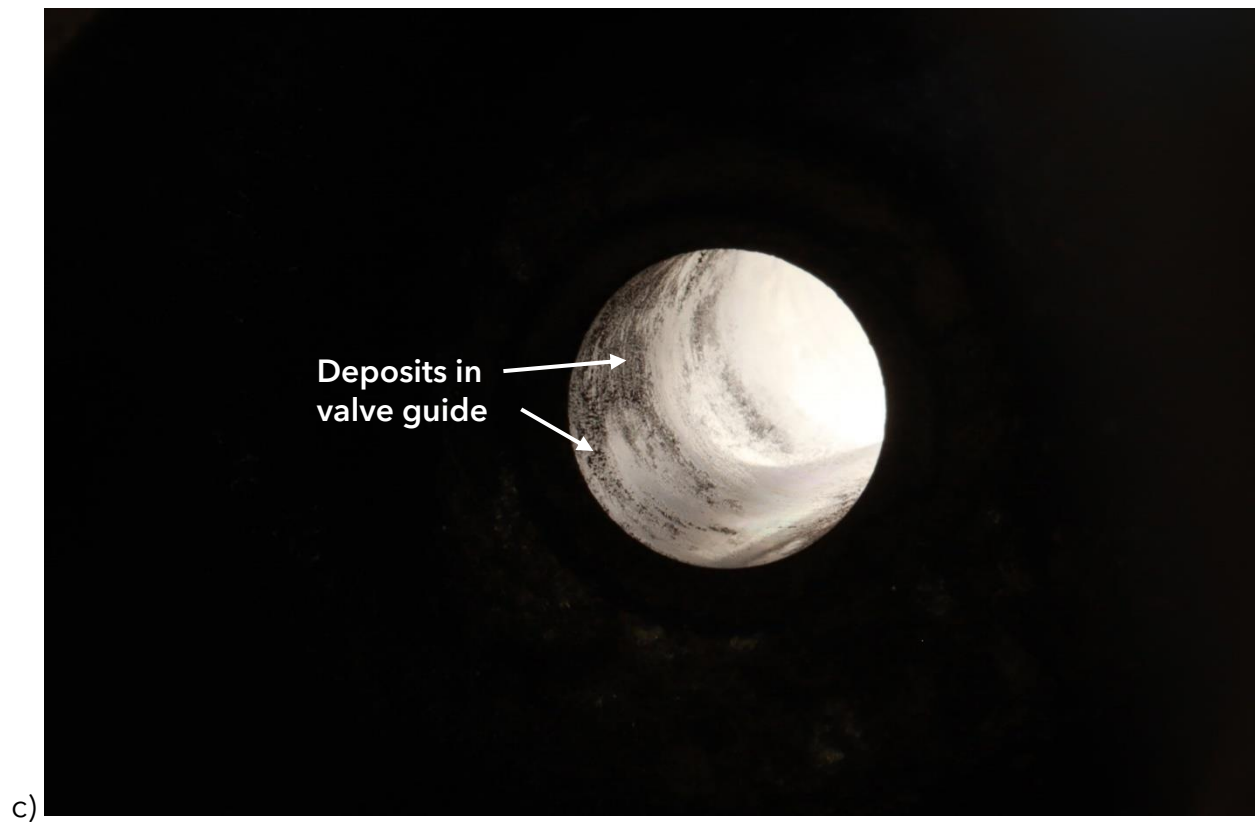


Figure 9 (cont.). c) backlit image of exhaust valve guide. Arrows indicate the locations of deposits on the barrel of the guide.



Figure 10. Number 6 exhaust valve rotocoil: a) post-disassembly and b) wear of flat race leaving behind impressions of the spring.