

NATIONAL TRANSPORTATION SAFETY BOARD

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



August 8, 2022

MATERIALS LABORATORY FACTUAL REPORT

Report No. 22-046

A. ACCIDENT INFORMATION

Place : East Sparta, Ohio
Date : September 28, 2021
Vehicle : Cessna T210N, N1925U
NTSB No. : CEN21LA472
Investigator : Andrew Todd Fox, ASI – CEN

B. COMPONENTS EXAMINED

Components from the number 2 cylinder assembly from a Continental Motors TSIO-520-R11B, ESN: 1032649; TSN: 1114 h (Approx.)

C. DETAILS OF THE EXAMINATION

Components from and ancillary to a Continental Motors TSIO-520-R11B Number 2 cylinder assembly were submitted to the NTSB Materials Laboratory for examination as shown in figure 1. Components included the cylinder, intake and exhaust pushrod assemblies, lifters, rocker arm assemblies, valve and valve spring assemblies, manifold flange fittings, piston pieces, wrist pin, and spark plugs. The exhaust valve had fractured through the stem as indicated in the figure.

The piston was fractured into multiple pieces. The skirt had separated from the crown, leaving the crown portion lodged in the cylinder barrel with a hole in its center, as shown in figure 2a. The remnant piston piece was extract from the barrel revealing the inside surface of the cylinder head, as shown in figure 2b. The head of the exhaust valve was situated on edge, embedded in the cylinder head adjacent to the intake valve seat, as indicated in the figure. The intake valve's head was fractured in multiple locations and was pushed through the valve seat. The exhaust valve seat was missing and much of the cylinder head material around the exhaust outlet exhibited erosion and impact damage, leaving only a small remaining segment of the valve seat's counterbored recess in the cylinder head, as shown in figure 2c.

The cylinder's rocker box region, shown in figure 3, exhibited heat signatures (dark brown surfaces) around the exhaust valve guide and exhaust valve rocker arm shaft bosses. The intake valve stem was visibly bent, as was the intake valve pushrod, shown in figure 1.

The exhaust valve stem and head pieces are shown in figures 4 and 5, respectively. The stem's surface, two views of which are shown in figures 4a and 4b, exhibited a typical appearance for an in-service exhaust valve, with a polished appearance mid-length and a black appearance from oxidation and/or deposits near the fractured end. The oxidized region of the stem was examined for any visually apparent material loss or pitting but none was found. The fracture surface on the stem piece, shown in figure 4c, exhibited a flat appearance, ratchet marks at one location along the edge, and crack progression marks on the fracture surface. The features were consistent with a fatigue fracture starting along the edge at the location of the ratchet marks. The origin was examined with the aid of a stereomicroscope and was found to have suffered post-separation impact damage. The end face of the stem's outboard tip, shown in figure 4d, was examined for any notable nonuniform wear patterns or pitting, but none was found. Two keys were present that formed a collar around the stem and located it within the upper spring retainer. Each key exhibited a deformed spot along the upper edge, the two spots being approximately 180° apart from one another but there were no other indications of deformation or wear of the keys. The tip of the rocker arm, shown in figure 4e, exhibited an asymmetric contact patch. The inboard side (biased towards the midline of the cylinder) exhibited a rubbed appearance while the outboard side (biased toward the outer cylinder wall) exhibited a matte appearance.

The valve head, shown in figures 5a and 5b, exhibited damage from multiple impacts. The fracture at the fillet to stem transition was smeared and featureless and the edge of the valve head was deformed and chipped. Portions of the valve head's fillet region (figure 5a) exhibited a silver metallic deposit. The composition of the deposit was examined using a scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectrometer (EDS). The spectrum, shown in figure 5c, exhibited primarily nickel (Ni), iron (Fe), chromium (Cr), and aluminum (Al).

The lifter body for the number 2 exhaust valve exhibited smeared metal deposits on its cam-following end face, as shown in figure 6a. The composition of the deposits was examined in the SEM by EDS. An SEM image from the center of the lifter end face is shown in figure 6b. A region that was not covered by the smeared metal is indicated in the figure and the corresponding spectrum is shown in figure 6c. A region covered by the smeared metal is also indicated in the figure and is shown in figure 6d. Both spectra consisted primarily of Fe, but the end face of the lifter body (absent the smeared metal) also exhibited a silicon (Si) peak. The adjacent lifter body for the number 2 intake valve did not exhibit any similar smeared metal features on its end face, as shown in figure 7.

The exhaust valve stem to valve guide clearance was then measured and was found to be outside the service limit as given in Continental Motors Service Bulletin SB19-05.¹ The stem outer diameter was measured using a micrometer and the exhaust valve guide inner diameter was measured using a split ball gauge and micrometer. The stem diameter was measured near the top, in the top third of the guide contact zone, and in the middle third of the zone. The valve guide was measured in the top and middle thirds.

¹ Continental Motors Service Bulletin SB19-05: "Valve Guild Application, Installation, and Reaming Procedures." Continental Aerospace Technologies, Mobile, AL, October 24, 2019.

The exhaust valve part number was 655771 with an as-new diameter of 0.4334 inch – 0.4341 inch. The valve guide part number ended in “242”, which was consistent with part number 636242, a Ni-resist valve guide with a length of 2.17 inch and an as-installed finished inner diameter of 0.4350 inch – 0.4362 inch. The clearance was calculated from the measured valves and compared to the service limit of 0.0085 inch as shown below in table 1.

Table 1: Valve stem to guide clearance measurements.

Location	Stem diameter, inch	Valve guide diameter, inch	Service limit, inch	Average clearance, inch
Top	0.4340	—	—	—
Top third	0.4331, 0.4330	0.4400, 0.4395	0.0085	0.0067
Middle third	0.4323, 0.4323	0.4434, 0.4434	0.0085	0.0111

The exhaust valve rocker arm shaft to bearing clearance was also measured and was found to be just outside the 0.004-inch service limit at the outboard end. The shaft and bearing diameters were measured at the inboard end and outboard end with outside and inside micrometers, respectively. The new-parts clearance was 0.0010 inch – 0.0025 inch as reported in the IO-520 Overhaul Manual.² The measurements are shown below in table 2. The clearance was 0.0041 inch at the outboard end, just outside the 0.0040 inch service limit.

Table 2: Exhaust valve rocker arm shaft to rocker arm bearing clearance measurements.

Location	Shaft Diameter, inch	Bearing Diameter, inch	Service Limit, inch	Average clearance, inch
Inboard	0.7485	0.7517	0.0040	0.0032
Outboard	0.7487	0.7528	0.0040	0.0041

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² Publication X30039: “Continental Motors IO-520 Series Engine Overhaul Manual.” Continental Motors, Mobile, AL, August 31, 2011.



Figure 1: Number 2 cylinder assembly and ancillary components, as received. Exhaust-related components are to the left of the cylinder and intake-related components are to the right of the cylinder.

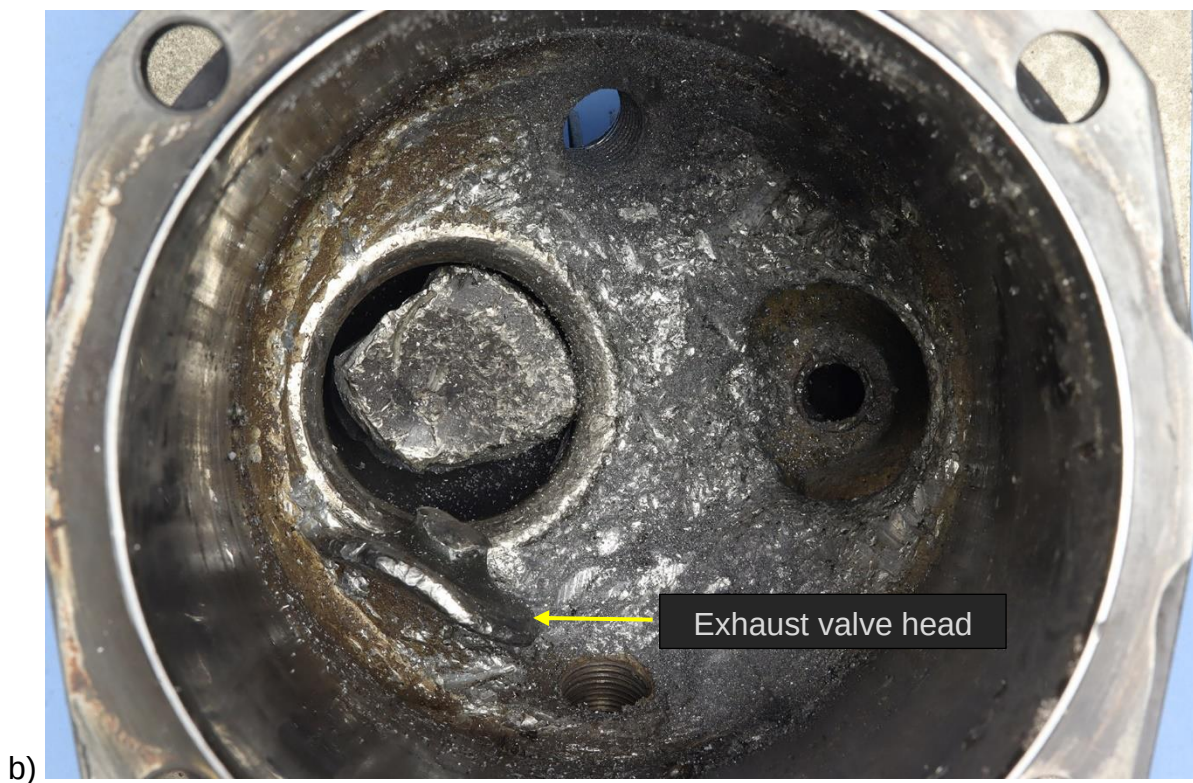
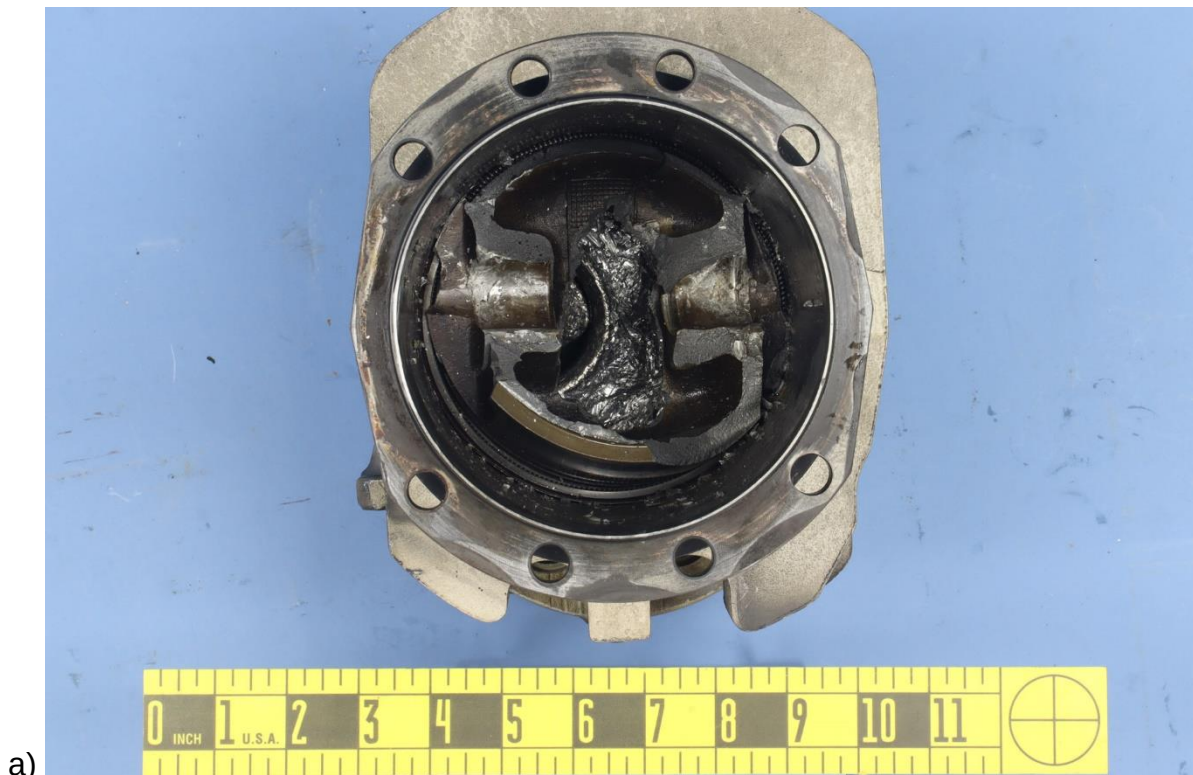


Figure 2: a) View of number 2 cylinder combustion chamber with seized piston fragment lodged in the barrel; b) image of the cylinder head after removal of the piston fragment revealing the exhaust valve, damage to the intake valve, and damage to the cylinder head; and

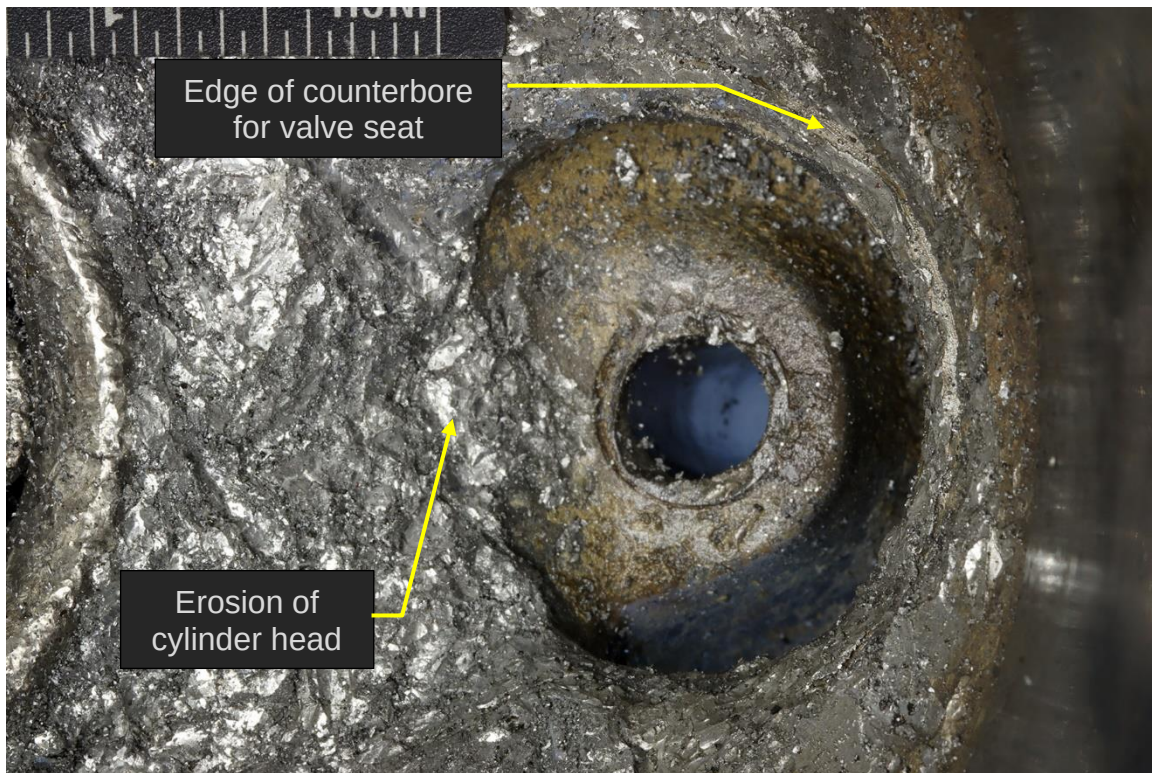


Figure 2 (cont.): c) Higher magnification image of the exhaust valve region highlighting the missing valve seat and eroded and damaged cylinder head material.

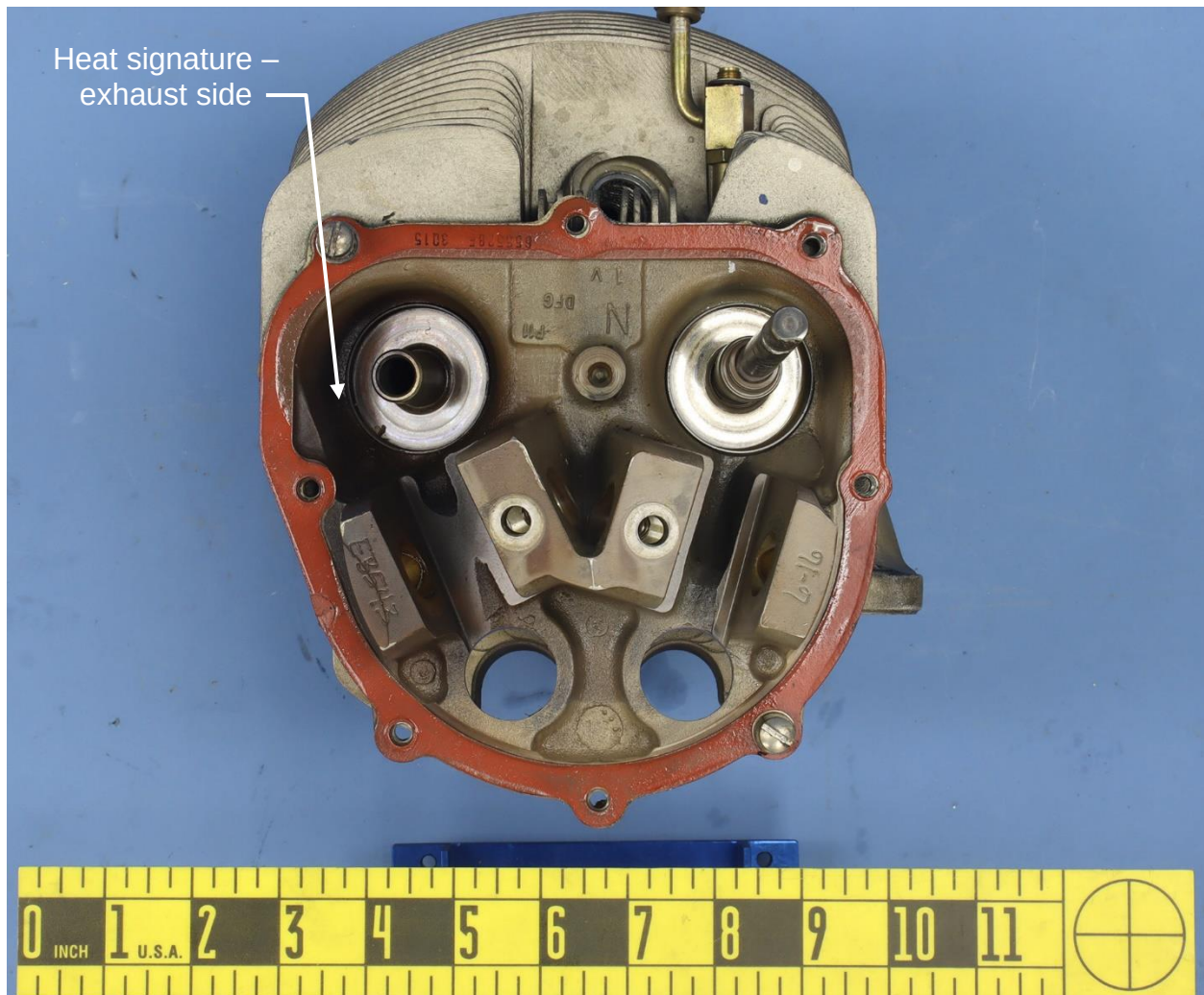


Figure 3: View of the number 2 cylinder rocker box region showing a heat signature around the exhaust valve guide and exhaust valve rocker shaft bosses.



Figure 4: Images of the number 2 exhaust valve stem; a) one side of the stem; b) the other side of the stem; c) the stem fracture surface;

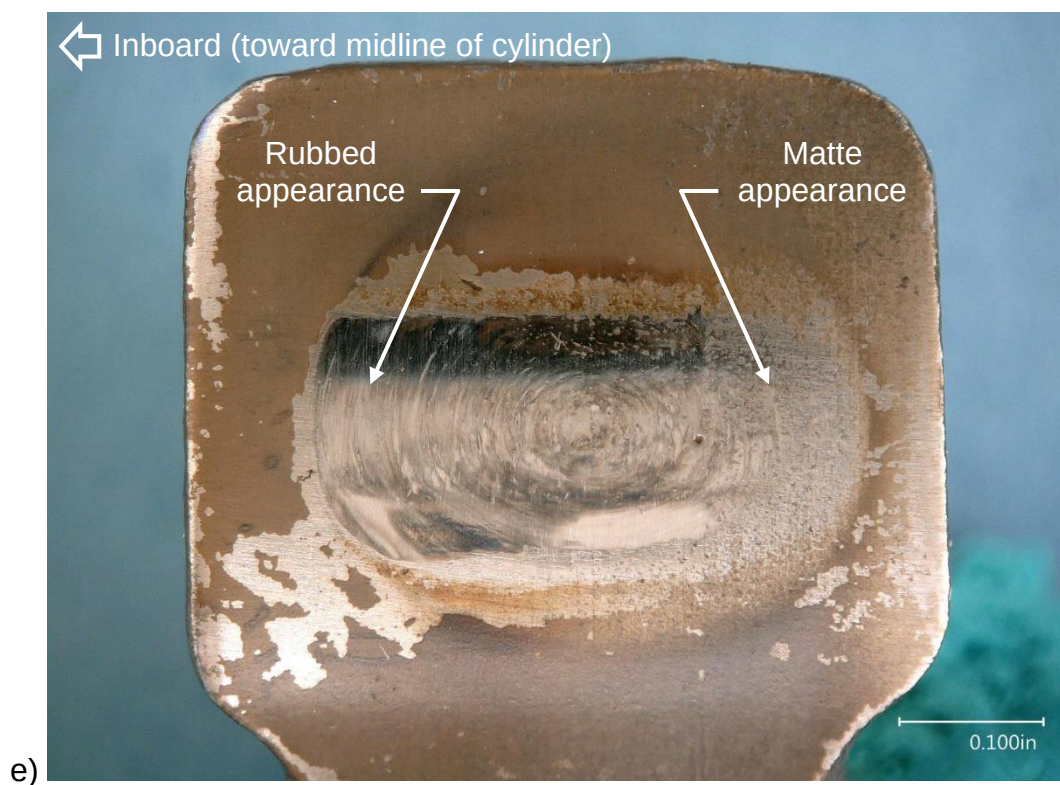
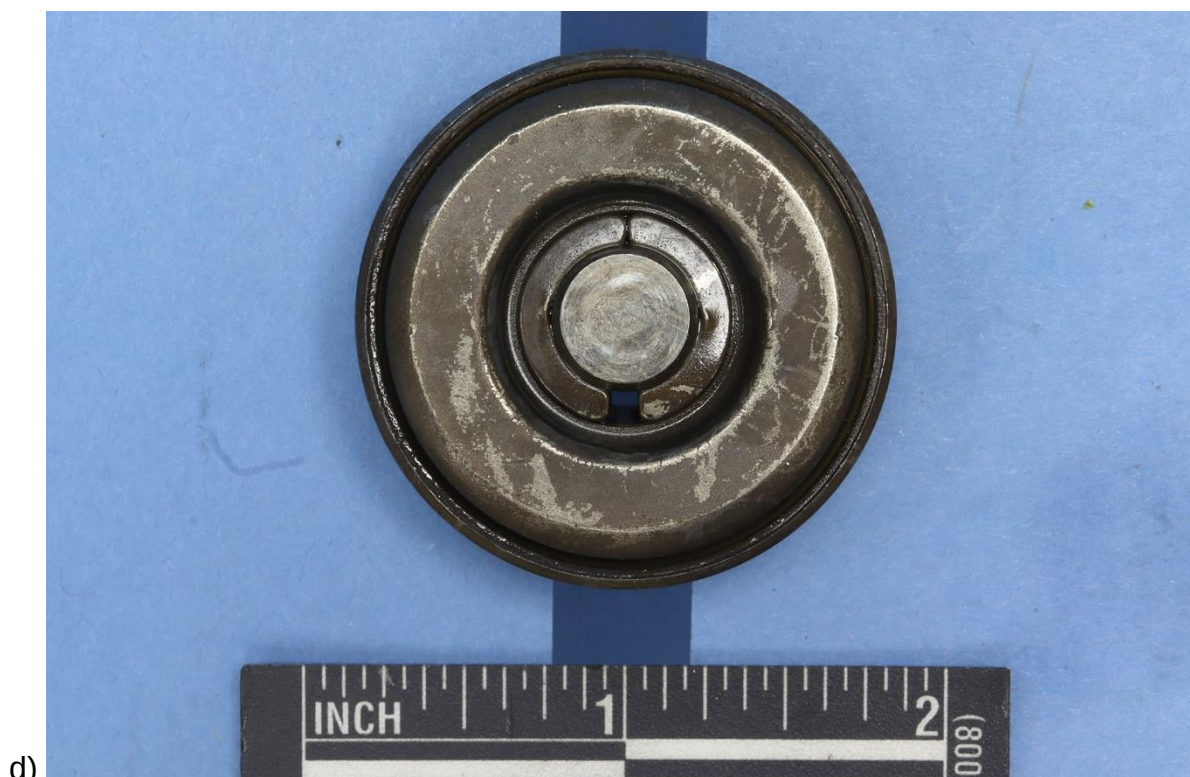


Figure 4 (cont.): d) image of the tip of the stem before removing the upper spring retainer and keys; and e) the tip of the rocker arm showing an asymmetrical contact patch.



Figure 5: a) Image of the valve head fillet region and smeared fracture at the fillet to stem transition; b) image of the combustion chamber-facing side of the head; and

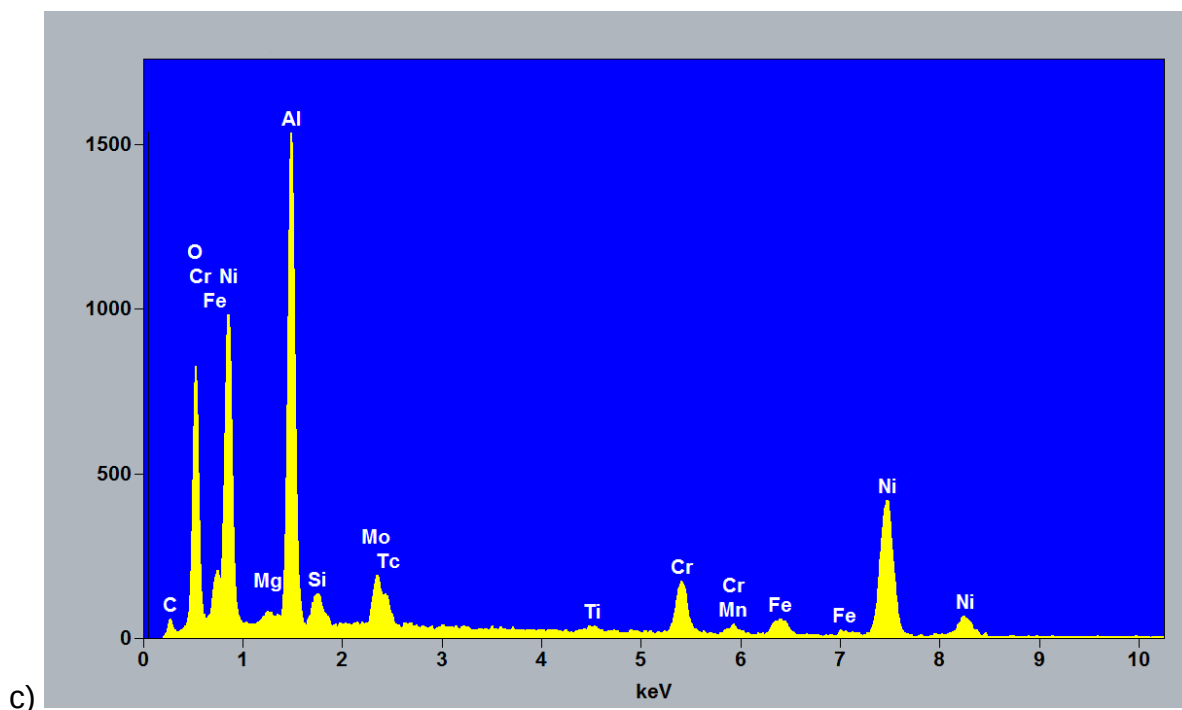


Figure 5 (cont.): c) EDS spectrum of a silver metallic deposit on the valve head exhibiting primarily nickel (Ni), iron (Fe), chromium (Cr), and aluminum (Al).

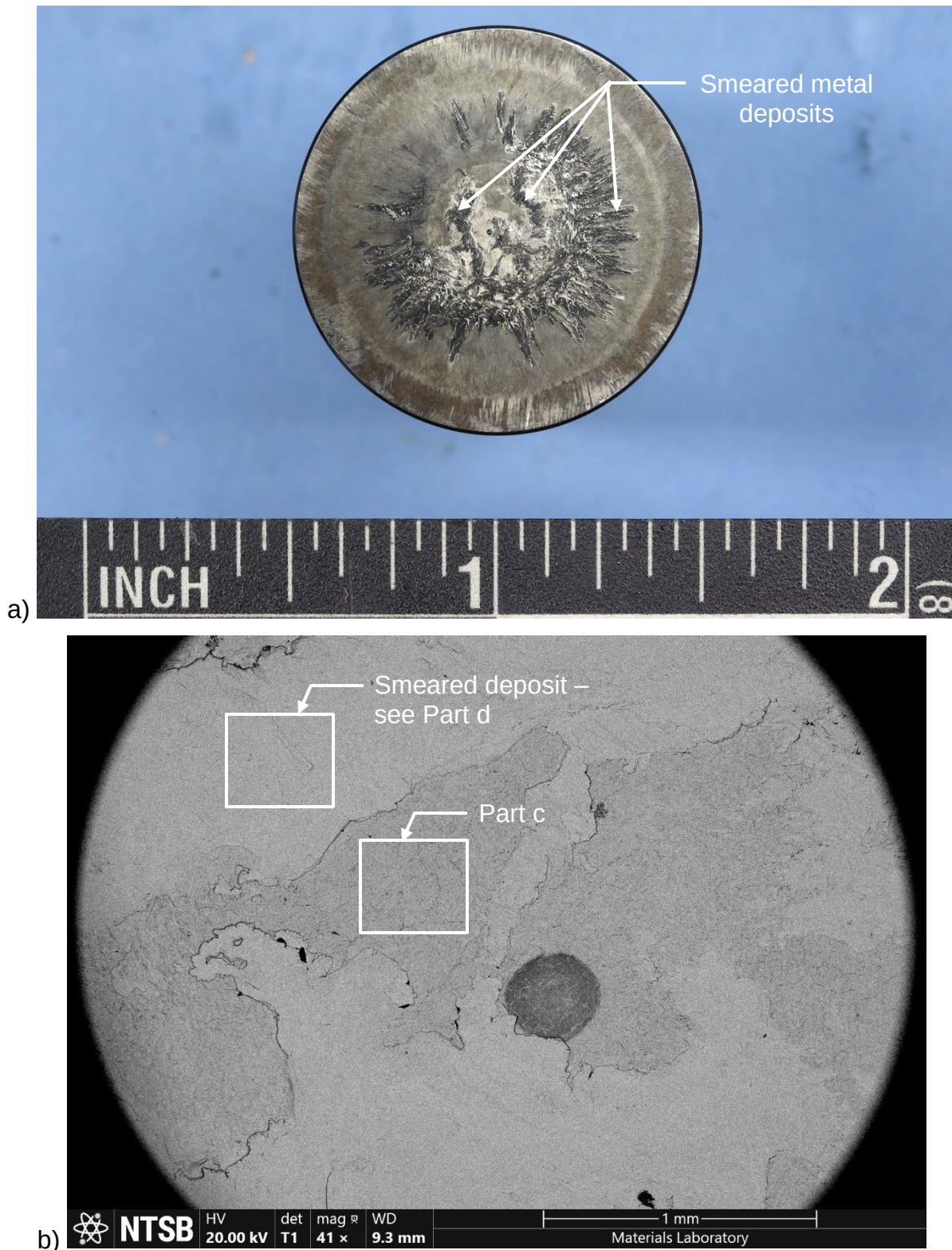


Figure 6: a) Image of the exhaust valve lifter body's cam-following end face exhibiting smeared metal deposits; b) SEM image of the end face highlighting two regions, one with smeared metal and one without, from which EDS spectra were taken.

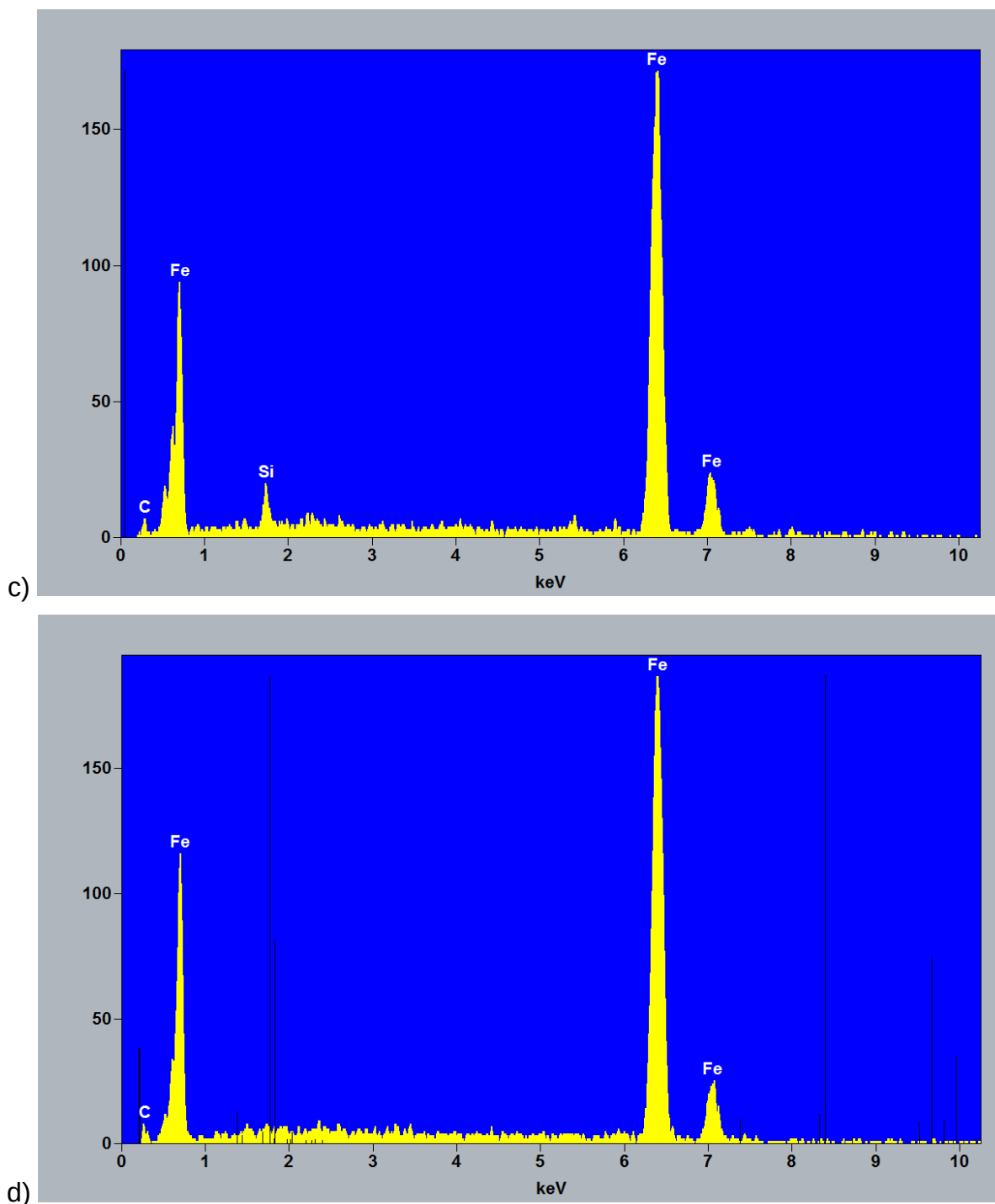


Figure 6 (cont.): c) EDS spectrum of the lifter body end face exhibiting primarily iron (Fe) and silicon (Si); and d) EDS spectrum of the smeared metal exhibiting primarily iron (Fe).



Figure 7: Image of the number 2 intake valve lifter body end face. There were no apparent smeared metal features.