

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



WPR22LA259

MATERIALS LABORATORY

Factual Report 23-032

July 26, 2023

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A. ACCIDENT INFORMATION

Location: San Marcos, California
Date: July 16, 2022
Vehicle: Socata TB21, N718TB
Investigator: Daniel Baker, ASI-WPR

B. COMPONENTS EXAMINED

Partially disassembled Crane / Lear Romec engine-driven fuel pump:
P/N: RG17980P/M; S/N: B-5197

C. EXAMINATION PARTICIPANTS

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

D. DETAILS OF THE EXAMINATION

A partially disassembled engine-drive fuel pump was submitted to the NTSB Materials Laboratory for examination as shown in figure 1. The pump consisted of a case-hardened steel rotor (figure 2) that spun inside a carbon bearing (figure 3), both enclosed in an aluminum housing. A rubber O-ring (figure 4) sealed the driven end of the rotor. The driven end of the rotor also contained a slot for interfacing with the tongue of the drive coupling (figure 5). The drive end of the rotor consisted of larger diameter section with two slots at 90° to one another for housing the pump vanes (figures 2, 6, and 7). The vanes rotated within an eccentric liner (figure 8), sliding within the slots as the rotor turned, thereby achieving pumping action. The pump had failed in flight and the rotor had seized. It was sent to the overhaul facility for an initial teardown examination before it was sent to the NTSB lab.

The pump was overhauled on May 18, 2022, approximately 2 months prior to the accident. The rotor and bearing were replaced, but the liner was not (other components, not discussed, were replaced as well). The rotor and bearing were PMA parts manufactured by Consolidated Fuel Systems and their respective part numbers were CFRA7791 and CFRA7754.

The rotor, shown in figure 2, exhibited severe thermal distress. The entire rotor was dark and discolored, except for the end face of the drive end (figure 6a). The rotor's bearing journal had spalled from the rotor over most of the region that contacted the carbon bearing and material had spalled from the edges of the drive coupling slot (figure 2, lower image). The rubber seal installed at the driven end of the rotor (near the groove) exhibited softening and deformation, also consistent with thermal distress, as seen in figure 4. The journal diameter was measured by

micrometer inside and outside of the spalled region. Outside the spalled region, the diameter was measured twice, both times reading 0.6237 inch, in accordance with the manufacturer's requirements. Inside the spalled region, the diameter varied, but read as low as 0.6175 inch. The thickness of the drive head was measured twice, reading 0.2998 inch both times, in accordance with the manufacturer's requirements. The larger diameter drive end of the rotor had worn into the thrust plate (figure 6b). Pieces of rotor material had chipped off along the edges where the vane slots met the outer diameter of the drive end, as shown in figure 7. Rub marks were observed on the outer diameter surface adjacent to the chipped regions.

The bearing, shown in figure 3, was also mechanically damaged. The bearing had fractured into three pieces and the bearing surface exhibited circumferential scoring marks. Examination of the fracture surfaces with the aid of a stereomicroscope revealed coarse fracture features radiating away from the inner diameter surface (consistent with overstress) and foreign debris on the fracture surface adjacent to the bearing's ID surface (see figures 3c and d and the chemical identification below). The inner diameter of the bearing was measured with an inside micrometer and read between 0.626 inch and 0.627 inch.

The tongue of the drive coupling is shown in figure 5. The tongue was fractured, and the drive shaft had sheared in the narrow-diameter section of the coupling, as seen in part b. Examination with a stereomicroscope revealed circumferential smear marks on the fracture that were consistent with a shear overstress fracture. During the initial disassembly, the tongue could not be separated from the rotor and was pushed through the bearing ID, causing damage to the bearing and possibly the tongue.

The liner, shown in figure 8, had a material scar on its inner diameter, as indicated in part b. The scar was located close to the face of the liner abutting the bearing and the pump body (as opposed to the side abutting the thrust plate). Chemical identification of the scar material is discussed below.

The pump components were examined by a scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectrometer (EDS). A backscatter image of the rotor is shown in figure 9 at the location indicated in figure 2. The image shows elemental contrast, with the lighter regions indicating heavier elements and the darker regions indicating lighter elements. The bright region on the left side of the image was from a region of the remaining journal surface. The dark region on the right side of the image was from a region where the surface had spalled from the rotor body.

Several EDS spectra are shown in figure 10. Figure 10a shows a reference spectrum of the rotor material, taken from a cross section through the rotor head (prepared for the purpose of case depth measurements as described below). The primary element was iron (Fe) with small alloy additions of chromium (Cr), aluminum

(Al), and silicon (Si). An EDS spectrum taken from the remaining journal surface (left side of figure 9) showed similar elements and relative peak heights, as shown in figure 10b. By contrast, the spectrum from the spalled region, shown in figure 10c, exhibited primarily aluminum (Al) and silicon (Si) with additional peaks of sulfur (S) and iron (Fe).

The foreign debris on the carbon bearing was examined by EDS as shown in figures 11a and 11b, at the locations indicated in figure 3d. The lighter contrast region exhibited primarily Fe peaks (as well as carbon and sulfur). The middle contrast region was similar but with an increase in the relative peak heights of Al and Si.

An SEM image of the scar on the liner is shown in figure 12a and the EDS spectrum is shown in figure 12b. The EDS spectrum consisted primarily of Fe, with additional peaks of Cr and Al, consistent with the rotor's base material.

Several of the ports on the pump exhibited metal shavings or burrs, as indicated in figures 13 and 14. Two of the three plugged ports on the mounting flange contained one or more metal shavings, as shown for one of the ports in figure 13a. A shaving/burr was observed on one of the fuel flow ports, indicated in figure 13b, and shavings were observed at the threaded port on the relief valve housing cover plate, shown in figure 14. A thread was removed from one of the plugged mounting flange ports and is shown by SEM in figure 15a. An EDS spectrum of the shaving, shown in figure 15b, indicated it consisted primarily of Al and Si, with a trace of zinc (Zn) from the zinc-plated port plug. A reference EDS spectrum of the pump housing, shown in figure 15c, consisted primarily of Al and Si. The surfaces of the pump housing were examined for any signs of notable mechanical damage, but none were found.

The case depth on the rotor was measured by Vickers hardness, in accordance with ASTM E384-17. A quadrant of the rotor head was sectioned with a wet abrasive saw and mounted in resin. The exposed surface was ground and polished in accordance with standard laboratory protocols. The case depth was then measured on the rotors outer diameter using a 500 g load. The resulting depth profile, shown in figure 16, was in accordance with the manufacturer's requirements.

The manufacturer of the bearing was asked about any quality issues associated with the bearing but reported none. There were no discrepancies noted on any lots in the last five years and a sampling procedure for attribute inspection based on lot size was in effect.

E. ATTACHMENTS

Attachment 1 – Fuel Pump Maintenance Manual Excerpts

Submitted by:

Donald Kramer, Ph.D.
Sr. Materials Engineer

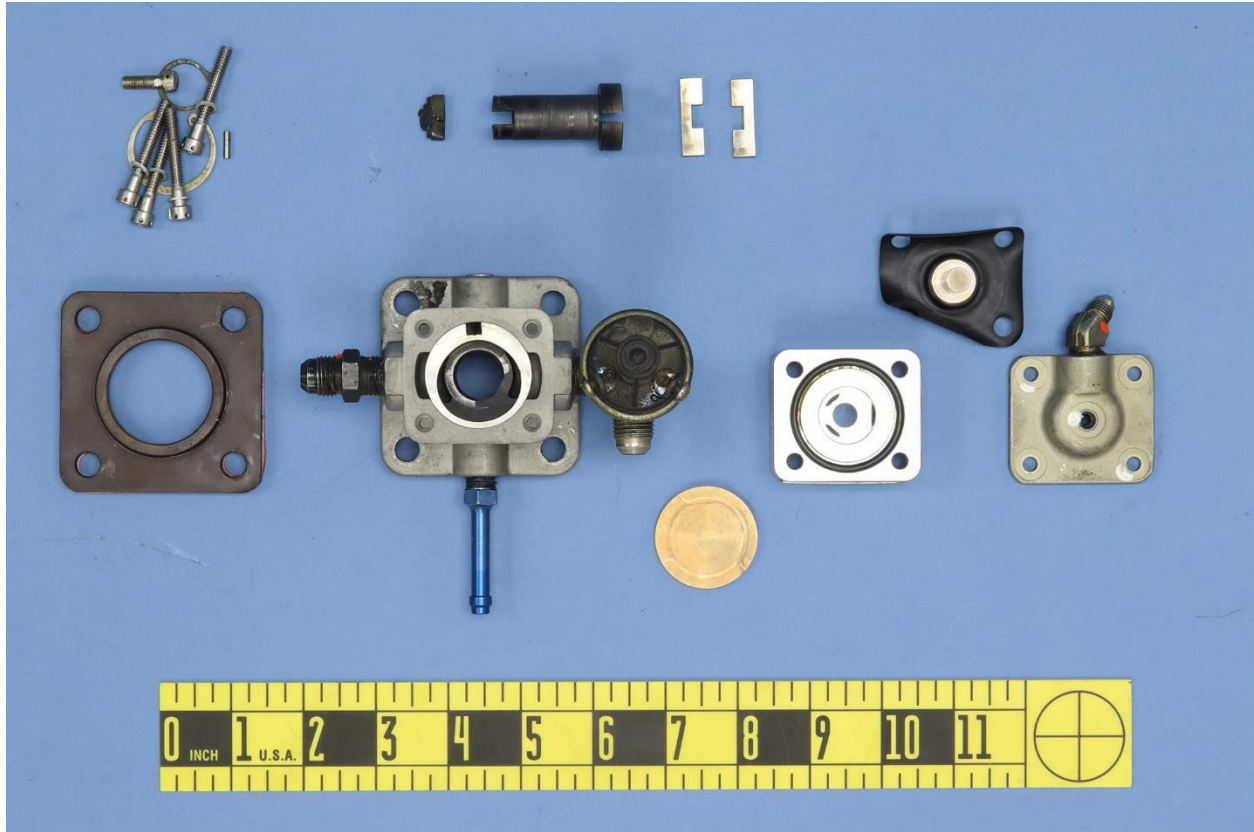


Figure 1. Fuel pump assembly pieces, as received.

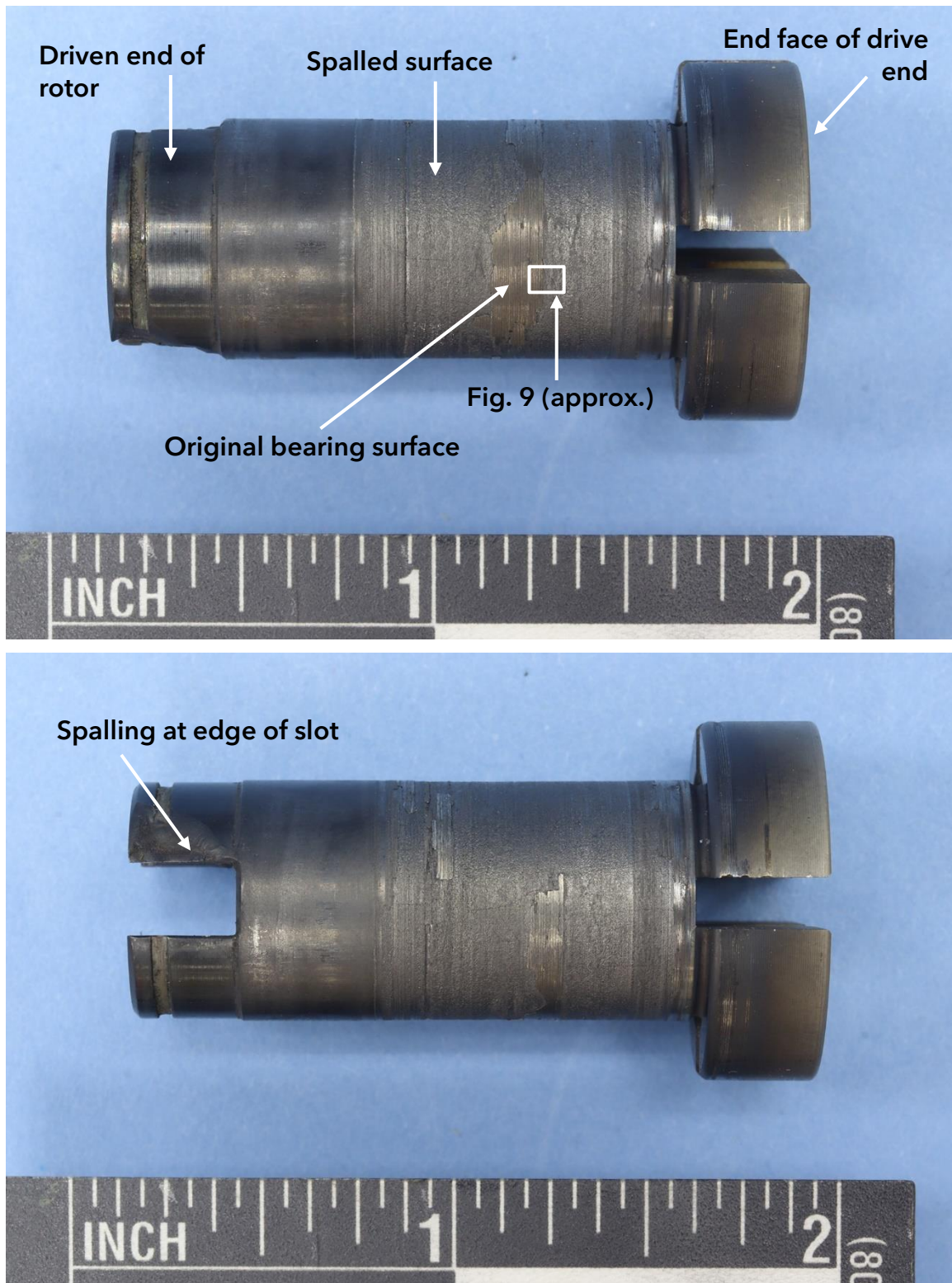


Figure 2. Two views showing extensive dark discoloration of the rotor surface and spalling of the rotor's bearing journal surface, consistent with thermal distress.

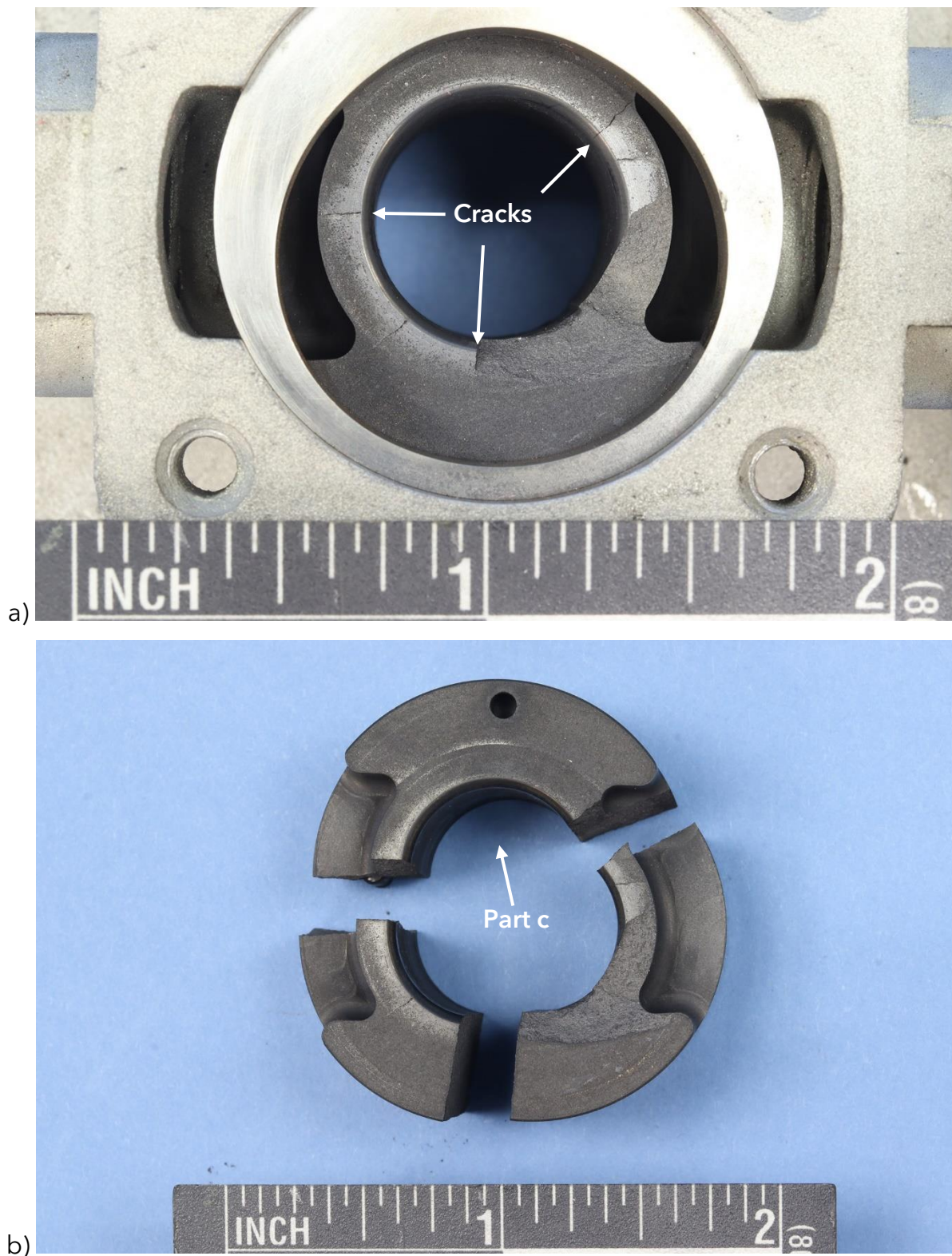


Figure 3. Images of the bearing: a) inside the housing and b) after heating the pump assembly in an oven and pressing the bearing out of the housing.

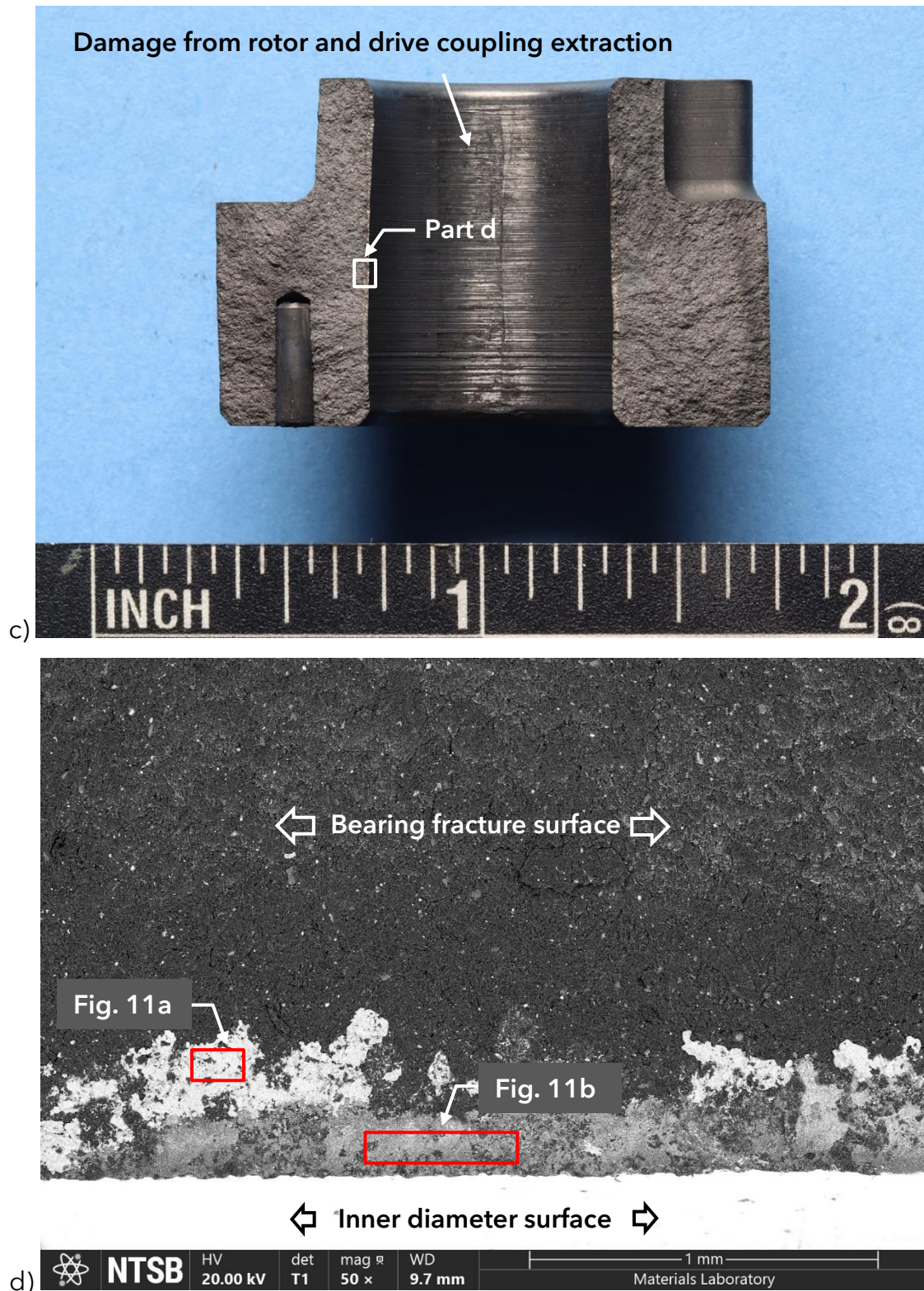


Figure 3 (cont.). c) fracture surfaces on one of the bearing pieces; and d) SEM image of bearing fracture surface adjacent to the inner diameter bearing surface.



Figure 4. Image of the rubber seal that is installed on the driven end of the rotor showing thermal damage to the rubber.

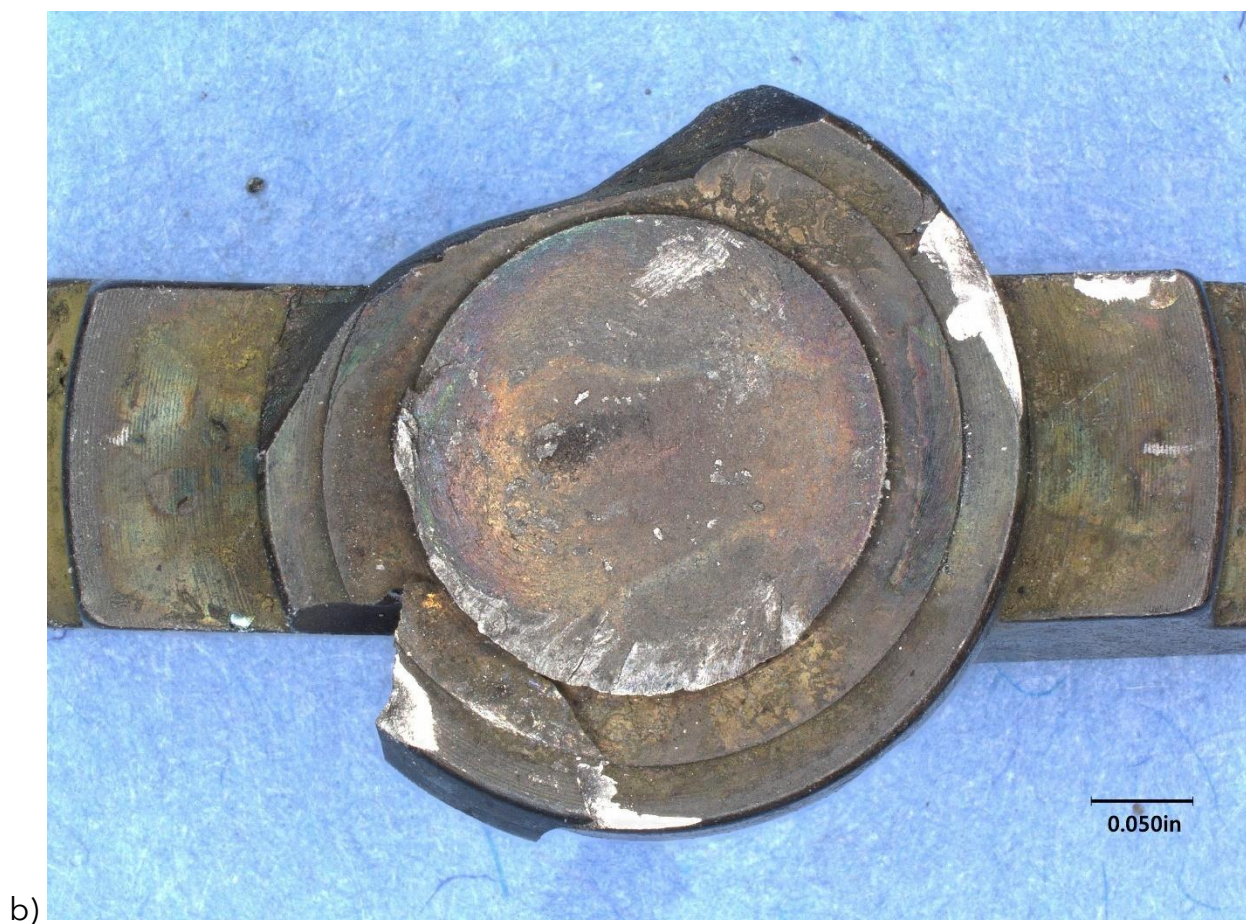


Figure 5. Images of the fuel pump drive coupling's tongue: a) cracked tongue and b) fractured drive shaft sheared by torsional overstress.



Figure 6. a) View of the rotor's drive end face and b) thrust plate against which the end face of the rotor rides.

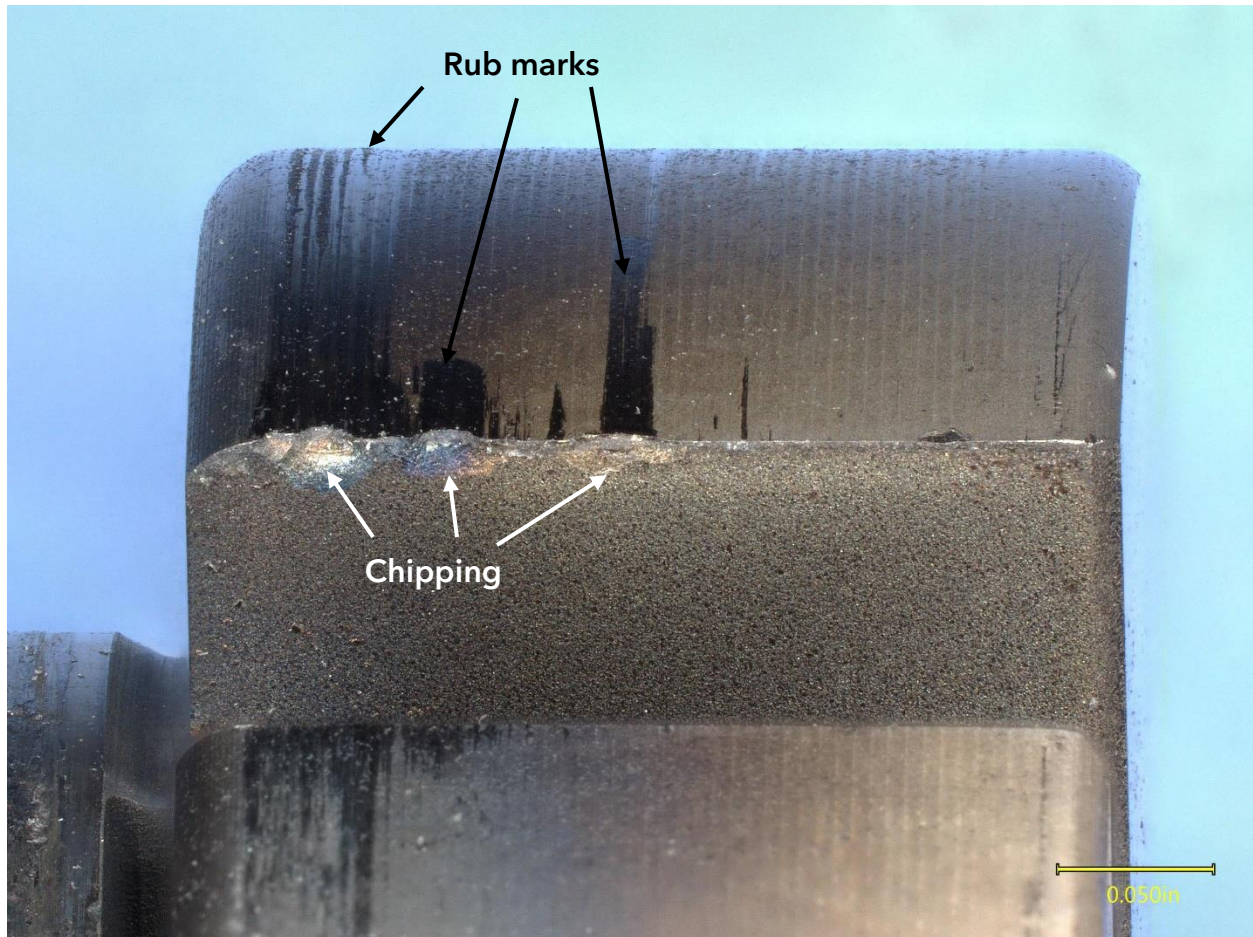


Figure 7. Image of the rotor's drive end outer diameter showing chipping/spalling of material at the edge of the slot and rub marks on the outer diameter surface at the same locations.

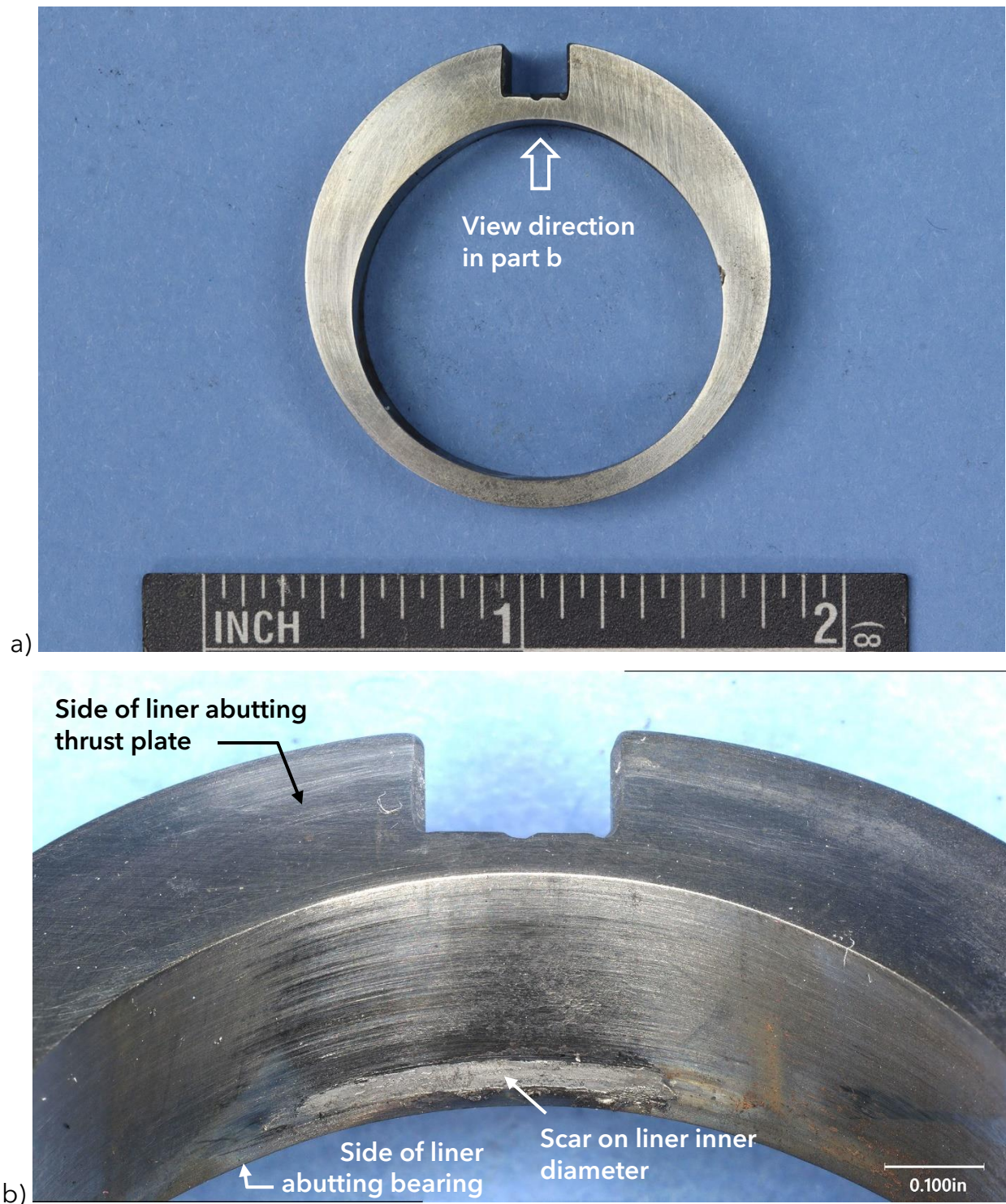


Figure 8. Images of the liner: a) overview image and b) oblique angle image with scar indicated on the inner diameter surface.

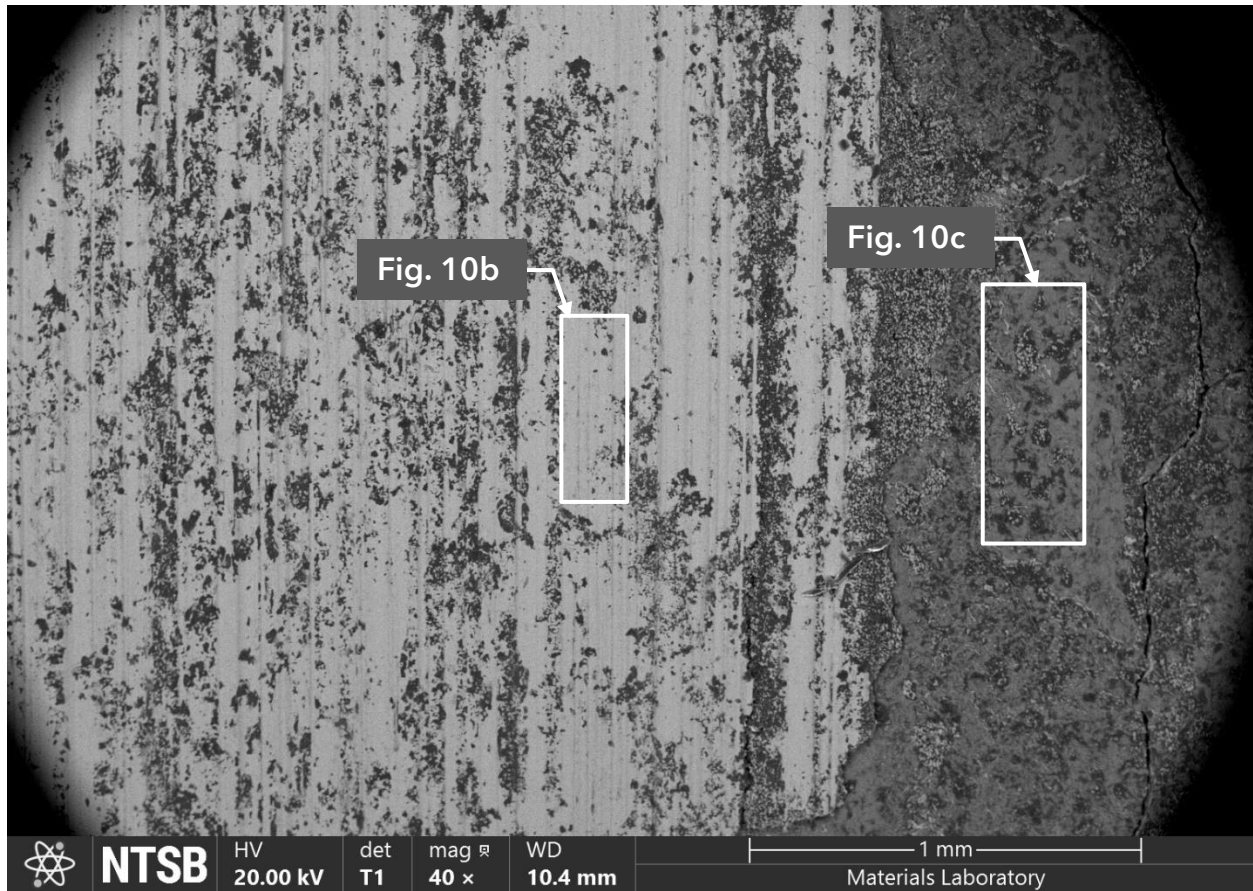


Figure 9. Scanning electron microscope image of the rotor bearing journal. The lighter colored region is intact bearing journal surface and the darker region is where the surface spalled from the rotor body.

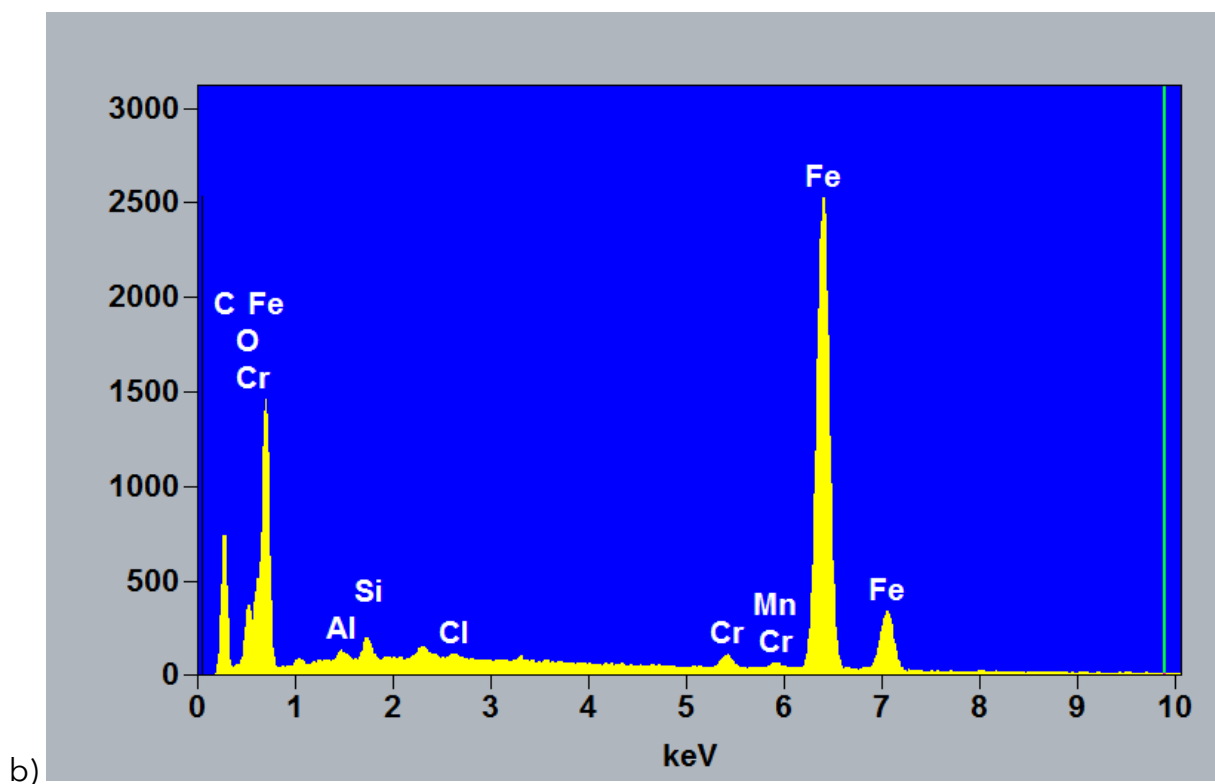
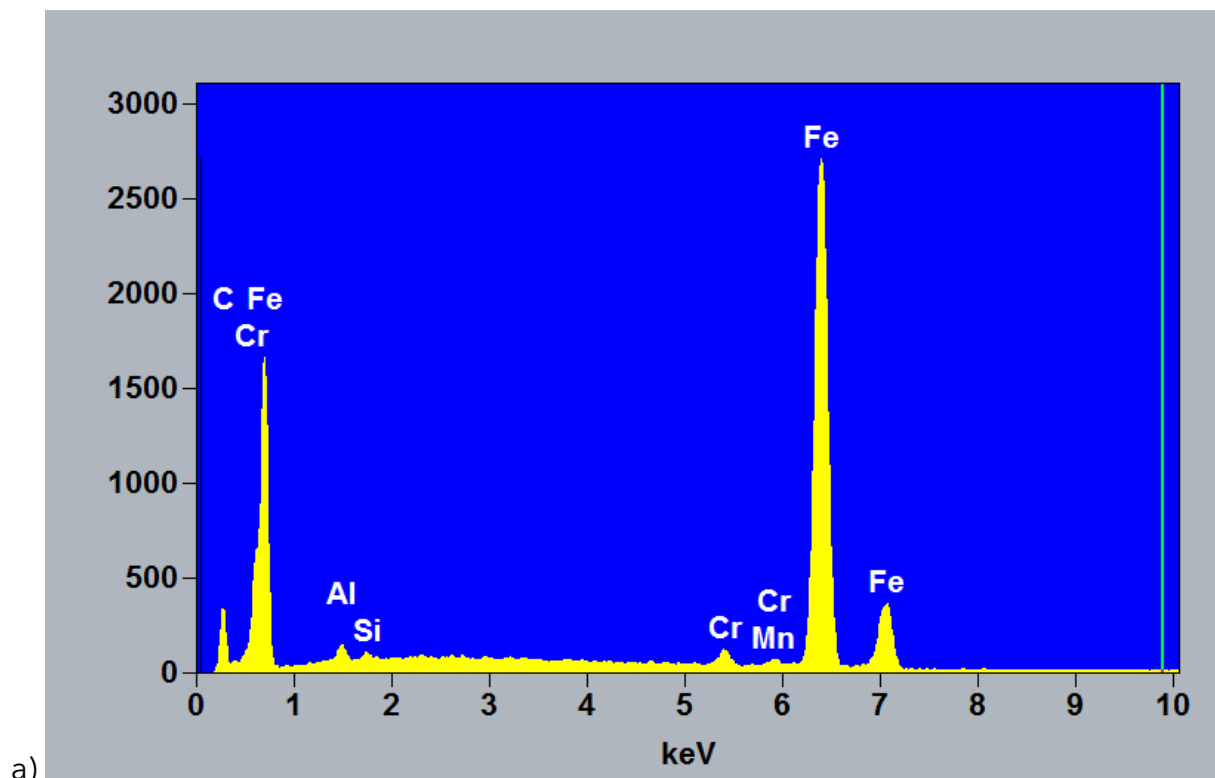
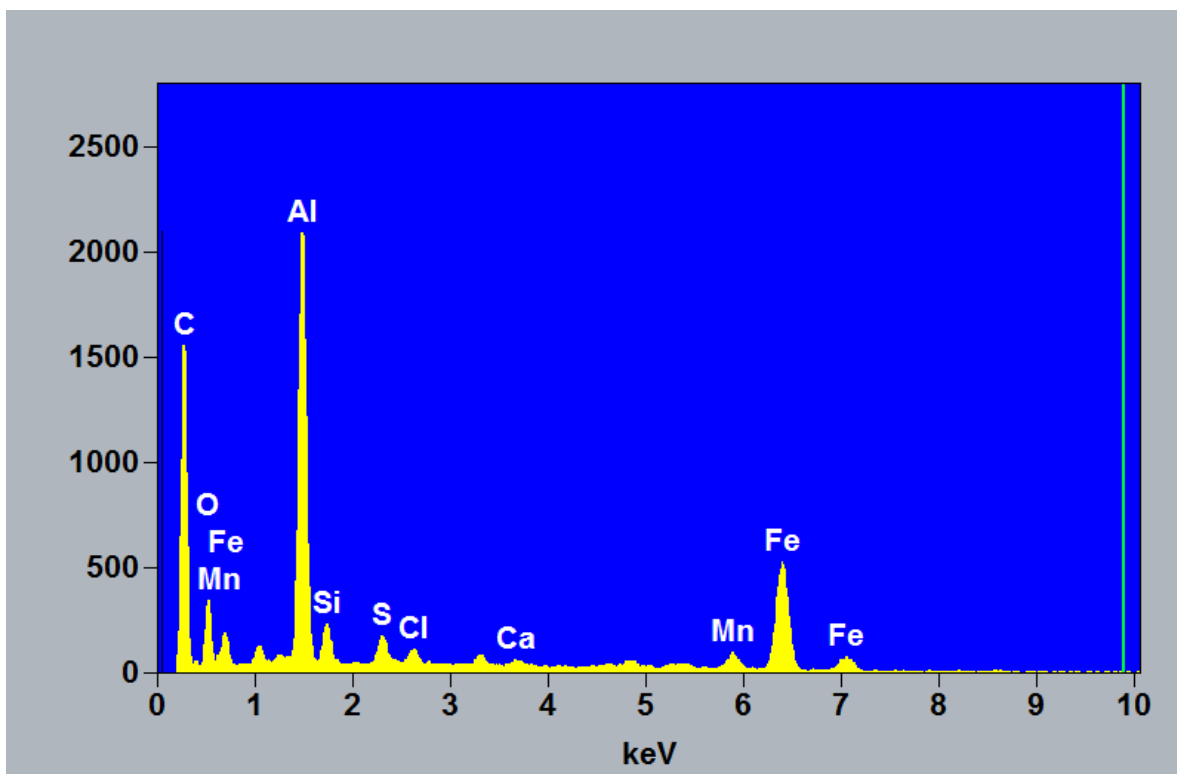


Figure 10. Energy dispersive X-ray spectra (EDS): a) Rotor base metal on a polished cross section; b) intact original bearing surface as indicated in figure 9; and



c)

Figure 10 (cont.). c) region indicated in figure 9 where the nitride layer spalled from the rotor body.

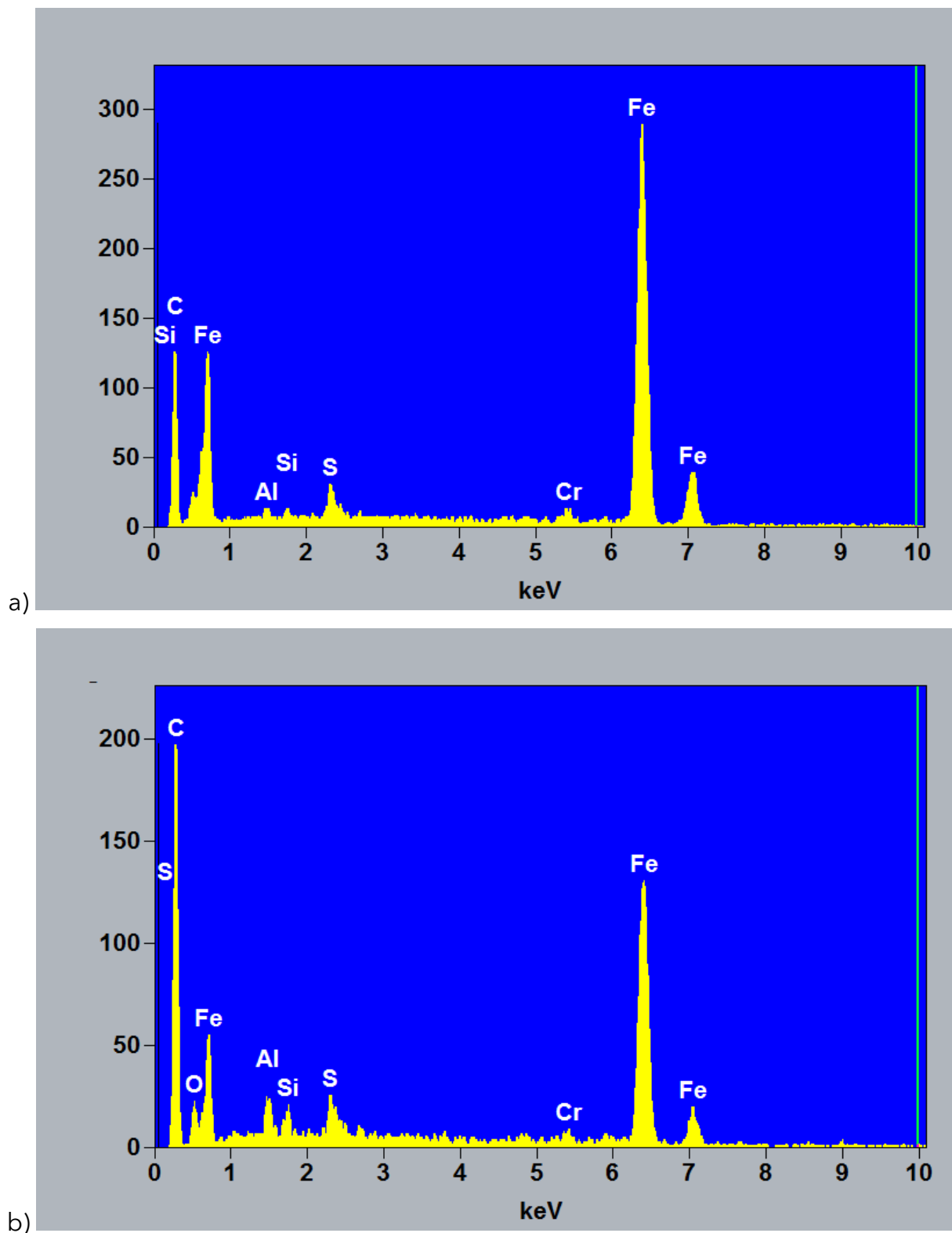


Figure 11. EDS spectra from carbon bearing fracture surface as indicated in figures 3b and 3d: a) from region indicated in the SEM image and b) second region indicated in the figure.

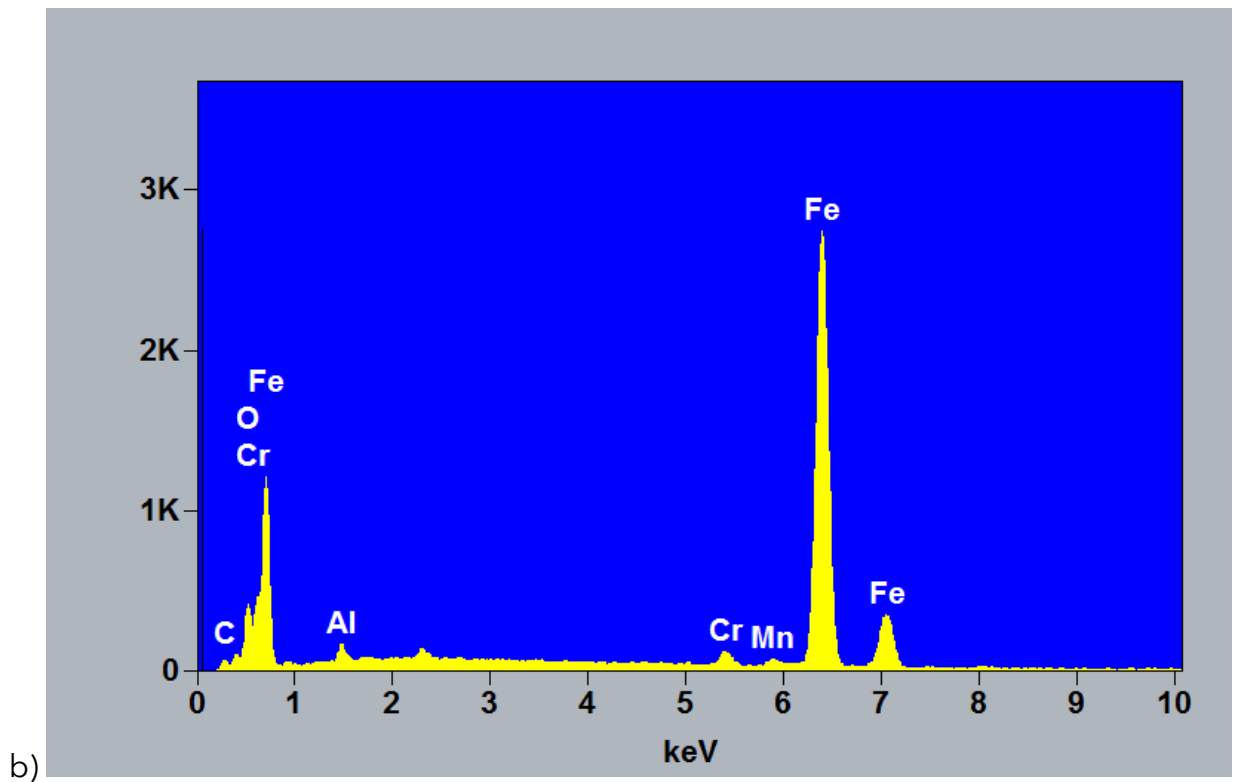
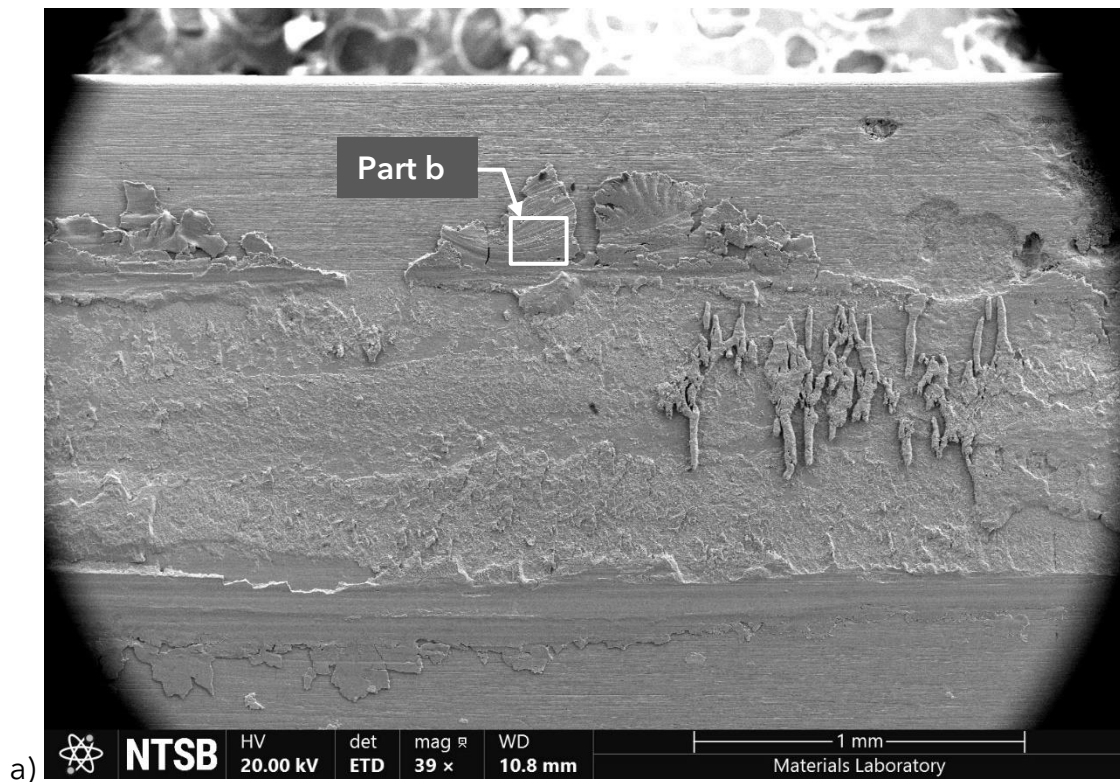


Figure 12. a) SEM image of scar on inner diameter of liner with region indicated and b) EDS from indicated region.

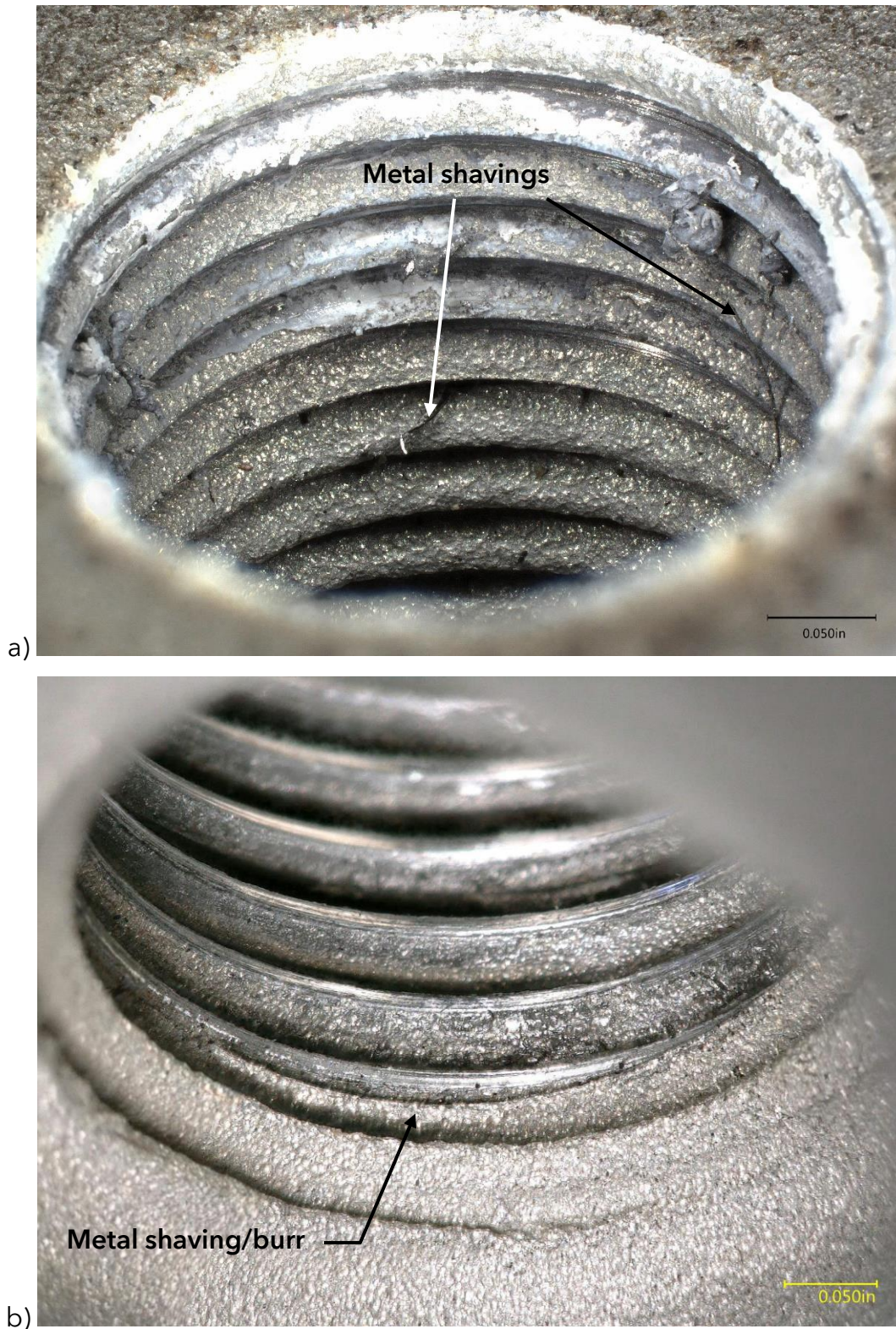


Figure 13. Metal shavings/burrs found in several of the pump's threaded connections: a) overflow port on mounting flange of pump with zinc-plated plugging screw removed and b) inlet/outlet fuel line connection port.

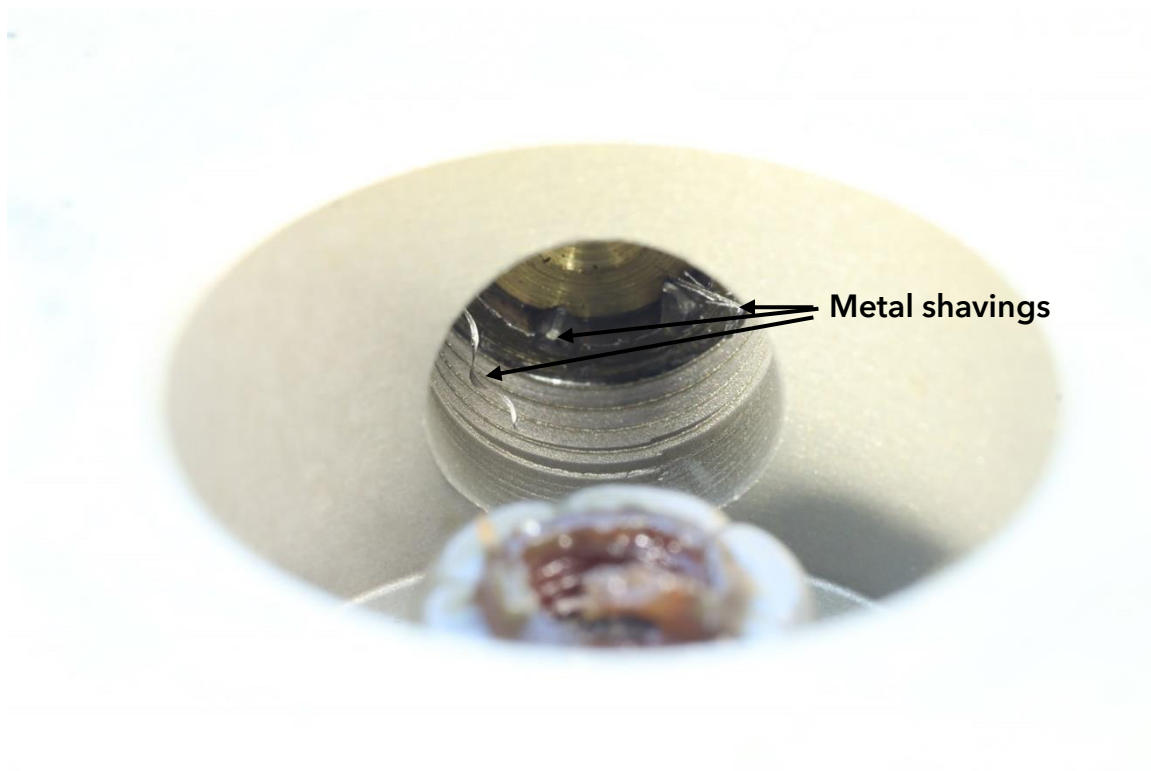
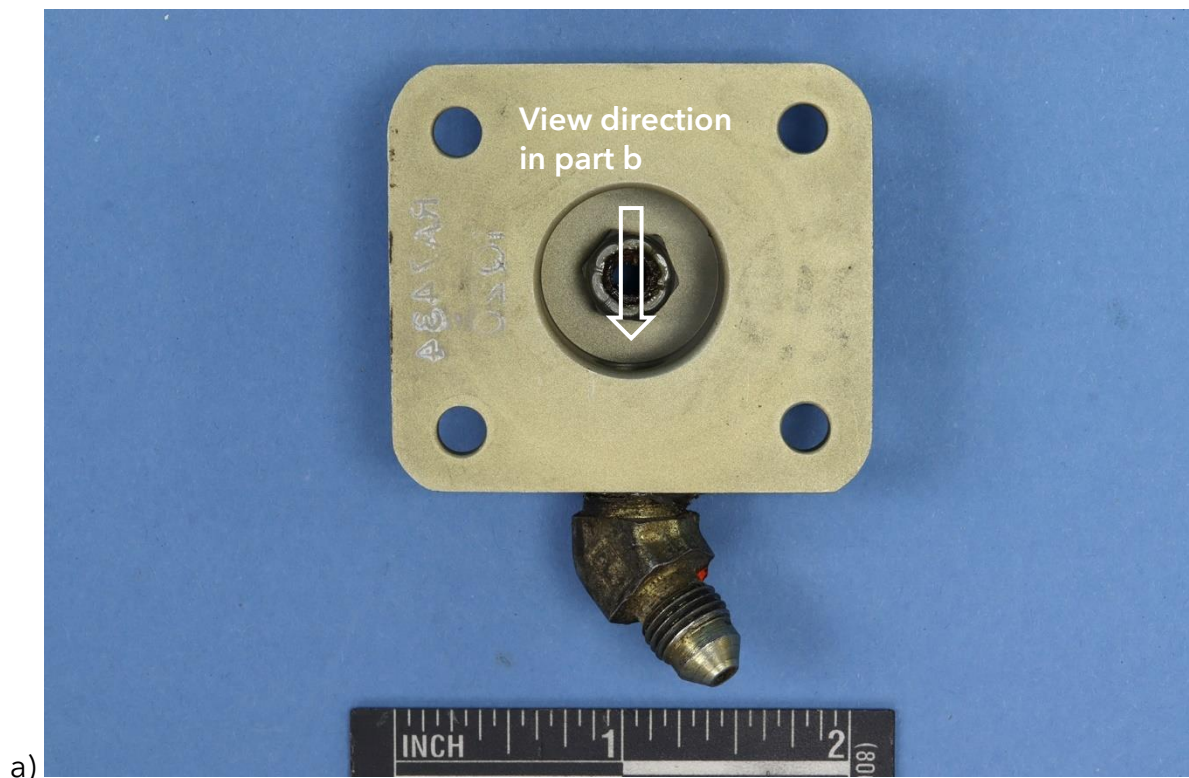


Figure 14. Image of underside of relief valve housing cover plate and b) oblique view showing metal shaving in threaded port connection.

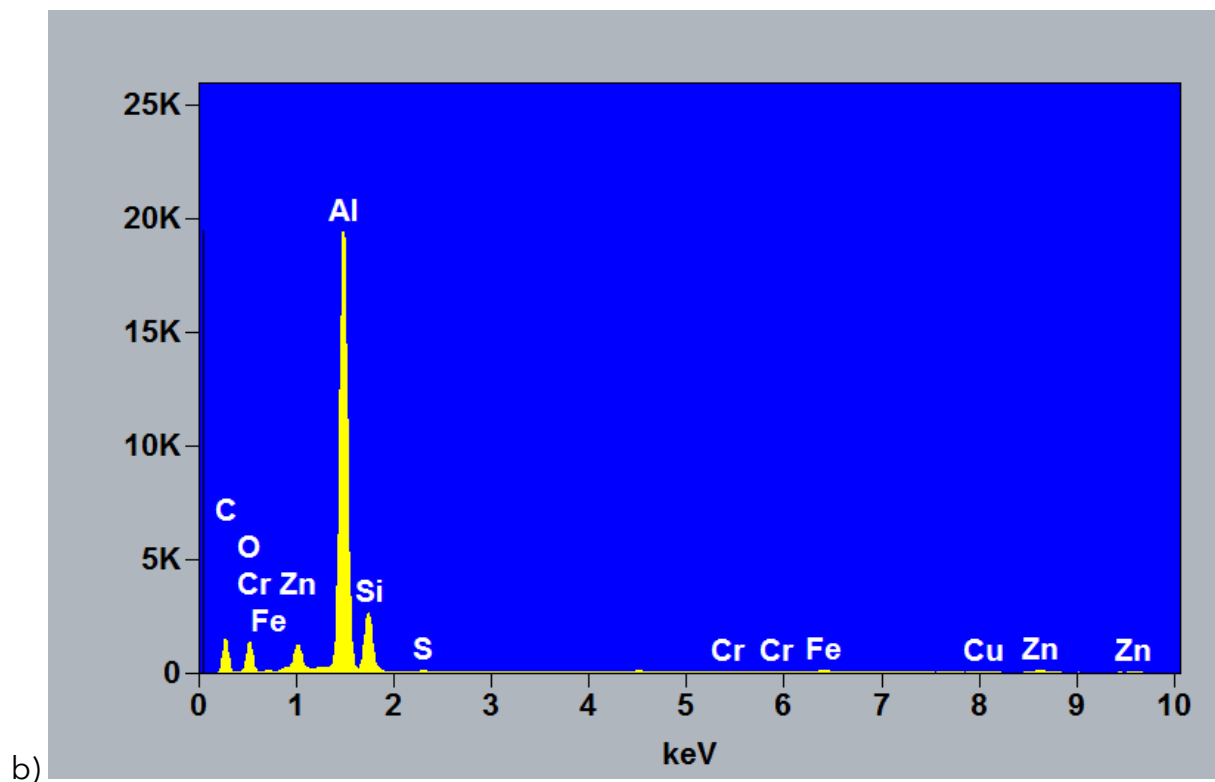
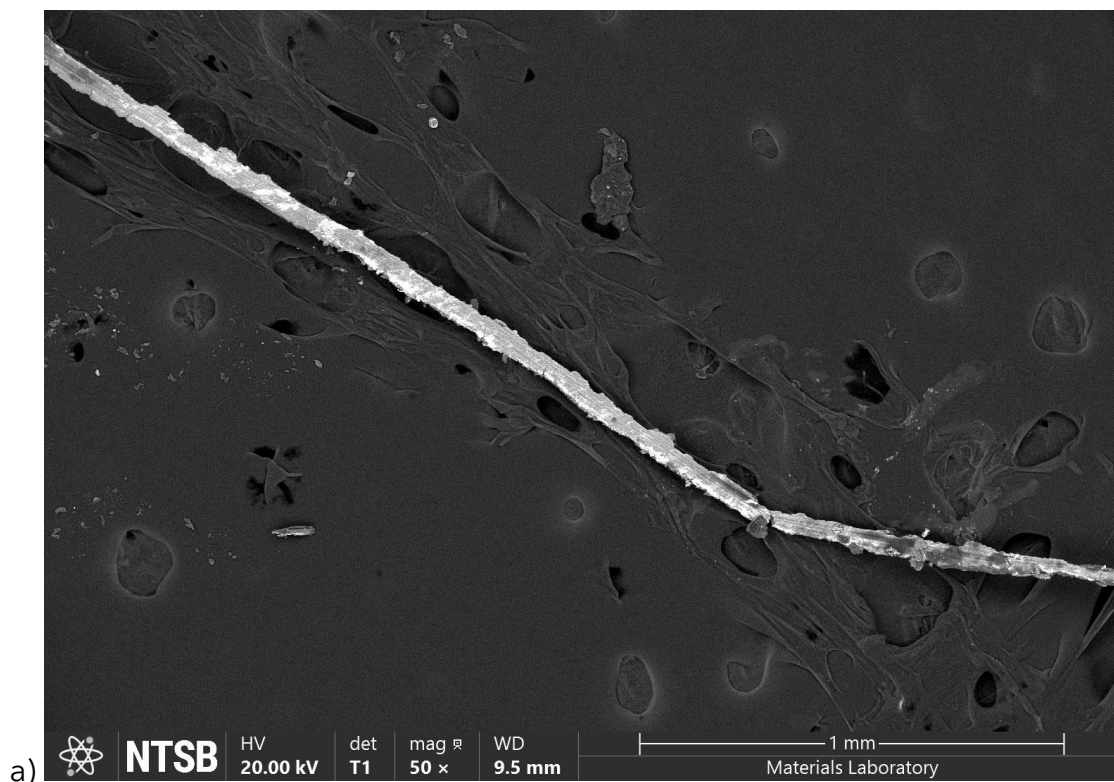


Figure 15. a) SEM image of metal shaving removed from the top plugged mounting flange port after the zinc-plated plug was removed; b) EDS of the metal shaving; and

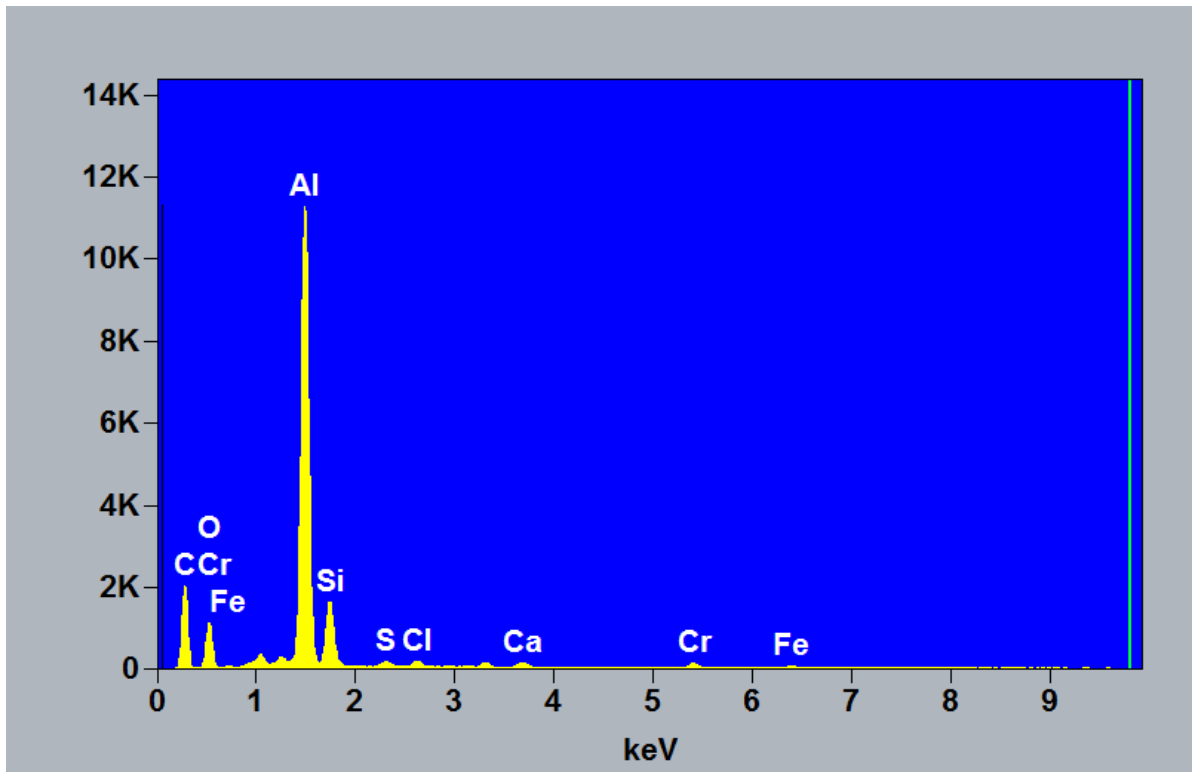


Figure 15 (cont.). c) EDS of the pump housing.

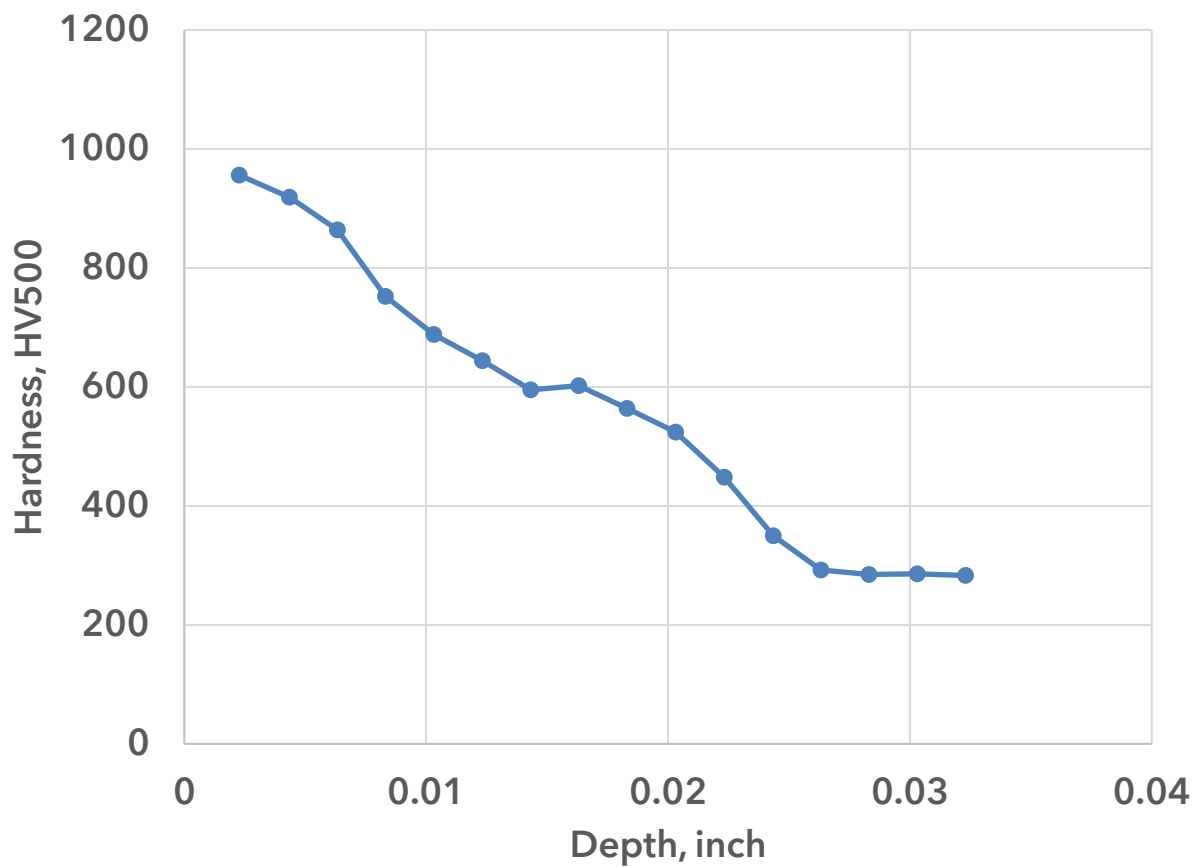


Figure 16. Case depth of nitride layer on pump rotor bearing journal. Case depth was taken on the outer diameter of the slotted drive end.