

NATIONAL TRANSPORTATION SAFETY BOARD

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



April 5, 2022

MATERIALS LABORATORY FACTUAL REPORT

Report No. 22-020

A. ACCIDENT INFORMATION

Place : Crab Orchard, Kentucky
Date : December 10, 2021
Vehicle : Beech V35, N5704V
NTSB No. : ERA22FA085
Investigator : Ralph Hicks, ASI – ERA

B. COMPONENTS EXAMINED

Pieces of an Airborne dry air pump, P/N: 216CW S/N: 48343.

C. DETAILS OF THE EXAMINATION

Pieces of an Airborne dry air pump were submitted to the NTSB Materials Laboratory for examination, as shown in figure 1. The pump's outlet cover plate had been previously removed, revealing a rotor that had fractured into multiple pieces and one rotor vane that had fractured spanwise. The other five rotor vanes were still intact. As shown in figures 1 and 2a, the drive coupling had fractured along the shaft's transverse plane in a reduced diameter section. Examination of the fracture surfaces revealed circular marks and a molten/resolidified polymeric appearance that was consistent with a torsion overstress fracture.

Examination of the inlet cover plate revealed that a fastener was missing, as indicated in figure 2a. The fastener was one of two used to attach the inlet cover plate to the stator housing. When viewed from the side, as seen in figure 2b, the stator housing and inlet cover plate were visibly offset relative to one another in the lateral direction. The screw that was still attached was removed and is shown in figure 3. The stator housing was then separated from the inlet cover plate. The screw was bent along its length approximately one-third of the distance from the threaded end. The screw was examined for indications of thread locking compound. A dab of torque seal compound was observed on the screw cap, but no thread locking compound was found on the screw threads. The stator's threaded holes were examined for indication of sheared screw fragments or damaged threads, but none were found.

The stator's inner anodized surface exhibited wear patterns as shown in figures 4a – 4d. Near the fastener holes, the surface exhibited comparatively light color banding and spots near one of the end faces where the coating had been worn through, as indicated in figures 4a and 4c. Between the major and minor axes of the oval-shaped cavity, the

inner surface exhibited an alternating light/dark banded appearance, as indicated for two such regions in figure 4b. The stator surface was examined for any gouges or any notable circumferential scratches, but none were found.

The end faces of the stator housing that butted against the inlet cover plate exhibited an appearance consistent with rubbing. Images of the stator housing's end faces are shown for the threaded hole with the retained fastener (right side in figure 2a) and for the threaded hole with the missing fastener (left side in figure 2a) in figures 5 and 6, respectively. Figure 5a shows the end face that butted against the outlet cover plate (the end plate that was previously removed) and figure 5b shows the end face that butted against the inlet cover plate. Machining marks were observed on the end face that butted against the outlet cover plate, whereas the end face that butted against the inlet cover plate exhibited a comparatively smooth matte appearance. White powdered debris was also observed on the inlet side end face, as seen in figure 5b. Similarly, for the threaded hole with the missing fastener, the end face butting the outlet cover plate exhibited machining marks, as seen in figure 6a, whereas the side that butted against the inlet cover plate exhibited some regions with a matte appearance and some regions where machining marks were still visible, as seen in figure 6b.

The pump's rotor hub was imprinted with Parts Manufacturer Approval (PMA) identifiers. The remaining pieces of the fractured rotor were removed as was the central screw that joined the hub to the drive coupling. The hub was removed from the inlet cover plate and wiped with alcohol. Information imprinted on the hub's base plate included "FAA-PMA" and "82-50135", as shown in figure 7. According to the FAA's PMA database (located at <https://drs.faa.gov/>), the PMA holder was Aero Accessories Inc.

The inlet cover plate was then visually examined, as shown in figures 8a and 8b. Regions of the inlet cover plate were coated with debris. Yellow-colored debris was observed in the space underneath the hub and white-colored debris was observed in a region that butted against the stator housing, as seen in figure 8a. A higher magnification image of the latter is shown in figure 8b. The debris was in a similar location as the debris previously observed on the stator housing, shown in figure 5b.

A sample of the white debris was lifted from the plate using a piece of conductive carbon tape and examined using a scanning electron microscope (SEM) equipped with an energy dispersive X-ray spectrometer (EDS), as shown in figure 9a. An EDS spectrum of the debris exhibited primarily aluminum (Al), oxygen (O) zinc (Zn), sulfur (S), silicon (Si), and fluorine (F), as shown in figure 9b. Some the yellow debris was also lifted from the plate and examined similarly. Its spectrum (not shown) consisted of Al and O. EDS spectra were also gathered from the stator's inner anodized surface and the attachment screw (figure 3), as shown in figures 9c and 9d, respectively. The anodization layer's spectrum consisted of Al, O, and S, while the attachments screw's spectrum consisted primarily of Zn with additional peaks for Al, iron (Fe), and chromium (Cr).

Finally, the stator housing and inlet cover plate were reassembled using exemplar screws with the same size, thread pitch, and length as the one that was removed. The

screws were torqued to 50 lb-in, the assembly torque indicated by the manufacturer. The torque as a function of time was measured using a torque gauge. The torque curves for the side that had the retained fastener and the side with the missing fastener are shown in figures 10a and 10b, respectively. Both sides were torqued to the 50 lb-in threshold.

Donald Kramer, Ph.D.
Sr. Materials Engineer



Figure 1: Image of the as-received vacuum pump pieces.

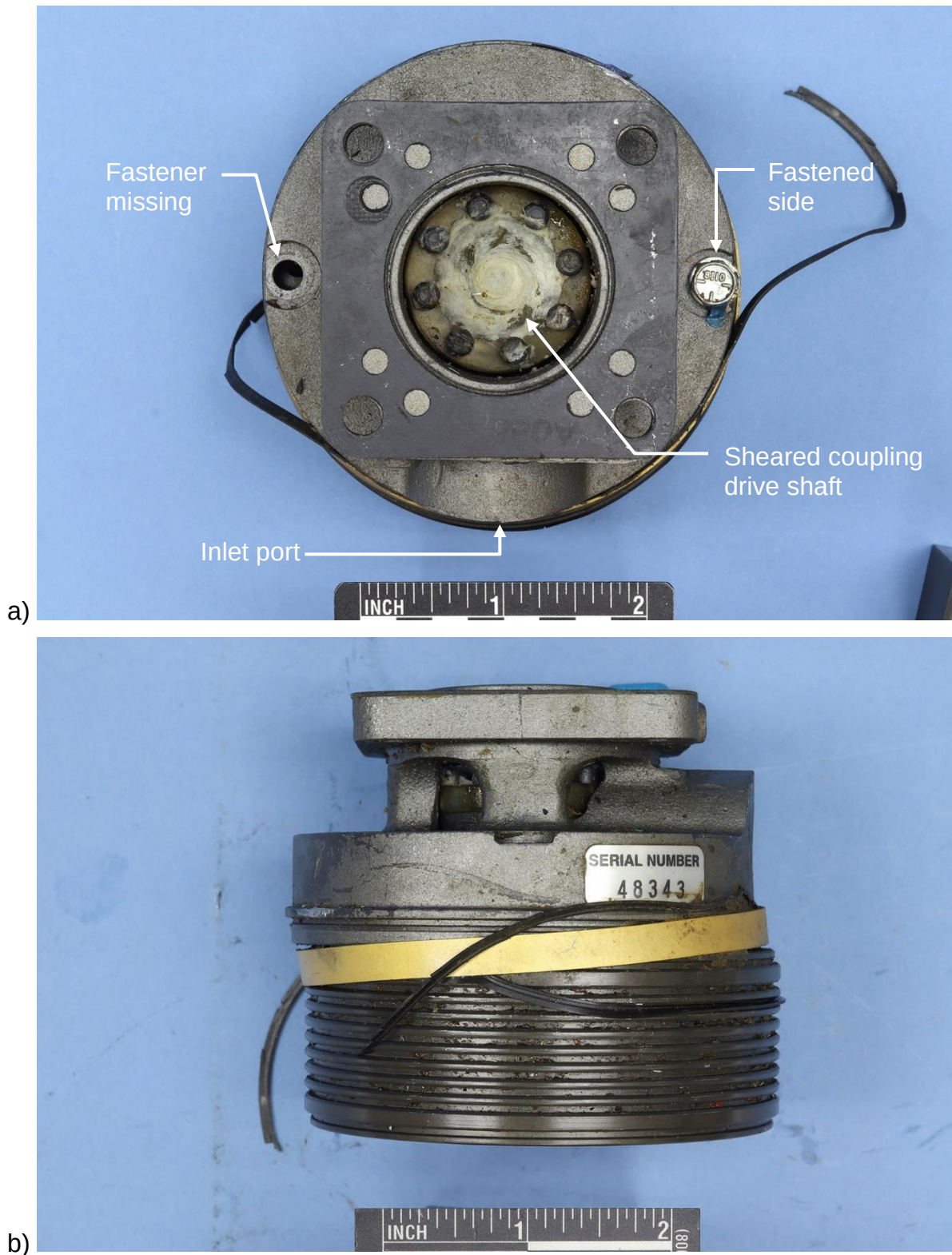


Figure 2: a) Image of the inlet cover plate showing a missing attachment screw and the sheared drive shaft and b) side view of the pump body showing the displacement of the inlet cover plate relative to the pump stator.



Figure 3: Image of the screw after it was removed from the pump. There was no apparent locking compound on the threads and the threaded section was bent.

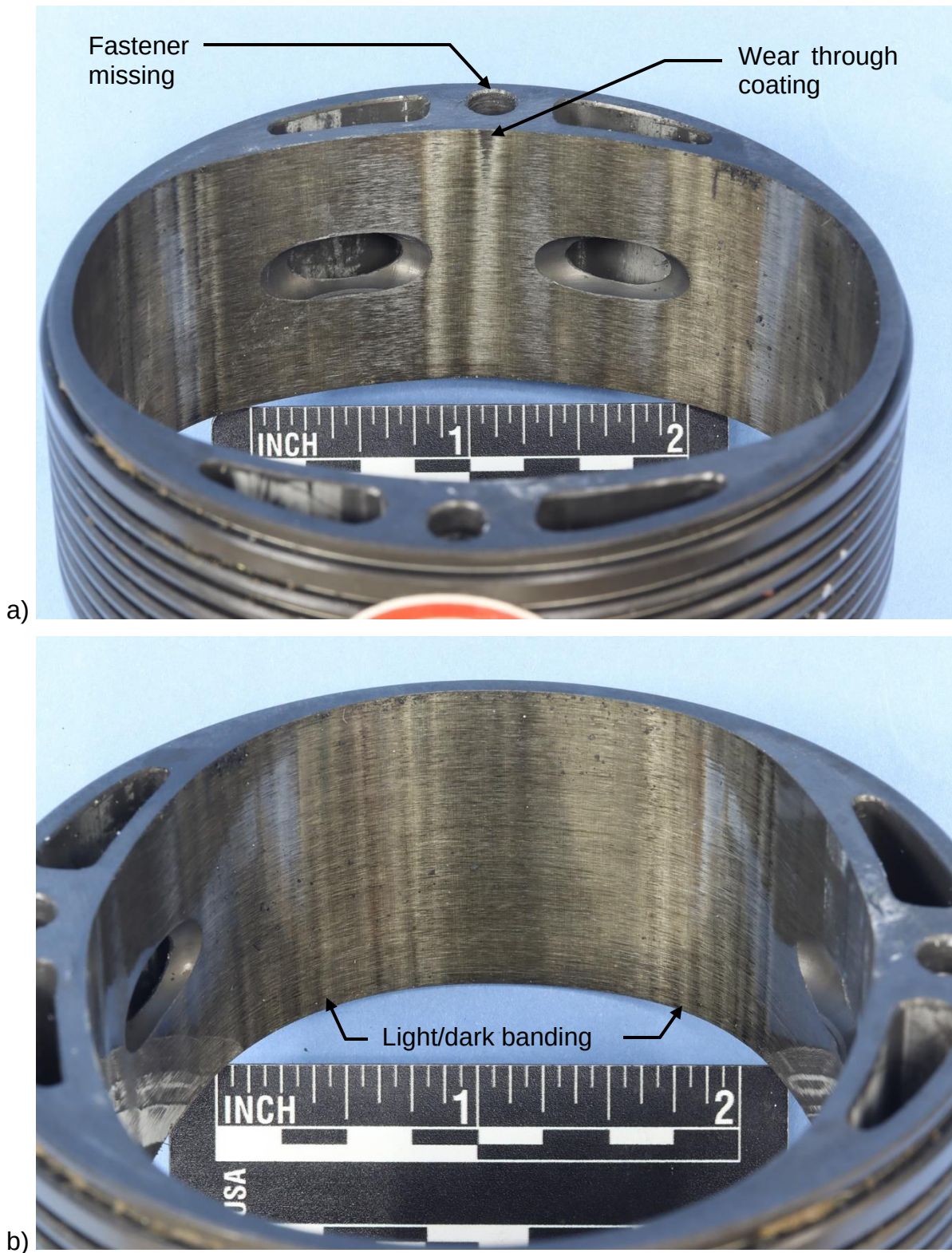


Figure 4: Image showing the typical condition of the pump stator's inner surface. The end face seen in the images butts against the inlet cover plate; a) side where fastener was missing; b) stator rotated 90° counterclockwise from part a);

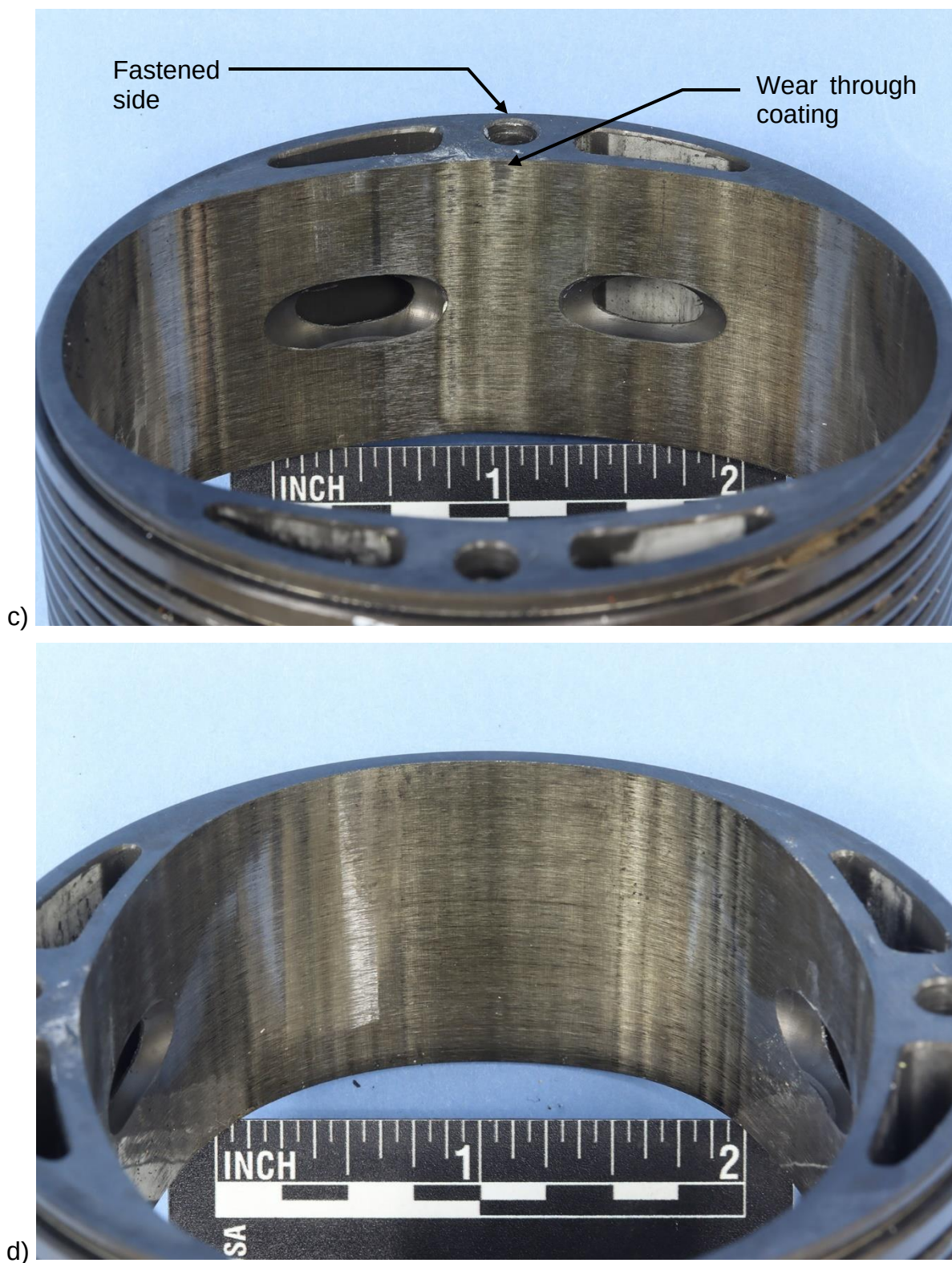


Figure 4 (cont.): c) side that was fastened; d) rotated by 90° counterclockwise from part c).

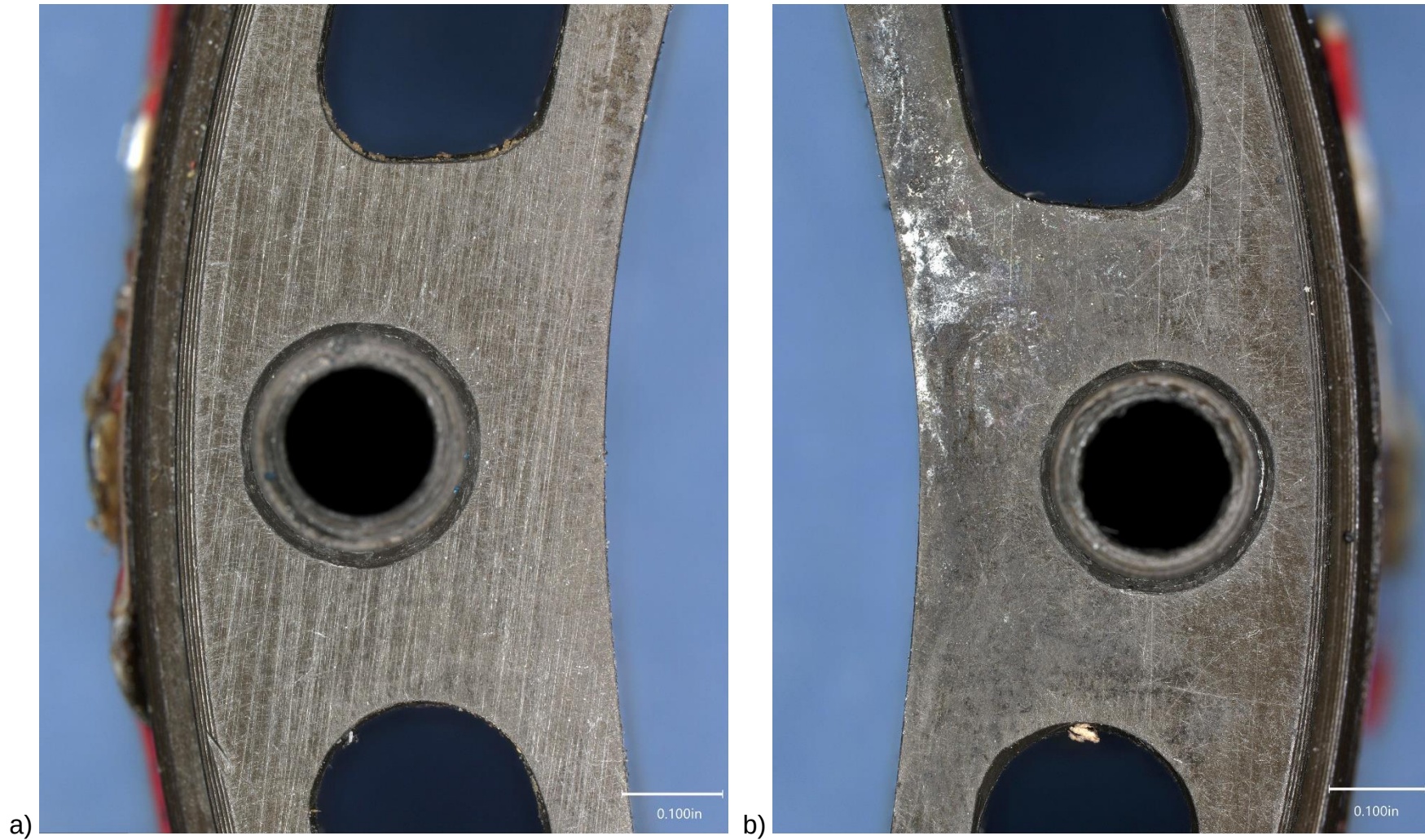


Figure 5: Images of the stator housing end faces around the threaded hole with the retained inlet cover plate fastener; a) end face that butted against the outlet cover plate and b) end face that butted against the inlet cover plate.

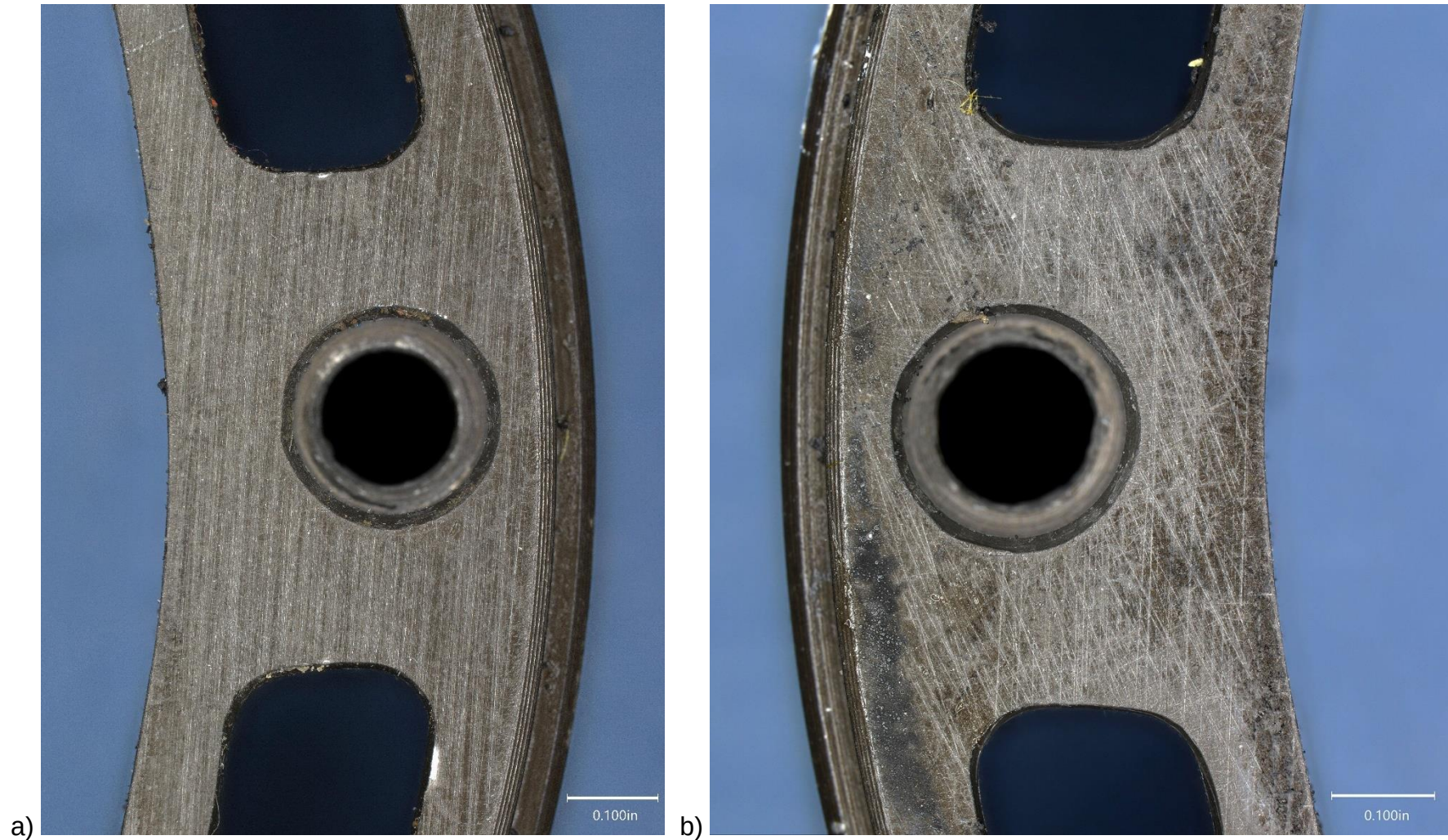


Figure 6: Images of the stator housing end faces around the threaded hole with the missing inlet cover plate fastener; a) end face that butted against the outlet cover plate and b) end face that butted against the inlet cover plate.



Figure 7: Image of information imprinted on the rotor hub: “FAA-PMA” and “82-50135”.

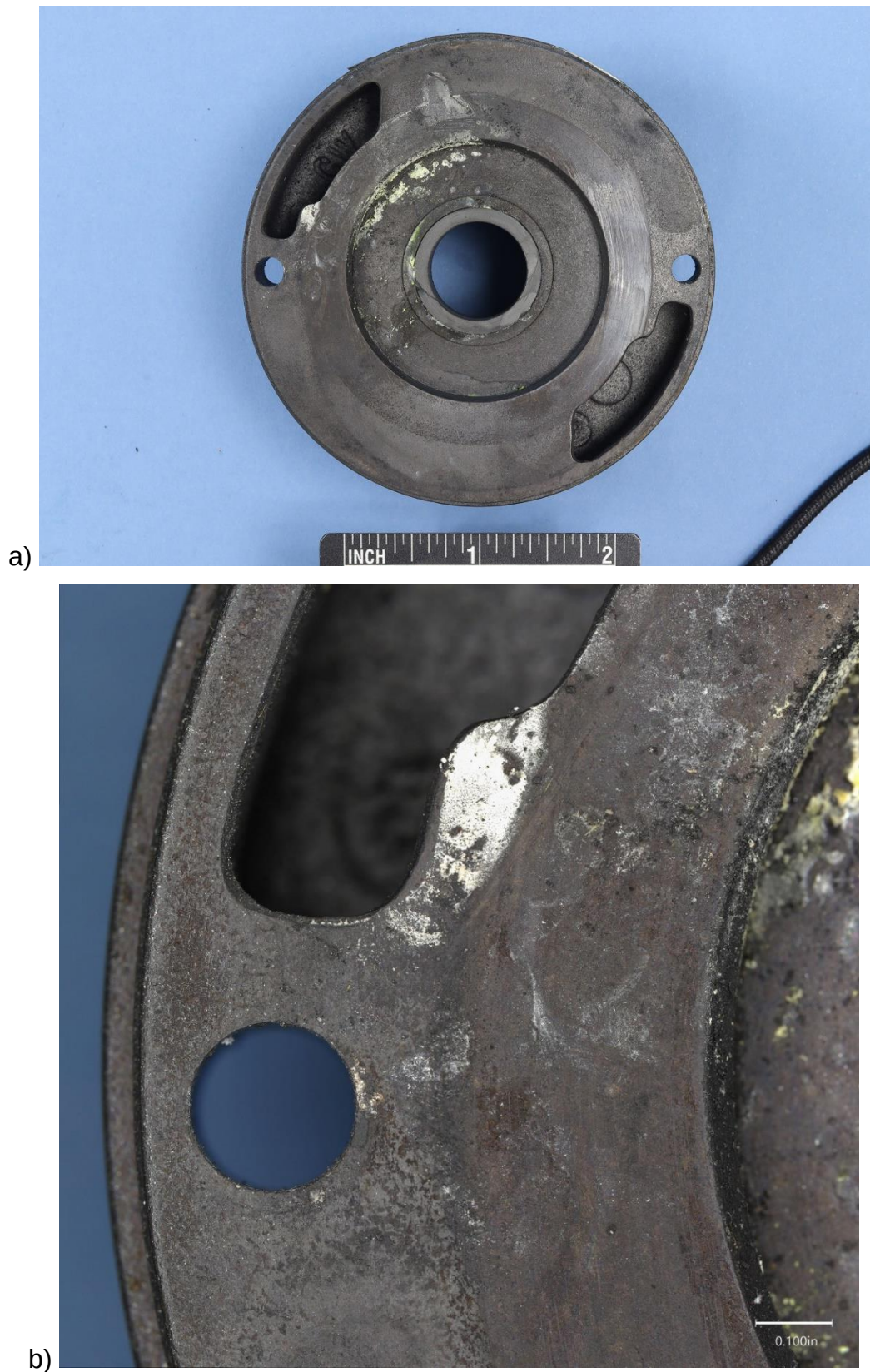


Figure 8: Images of the stator-facing side of the inlet cover plate after rotor hub removal; a) overview image and b) higher magnification image showing debris on the plate.

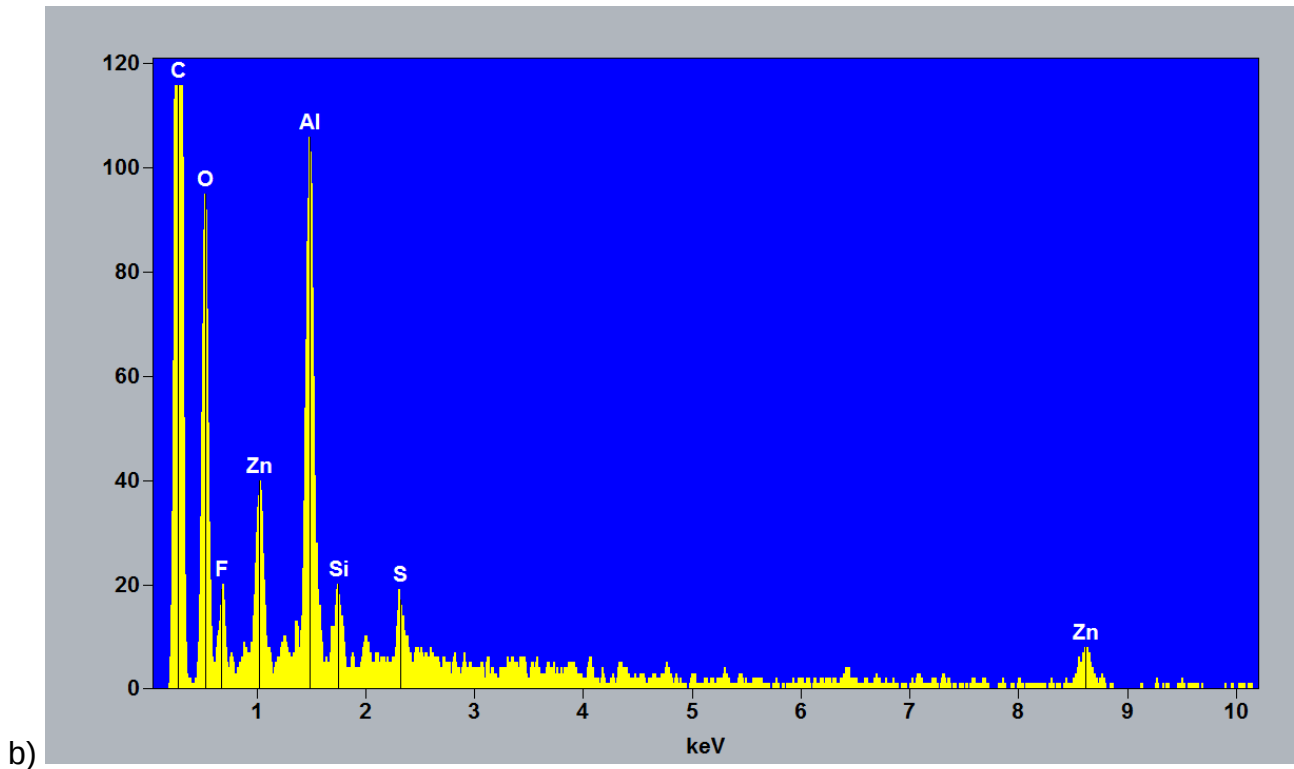
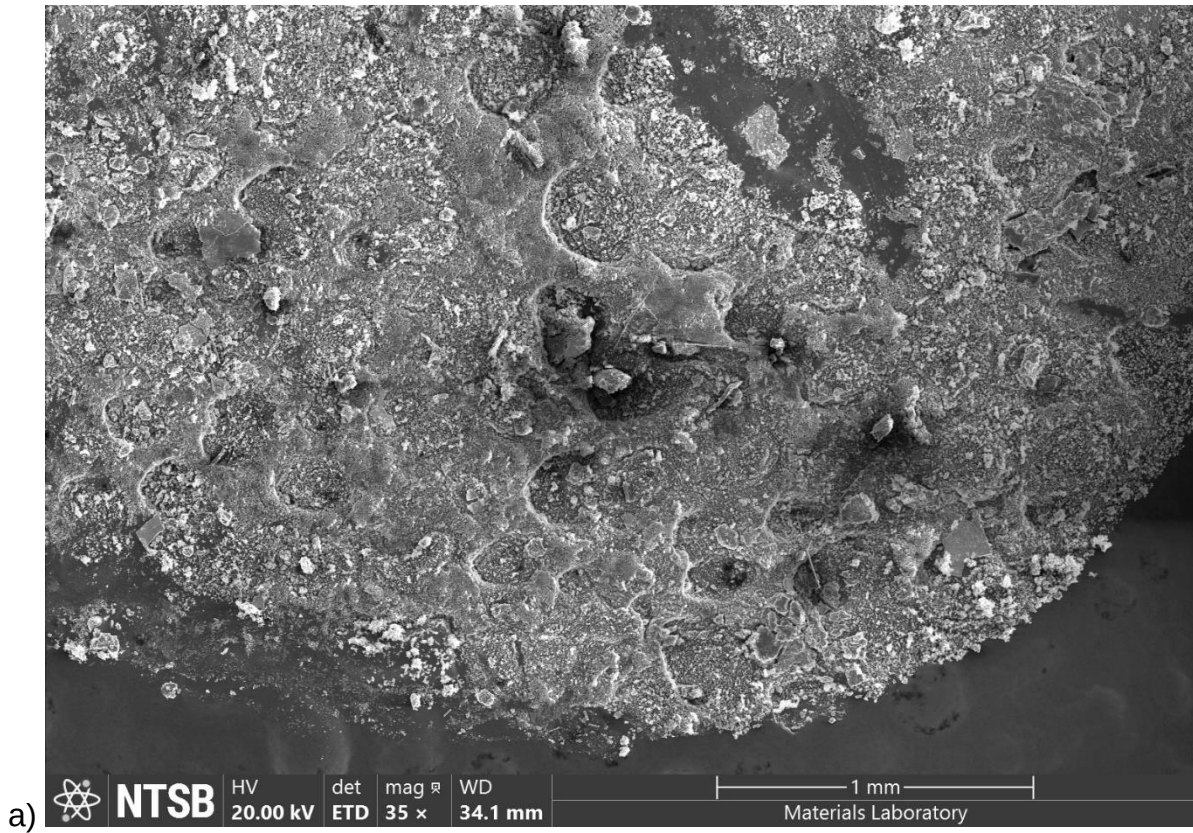


Figure 9: a) SEM image of the debris taken from the inlet cover plate; b) EDS spectrum of the debris exhibiting aluminum (Al), oxygen (O), zinc (Zn), sulfur (S), silicon (Si), and fluorine (F);

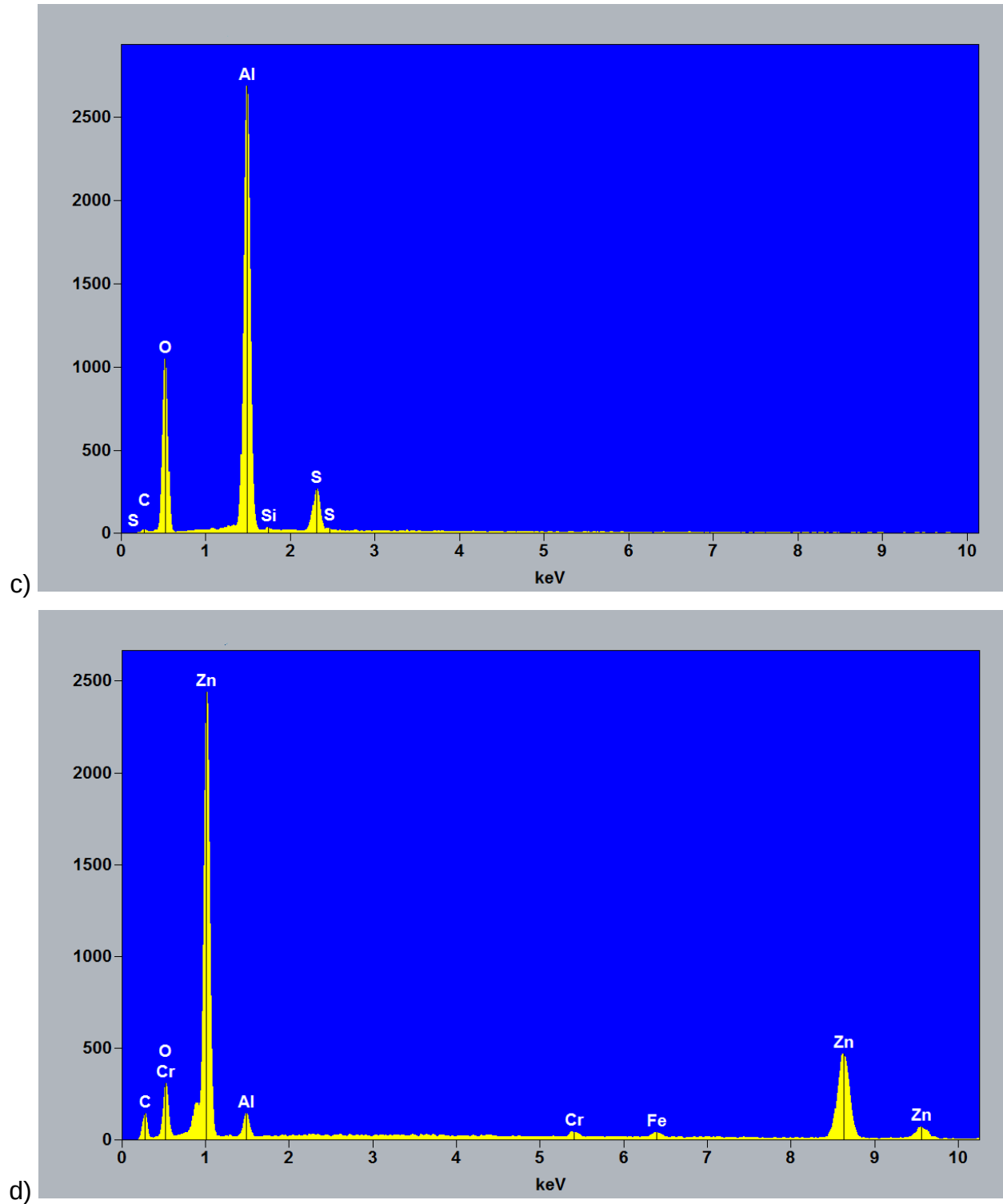
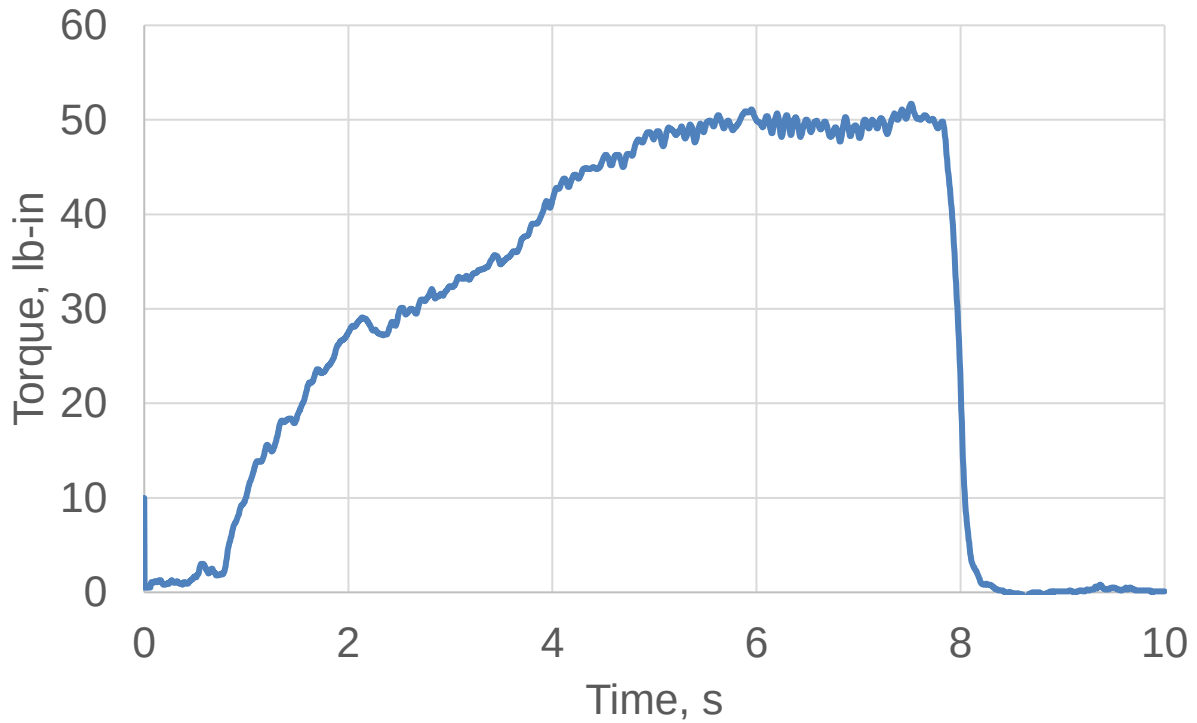
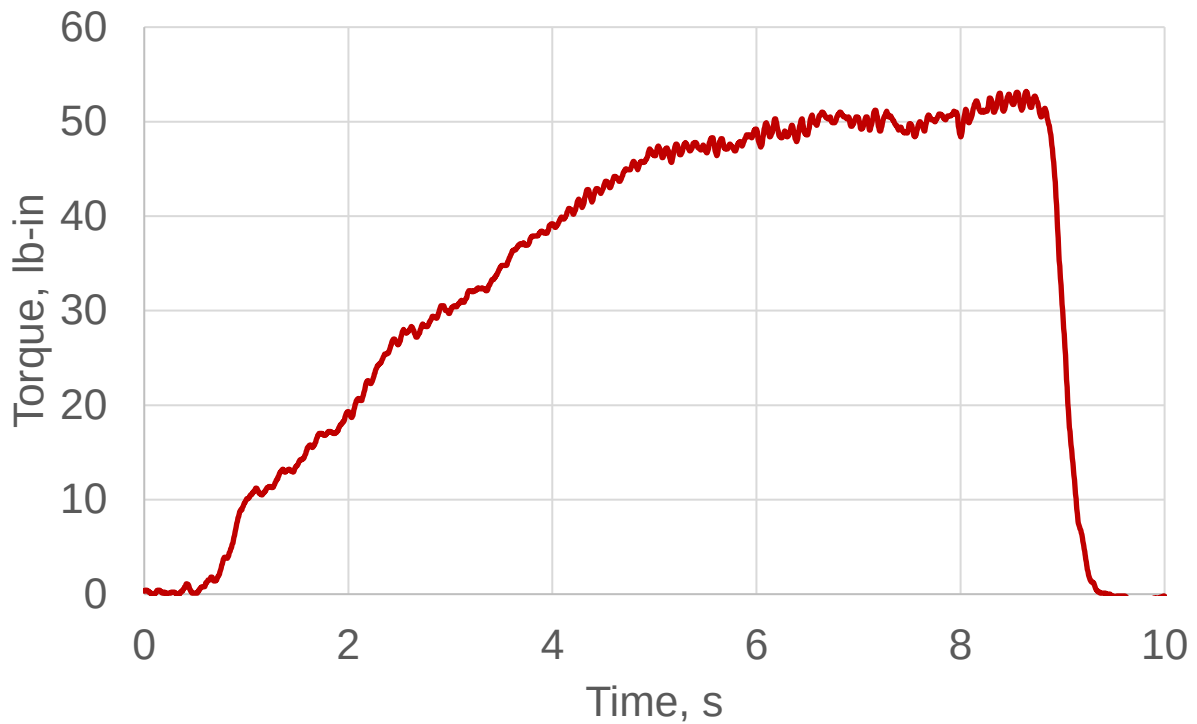


Figure 9 (cont.): c) EDS spectrum of the stator's inner surface exhibiting Al and S; and d) EDS spectrum of the inlet plate's attachment screw exhibiting primarily Zn with traces of Al, iron (Fe), and chromium (Cr).



a)



b)

Figure 10: Torque vs time data for each cover plate screw hole using exemplar screws; a) the side with the retained fastener and b) the side with the missing fastener.