

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



CEN21LA351

MATERIALS LABORATORY

Factual Report 22-087

November 10, 2022

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A. ACCIDENT INFORMATION

Location: Rushville, Nebraska
Date: August 2, 2021
Vehicle: Cozy MK IV, N1361S
Investigator: Michael Hodges, AS-CEN

B. COMPONENTS EXAMINED

Air brake actuator.

C. EXAMINATION PARTICIPANTS

Specialist Matthew R. Fox, Ph.D.
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Specialist Tom Jacky
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Specialist Ed Komarnicki
NTSB
Washington, DC

D. DETAILS OF THE EXAMINATION

The submitted linear actuator is shown as received in figure 1. The linear actuator had been installed on the accident airplane to extend and retract the air brake, a hinged panel on the lower side of the fuselage. The rear housing, motor, and two gears from the rear housing had been disassembled from the actuator as shown, and the extension tube was positioned approximately halfway between extended and retracted.

A data label on the side of the cover tube indicated that it was a Warner Electric (Thomson) Electrak 1 linear actuator, model number S12-17A8-04. Although the date of manufacture was not readily available, a representative from Thomson Industries indicated the label, which included a Dana Corporation logo, was consistent with those manufactured 20 to 22 years ago.

A schematic cross-sectional diagram of selected components of the linear actuator are shown in figure 2. The upper end of the extension rod is crimped to a nut made of nylon that translates linearly on an acme screw within the cover tube. The extension rod extends and retracts by turning the acme screw, which translates the nut and extension rod. The acme screw rotation is driven by an electric motor

through gears within the rear housing. A brush is pressed onto the upper end of the nut and secured with Loctite adhesive. Electrical stops within the cover tube turn off the motor when the stops are engaged by the brush attached to the nut. The electrical stops are located near the fully extended position or the fully retracted position. Depending on the load, the actuator can continue to coast past the electrical stop. Extension is mechanically limited by a bumper stop at the lower end of the acme screw.

Before disassembly, the linear actuator was examined using x-ray radiography to assess the condition of the internal components. Radiographs at the upper end, middle, and lower end of the cover tube are shown in figure 3. At the upper end of the cover tube, a medium gray area consistent with the brush was observed near washers at the upper end of the acme screw. The brush was separated from the nut and was tilted slightly off axis consistent with a spring load from the contacts. The middle left image in figure 3 shows the upper end of the extension tube in the middle of the cover tube and a medium gray area consistent with the nut located within the extension tube. The nut is outlined with a dashed rectangle in the lower right image in figure 3 based on the nut dimensions and the extent of the medium gray area within the extension tube. The nut appeared to be against the lower mechanical stop.

Next, the linear actuator was disassembled to view the internal components. A gear, retainer, snap ring, and washer were removed from the upper end of the acme screw, which allowed the acme screw to push into the cover tube. The front housing was pried off the upper end of the cover tube, revealing the upper end of the cover tube interior. A notch was cut in the side of the cover tube at the lower end, and a hammer and chisel were used to push the tube housing out the lower end.

A view of the internal actuator components at this stage of the disassembly is shown in figure 4. The acme screw and the upper end of the extension tube were covered in grease. Fractured flange pieces from the nut were also recovered in the grease on the extension tube. The tube housing was retained on the extension tube and rotated and translated on the extension tube with some resistance. The nut was observed within the extension tube and slid easily along the length of the tube. The acme screw also turned easily, but it was unclear if the screw turned within the nut and/or the nut turned within the extension tube in response to the applied torque on the acme screw.

In an attempt to separate the acme screw and nut from the extension tube, the acme screw was pulled upward relative to the extension tube. However, the motion stopped when the upper end of the nut contacted the crimps in the extension tube; the nut was essentially trapped within the extension tube by the crimped end. To accomplish separation of the nut and screw from the extension tube, a transverse cut was made near the lower end of the tube, and the nut and acme screw were removed

through the cut end. A view of the components after this disassembly step are shown in figure 5.

The nut shown in figure 5 was covered with grease that also covered the acme screw and the interior surfaces of the extension rod. The nut turned easily on the greased acme screw, translating along the axis of the screw consistent with intact nut threads. Next, the stop was removed in an attempt to remove the nut from the lower end of the acme screw. However, the nut did not easily screw off the lower end. Instead, the washer was removed from the upper end of the acme screw, and the nut was easily unthreaded from the upper end of the acme screw.

The lower end of the cover tube is shown in figure 6 after removal of the internal components. Grease was observed on the side of the housing as indicated in figure 6 corresponding to sliding contact with the side of the brush. The grease was observed as low as 1.2 inches from the lower end of the cover tube.

The brush remained within the cover tube, and electrical contacts at each end of the contact raceway on the side of the cover tube prevented the brush from sliding out either end of the tube. To facilitate removal of the brush, cuts were made using a Dremel tool to make a rectangular cutout in the side of the cover tube through which the brush was removed. A view of the brush after removal is shown in figure 7. The brush was lightly covered in grease and showed no evidence of wear or binding from contact with the side of the cover tube shown in figure 6. Remnants of clear adhesive were observed around the interior surfaces.

The nut was cleaned in a degreasing liquid, and a view of the resulting cleaned nut is shown in figure 8. The threads within the nut appeared to be intact. A few isolated areas of clear adhesive were observed on the outer surface corresponding to the brush installation position. The flange in the middle of the nut was fractured around the circumference, and three pieces of the flange representing about $\frac{3}{4}$ of the circumference were recovered as shown in figure 5. Four recesses associated with the crimps on the extension rod were observed below the flange fractures. The fracture surfaces above the crimp recesses were obliterated by post-fracture rubbing from sliding contact with the crimped end of the extension rod as the rod moved upward (retraction direction) relative to the nut.

The nut flange pieces shown in figure 5 were cleaned in an ultrasonic cleaner while submerged in a solution of Alconox detergent and hot water. The cleaned fracture surfaces were then examined using a scanning electron microscope (SEM). An overall view of a typical origin area on one of the pieces and a closer view of typical fracture features near the origin area are shown in figures 9 and 10. Fractures on each of the pieces had broad origin areas on the lower side of the flange located above the crimp recesses. Near the origin area, the fracture surfaces had a rubbed appearance with tear ridges, fibrils, and elongated voids and dimple features, features consistent with overstress fracture in a plane of shear stress. The orientations

of the elongated features were consistent with the flange moving upward relative to the nut body, which was also consistent with the post-fracture sliding contact damage to the fracture surfaces from the crimped end of the extension rod. Further from the origin areas, the fracture features had rough features with tear ridges and circular voids, consistent with overstress fracture in a plane of tensile stress.

Submitted by:

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

Figure 1. Overall view of the partially disassembled air brake actuator as received.

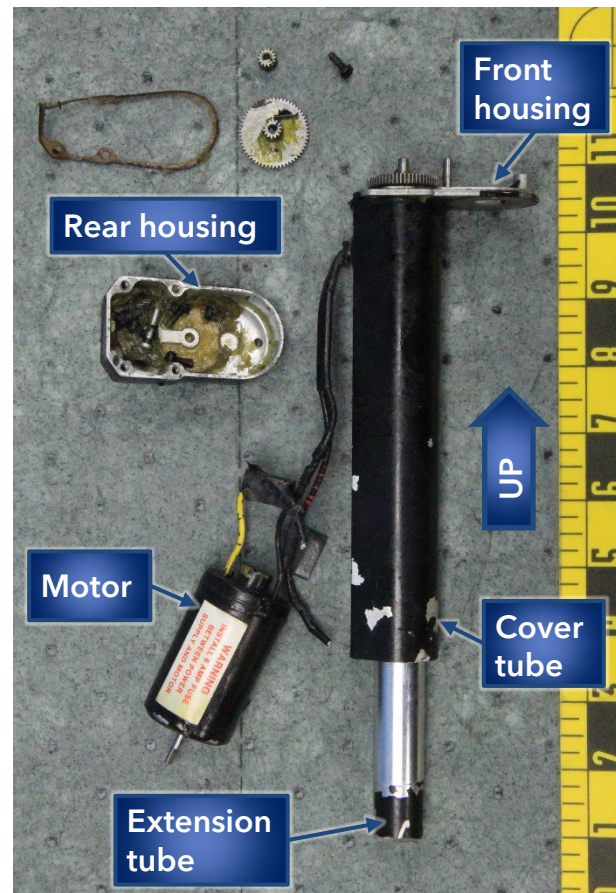
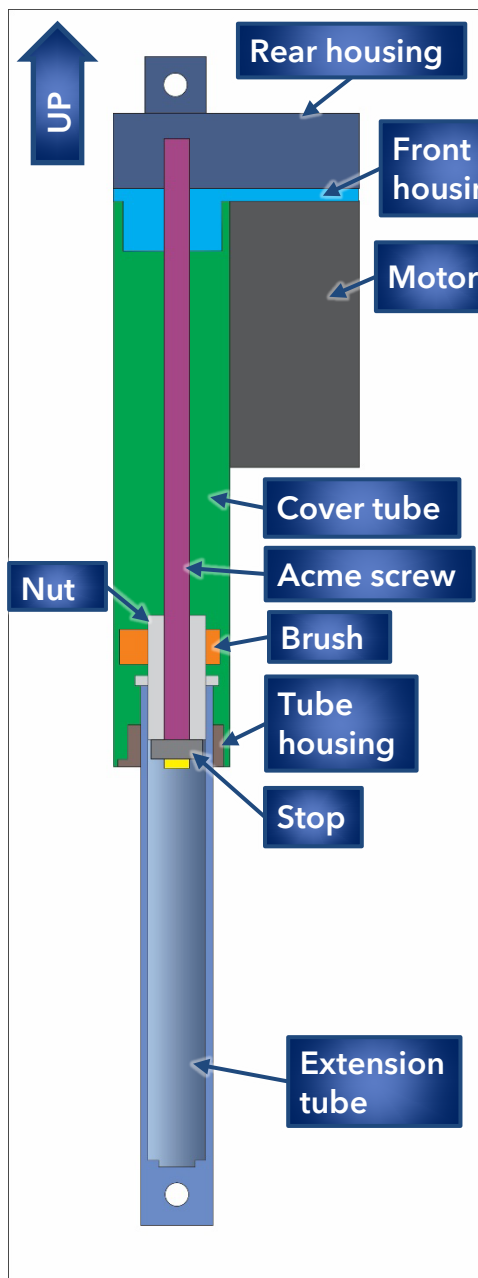


Figure 2. Schematic cross-sectional diagram of the linear actuator in the extended position showing selected internal components.

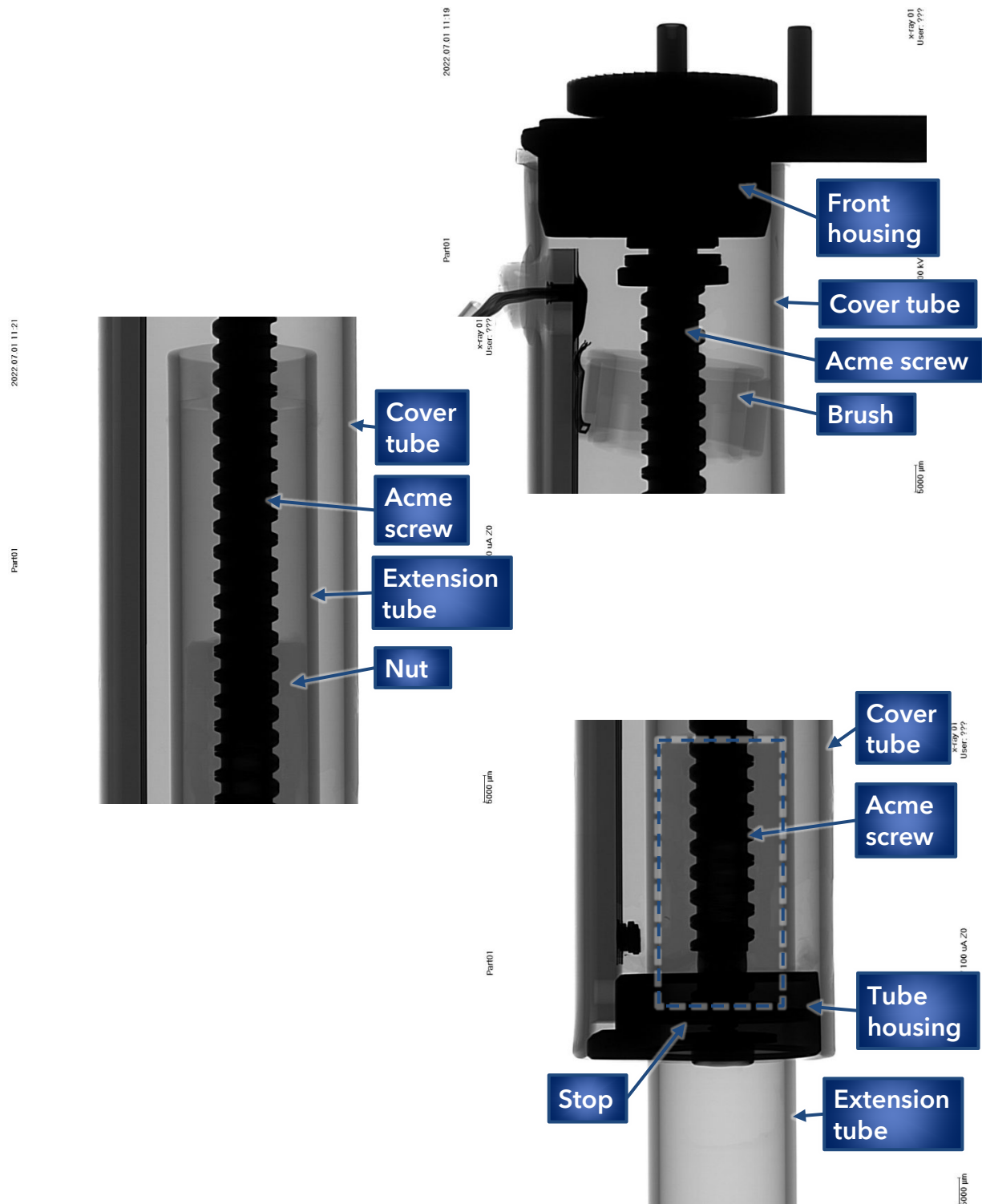


Figure 3. Radiographs of the upper end, middle, and lower end of the actuator cover tube as received. A dashed line in the lower right image indicates the location of the nut against the stop within the extension tube.



Figure 4. Linear actuator after disassembling the extension rod and acme screw from the cover tube.

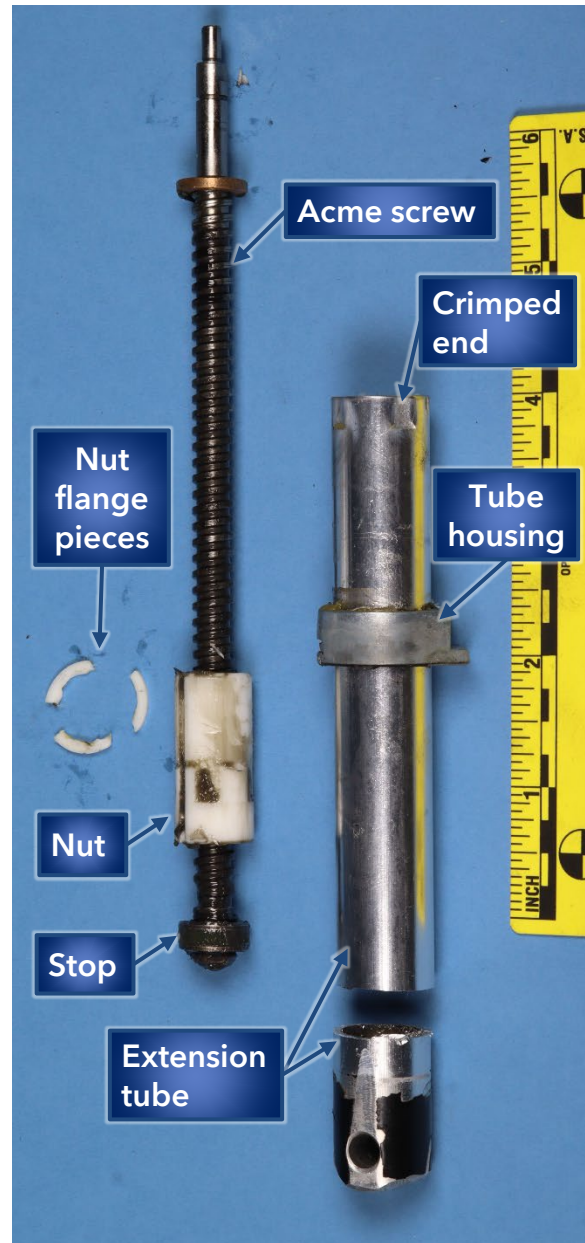


Figure 5. Acme screw and nut after disassembly from the extension tube.

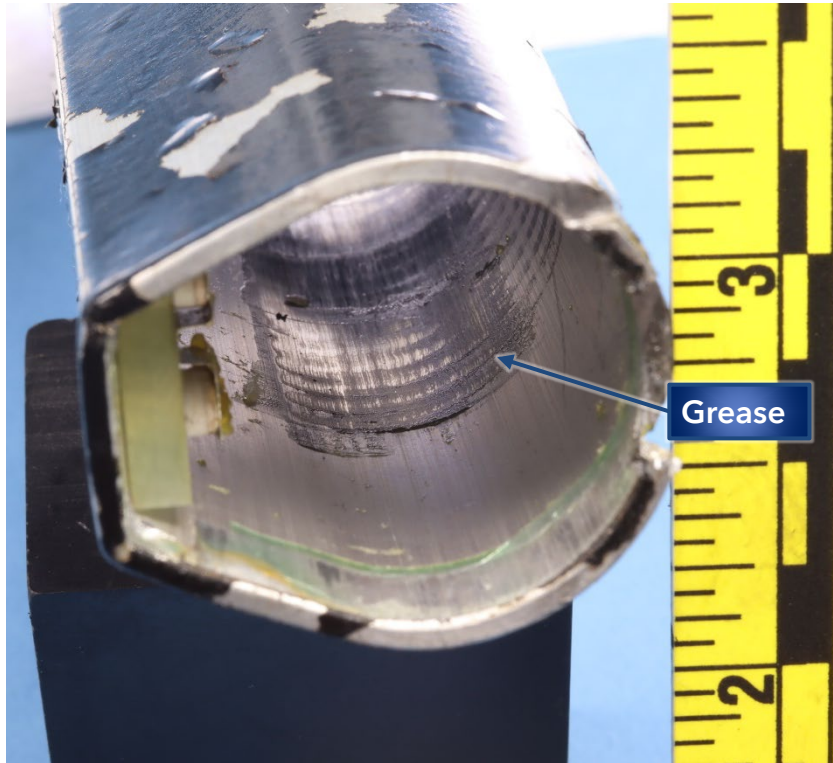


Figure 6. Interior of the cover tube after disassembly as viewed looking up from the lower end. Grease corresponding to contact with the side of the brush was observed.

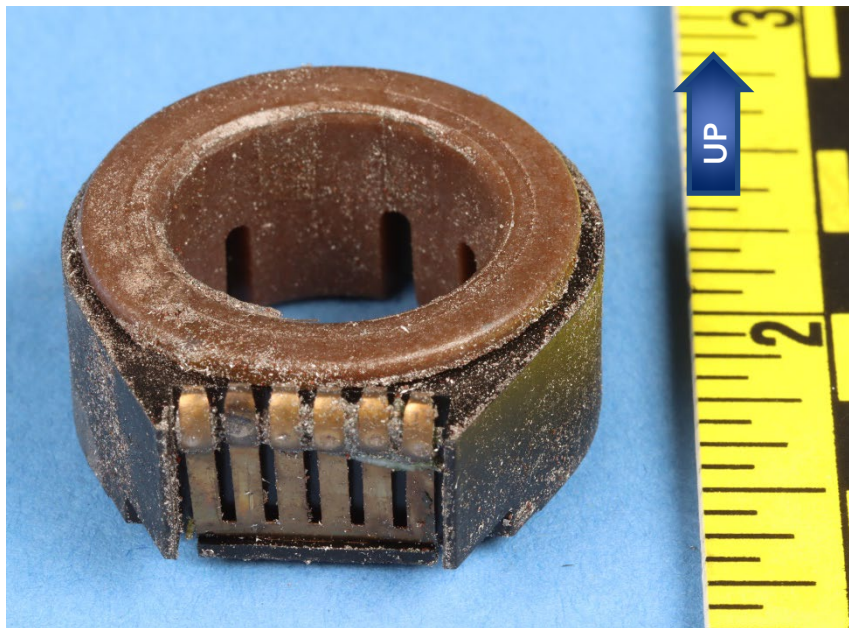


Figure 7. Brush assembly after removal from the cover tube.

Figure 8. Nut after removal from the acme screw and after cleaning.

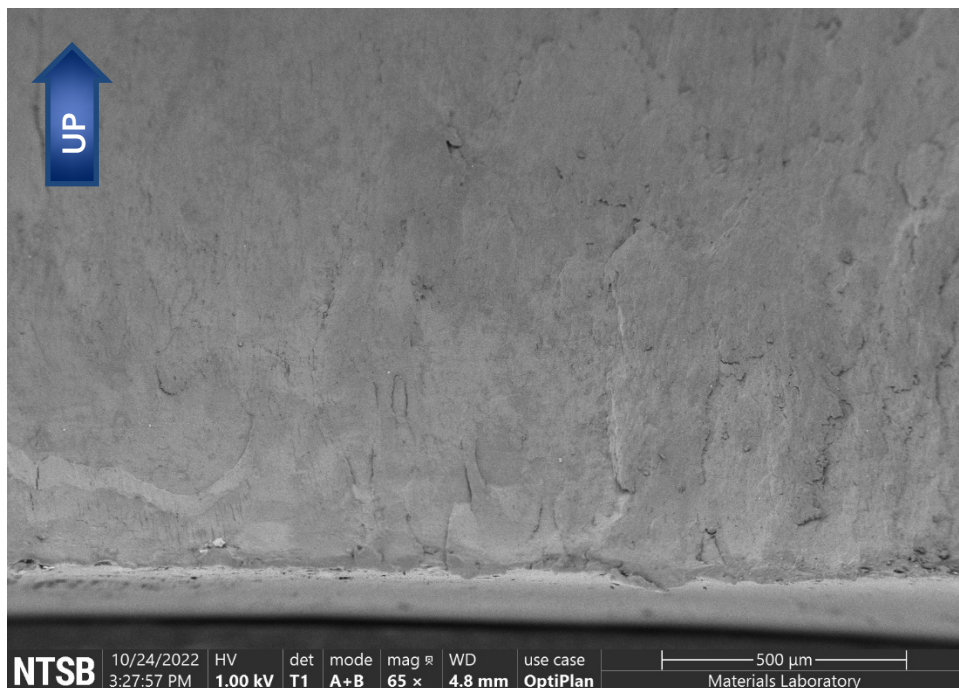
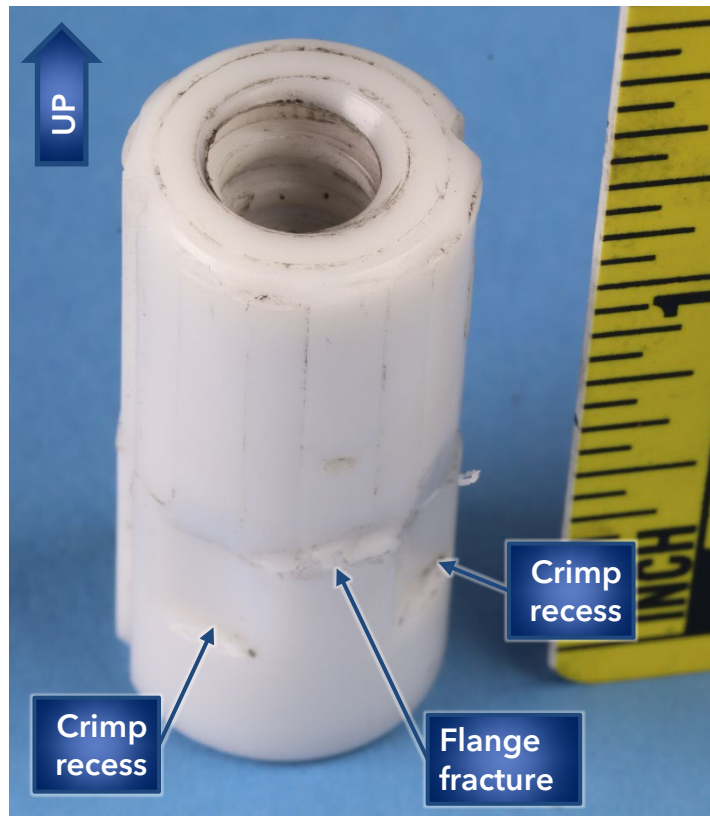


Figure 9. SEM image of typical fracture features on one of the nut flange fractures showing overstress features at a broad origin area.

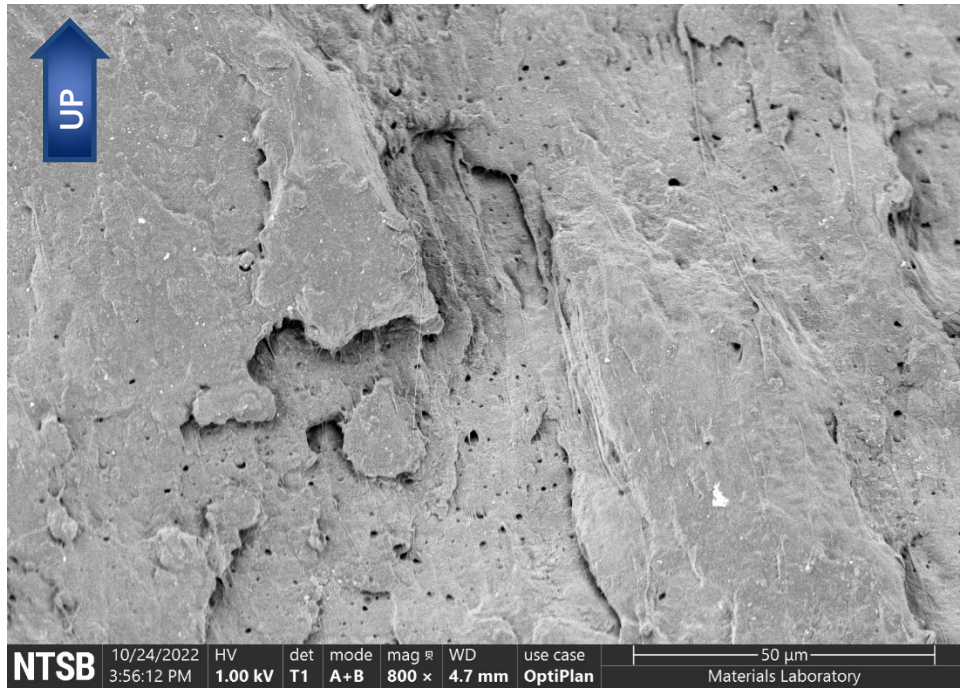


Figure 10. SEM image of typical fracture features on the nut flange near the origin area shown in the previous figure.