NATIONAL TRANSPORTATION SAFETY BOARD

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

March 17, 2000

MATERIALS LABORATORY FACTUAL REPORT Report No. 00-045

A. ACCIDENT

Place	:	Near Port Hueneme, California
Date	:	January 31, 2000
Vehicle	:	MD-83, N963AS
Operator	:	Alaska Airlines, Flight 261
NTSB No.	:	DCA00-M-A023

B. COMPONENTS EXAMINED

Upper and lower mechanical stops from horizontal stabilizer jackscrew, corresponding mechanical stop contact areas on the gimbal nut, splined lower end of the jackscrew.

C. ACCIDENT SUMMARY

On January 31, 2000, at about 1621 PST, Alaska Airlines flight 261 a Boeing MD-83, N963AS, crashed approximately 2.69 miles north of Anacapa Island, California into the Pacific Ocean. The flight, from Puerto Vallarta, Mexico to Seattle Washington with an intermediate stop in San Francisco, was operating under title 14 CFR part 121. All 83 passengers and 5 crewmembers were fatally injured and the aircraft was destroyed. Visual meteorological conditions prevailed at the time of the accident.

D. DETAILS OF THE EXAMINATION

This report contains information only on the upper and lower mechanical stops of the jackscrew assembly, portions of the gimbal nut that contact the stops, and the splined lower end of the jackscrew. Additional Materials Laboratory reports will address other aspects of the laboratory examinations of the jackscrew and gimbal nut from the accident airplane.

The mechanical stop assemblies are attached to upper and lower splined regions on the jackscrew and are secured to the screw by tangential (clamp) bolts that pass through circumferential grooves in the splined regions. The mechanical stops rotate with the jackscrew as it turns. As the jackscrew reaches the mechanical limits of its range of travel, stopping action is provided by contact between the head of a steel bolt in the mechanical stop and the

head of a similar bolt in the ACME (gimbal) nut. An example of proper contact for a jackscrew assembly similar to that of the accident assembly is shown in figure 1, where an unlabeled arrow indicates the contact location between the gimbal nut “N” and the mechanical stop “S”. Neither the upper nor lower stop bolt faces showed evidence of contact at this location. The electrical control system for the jackscrew assembly also contains electrical stops, which during normal operation, stop screw rotation before the mechanical stops contact. A torque tube (quill shaft) passes through the center of the jackscrew with a threaded region extending below the lower surface of the jackscrew. The lower end of the quill shaft is secured against the lower surface of the jackscrew by a nut and washer, as shown in figure 1, leaving a gap, “G”, between the washer and the lower surface of the lower stop.

An overall view of the jackscrew assembly with the attached gearbox is shown in figure 2. The lower stop, labeled “ls” in figure 2, was received separated from the jackscrew, labeled js” in figure 2. The lower stop is shown as received in figure 3. The tangential bolt that clamps the lower stop to the splines of the jackscrew was still in place within the stop. Two lengths of the safety wire, labeled “sw” in figure 3, (0.050 inch diameter) remained attached to the clamp bolt, and were separated from the torque tube nut. The upper stop, labeled “us” in figure 2, was disassembled from the jackscrew in the Materials Laboratory. After visual examination, the stops were ultrasonically cleaned in an Alconox solution, removing residual grease from the surface. The stops were then examined using optical microscopy, scanning electron microscopy (SEM), and energy dispersive x-ray spectroscopy (EDS).

Lower Stop, Upper Surface

A view of the upper surface of the lower stop after cleaning is shown in figure 4. The upper surface showed multiple damage features, indicative of contact with another object. These features ranged from light marks in the primer to severe dents and deformation of the metal. Based on relative locations and feature shapes, features labeled “a” to “g” in figure 4, were all consistent with contact between the upper surface of the mechanical stop and various portions of the lower end of the gimbal nut, shown in figure 5. The lower stop lug of the gimbal nut protrudes below the main body of the nut, and as installed on the aircraft, is located on the aft side of the nut, indicated by bracket “2” in figure 5. The forward right corner of the lower stop lug was deformed at the position labeled “l” in figure 5, with wear of the right edge and deformation of the forward edge in the forward direction. Using the alignment pin hole (labeled “p” in figure 2) as a reference, the markings on the lower stop were used to determine the axial rotational orientations of probable contact between the lower stop and the gimbal nut. When assembled onto the jackscrew, the alignment pin is inserted through the alignment pin hole in the lower stop into a vertical slot (index spline) in the jackscrew splines. The angular orientations provided below are the clockwise rotational angle between the alignment pin hole and the aircraft forward direction as viewed from above. In other words,

- at a relative angle of 0 degrees, the alignment pin hole in the lower stop is positioned at the forward side of the gimbal nut,

- at a relative angle of 180 degrees, the alignment pin hole in the lower stop is positioned at the aft side of the gimbal nut,
- at a relative angle of 90 degrees, the alignment pin hole in the lower stop is positioned at the right side of the gimbal nut.

A total of seven different features on the lower end of the gimbal nut were identified as areas with a shape and radial location (from the axis of the jackscrew) consistent with the various damage areas on the lower stop. Those seven areas are described in the following table and are shown within the numbered circles or by numbered brackets in figure 5. Also listed in the table are the damage areas on the lower stop that correspond to each of the contacting areas described. The remainder of this section of the report discusses each of the lower stop contact areas in detail.

Gimbal Nut Contacting Area	Description	Corresponding Damage Area on the Lower Stop
1	Gimbal nut stop bolt head and adjacent corner of the gimbal nut stop lug.	a, b, f, h
2	Inboard circumferential edge of the gimbal nut stop lug.	c, i, j
3	Right forward corner of the gimbal nut stop lug.	d, f
4	Nut and/or threaded end of the gimbal nut stop bolt.	e
5	Outer circumferential edges of the gimbal nut (2 areas circled).	g
6	Right forward corner at outer edge of gimbal nut.	f
7	Forward portion and right forward corner at outer edge of gimbal nut (2 areas circled or bracketed).	f

Figure 6 shows a closer view of damage areas “a” and “b” on the lower stop. Damage at location “a” is consistent with rotational sliding contact by area “1” of the gimbal nut. The damage covered an arc of about 20° at an orientation ranging from 110° to 130°. As can be seen in figure 6, the paint in area “a” was disturbed with little or no deformation to the metal below. Rotational scoring was observed, but the direction of the scoring was inconclusive by optical microscopy.

Substantial deformation at location “b” is also consistent with sliding contact by area “1” of the gimbal nut, but at an angle of orientation ranging from 133° to 140°. This marking showed significant deformation of the metal, consistent with greater contact loading than that associated with marking “a”. Raised lips of metal were observed at the edge of location “b” where it mated with the damage of location “a”, indicating that damage associated with

location “a” occurred before the damage at location “b”. Scoring and deformation near the edge of the lower stop at location “b” indicate that the lower stop was rotating clockwise (as viewed from above) relative to the gimbal nut as most of the damage at location “b” was created.

At one location within area “b”, deformation was in the clockwise direction, indicating that the lower stop also rotated counter-clockwise relative to the gimbal nut while in contact with the lower stop. This area with clockwise deformation is indicated by arrow “q” in figure 6.

Figure 7 shows a closer view of damage areas “c” and “d” on the lower stop. Substantial deformation of the metal of the lower stop and rotational scoring was observed at location “c”, corresponding with contact by the forward (circumferential) edge of the gimbal nut stop lug (area “2” in figure 5) at possible angles of orientation ranging from 133° to 174°. This deformation is consistent with contact by the forward edge of the stop lug on the gimbal nut lower surface before the edge was deformed forward.

Another area of large metal deformation in the lower stop was location “d”, shown in figure 7, corresponding with contact by area “3” (figure 5) of the gimbal nut at an angle of orientation ranging from 167° to 183°. Multiple impressions were present in area “d”, corresponding to an angle of orientation of approximately 174°. Rotational scoring was observed on both sides of these multiple impressions.

Figure 8 shows a closer view of damage areas “e”, “f”, and “g”. The deformation at location “e” is consistent with contact by area “4” (figure 5) of the gimbal nut, in particular, the nut of the gimbal stop bolt. The angle of orientation associated with the creation of damage area “e” was 190° to 195°. Rotational scoring and a lip at the edge of the deformation area indicate the lower stop rotated clockwise (as viewed from above) relative to the gimbal nut as the damage in area “e” was created.

Damage at location “f” was relatively light, with disturbance of the paint and some rubbing deformation of the underlying metal. The damage in this area was consistent with contact from several portions of the gimbal nut. One area that matched well was area “6” (figure 5) of the gimbal nut with an angle of orientation from 345° (-15°) to 22°. Other portions of the gimbal nut, including areas “2”, “3”, and “7” (figure 5), also appeared to have contacted area “f” with angles of orientation ranging from 195° to 260° for areas “2” and “3” and from 22° to 110° for area “7”. Scoring and deformation of the metal near the edge of location “f” indicate that the lower stop rotated clockwise (as viewed from above) relative to the gimbal nut as the damage in area “f” was created.

Damage at location “g”, as shown in figure 8, was consistent with contact by area “5” (figure 5) on the right side of the gimbal nut with possible angles of orientation ranging from 110° to 160°. This damage was also consistent with contact with area “5” of the left side of the gimbal nut with possible angles of orientation ranging from 294° to 345° (-15°). Rotational scoring was observed, and general deformation at the edge of location “g” indicates that

rotation of the lower stop was clockwise (as viewed from above) relative to the gimbal nut as the damage in area “g” was created.

The damage at location “h” is shown in figure 9. Disturbance of the paint in area “h” was observed with rotational scoring, although the direction of relative rotation was not apparent because of the minimal deformation of the metal in this area. This mark in area “h” is consistent with contact with area “1” (figure 5) of the gimbal nut at an angle of orientation ranging from 294° to 298°.

Disturbance of the paint on the lower stop was observed at locations “ in figures 9 to 11. Some circumferential scoring was observed at location “ location “j” was primarily radial. Little or no deformation of the metal was observed. These locations correspond to contact with area “2” (figure 5) of the gimbal nut at an angle of orientation ranging from 298° to 345°. Paint disturbances similar to those found in areas “ and “j” were observed on various other edges of the lower stop, but these other disturbances could not be correlated to any specific location on the gimbal nut.

Damage locations “a” through “j” were examined using SEM and EDS. In locations “b” through “g”, areas were observed that appeared lighter by SEM, such as that shown in figure 12 for location “b”. EDS spectra of these lighter areas showed major peaks of cadmium. Also, the smearing of the lighter area in figure 12 indicated a clockwise rotation of the lower stop relative to the gimbal nut at that location.

Three impressions, labeled “r” in figure 4, were observed at the inside radius of the lower stop upper surface. The sizes, spacing, and geometry of the impressions are consistent with contact with the jackscrew splines. The raised lip of metal on the surface at the edge of the deformation indicates an upward motion of the jackscrew splines relative to the lower stop as the damage was created.

The inner portion of the alignment pin was missing from the alignment pin hole, labeled “p” in figures 4 and 7. The clockwise side of the inner portion of the alignment pin hole was deformed, consistent with movement of the alignment pin clockwise relative to the lower stop.

Lower Stop, Splines

For notation purposes, the spline teeth in the lower stop were numbered clockwise (as viewed from above) starting with the spline tooth intersected by the alignment pin hole (labeled “p” in figure 4). The spline teeth are numbered 1 through 44, except that spline tooth numbers 6 through 10 are not present because of the gap in the stop clamp bolt region. In addition, angular positions will also be used, defined clockwise as viewed from above starting from the alignment pin hole.

Rotational stripping was observed on different circumferential regions of the upper and lower portions of the spline teeth, as shown in figures 13 and 14. Stripping was defined as

being present in any region where individual spline teeth were nearly indistinguishable from each other. The middle portion of the splines, approximately ¼ inch wide, was damaged but not stripped at any circumferential location. This area corresponds to the gap in the jackscrew splines for the stop clamp bolt. In the upper portion, the stripping region extended from spline tooth 11 (adjacent to the spline gap for the clamp bolt) through 32 (angles of 90° through 262° from the alignment pin), as shown in figure 13. Note that the position opposite from spline tooth 32 was located in the gap for the stop clamp bolt. In the lower portion, stripping was observed in spline tooth 37 through the gap for the clamp bolt, and up to spline13 (angles of –57° through 106°), as shown in figure 14. The remaining spline teeth showed decreasing levels of damage, with the minimum deformation observed in spline teeth 41 (angle of 335°) and 23 (angle 188°) for the upper and lower portions, respectively.

The circumferential scoring marks associated with the stripped areas of the spline teeth were slightly offset from directly circumferential. The stripping pattern and offset circumferential marks were consistent with the lower stop being at two or more skewed angles to the splines of the jackscrew during stripping. Smearing of the spline tooth peaks was observed in most of the spline teeth. Predominantly, the peaks were smeared in a counter-clockwise direction, consistent with a clockwise rotation of the jackscrew relative to the lower stop (as viewed from above). However, in spline teeth 22 to 32 (angles of 180° through 262°) smearing occurred in both directions, indicative of relative jackscrew rotation in both directions during stripping at that location. Similar smearing in both directions was not observed in the upper or lower region opposite to spline teeth 22 to 32, but a portion of that region corresponded to the gap for the stop clamp bolt.

Damage was also observed in the middle portion of the lower stop spline teeth. In spline teeth 11 to 16 (angles 90° to 131°), grooves consistent with contact with the jackscrew spline teeth were observed intersecting the peaks of the spline teeth in the stop, as indicated by unlabeled arrows in figure 15. The grooves angled counter-clockwise from the lower to upper portions, and the direction of scoring indicates upward motion of the jackscrew relative to the stop. The scoring continued into the upper stripped portion, appearing to have been created after the stripping. In the middle portion of spline teeth 26 to 42 (angles 213° to 344°), grooves were observed on both sides of the spline tooth peaks, consistent with contact with the jackscrew spline teeth. Unlabeled arrows in figure 16 indicate this damage, where spline teeth 26 to 35 are shown. The spline tooth peaks were deformed counter-clockwise with upward scoring.

The portion of the lower stop clamp bolt visible in the gap in the lower stop is shown in figure 14. The exposed portion of the bolt contained damage along its length consistent with the rotational contact with the jackscrew spline teeth. The exposed portion of the bolt also had transversely oriented imprint marks consistent with contact with jackscrew splines. The marks showed sliding deformation indicative of a downward movement of the stop bolt relative to the jackscrew. These transverse marks were superimposed upon the rotational damage, consistent with the transverse damage being created, at least in part, after the rotational damage of the lower stop spline teeth.

The spline teeth on the lower end of the jackscrew to which the lower stop is assembled were also examined. Figure 17 shows a side view of these spline teeth, with the gap for the lower stop clamp bolt readily visible. The upper ends of several lower portion jackscrew spline teeth were deformed on either side of the index spline area, as indicated by the unlabeled arrows in figure 17. The damage is consistent with contact with the stop clamp bolt due to a downward motion of the lower stop relative to the jackscrew. The number of damaged spline teeth on the jackscrew was greater than the number of transverse imprints on the clamp bolt, further indicating a relative rotation of the jackscrew and lower stop.

Lower Stop, Lower Face

A circumferential impression consistent with contact with the quill nut washer was observed on the lower surface of the lower stop, as shown in figure 14. Unlabeled arrows indicate the outer circumferential boundary of this contact area. Associated disturbance of the paint was observed from an angle of 287° to 41° relative to the alignment pin. The contact area ended adjacent to the gap for the lower stop clamp bolt at an angular position of 41°. (Angular notation is same as that used above). This contact area on the lower face of the lower stop was examined in the SEM. The direction of the circumferential scoring damage visible on the SEM was consistent with counter-clockwise rotation of the lower stop relative to the washer. Figure 18 shows an example of the scoring damage on the lower surface of the lower stop, as observed on the SEM.

Upper Stop

The lower surface of the upper stop is shown in figure 19 after disassembly from the jackscrew. There were multiple locations where disturbance of the paint was observed, but none were indicative of contact with any portion of the upper surface of the gimbal nut. Damage was observed at the edge indicated by arrow “m”, with directional scoring both upward and downward relative to the stop. The clamp bolt was slightly bent and had impressions consistent with contact with both the upper and lower portions of the jackscrew spline teeth, with three impressions from the lower portion and four heavier impressions from the upper portion.

The unlabeled arrow in figure 19 indicates the location where the stop bolt is normally assembled in the upper stop. When received in the laboratory, the stop bolt was missing from the upper stop. Evidence of sliding contact with other structure, as shown in figure 20, was observed on the side of the upper stop (upper side as shown in figure 19). Arrow “n” in figure 20 indicates the nut end of the hole for the stop bolt. This end of the hole contained thread impressions as shown at higher magnification in figure 21. The location of these impressions is indicative of large side loading, approximately 45° upward, of the nut end of the stop bolt.

Matthew R. Fox
Materials Engineer

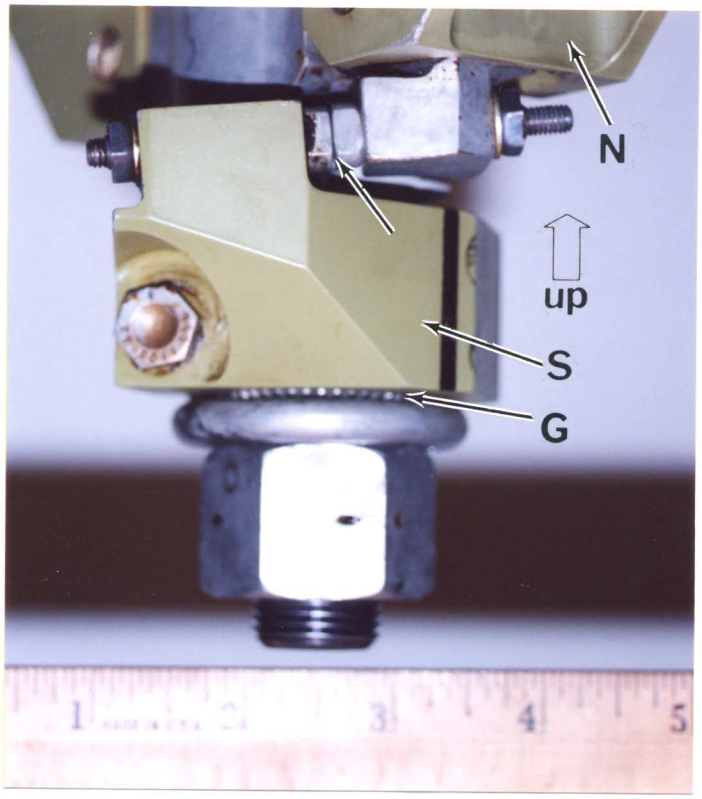

Figure 1. View of the lower end of a jackscrew assembly similar to the accident assembly. An unlabeled arrow indicates the location of contact between the gimbal nut "N" and the mechanical stop "S".

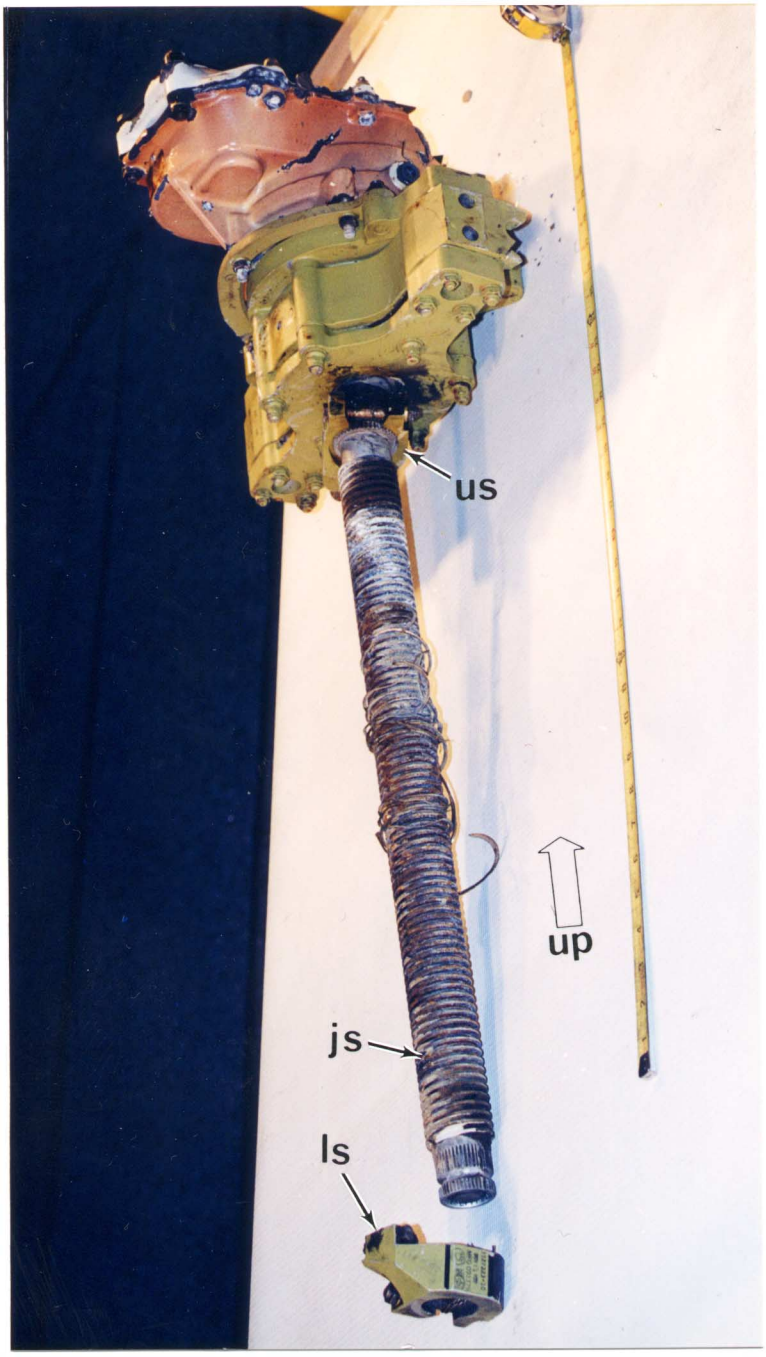

Figure 2. An overall view of the jackscrew, "js", with the attached gearbox (photographed on-scene after removal from the horizontal stabilizer). Arrows "us" and "ls" indicate the attached upper stop and separated lower stop, respectively.

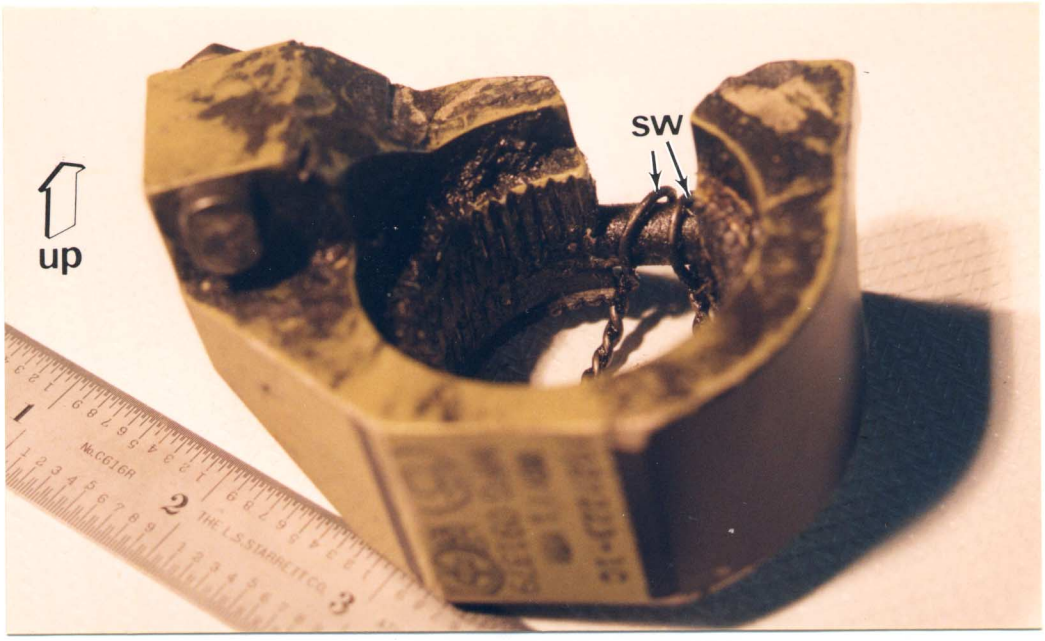

Figure 3. View of the lower stop as received. Arrows "sw" indicate safety wire attached to the clamp bolt.

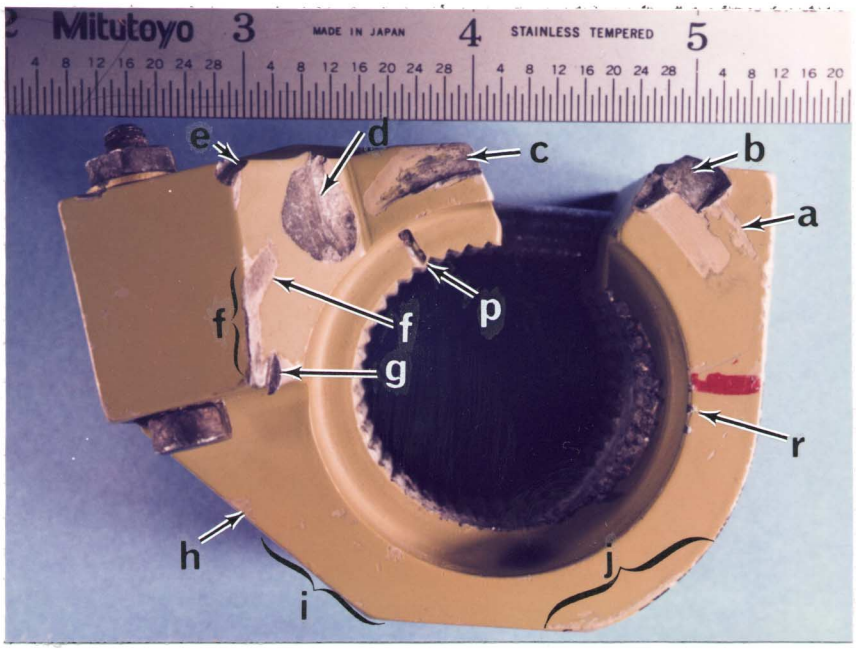

Figure 4. A view of the upper surface of the lower mechanical stop after cleaning. Areas of damage are labeled "a" through "j" and "r". The through hole for the alignment pin is labeled "p".

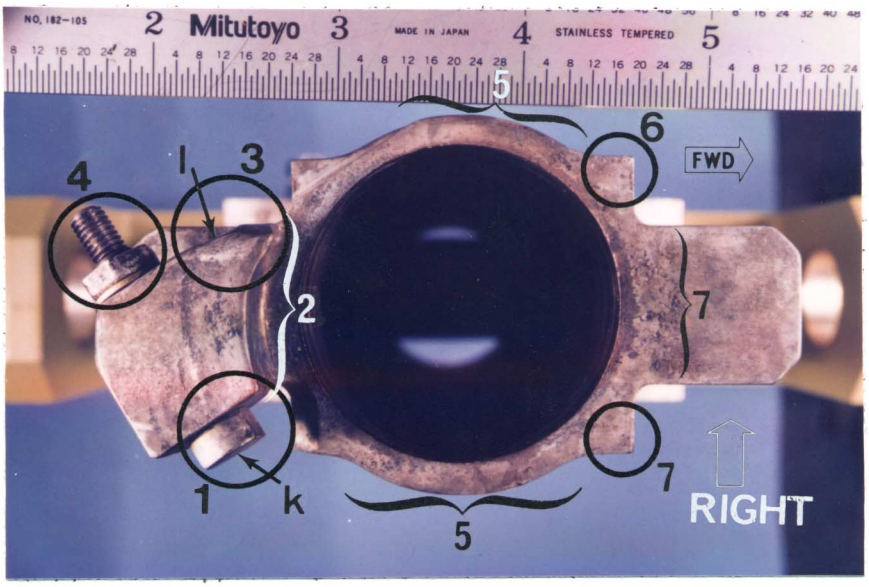

Figure 5. A view of the lower surface of the gimbal nut (looking up from below), where the head of the stop bolt is labeled "k", and the deformed forward right edge of the stop is labeled "l". Areas of probable contact with the lower stop are labeled "1" to "7".

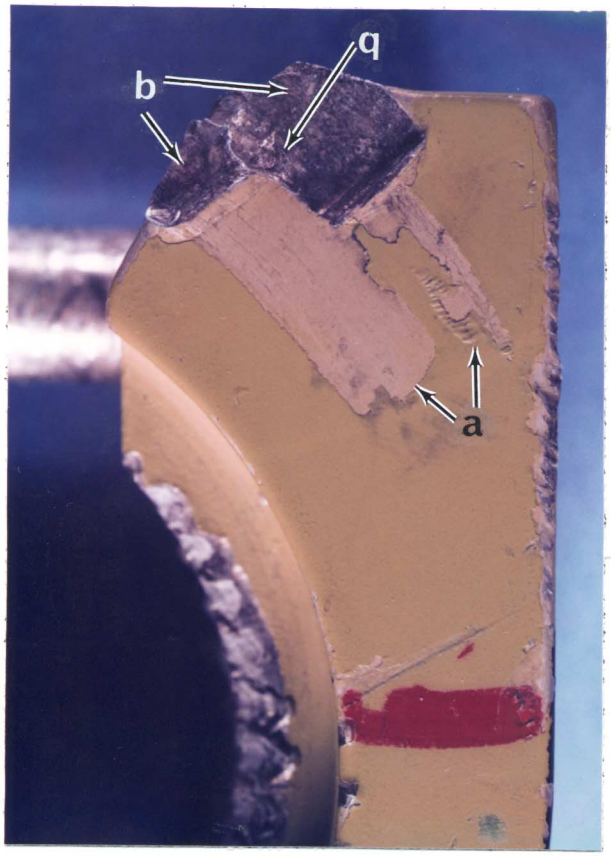

Figure 6. A higher magnification view of damage at locations "a" and "b" on the lower stop. Arrow "q" indicates secondary features in location "b". (3.1x)

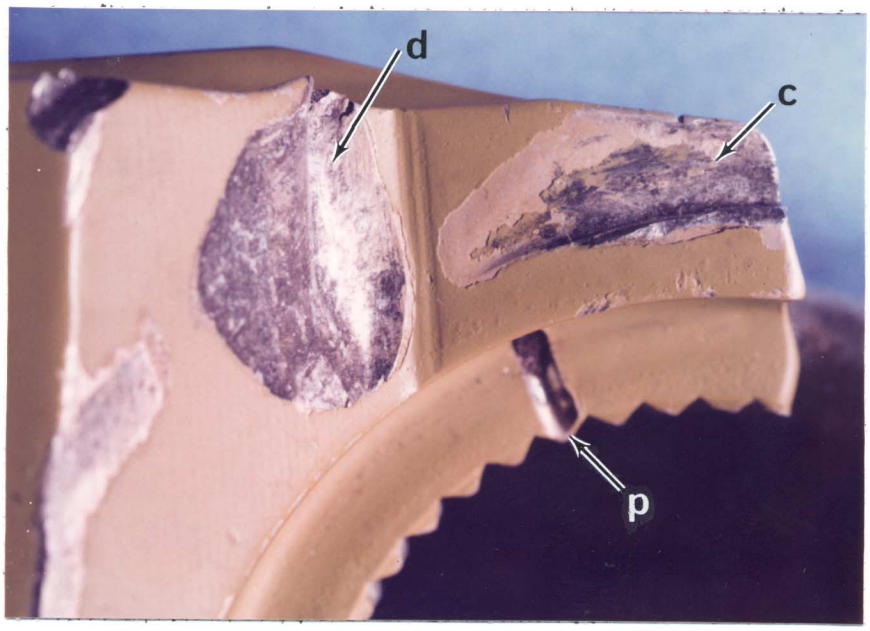

Figure 7. A higher magnification view of damage at locations "c" and "d" on the lower stop. (3.1x)

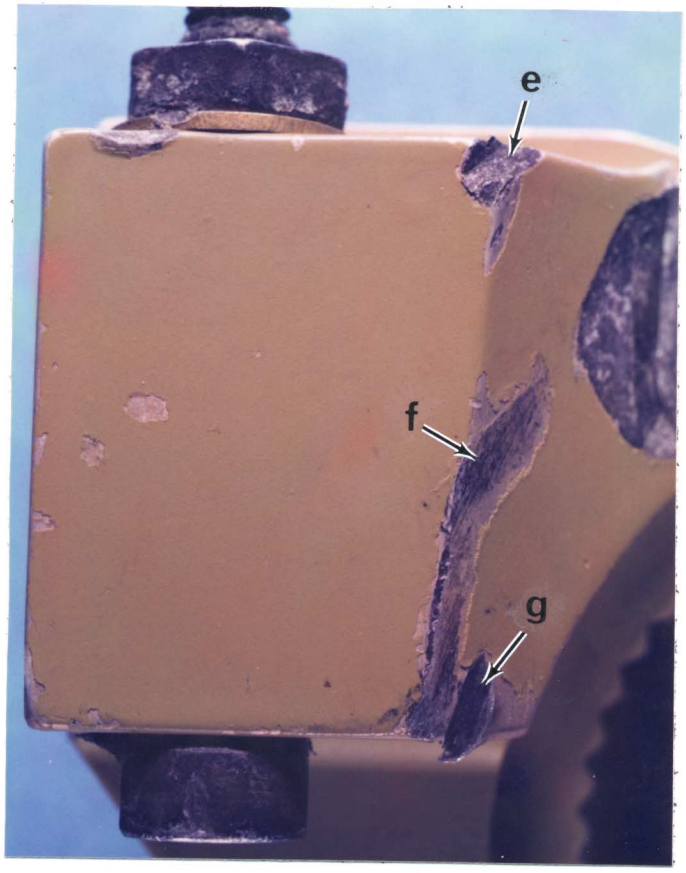

Figure 8. A higher magnification view of damage at locations "e" through "g" on the lower stop. (3.1x).

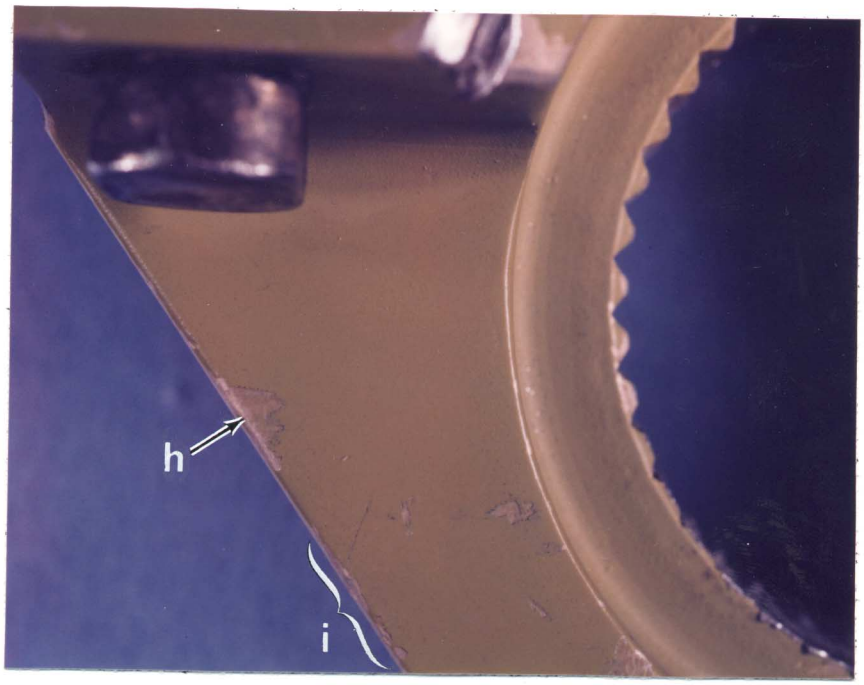

Figure 9. A higher magnification view of damage at locations "h" and "i" on the lower stop. (3.1x)

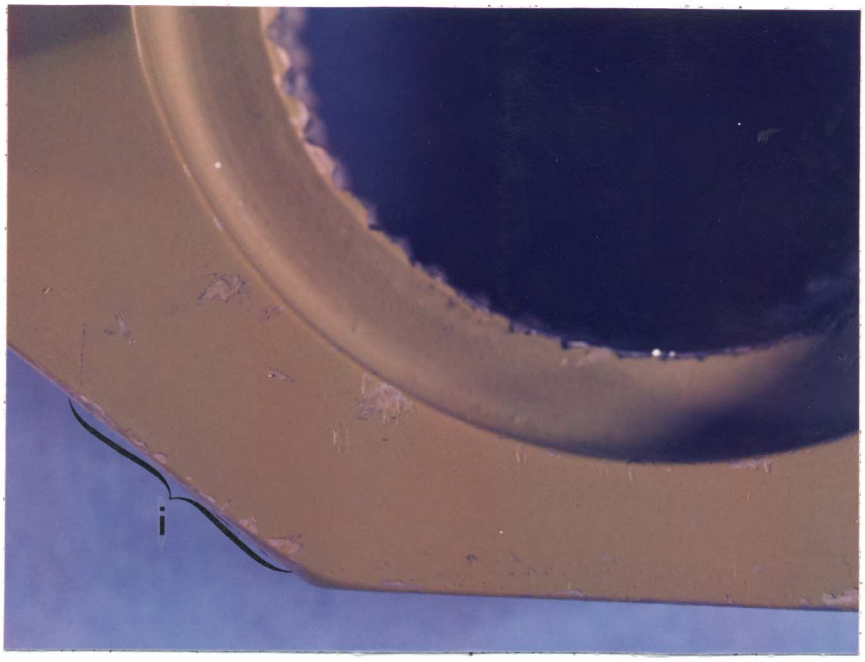

Figure 10. A higher magnification view of damage at location "i" on the lower stop. (3.1x)

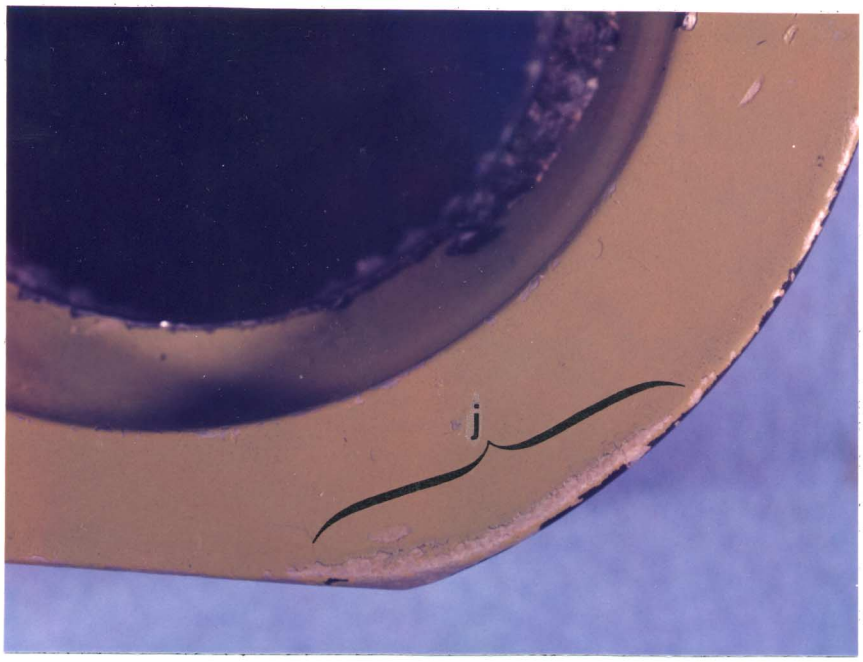

Figure 11. A higher magnification view of damage at location "j" on the lower stop. (3.1x)

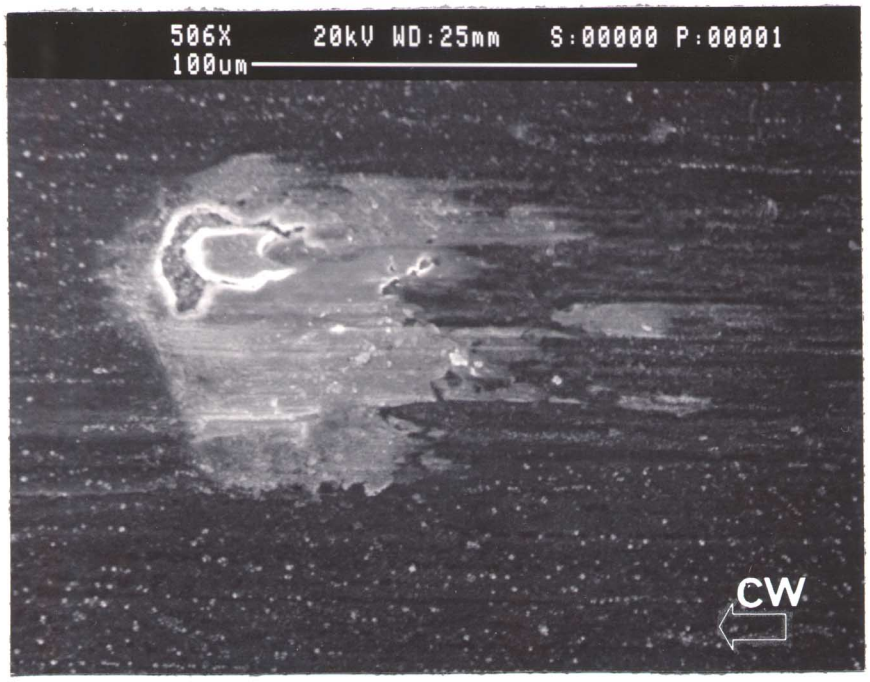

Figure 12. SEM image of damage at location "b" on the lower stop. The EDS spectrum for the light region had a major peak of cadmium. (506X)

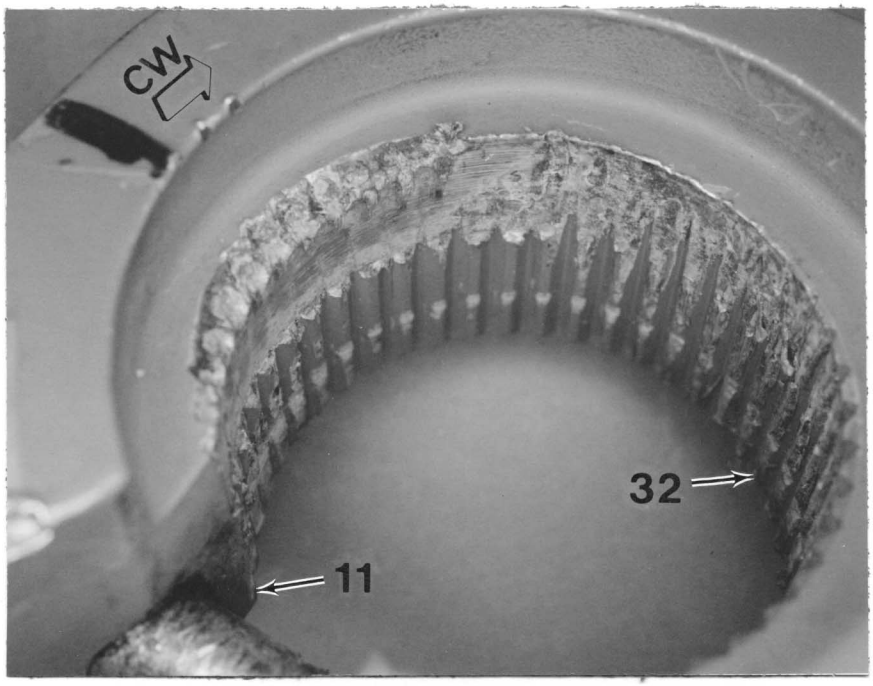

Figure 13. A view of the lower stop from above showing the stripped upper portion of the splines, where numbered arrows indicate spline teeth at the ends of the stripped area. (2X)

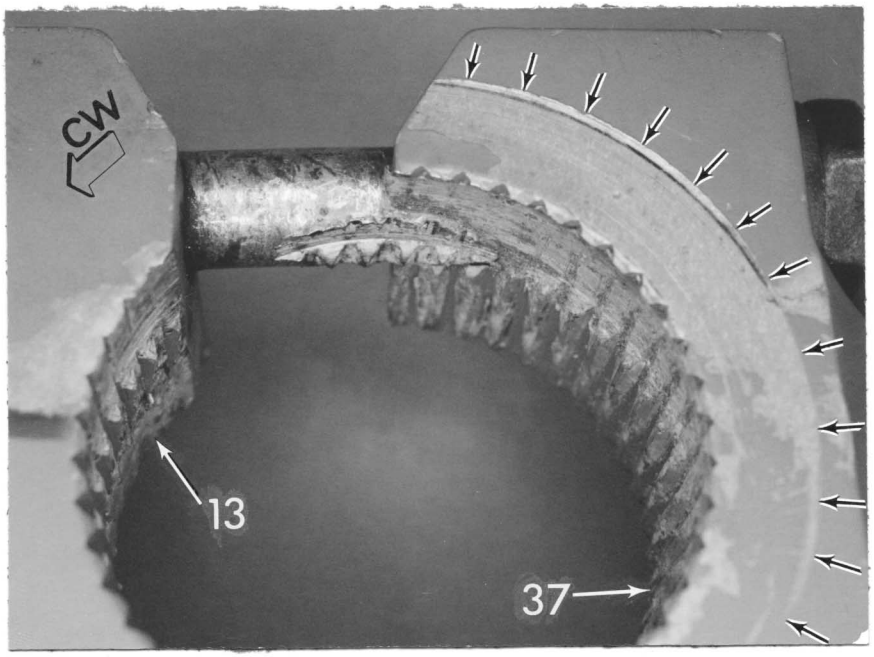

Figure 14. A view of the lower stop from below showing the stripped lower portion of the spline teeth, where numbered arrows indicate spline teeth at the ends of the stripped area. Unlabeled arrows indicate circumferential scoring consistent with contact with the quill nut washer. (2X)

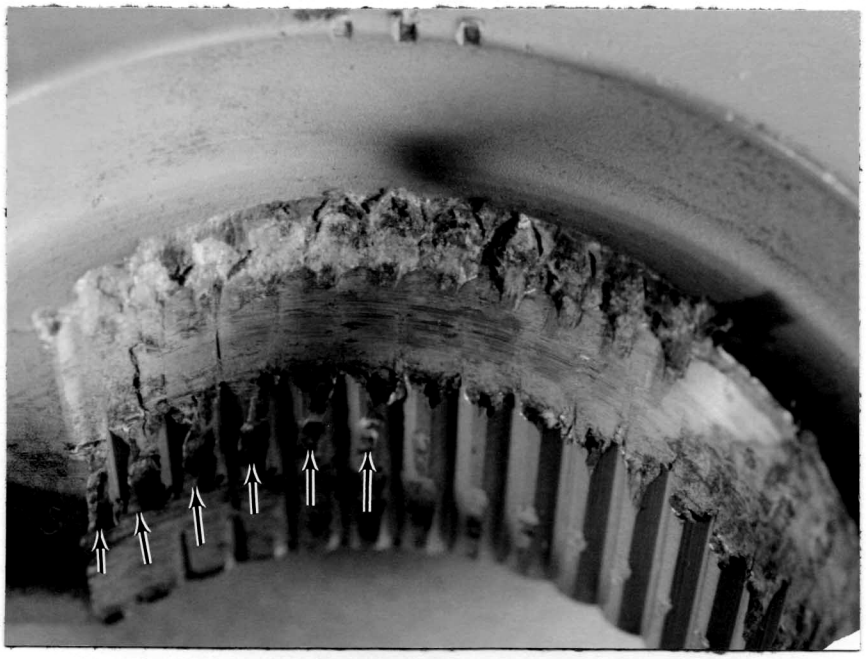

Figure 15. The stripped upper portion of the lower stop spline teeth viewed from above at higher magnification. Arrows indicate grooves in the middle portion of some spline teeth. (3.1X)

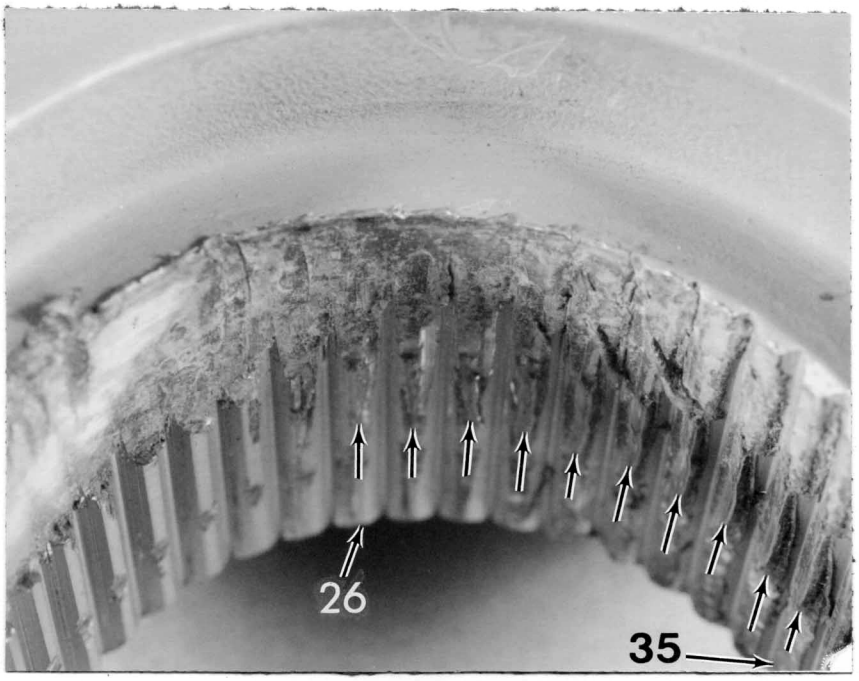

Figure 16. Lower stop spline teeth opposite to those of figure 15, viewed from above. Unlabeled arrows indicate deformation in middle portion of spline teeth 26 to 35. (3.1X)

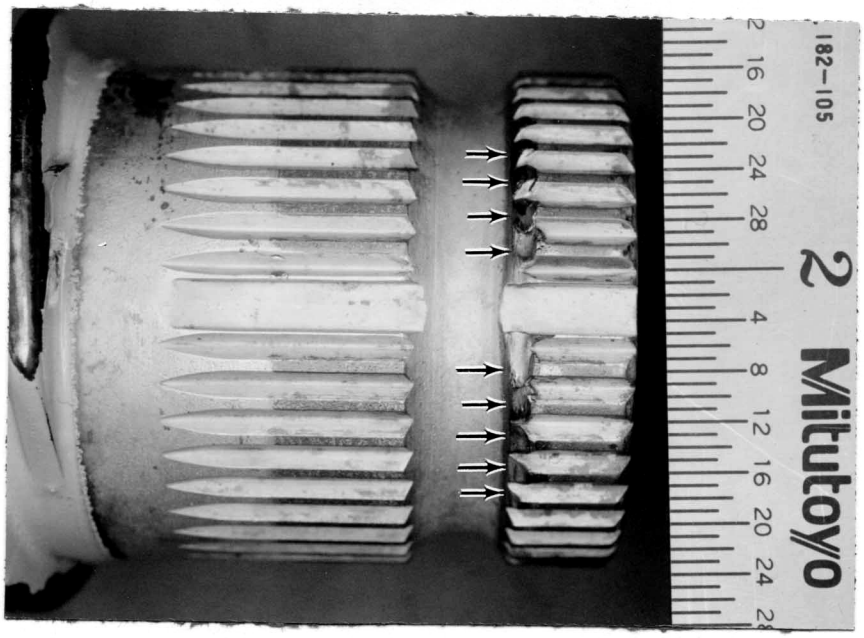

Figure 17. A view of the spline teeth on the lower end of the jackscrew. Unlabeled arrows indicate deformation to the upper end of some lower portion spline teeth.

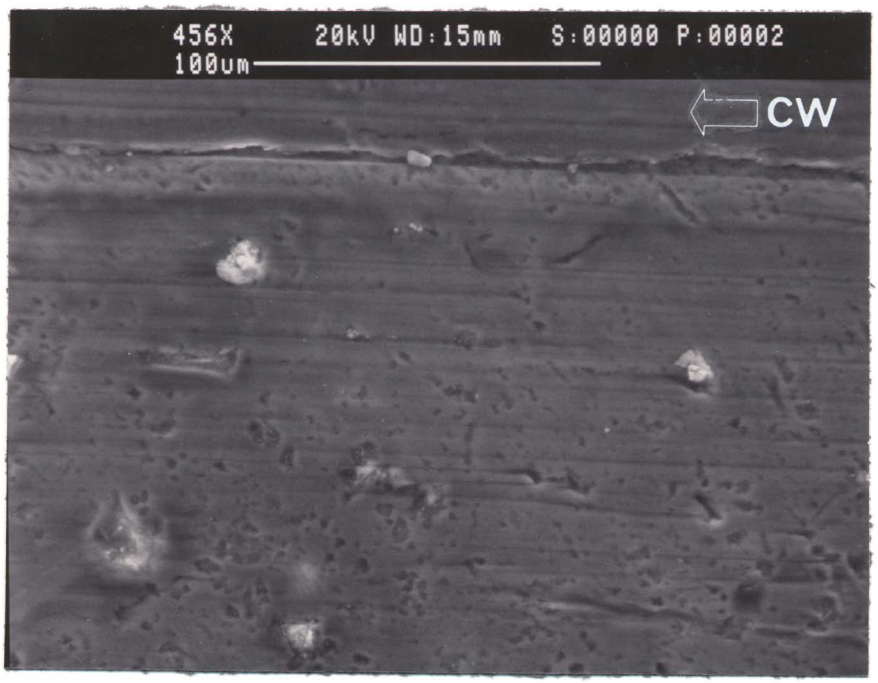

Figure 18. Circumferential scoring on the lower surface of the lower stop as viewed using SEM. Arrow "CW" indicates the clockwise direction as viewed from above. (456X)

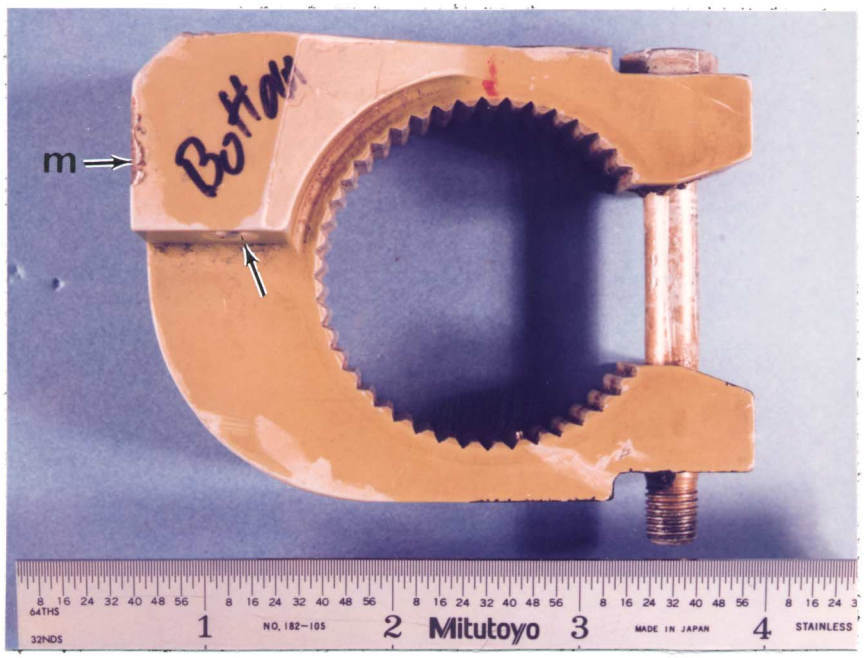

Figure 19. A view of the lower surface of the upper stop. Arrow "m" indicates damage to the edge. The unlabeled arrow indicates where the missing stop bolt should be assembled to the upper stop.

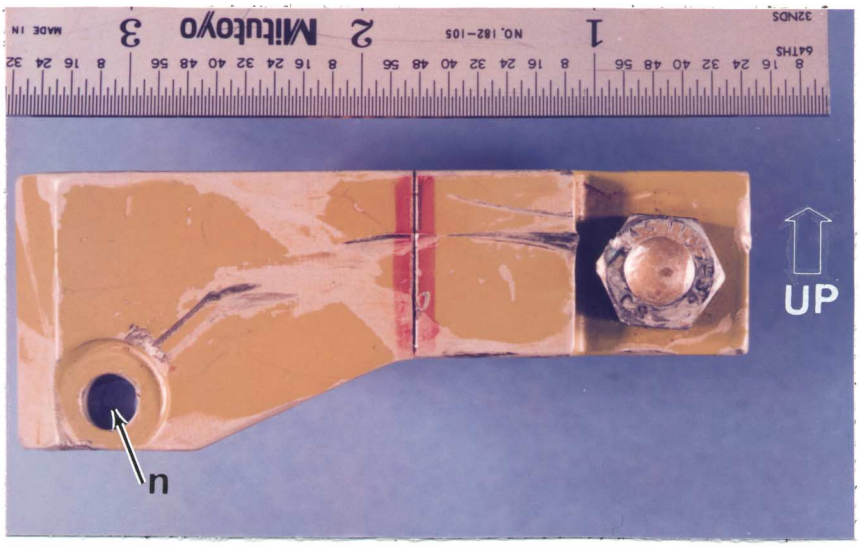

Figure 20. A side of the lower stop (top side of the stop as it is oriented in figure 19) showing evidence of sliding contact. The nut end of the stop bolt hole is labeled "n".

Figure 21. A higher magnification view of the nut end of the stop bolt hole "n" shown in figure 20. Thread impressions are shown in the hole for the stop bolt. (3.3x)