NATIONAL TRANSPORTATION SAFETY BOARD

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

November 12, 2000

MATERIALS LABORATORY FACTUAL REPORT Report No. 00-145

A. ACCIDENT

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

B. 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.

C. MATERIALS GROUP MEMBERS

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D. DETAILS OF THE EXAMINATION

Introduction

This report is divided into two main sections, **On-Scene** and **Laboratory Examinations**. The On-scene section deals directly with findings and observations made at Port Hueneme, California over the course of three days. Many of the areas addressed in the On-scene section are further detailed in the Laboratory Examination section and are noted where appropriate. NTSB staff, prior to the formal founding of the Materials Group performed the on-scene phase of the investigation. However, some members of the group were also on-scene as part of other investigative groups. The entire Materials Group reviewed the finding and observations at later dates.

The Laboratory Section covers detailed examinations that occurred in the months following the accident. The majority of these tests and examination took place at the NTSB Materials Laboratory, but several were performed at off-site facilities. These will be noted where appropriate. The laboratory section of this report documents only the accident components. The NTSB Materials Laboratory received other jackscrew assemblies for examinations. Examinations of these assemblies are reported separately except where a direct comparison is made for illustration purposes in this report. The comparison items will be duly noted.

ON-SCENE INVESTIGATIONS

The recovered wreckage was examined at the dock side facility at Port Hueneme, California on February 9, 10 and 11, 2000. Metallurgical examinations centered on the horizontal stabilizer trim jackscrew assembly and related components. All directional references in this report represent normal aircraft orientations unless otherwise noted.

Jackscrew Assembly with Horizontal Stabilizer Structure

The portion of the recovered horizontal stabilizer with the attached pieces of the jackscrew assembly is displayed from various perspectives in figures 1, 2, 3 and 4. As recovered, the major portion of the jackscrew assembly was attached to the forward face of the forward spar of the horizontal stabilizer and included the gearbox, the gearbox support plates, the Acme[1] screw and the upper "mechanical" stop. The illustration in figure 5 shows the components of a typical jackscrew assembly with nomenclature[2]. The gearbox support plates serve as the jackscrew structural attachment to the stabilizer and have the trim motor gearbox attached to the top. The Acme screw with the internal torque tube project downward from the gearbox support plates.

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[1] Acme threads are specialized threads used with the intent to translate mechanisms along the axis of the screw.

[2] A more detailed discussion of the jackscrew assembly and operation is attached.

General visual inspections of the jackscrew assembly found that the Acme screw was complete but that the lower “mechanical” stop assembly was separated from the jackscrew assembly and the lower end of the torque tube was fractured. The lower “mechanical” stop assembly was recovered later and is discussed in a later section of this report. The lower end of the torque tube along with the retaining nut and washer has not been recovered as of this date. The Acme screw was also separated from the Acme nut, which is normally attached to the structure of the vertical stabilizer. The Acme nut was later recovered and is discussed further in this report. The trim motor gearbox was heavily fractured and corroded but remained partially attached to the support plates. However, the trim motors were completely missing from the assembly. The trim indicator cable crank assembly was fractured from the top of the gearbox support plates. The major portion of the crank was not recovered but a smaller piece with one face of the fracture remained attached to the gearbox support. Visual and later microscopic examinations established that the fracture was overstress in nature. Fracture and deformation features were consistent with loading the crank to the left.

The Acme screw shown in figures 1 through 4 showed general pitting corrosion with red rust areas over most of its length with the heaviest areas toward the lower half. The Acme screw also had large areas covered by white deposits. The white deposits were consistent with corrosion products from the corroded magnesium gearbox case. Later chemical analysis confirmed that the white deposits were magnesium based.

As can also be seen in figures 1 through 4, many metallic filaments or shavings were found wrapped around the central portion of the Acme screw. The filaments generally spiraled around the Acme screw in the direction of the screw threads but were also tangled together and bent in multiple directions. The filaments were generally clustered into two closely spaced groups spread over about 6 to 8 inches of the Acme screw. Due to the intertwining nature of the filaments it was difficult to determine the number of individual filament pieces, however there were estimated to be between 8 and 12. Close inspections found that the filaments had a copper color with a general greenish tint, consistent with oxidation on copper alloys. The individual filaments had a generally rectangular cross section estimated at the scene to be about 0.025 inches thick by 1/8 inch wide, with a smeared outer diameter edge that was initially identified as shearing deformation. The metallic filaments were tentatively identified as remnants of the Acme nut’s internal threads.

Prior to metallurgical examination, the Systems Group removed an entire filament and examined it with metallurgists at Boeing Long Beach Division. Boeing report Lab Record No. 00-14-0026 details the findings of this examination. The Boeing report[3] (attached) and further findings on the metallic filaments will be discussed in a later section of this report.

Visual and tactile inspections of the threaded regions of the Acme screw found no evidence of grease or other lubricant in the central “working” region[4] of the screw threads. The

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[3] Boeing Report, Materials and Process Technology Lab, Lab Record No 00-14-0026, 2-/10/00

[4] The working region is roughly defined as the threaded screw area that is contacted by the Acme nut during operation between the upper and lower electrical stop limits.

lower threads of the Acme screw were partially packed with a mixture of what appeared to be sand and grease, as shown in figure 6. A sample of the material between the lower threads was removed and retained for later analysis[5]. Portions of the upper 6 to 8 threads of the Acme screw had a slight oily sheen and some small clumps of grease-like material between the threads. The sheen can be seen between the upper threads shown in figure 8. At both the upper and lower threads the material between the threads tended to be heaviest in the aft left quadrant (as recovered) of the Acme screw.

The Acme screw was visibly bent and had a through the wall crack in the area above the Acme threads and below the upper stop splines, as shown in figure 7 and 8. In the as-recovered position of the Acme screw, the lower end of the Acme screw was displaced rearward and to the left. This is best seen in figure 1. The through-wall crack was gapped open and ran around approximately ¾of the Acme screw circumference. At both ends, the crack turned to a longitudinal direction, figure 8. The central region of the crack was open sufficiently to allow viewing of the surfaces. The crack appeared typical of an overstress separation with no indications of preexisting cracking. This was later confirmed by microscopic examinations in the NTSB Materials Laboratory. The through-wall crack was accompanied by a multitude of surface cracks running generally parallel to the through wall crack. These cracks are also visible in figure 7.

During examination of the Acme screw crack several contact marks were noted on the screw surfaces. On the aft side of the Acme screw, a downward facing “C” shaped mark was noted overlaying one end of the through-wall crack, as shown in figure 8. The mark did not dent the Acme screw but rather was a disturbance in the cadmium plating in this area of the Acme screw. Inspections of the adjacent structure of the stabilizer uncovered a mating dent in the lower flange of the stabilizer forward spar, as shown in figure 9. The spar flange dent was smoothly curved, with a radius that approximately matched that of the Acme screw at the “C” contact mark location. In the as-recovered position, the spar dent was located approximately 2 inches to the left and 2.25 inches behind the Acme screw. The relative locations of the spar dent and the Acme screw are also shown in figure 2.

The Acme screw also made contact near its upper end with the bore of the pass through hole in the lower gearbox support plate as shown in figure 10. The indications were the result of several impacts at various aft clock positions within the bore.

The jackscrew assembly was attached to the front of the horizontal stabilizer forward spar by 6 bolts (3 on either side of the assembly). The bolts passed through aluminum plate brackets projecting forward from the stabilizer spar and into the gearbox support assembly. As examined, the spar brackets were severely bent, offsetting the jackscrew assembly an estimated 1 to 2 inches to the left. This can be seen in figure 9, where the brackets are indicated and the yellow lines denote the original positions of the brackets. The lower legs of both brackets were fractured at bend locations as shown in figure 11. Close visual examination established that the fractures were consistent with overstress separations. The

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[5] A list of the grease samples removed by the Materials Group during the course of the investigation is attached.

four most forward attachment bolts (two in either side) were intact and in place but the two rearward attachments (one bolt on either side) were found disconnected from the structure. The bolt at the right rear was pulled through the stabilizer bracket and was still attached to the jackscrew assembly. The jackscrew attachment ear at the left rear attachment point was fractured. Visual examination indicated an overstress fracture. The bolt at this location remained in the stabilizer structure.

The jackscrew assembly torque tube was fractured at the lower end approximately in line with the bottom of the Acme screw as shown in figure 12. Closer examinations after the jackscrew assembly was removed from the horizontal stabilizer found gross macroscopic features indicating that the fracture initiated in the thread root of one of the torque tube retaining nut threads and propagated across the tube. As recovered, the initiation area was located in the forward right quadrant of the tube. Detailed examinations of the torque tube and the fracture are presented in the Laboratory Examinations section of this report.

Although many of the photographs presented to this point in this report were taken after the jackscrew assembly was removed from the horizontal stabilizer, the findings and observations were based on examinations prior to the removal of the jackscrew assembly.

Following removal of the jackscrew from the spar of the stabilizer, the gearbox assembly was removed from the gearbox support ring and plates as shown in figure 13 and 14. The gearbox was only partially attached to the support by three threaded fasteners (studs). No attempt was made to rotate the gearbox following removal. The gearbox was turned over to the Systems Group for examination and reporting.

With the gearbox removed, the spline adapter shaft was removed from the gearbox support. The spline and surrounding area were covered in large quantities of a brown oily grease substance. No damage was noted to the spline adapter after removal. This was further confirmed during laboratory examination after cleaning.

Lower “Mechanical” Stop

The lower “mechanical” stop of the jackscrew assembly was recovered separate from the Acme screw. The as-recovered stop is displayed in figures 15 and 16. The surfaces of the stop were covered in varying amounts of a black greasy material with the upper surface containing the most, as seen figure 15. Samples of the greasy material were removed for later analysis. The stop was recovered with the pinch bolt and nuts intact and still fastened along with two lengths of heavy gage (0.050-inch diameter) safety wire attached. The safety wire lengths were stretched and fractured at the free end, see figure 16. Later microscopic examination determined the fractures to be consistent with tension overstress breaks. Visual examination of the stop showed many dents and mechanical marks in the upper and lower surfaces and mechanical damage to the internal splines and the pinch bolt. Detail examinations of the stop are reported in Materials Laboratory Factual Report No. 00-045 and are not further discussed in this report.

Acme Nut and Vertical Stabilizer Structure

The Acme nut (also referred to as the gimbal nut) was recovered attached to wreckage of the vertical stabilizer, as shown in figures 17, 18, 19 and 20. Visual examinations found that although the interior of the nut had a spiral pattern reminiscent of threads, no significant threads remained. The interior was relatively smooth to the touch with only a regular pattern of small bumps present. No other major damage was visible on the interior.

As recovered, quantities of reddish brown to black grease were present on the exterior surfaces of the nut assembly and gimbal ring, and greenish, black and reddish grease was found on the surrounding structure. Two samples of grease from the exterior of the nut assembly and one sample from the aircraft structure below the jackscrew assembly were taken for further analysis.

In contrast, the interior of the Acme nut showed no visual or tactile indications of grease on the surface where the threads would normally be present. The surface had a spiraling pattern of dried black deposits following the original thread pattern and random spotty areas of white deposits.

As recovered, the nut assembly would easily gimbal in all directions with light hand forces and no interference with other structure was noted. The exterior of the assembly had slight impact damage to one edge of one of the Acme nut support plates and a slight rolling of an edge on the lower stop lug but no other damage was noted. The lower stop lug damage is discussed in report 00-045. The nut assembly was easily removed from the structure after the outer gimbal pivot pins were extracted.

Components Removed for Further Analysis

The following parts and components were hand transported to the NTSB Material Laboratory for more detailed examinations and teardowns; the jackscrew assembly removed from the stabilizer spar less the gearbox, the Acme screw upper and lower “mechanical” stops and the Acme nut assembly along with the outer pivot pins. Also five grease samples were retained for further analysis; a black cakey sample from the Acme screw lower stop spline area, a sandy black sample from the lower threads of the Acme screw, two samples from the exterior of the gimbal nut and one sample from the structure under the jackscrew.

LABORATORY EXAMINATIONS

The components removed from the on-scene phase of the investigation were transported to the NTSB Materials Laboratory for further examinations, tests and documentation. These examinations occurred during the months following the accident under the supervision of the Materials Investigative Group. Portions of the trim motor and gearbox were received at a later date.

Identification Markings

The components received in the laboratory are displayed in figure 21. As received, the manufacturing identification (ID) tag was missing from the gearbox support assembly as shown in figure 22. Close inspections however, found that some of the adhesive material originally used to attach the ID plate was present and that it had formed outlines of much of the information stamped into the ID plate. The recognizable portions identified the assembly as serial number DCA-2064 Assembly part number 5910962-71 A(P) ED(1). Characters listed in parentheses were either not readable or unclear. The Acme screw was marked in the area above the upper "mechanical" stop with part number 5914168-505M and serial number P-2663. The Acme nut was also marked with serial number P-2663 and part number 5914169-507.

Trig Aerospace[6], (the manufacturer) Santa Ana, California, indicated that Acme screw and nut assembly serial numbers P-2663 was assigned to a 5910962-71 jackscrew assembly in a lot of 18 assemblies (WO 14652) with serial numbers ranging from DAC 2051 to DAC 2069. The units were shipped on June 28, 1990.

During the following examinations, numbers and other identification markings on individual parts were recorded and a listing is attached along with the part's nomenclature as taken from either the engineering drawing for the part or from illustrated parts breakdown (IPB) listings.

Assembly Inspection

Prior to disassembly of the jackscrew, the Acme screw was manipulated in both the rotary and pivoting directions. The Acme screw with the internal torque tube would rotate and pivot but with significant difficulty. No attempt was made at this time to quantify the forces necessary for movement. General visual inspections found that the gearbox adapter ring was fractured at one hole and bent upward at another (see figure 22) and that one fastener remained in the gearbox housing. It was also noted the jackscrew pivot bearing grease fitting on the forward face of the gearbox support assembly was missing. Local damage around the fitting hole was indicative of it being forced out under upward bending. The shim pack between the lower support plate and the bearing plate was spread apart, deformed and partially fractured on the

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[6] Through mergers and acquisitions, Trig Aerospace was formerly known as Derlan Inc. and originally Peacock Engineering. The accident jackscrew was manufactured by Peacock Engineering.

forward right side, under the location of the missing ID plate. The forward faces of the support plates were also damaged and scraped in the same general area.

Disassembly

Unfastening several vertical bolts disassembled the gearbox support portion of the jackscrew assembly, and the gearbox adapter ring, upper support plate assembly, and upper shim pack lifted off. No additional mechanical damage was visible on these parts. The lower support plate and shim pack was removed from the torque tube along with the upper stop and Acme screw. Considerable force was necessary to pull the bent Acme screw over the corresponding bend in the torque tube. During removal of the Acme screw particular care was exercised so as not to damage the torque tube fracture or to dislodge the remnants of the Acme nut still wrapped around the Acme screw. However, during removal of the Acme screw, the surface of the torque tube was marked and scored along its mid length. The surfaces of the torque tube and bearing were covered with a heavy coating of dark brown oily grease. The disassembled Acme screw and torque tube are displayed in figure 23 after the tube has been wiped clean.

Following separation from the Acme screw, the fractured end of the torque tube was saw cut off above the external splines to prevent damage during disassembly of the bearing support.

As previously noted, the left side, structural attachment ear of the gearbox support assembly was fractured. Microscopic examination established the fracture was overstress.

With the upper and lower support plates and the Acme screw removed, surface corrosion and pitting were visible on the exposed lower surface of the torque tube spherical bearing, as shown in figure 24. The torque tube was separated from the spherical bearing by tapping it upward. The bearing was then pressed out of the support plate with a hand press. The bearing separated smoothly and without binding. No corrosion was visible on the exposed upper surfaces of the bearing after it was wiped clean.

Close inspection of the grease fitting hole at the forward side of the gearbox support assembly found that the fitting was fractured and a portion remained in the hole. Dark grease was visible in the passage and on the upper surfaces of the spherical bearing. With the bearing removed reddish grease was visible in the passage way between the fitting and the bearing bore. A sample of the grease from the passageway was removed for later analysis. The diameter of the bearing bore in the support plate measured 4.4375 inches. The bearing had a measured outer diameter of 4.4375 inches with an inner diameter of 2.126 inches.

The internal bearing components were inspected after the upper and lower seals were pried out and the bearing outer race was abrasively cut at two locations. The cuts opened a window to the bearing interior as show in figure 25. Darkened grease and rusty red corrosion products obscured the interior bearing components. The grease was soft and black without visible metal fragments. A grease sample from between the rolling elements was retained for analysis. Wiping the components cleaned uncovered large areas of surface and pitting corrosion on the inner and outer races and on the rollers, as shown in figure 26 and 27. For comparison, the spherical bearing from another jackscrew assembly[7] was similarly sectioned and is show in figure 26 to the right of the accident bearing.

The lower support plate and upper Acme screw "mechanical" stop were disassembled and removed from the Acme screw. Detailed examinations of the upper "mechanical" stop are addressed in Materials Laboratory Report No. 00-045. The bottom surface of the upper support plate is displayed in figures 28 and 29. The lower edge and bore of the pass through hole for the Acme screw was deformed at several locations as previously noted. Close examination uncovered three major areas of deformation consistent with contact by the Acme screw and two smaller minor areas. As shown in figure 30, the major damage areas were all located in the aft half of the hole with the largest dent in the aft left quadrant. The two smaller contact marks were located on the forward half of the hole, as shown in figure 31.

Thread Remnants

The Acme nut thread remnants remained coiled loosely around the screw during disassembly, as shown in figure 32. Prior to removal of the thread remnants from the Acme screw their overall locations were measured relative to the lower end of the Acme screw. The locations are depicted in the upper drawing in figure 33. The three additional drawings in figure 33 depict the portions of the Acme screw that would be covered by the Acme nut. They show the position of the nut when the trim was positioned at 7 degree aircraft nose up (ANU), at 0.4 aircraft nose down (AND) and with the lower surface of the Acme nut sitting on the upper surface of the lower stop assembly. The depicted positions of the nut were arrived at by scaling the "PK"[8] dimension onto a scale drawing of the Acme screw.

Eleven thread remnants were carefully removed from the Acme screw from the top down, see figure 34 upper view. As they were removed they were individually numbered on their upper sides and the average width and maximum thickness were measured. Additionally, estimates were made of their uncoiled lengths and of the number of 360-degree rotations (turns) for each remnant. Based on the length and turn estimates and on the calculated total design length of threads in the Acme nut, it was estimated that the recovered thread remnants accounted for approximately 75% to 83.5% of the total length of the original threads. This estimate includes the thread fragment removed on-scene and examined by the Systems Group at Boeing Long Beach Division. It is listed below as the Long Beach sample. Data on individual remnant measurements and cumulative length and turns is presented in the table below.

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[7] Bearing from Jackscrew assembly, DCA-3000, Alaska Airlines, N982AS.

[8] "PK" dimension is the installed distance from the lower edge of the Acme screw to the longitudinal center of the Acme nut, as listed in a Boeing supplied document. The Acme nut is 8 inches long.

Thread Remnant Samples

Sample No.	Max. Thickness	Ave. Width	Length	No. Turns
	(inches)	(inches)	(est. inches)	(est.)
1	0.026	0.125	12.13	2
2	0.026	0.120	16.63	3
3	0.025	0.105	8.25	1.5
4	0.024	0.115	9.88	2
5	0.027	0.118	5.75	1
6	0.024	0.118	17.50	3
7	0.023	0.120	5.50	1
8	0.024	0.121	11.50	2
9	0.024	0.117	13.50	2.5
10	0.024	0.120	10.50	2
11	0.026	0.115	17.00	3
		total	128.13	23
Long Beach Sample estimated			6.2	1
		grand total	134.33	24
		nominal number of turns in nut=		32
Spiral length of threads @ Average Pitch Dia ~= 2*sqrt((16* Pi * Avg PD nut)^2 + (8^2))[9]				**161 inches**
	% thread based on total length of remnants			83.5%
	% thread based on the number of turns			75.0%

Visual examinations found that most of the remnants had areas with a green patina, typical of oxidized copper alloys. The remnants had a roughly rectangular cross section with the width much greater than the thickness, oriented like a common washer. Closer inspection found that one face of each remnant was relatively flat. Where the remnant was between the threads the flat face was the upper face as removed from the Acme screw. The other face (lower) had a multi-angle beveled appearance with a high ridge near the center. The beveled lower face was, in general, cleaner and more lustrous than the flat side. The lower view of figure 34 shows the lower face of remnant #6 note the copper luster. The outer diameter edges of the remnants had a smeared and fractured appearance while the inner diameter edges were slightly rounded on the flat side and had a machined appearance. Several of the remnants had additional radial marks and scrapes indicative of contact with other objects after formation of the bevels.

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[9] The formula was derived from the Pythagorean theory of triangles where $a^2 + b^2 = c^2$, the normal legs a and b equal the height of the nut and 16 times the diameter of the thread at the pitch diameter and c is the spiral length of the thread. The thread is a two-start thread so this value is doubled.

During visual examination some small dark flakes of what appeared to be dried and hard grease were found attached to some of the thread remnants. The grease flakes from thread remnants 1 through 6 were retained as one sample and those from 7 through 11 as another grease sample.

The #4 thread remnant was selected for initial scanning electron microscope (SEM) examination after it was ultrasonically cleaned in detergent solution (Alconox[10]). Initial energy dispersive x-ray spectra acquired during SEM examination were consistent with the specified Acme nut material, aluminum nickel bronze per ASTM-B271[11] (UNS[12] C955000) along with other surface contaminants, see EDS spectrum in figure 35. SEM viewing at high magnification found mostly smearing deformation and some shearing dimples along the outer diameter edge of the remnant, see figure 36. The orientation of the shear dimples was consistent with the remnant moving upward (toward the flat face) relative to the body of the nut.

Both ends of the #4 remnant were radially fractured and showed mechanical damage and ductile dimples indicative of tensile separations. The views in figure 37 show one fractured end in two slightly different perspectives each with the flat face up. The beveled face (down in the figures) had three separate angled planes, labeled “Bevels 1, 2 and 3” from the inner diameter to the outer diameter. Thickness varied across the remnant cross section with the outer diameter shear area measuring 0.0131 inches (measured along the fracture). The minimum section thickness was to the slightly to the right (in figure 37) of the shear area and measured 0.0076 inches. Maximum section thickness was at the central ridge and measured 0.0184 inches. Bevels 1 and 2 were both about 0.040 inch wide and bevel 3 was about 0.012 inch wide. The lower view in figure 37 is annotated with some of these measurements and others.

Circumferential cracking was noted in the flat face near the minimum section area. As visible at the radial fracture, the circumferential cracks were oriented at 45 degrees to the flat face of the remnant and penetrated about a third of the section thickness. These cracks were visible on the upper face around most of the circumference of remnant #4 and appeared to follow machining lines. The beveled side of thread remnant #8 was also examined on the SEM and is shown as the lower view of figure 38.

On thread remnants #4 and #8, both the flat (upper) and beveled (lower) sides displayed circumferential machine-like marks. The upper surfaces were smoother than those on the lower surface with some areas of corrosion and more prominent machining marks toward the outer diameter see upper view of figure 38. The surfaces on the beveled sides were slightly rougher but showed similar machined-like appearances as seen in the lower view of figure 38.

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[10] A commercially available laboratory detergent manufactured by Alconox Inc. NY, NY.

[11] ASTM American Society for Testing and Materials, “Standard Specification for Copper-Base Alloy Centrifugal

[12] Unified Numbering System

After SEM examination, the thread pieces were optically reexamined at higher magnifications. All of the pieces displayed the same flat-side beveled-side shape shown during SEM examination (Figure 37) but many showed a slight variation in the location of the shear fracture. Some pieces showed two slightly offset radial locations for the shear fracture. For the most part the fracturing was at the location outboard of the minimum section thickness area as shown on remnant #4. But many also showed some portion of fracturing at the minimum section line between bevels “2” and “3”, see figure 39.

The reexaminations also found some local twisting or bending deformation accompanied the fractures at the ends of the remnants. Also, two of the four original manufactured thread ends were identified on pieces 3 and 9.

Two metallographic cross sections were cut radially through remnant #6. These were supported on end by stainless steel spring clips, mounted in thermosetting phenolic and polished. The as-polished sections are presented as figures 40 and 41. Remnant #6 showed mostly minimum section fractures but the sectioning cuts were through areas that fractured outboard of the minimum section. Note that the pressure of mounting fractured one of the sections, figure 41, through the existing cracking at the minimum section location.

The Metallographic section also showed that the flat face of remnant #6 actually had a slight concave curvature, as can be seen in figure 40. The curvature was also apparent on remnant #4, see figure 37, and may have been present on most or all of the remnant pieces.

Additional section thickness measurements[13] were made on the intact metallographic section and are noted on figure 40. The minimum section thickness was 0.00985 inches, and the thickness was 0.01736 inches at the shear fracture location. The angle between the surfaces on the beveled side measured 146 degrees at the minimum section location, (between bevels 2 and 3), and 204 degrees between the large surfaces, bevels 1 and 2.

Shear Calculations

The shear load capability for the Acme nut threads was calculated for three conditions.

1) Full size as manufactured thread.
2) 0.013 inch thick thread as measured on remnant #4
3) 0.017 inch thick as measured on remnant #6.

The following table summarizes the results of the calculations and lists the assumptions.

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[13] Measured on a Smartscope© video based computerized measurement system.

Shearing Load Calculations, Acme Nut

	Shear load for full (0.1496) thickness thread	Shear load for .013 thickness thread	Shear load for .017 thickness thread	
Load for 32 threads	**2,200,999**	**191,263**	**249,782**	Pounds
Load for 1 thread	**68,781**	**5,977**	**6,806**	Pounds
	Per drawing	#4 SEM sample	#6 met sample	
Assumptions				

Shear Area =	2*sqrt((16*Pi*Major Diameter)^2+8^2) * Thread Thickness at Major Diameter
Shear Strength =	77% of ultimate tensile strength
Ultimate Tensile Strength =	110,000 psi
Fracture at average Major Diameter of nut =	1.7205 inch
Shear Load =	Shear strength / Shear Area

Acme Screw

The side bar at right details the significant metallurgical specifications for the Acme screw, as summarized from the engineering drawing.

After the thread remnants were removed another grease sample was taken from the area of the lower stop splines. The Acme screw was then cleaned in soap and water for more detailed examination. The cleaning removed the lightly adherent particles, most of the grease and some of the white magnesium oxide deposits. As a whole, the rusty red corrosion spots remained.

The cleaned Acme screw is displayed in figure 42. The bend is evident. The angle of the bend was estimated to be about 5 degrees. The bend was centered at the through-wall crack between the upper stop splines and the top of the Acme thread section as shown in figure 43. The crack extended around approximately 270 degrees of the Acme screw circumference and was gapped open about 1/16 of an

The ACME Screw, P/N 5914168

ACME screws for MD 80 series aircraft are made from an AISI 4140 steel forgings per Mil-S-5626. The AISI 4140 steel is heat-treated to an ultimate tensile strength (F_{tu}) of 160 to 180 ksi (HRC 36-40)(1). The threaded region is glass bead cleaned to a $^{32}\sqrt{}$ finish and then the part is Malcomized (2) per DPS 5.00-3. Case depth is 0.003-0.005 inch. and the minimum case hardness is HR_{15N} 85(3) (HRC 49). The threaded region is black oxide coated per DPS 9.27. The splined regions are cadmium plated per DPS 9.14.

(1) HRC: Rockwell hardness, C scale.
(2) A proprietary nitriding treatment.
(3) HR_{15N}: Rockwell hardness, 15N scale.

AISI 4340 is used for MD 90 airplanes. For these applications, it is not nitrided but through hardened to 260 to 280 ksi ultimate tensile strength (F inch. Visual and microscopic inspections into the gapped open crack revealed features consistent with an overstress separation. The adjacent region of the Acme screw section also showed a multitude of parallel surface cracks on the side of the Acme screw where the through-wall crack is gapped open. The engineering drawing indicates that this area is included in the Malcomize®[14] (nitride) region.

The through-wall crack was fully opened by laboratory induced bending stresses applied across the crack. The opened crack is shown in figure 44. Microscopic inspections found features typical of a tensile shear overstress in nitrided material. No indications of preexisting cracking were uncovered.

Inspections of the threaded portion of the Acme screw found extensive corrosion pitting and red rust spots all along the Acme screw. The pitting appeared slightly less at the upper and lower portions of the Acme screw where the black oxide coating[15] was more intact. The black oxide coating was evident throughout the threads except on the upper surfaces of the threads in the central and on portions of the thread crest at the major diameter (outer diameter). A slight copper hue was present at the worn areas of the major diameter. The presence of the rust made it difficult to accurately determine the extent of wear on the threads. No wear was apparent on the flanks of the ten lower and seven upper threads. Between these areas the upper flanks showed some polishing and removal of the black oxide coating that increased toward the center of the length. In the central region of the threads the major diameter was polished about half way around the circumference. No wear steps were visible at any locations on the threads.

Under the black oxide coating, the surfaces displayed a fine textured appearance typical of a bead blasted surface as shown in figure 45 at the crest of a thread. No machining steps or sharp features were noted. In the areas where the black oxide was not present, the surfaces had a circumferentially worn and somewhat shiney appearance. No wear steps were noted in these areas. Portions of the two bottom threads were partially coated with what appeared to be light gray paint, as required by the assembly drawing.

Estimates were made of the surface roughness by magnified visual comparison to a standard Microfinish Comparator[16]. Several group members made comparisons on the Acme screw in four quadrants at the top, center and bottom of the threaded area. Both thread flanks (upper and lower) and crests were examined. All locations recorded a 32 RMS[17] or finer finish including the worn areas. The drawing requires a 32 or finer finish.

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[14] A Lindberg Heat Treating Co. trade mark name used on the engineering drawing to indicate a nitriding operation.

[15] Black oxide coatings are a surface finish treatment used to impart a black color to the surface. They provide limited corrosion protection.

[16] A GAR Precision Danbury, CT. G-6 Grit Surfaces Microfinish Comparator®.

[17] RMS root mean squared. A numerical measurement of the surface roughness.

Additional surface roughness and other dimensional measurements were made on the Acme screw at the manufacturer (Trig Aerospace) and in the NTSB Materials Laboratory. These measurements are reported in Materials Group Factual Reports 00-068 and 00-074.

The lower end of the Acme screw including about 19 threads was further electrolytically cleaned in a solution of Endox 214[18]. The cleaning completely removed the corrosion products in the cleaned area as shown in figure 46 but generally left the black oxide, paint and cadmium plating. Microscopic examination found that the corrosion had deeply pitted the screw surface but that the damage was confined to the pit locations. Surface roughness comparisons were made in the cleaned area and found to be the same as the previous measurements (32 RMS or finer).

Superficial surface hardness measurements were performed on the crests of several threads along the length of the Acme screw. The resulting readings ranged from 86.5 to 88.5 Rockwell 15N[19] scale. The engineering drawing required 85 minimum for case hardness. Details of these measurements are reported in report 00-074.

A longitudinal micro-section was cut through the upper five threads of the Acme screw. The section was mounted, polished and initially examined unetched. Some small longitudinally oriented stringers were visible. The depth of the nitrided case was measured by micro-hardness at the root between two threads and at the flank of a third thread. At the time of manufacture for the accident screw, the case depth requirement was 0.003 to 0.005 inches deep. It has since been increased and the latest revision of the drawing it is 0.003 to 0.010 inches. Douglas Production Specification (DPS) 5.00-3 for nitrided parts defines the case depth as the depth below the surface were the hardness (HK or HV) is 50 points or greater than the average core hardness. Using this criterion and Knoop (HK) measurements at 500 gram load, the measured case depth was 0.004 inches deep at the flank and 0.007 at the root. When etched with 2% Nital[20] reagent, the case and core microstructures appeared typical of a nitrided, quenched and tempered steel with no evidence of a white layer, as shown in figure 47. Core hardness measured on the specimen averaged 40 HRC (402 HK). Using a Wilson Chart 70 conversion table, the engineering drawing's requirement for heat treatment to 160,00 psi to 180,000 psi corresponds to an approximate hardness range of 36 to 40 HRC.

Acme Nut

The side bar on the following page details the significant metallurgical specifications for the Acme nut, as summarized from the engineering drawing.

The as-received Acme nut assembly with gimbal ring is displayed in the two views of figure 48, looking generally downward into the thread bore of the nut. The bore showed only the spiraling traces of the original threads. Two bright spiral lines were visible with dark surfaces in

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[18] A commercially available cleaner manufactured by Enthone-OMI, New Haven CT.

[19] Performed on a calibrated instrument after tests on certified test blocks were satisfactory.

[20] 2% concentrated Nitric acid in ethanol.

between and some overlaying powdery white deposits. White deposits were particularly apparent at the interior exit of the grease passageway the top of the nut bore. On the interior of the nut the grease passageway was enlarged by a 0.5 inch counterbore.

Close visual examination of the gimbal nut interior (prior to dissection) noted a thick, black, dry residue coated with a white powdery material at the exit counterbore of the Acme nut grease passageway located near the top of the nut. Due to the hardness of the residue and its location within the nut, it was difficult to extract a sample for examination. Therefore, the grease fitting was removed from the upper forward side of the nut to allow removal of a sample from the grease passageway.

As the grease fitting was removed, translucent reddish grease was present on the threads of the fitting as shown in the left view of figure 49. No grease was apparent in the passageway in the nut or in the bore of the grease fitting, see right view of figure 49. Probing the depth of the grease fitting bore with a slender wire removed a small amount of reddish grease that appeared consistent with the grease on the external threads.

The Acme Nut, P/N 5914405

The Acme nut is made from a centrifugally cast and heat treated nickel aluminum bronze, alloy C95500, per QQ-B-671, Type 2 Class 4, Cond. HT TR.(1) The minimum tensile properties of the heat treated alloy are: ultimate strength (F_{tu}), 110 ksi; yield strength (F_{ty}), 60 ksi and; elongation (e), 5%. While the drawing lists tensile property requirements, heat treat verification is performed to hardness standards, 93 HRB minimum, set forth in the specification. The threads are machined and the required surface finish is $^{125}\surd$. The part is cadmium plated per DPS 9.74 Type I, except in the threaded region where no coating is required.

(1) This specification has been superceded. The present standard is ASTM B271

To extract a sample from the grease passageway in the gimbal nut, a flat tipped punch was pushed into the grease fitting passageway from the outside of the nut, forcing the sample to the interior of the nut. A piece of clean paper was inserted into the interior diameter of the nut to collect the sample. Slight pressure was required to push the sample through. A small amount of translucent reddish grease was evident on the tip of the punch after it was extracted from the fitting hole.

A significant amount of material remained in the counter bore of the grease passage in the nut interior. A sharp tipped probe was used to scrape residue from the counter bore. The entire sample, shown in figure 50, was retained for later analysis. One large piece of the removed material retained the cylindrical shape and approximate diameter of the grease passageway before the counterbore.

Visual microscopic examination showed that the residue was mostly black powdery material with larger chunks of black and white material and particles of copper colored metallic debris.

The upper view in figure 51 shows the exit side of the grease passageway from the grease fitting after the fitting and the sample residue were removed and the nut was cut open. The lower view of figure 51 schematically illustrates the arrangement of the grease fitting, passageway and counterbore in relation to the nut. The approximated extent of the material removed from the passageway is also indicated. The Acme nut threads are shown in this view for reference only.

Additional grease samples were removed from the exterior of the nut and gimbal ring prior to further disassembly.

To disassemble the Acme nut assembly, the gimbal ring was removed by pulling out the pivot pins after unthreading the locking bolts. The pins easily slide out of the nut and the ring. The lower forward and aft support blocks were removed by extracting the three pins in each. These were tight in the assembly and required using a punch to hammer them out. During disassembly the flanges on the lower aft support were slightly dented. Figure 52 shows the lower end of the Acme nut after removal of the lower support blocks.

Both grease fittings at the pivot points in the undamaged gimbal ring were unthreaded and removed. The fittings were located on the upper surface of the ring, one was on the left side aft of the pivot point and the other was on the right side forward of the pivot point. Clean red translucent grease was visible in both passageways and in the bores of the fittings, see figure 53. Samples were taken from the openings with wooden probes and retained for further analysis. Also, the fittings were retained in the as-removed condition.

A grease fitting from an exemplar gimbal ring was installed into the gimbal ring at each of the grease fitting opening. Green Aeroshell-33 grease was then pumped into the grease fitting by means of a hand grease gun. Red grease was observed to come out of some of the grease passages followed by green Aeroshell-33 grease. No attempt was made to remove the Aeroshell-33 grease from the ring following the test.

Prior to sectioning the nut, the inner diameter was measured with calipers at three 60-degree spaced positions at the top and bottom. The top measured 1.719 inches at all positions. The bottom measured 1.718, 1.722 and 1.721 inches. For reference, the major diameter of the nut's Acme thread is between 1.7182 to 1.7228 inches. Indicating that the threads of the Acme nut had been removed to the major diameter of the Acme screw.

The Acme nut hardness was also measured prior to sectioning. Readings averaging 98.3 and 99.5 HRB[21] were measured on the support lug areas on opposite sides of the nut. The current specification for the nut material, ASTM[22] B-271–96 requires a minimum hardness of 200 HB[23] (3000kg). Per Wilson Chart 70 this is approximately equivalent to 93 HRB. These readings are also reported in report 00-074.

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[21] Hardness Rockwell B scale.

[22] American Society for Testing and Materials

[23] Brinell Hardness at a 3000 kG load

To section the nut and more closely examine the interior, the lower ½ inch of the nut was first transversely cut off using a wire EDM[24]. This cut retained the physical relationships between the nut bore and the lower stop lug for further examinations as reported in report 00-045. The remainder of the nut was then longitudinally split into forward and aft halves roughly along the nut centerline. The opened nut is displayed in figure 54. The left side of the aft half was then cut further along the line depicted in figure 54 for metallographic and SEM specimens.

Magnified visual inspections of the exposed nut interior found a regular spiraling pattern down the length of the nut having a frequency consistent with the specified pitch of the internal nut threads. For comparison, an exemplar nut[25] was cut on the thread centerline and is shown beside the accident nut in figure 55.

From the bottom up, the pattern generally consisted of a raised ridge followed by a lustrous depression showing spiral machining or wear marks transitioning into a dark band of surface deposits that rose to the next ridge. The features of the pattern on the inner surface are shown in figure 56 and the profile is visible in figure 57 on the longitudinal cut surface of the nut. Under high magnifications, the distinct raised ridges showed mostly a longitudinally smearing but in some area clear shearing fractures were discernable. The smearing and shearing both indicated a relative upward movement of the threads in relation to the nut body. Along most of the ridges material could be seen folded upward and smeared over the adjacent surfaces. The measured widths of typical ridges ranged from about 0.013 to 0.020 inches and appeared to depend on the amount of smearing. The lower view of figure 56 has been annotated to show the approximate original specified thickness of the thread at its base, assuming that the upper edge of the ridge corresponds to the original upper edge of the thread.

The vast majority of the markings on the interior nut surface spiraled around the bore. However, some circumferential and longitudinal marks were noted in isolated locations overlaying the spiral marks, such as those shown in figures 58 and 59. At the location of figure 58 on the upper end of the forward side of the nut, two circumferential running bands of scratches were present partially around the inner diameter. In other locations, the black surface deposits were locally removed in circumferential patterns. At the location of figure 59 near the top of the nut, several longitudinal scuff marks were present on the aft side above the grease orifice. The scuff marks appeared to be running upward.

The longitudinal piece cut from the aft half of the nut was further reduced in size to produce specimens for SEM examination and metallographic viewing.

The SEM specimen was about 1 inch long near the lower end of the nut. Prior to examination a region of the interior nut surface was scraped to remove surface deposits and expose the underlying base metal. Figure 60 depicts a typical area of the surface with a raised ridge at left center and a region of surface deposits immediately to the right. A portion

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[24] Electrical Discharge Machining using an expendable wire as the cutting electron.

[25] The exemplar nut was removed during overhaul of the jackscrew assembly s/n DCA-2264. The assembly reportedly had 0.036 inches of endplay at overhaul.

of the scraped area is in the upper right of the view. Closer examination of the ridge uncovered smearing deformation as shown in figure 61. The indicated direction of smearing is from bottom to top.

Energy dispersive x-ray spectra of the deposits and the base metal in the scraped area were acquired during SEM examination. The spectra are displayed in figure 62. The base metal showed constituents consistent with the specified Acme nut material, aluminum nickel bronze per ASTM-B271 (UNS C955000). In addition small peaks of chlorine and sulfur were present. The surface deposits (optically black) showed the base metal elements with additional peaks for zinc, chlorine, sulfur, potassium and silicon along with peaks for oxygen and carbon.

The metallographic specimen was about 0.5 inches long and contained two of the ridges. The sample was mounted, polished, and etched with 50% concentrated nitric acid in water to reveal the microstructure. The microstructure had a dendritic shape consistent with a cast structure. The random orientation and small size of the dendrites were typical of a uniform fast cooling. No indications of porosity, shrinkage voids or major segregation were visible in the area of the specimen.

The metallographic section also showed the upward deformation and smearing associated with the raised ridges as depicted in the two views of figure 63. On the specimen, the ridges measured about 0.006 inches above the surrounding surfaces.

Torque Tube

The side bar at right details the significant metallurgical specifications for the torque tube, as summarized from the engineering drawing.

Figure 64 shows the torque tube after it was extracted from the Acme screw but before it was removed from the spherical bearing. Some chatter marks and surface damage were produced on the tube surface during removal of the Acme screw. The tube was bent an estimated 5 degrees just below the spherical bearing. This location approximately corresponds to the location of the crack in the Acme screw.

When removed from the spherical bearing a step was found worn into the outer diameter of the large diameter upper section of the torque tube as shown in figure 65. The step was at the lower end of the large diameter where the upper end of the Acme screw would sit after assembly.

Torque Tube-Drive, P/N 5914170

For MD 80 series airplanes, the torque tube-drive is made from a solid titanium alloy forging (Ti-6Al-4V) per DMS 1583, heat-treated to the HT140 condition (140 ksi F_{tu}, min.). The inside and outside surfaces of the larger diameter upper end as well as the threaded and splined regions at the lower end are coated with solid film lubricant, per DPS 3.177 Type 2.

Although the drawing calls the part a torque tube, it is actually solid, therefore the torque tube is sometimes referred to as a quill shaft.

For the MD-90, however, Ti-6Al-6V-2Sn alloy, heat-treated to 170 ksi min. F_{tu}, is used.

The wear area was approximately 0.1 inch wide and had reduced the outer diameter from about 2.127 inches to 2.071 inches.

No markings or identification stamps were found on the tube. The upper large diameter end of the torque tube that fits into the spherical bearing was coated with a dark gray layer consistent with a dry film lubricant. Dry film lubricant was also apparent at the lower end covering the remaining thread area and the external splines. Both areas of the torque tube are specified for dry film lubricant by the engineering drawing. The outer diameter of the torque tube was measured at several locations between the large upper end and the external splines at the lower end. The measured diameters (1.0645 to 1.0665 inch) were within the drawing limits for –1 and –501 tubes (1.063 to 1.073 inch).

The torque tube was fractured through the first full thread just below the external splines at the lower end of the tube. A 7/8 – 14 UNF –3A left-hand thread is called out by the drawing at the lower end of the tube. Only a portion of one thread was present on the recovered piece of the torque tube making most thread dimension measurement impossible. However, the major and minor diameters of the thread were measured using a computer base optical measurement system. The measured major (0.8687 inch) and minor (0.77049 inch) diameters were within the tolerance rage listed in the Machinery's Handbook, 22nd edition[26] for the specified thread.

The lower end of the accident torque tube contained threads up to the shoulder for the splines and did not have the optional thread relief cut allowed in the engineering drawing. Figure 66 shows the accident torque tube positioned between two exemplar tubes. The upper[27] tube contained the optional thread relief while the lower[28] one did not.

The fractured end of the torque tube was saw cut off the shaft along with a ¼plug shown in figure 67. Macroscopic fracture traces indicated that the fracture initiated from a broad front at the right forward quadrant (as recovered) of the tube and propagated across the cross section. A vertical shear edge between adjacent threads was apparent opposite the initiation area. A direct view of the fracture face is displayed in figure 68 with the initiation region and the shear edge denoted. Future directional references about the fracture will maintain this perspective. The fracture face was cleaned with acetone and ultrasonic agitation.

Closer inspections found that the macroscopic fracture traces emanated from a thin band of features immediately adjacent to the thread root. This band had a slightly different reflective quality that was not visible in all lighting conditions and in many places had a poorly defined boundary. The band extended almost entirely around the circumference of the torque tube staying in the thread root. In the initiation area, the band extended about 0.03 inches onto the fracture surface, see figure 69.

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[26] Machinery's Handbook, 22nd edition, Industrial Press Inc, page 1237. Major diameter 0.8647 to 0.8750, Minor diameter 0.7874 inch maximum.

[27] From Northwest Airlines, jackscrew assembly s/n 00060

[28] From AirTran, jackscrew assembly s/n DCA 459

To the right, in the view of figure 68, the band spiraled downward following the thread root below the level of the main fracture plane, as shown in figure 70. In this direction, the width of the band thinned slightly to about 0.019 inches thick when measured 90 degrees from the initiation region, see figure 71. The band extended around the thread root and was visible opposite the initiation region and appeared to eventually undercut the fracture as a crack at the shear edge. To the left, the band raised slightly above the main fracture but became much thinner until it disappeared about 135 degrees from the initiation region, see figure 72. At 90 degrees left of the initiation, the band measured 0.012 inches thick. In total, the band was present for an estimated 330-degrees around the torque tube fracture.

Scanning electron microscope examinations of the fracture surface found ductile dimple fracture features, as shown in figure 73, over the majority of the fracture except in the previously mentioned band. Within the band, the feature consisted of small irregular plateaus with fissuring running generally parallel to the circumference of the tube. Further examination at the Boeing Huntington Beach laboratory uncovered fatigue striation-like features throughout the band, as shown in figure 74.

Energy dispersive x-ray spectra were acquired during SEM examinations of the torque tube fracture. The spectra showed the presence of titanium, aluminum and vanadium consistent with DMS 1583F (Ti-6-4) titanium alloy as specified by the engineering drawing.

Further quantitative chemical analysis[29] of the torque tube material performed by Durkee Testing Laboratories Inc, Paramount California determined that the material met the drawing's material requirements, DMS 1583F.

The microstructure of the torque tube was examined on a transverse metallographic specimen made from the previously cut plug at a location about 2 inches above the fracture. The specimen was polished and etched with Kroll's[30] reagent to revealed fine alpha islands in an alpha plus beta matrix as displayed in figure 75. No indications of an alpha case were found. The microstructure appeared typical of a properly heat treated Ti-6-4 forging.

Further mechanical testing were performed at Durkee Laboratories to measure the tensile strength of the torque tube material. Two approximately 4-inch lengths of material were cut from the upper end of the torque tube just below the enlarged end and supplied to Durkee. These were subsequently cut along the longitudinal centerline to make two half round specimens each. One specimen of each length was machined into ASTM E-8, 0.25 standard tensile bars and tested in accordance with ASTM procedures. The specimens were labeled T1 and T2 and tested to fracture. Due to a recording anomaly in the stress-strain curve for specimen T1, its results were considered invalid, and two additional specimens were

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[29] Analysis performed by emission spectroscopy and inert gas fusion method. Durkee Report Lab No S5737 Log No. 58118N dated 10-3-2000 attached.

[30] A general-purpose etchant for titanium and titanium alloys.

machined from the remaining halves of the original lengths of the torque tubes specimens. These were labeled T1-RETEST and T2-RETEST and tested to fracture.

The resulting data for tensile and yields strengths along with the percent elongation and percent reduction in area for specimens T2, T1-RETEST and T2-RETEST were within the limits set forth in the material specification DMS 1583F (Ti-6-4) and the engineering drawing. The test results are contained in the attached Durkee reports[31].

Vendor Information Requests

Vendor Information Requests[32] (VIRs) for the jackscrew assembly (excluding the gearbox and motors) were requested and received from Boeing. A review by the Materials Group found that of the 36 requests only one (#61653) was made prior to June 28, 1990 (the manufacture date of the accident assembly). The VIR requested approval to "vibra-pencil" the serial number onto the jackscrew for "in-process control". The VIR was approved but no drawing change was made.

Approximately 1 year after the manufacture date of the accident jackscrew, VIR OM80381 requested a change in the nitride case depth requirement from 0.003 to 0.005 to 0.003 to 0.007 inches. On 2-20-96 VIR number 13935 requested a further change in the case limits to 0.003 to 0.010 inches. Both requests were approved and drawing changes were instituted.

A summary table of the VIRs is attached.

Drawing Change History

A history of engineering drawing changes for the Acme screw and nut of the jackscrew assembly was request and received from Boeing. The table of changes is attached. A review of the table did not find any significant metallurgical changes to the MD80 series Acme screw or nut after 1970 except for the previously noted changes in case depth requirement.

With the introduction of the MD90 series aircraft, the Acme screw material was changed to 4340 steel through hardened to 260,000 to 280,000 psi ultimate tensile strength. Malcomizing (nitriding) was eliminated. The material and size of the torque tube also changed from Ti-6-4 to Ti-6-6-2 (AMS 4971) for the MD90 series.

Trim Motor and Jackscrew Gearbox Components

Following disassembly of the related assemblies, the following components were received for examinations; 5 rotating disks and 10 reaction plates from the trim motor system and two

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[31] Durkee Report Lab No. S5743 and S5744, Log No. 58364N dated 10-03-00, attached.

[32] Vendor Information Requests are requests from the vendor to Boeing for changes in procedures or specifications or for additional information and clarifications on procedures or specifications.

planetary gear assemblies (primary and alternate) from the jackscrew gearbox assembly. The received parts are displayed in figure 76.

The rotating disks and reaction plate make up part of the jackscrew brake system. As installed, the rotating disks separate pairs of reaction plates. Visual examinations of the reaction plates found several different deposits on the plate surface outboard of the contact area with the rotating disks. The deposits were of three types, white consistent with magnesium corrosion products, red consistent with iron rust, and blue-green consistent with aqueous corrosion products of copper alloys.

The disk contacting surfaces displayed fine circumferential scratch patterns, and some of the plates had pieces of friction material firmly attached to the disk contacting surfaces. However, there were no indications of rotation after the transfer of the friction material.

The rotating disks were internally splined and had friction material applied to both sides. The disks also showed deposits of white magnesium corrosion on the outer diameter and of blue-green copper corrosion products on the splined inner diameter surfaces.

The friction surfaces displayed fine circular scratch patterns but no visual indications of high temperature exposure. The friction material was missing from several of the disks. The areas of missing material matched the areas of material attached to the reaction plates.

The primary gear assembly marked P/N 4372501 s/n 2752 had light corrosion on the exterior surface of the assembly but rotated freely and easily in both directions. No visual damage was noted to the outer gear teeth. Visual inspection found three longitudinal cracks in the drive input spline socket and downward denting damage to several of the spline teeth. The diameter of the socket was bulged outward in the cracked areas shown in figure 77.

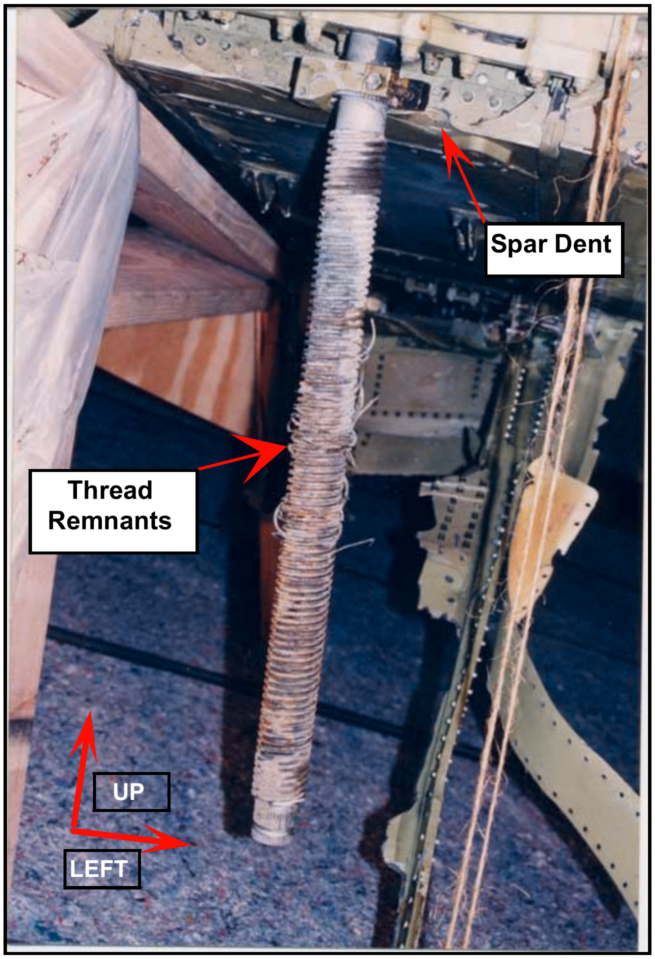
The alternate gear assembly, marked P/N 4372901 and s/n 2147, did not exhibit exterior corrosion. Dark soft grease was found inside the output spline socket. The assembly was rotated freely by hand. The lower ends of several of the output spline teeth were slightly dented, as was the adjacent lower edge of the socket.

Joe Epperson
Senior Metallurgist

ImageNo:010A0169, Project No:A00095

Figure 1--An overall view of the as-recovered jackscrew assembly mounted on the horizontal stabilizer. One thread remnant has been removed.

Figure 2--A closer view of the Acme screw showing the location of the thread remnants. The relationship between the screw and the dent in the lower edge of the stabilizer spar is also apparent.



ImageNo: 010A0180, Project No:A00095

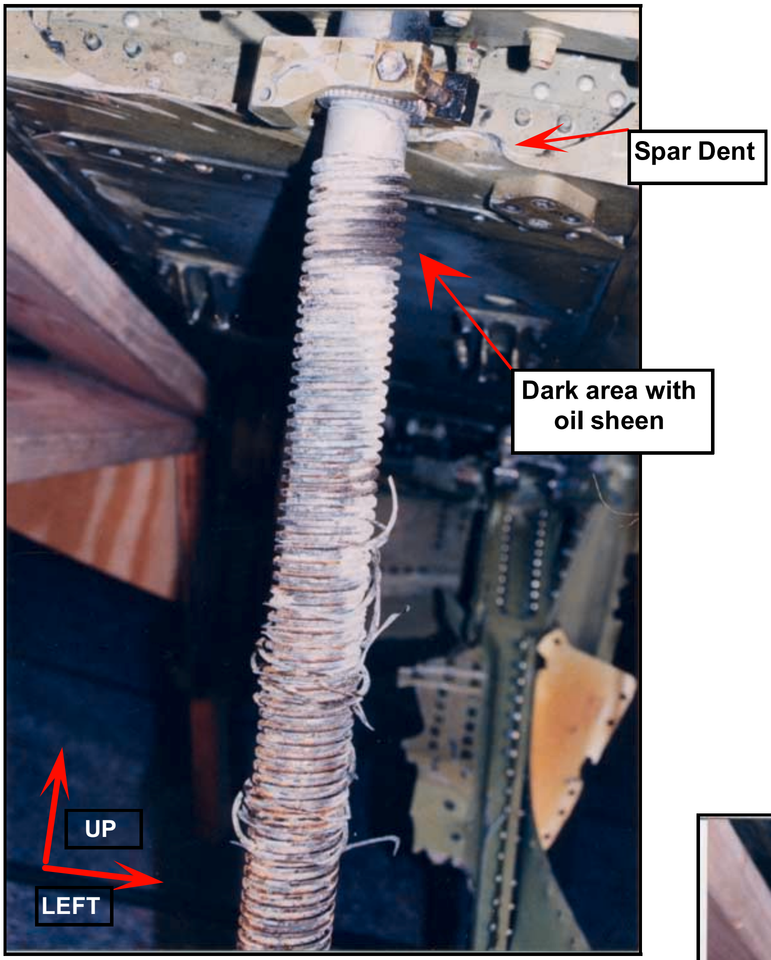


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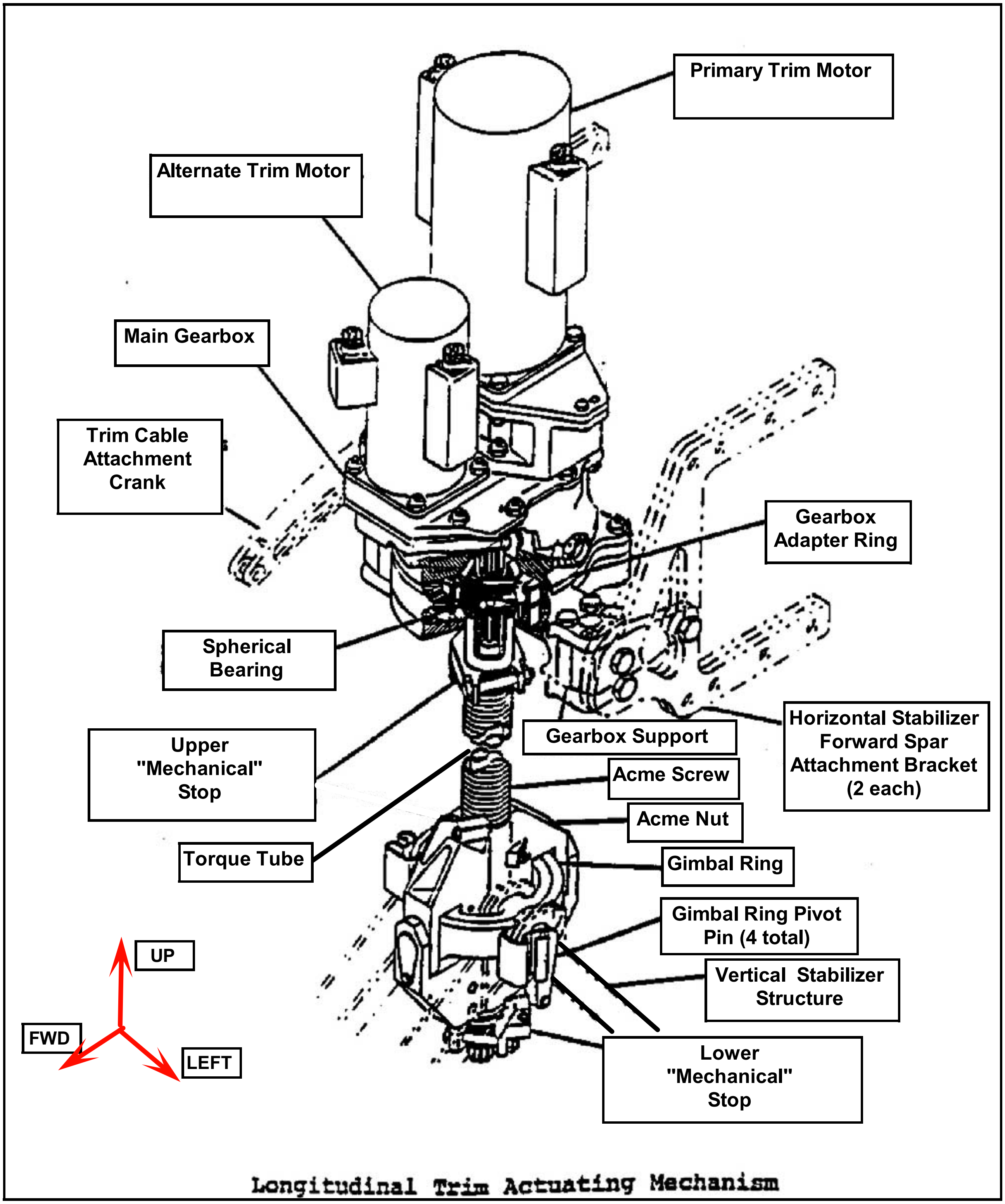
Figure 3--As recovered jackscrew showing the upper portion of the Acme screw and upper stop. Note dark area on the upper end of the screw.

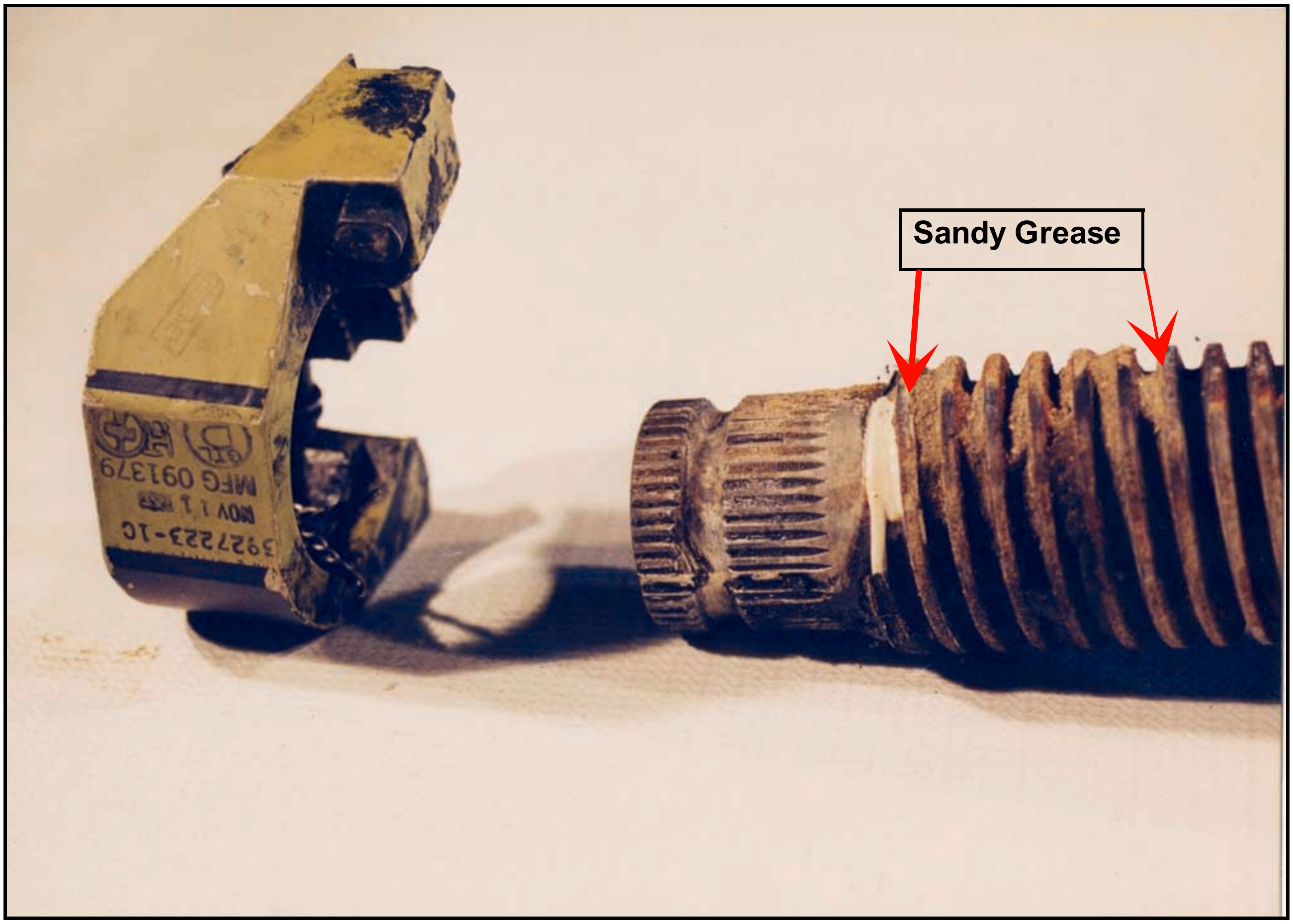
Figure 4--Closer view of the thread remnants on the screw. One remnant has been removed.

ImageNo: 010A0197, Project No:A00095



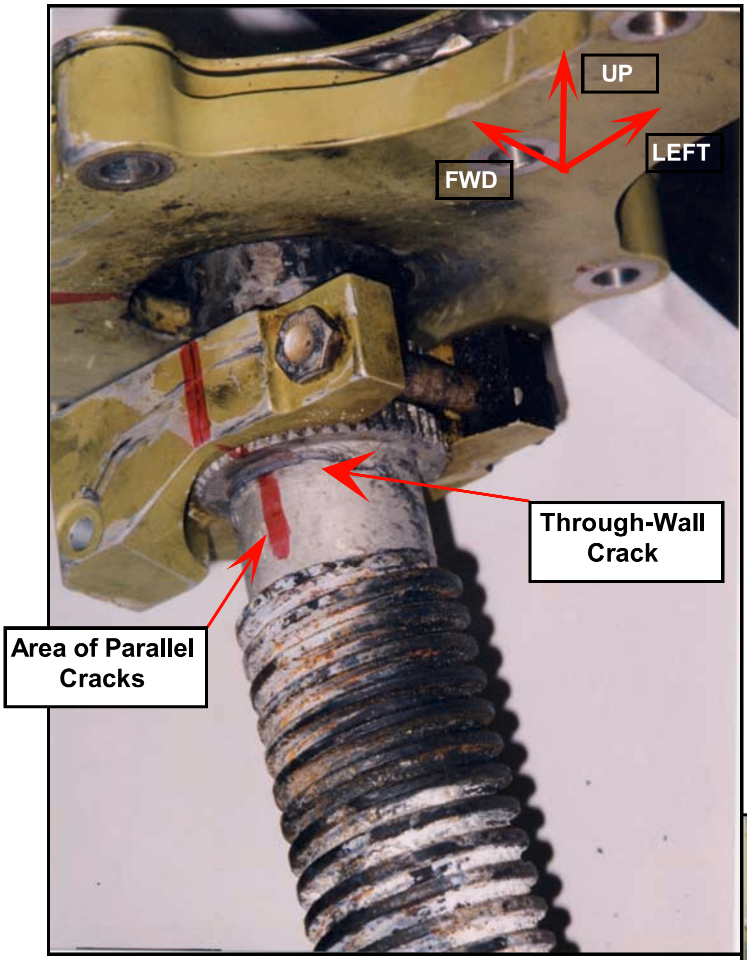
ImageNo:010A0351, Project No:A00095

Figure 5-- An illustration showing the typical components and arrangement of the longitudinal trim actuating mechanism (jackscrew assembly) with the major components identified.



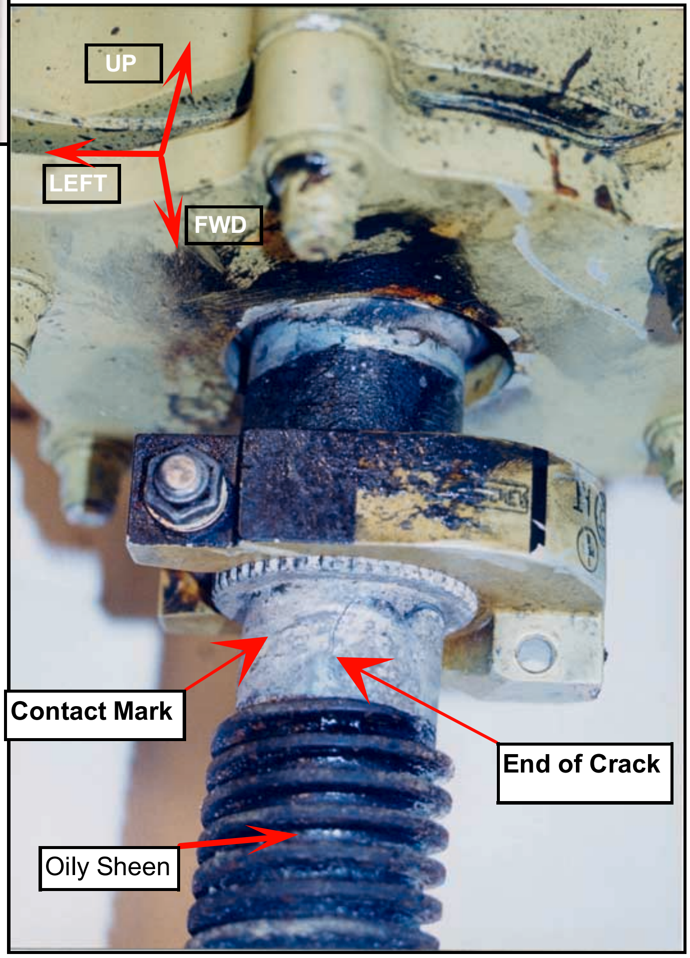
ImageNo:010A0199, Project No:A00095

Figure 6--Lower end of Acme screw showing sandy material between the threads in the indicated area. Lower stop also shown.



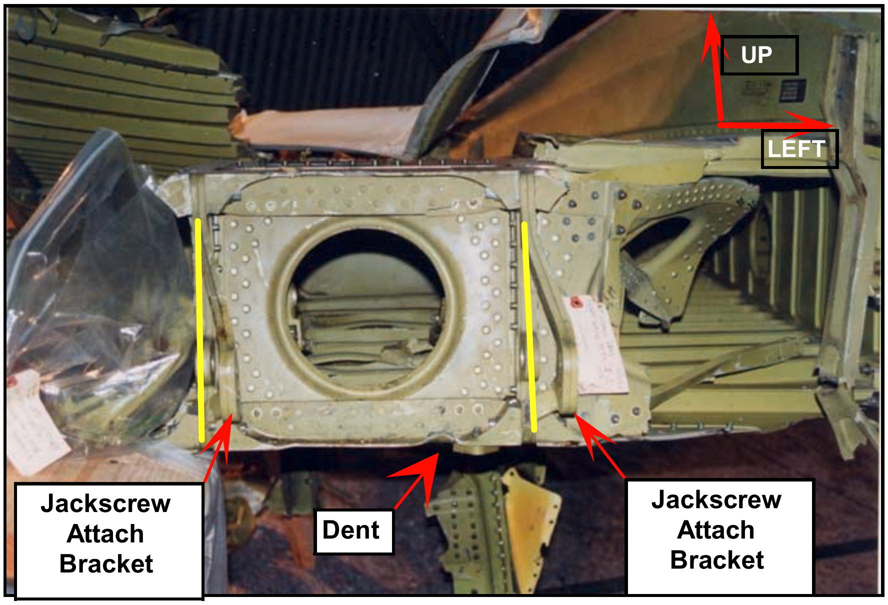
ImageNo:010A0200, Project No:A00095

Figure 7--The upper end of the Acme screw showing the gaping through-wall crack.



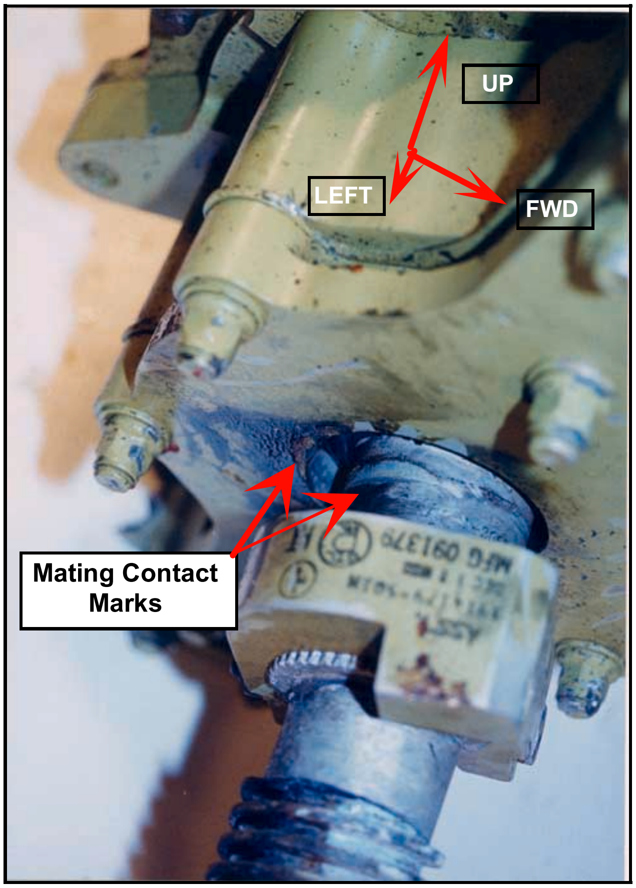
ImageNo: 010A0201, Project No:A00095

Figure 8--Side view of the upper end of the Acme screw showing the end of the crack and the "C" shaped contact mark. Also note the oily sheen in the root of the visible threads of the Acme screw.



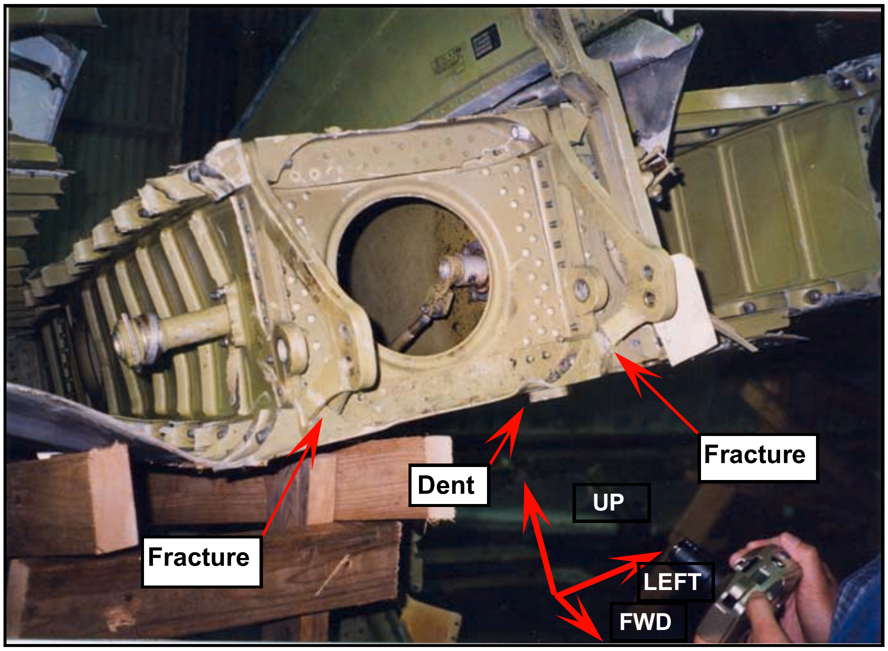
ImageNo:010A0168, Project No:A00095

Figure 9--Looking aft at the horizontal stabilizer showing the left deflection of the jackscrew attach brackets. Vertical lines (yellow) denote the original positions of the brackets. Also note the dent in the forward edge of the of the spar lower flange.



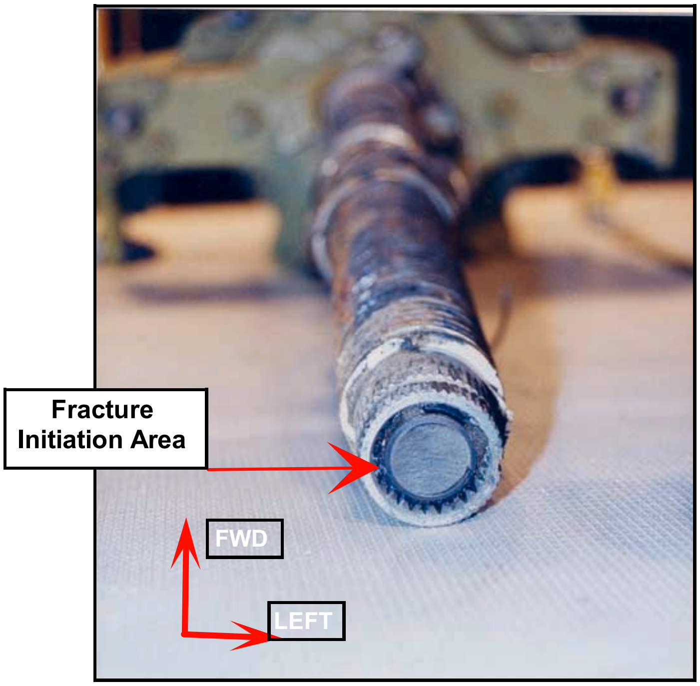
ImageNo: 010A0170, Project No:A00095

Figure 10--Upper end of the Acme screw showing contact mark from the lower gearbox support plate.



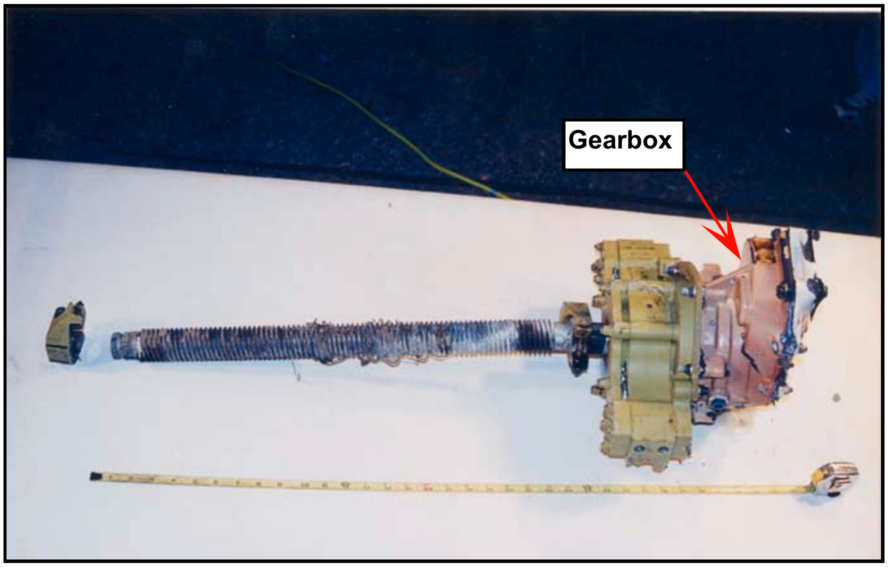
ImageNo:010A0171, Project No:A00095

Figure 11--Oblique view of the spar attachment brackets after jackscrew removal. Fractures at arrows in lower legs of the brackets. Also note the dent in the forward edge of the spar lower flange.



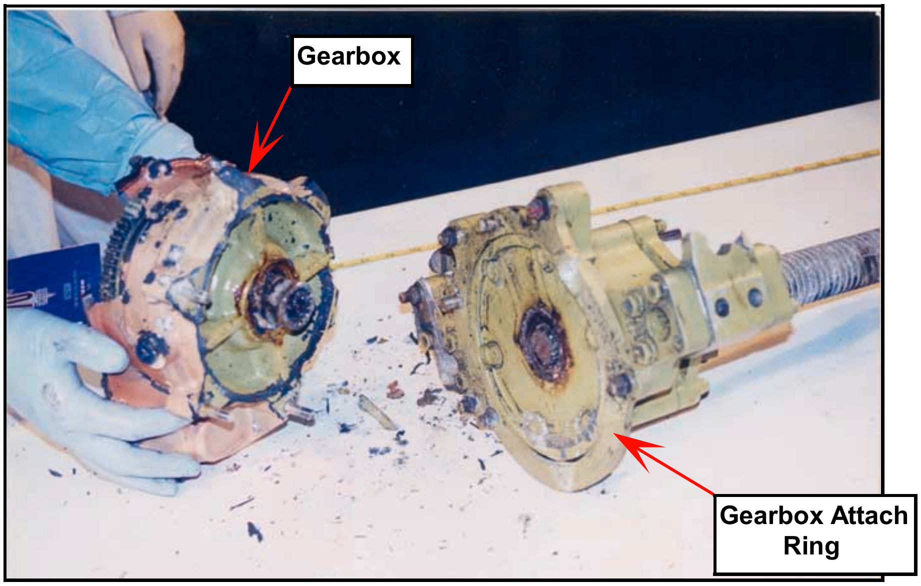
ImageNo: 010A0172, Project No:A00095

Figure 12--Bottom view of the jackscrew showing the fractured internal torque tube. Fracture initiation at left side in this view.



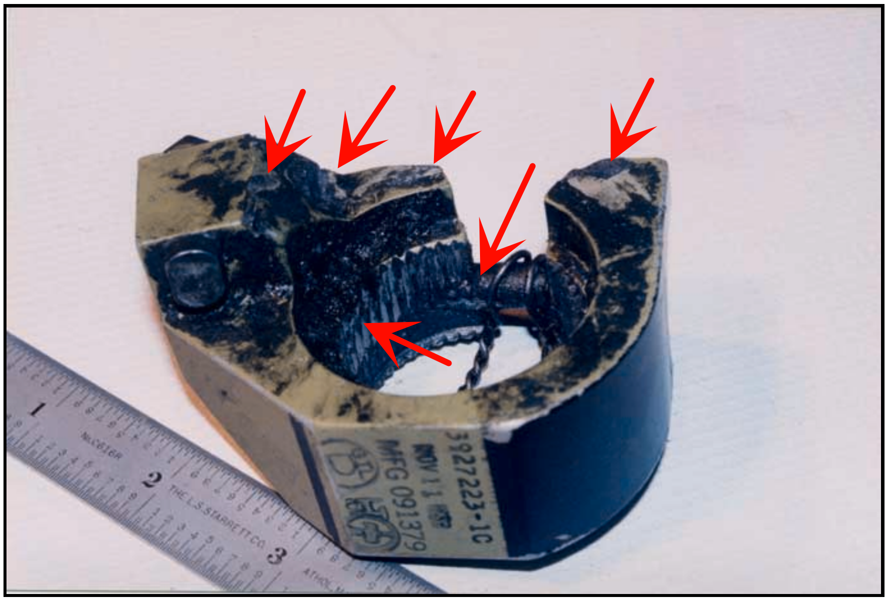
ImageNo:010A0173, Project No:A00095

Figure 13--Overall view of the removed jackscrew assembly with the gearbox mounted (right in view).



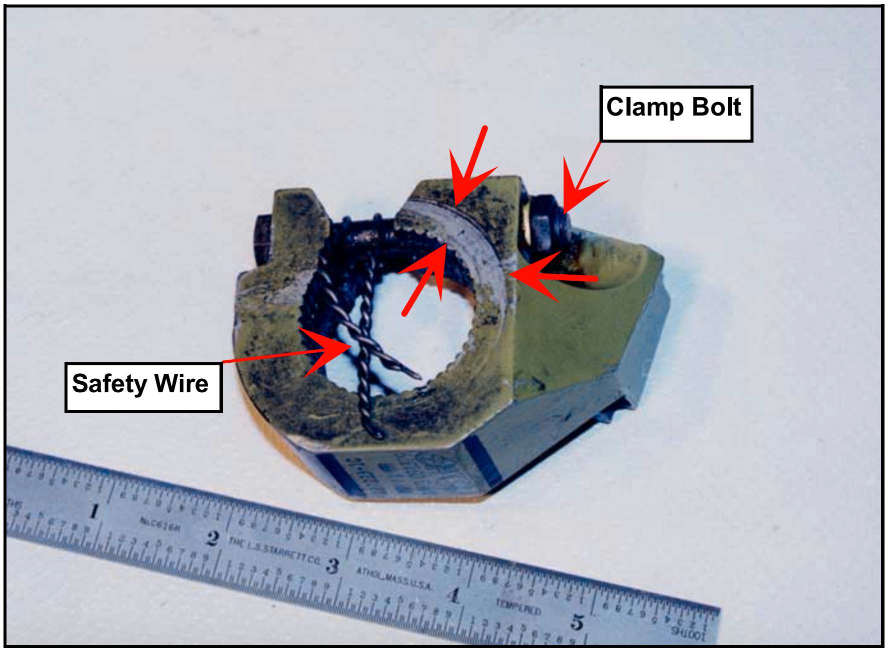
ImageNo: 010A0174, Project No:A00095

Figure 14--View showing the gearbox removed from the jackscrew assembly.



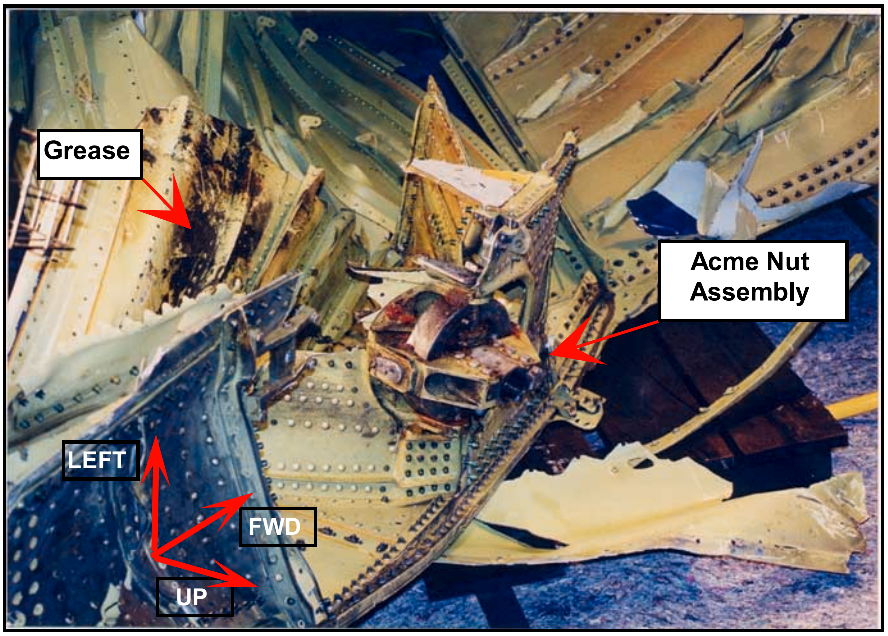
ImageNo:010A0175, Project No:A00095

Figure 15--A view showing the as-recovered lower stop assembly. Note the black grease. Locations of some of the mechanical damage are arrowed.



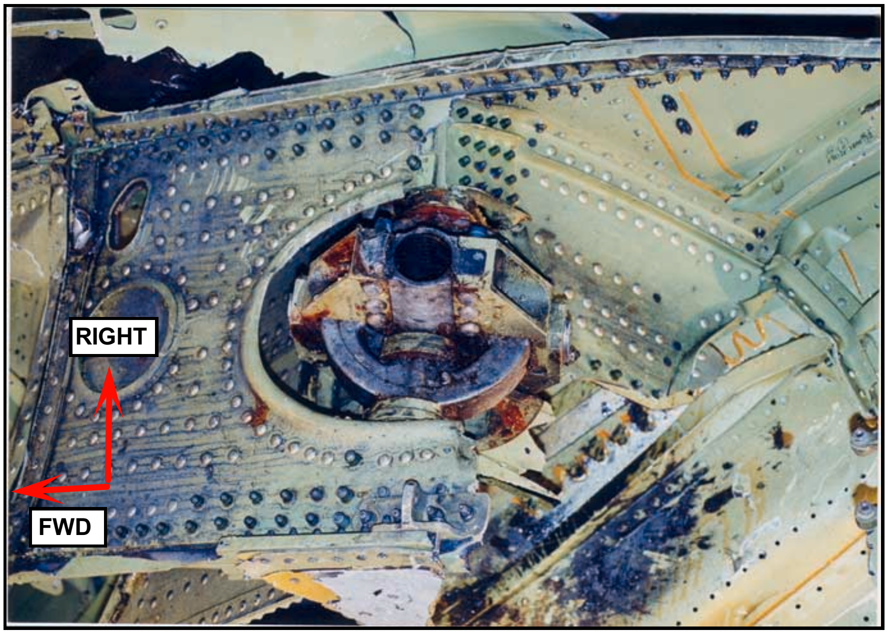
ImageNo: 010A0176, Project No:A00095

Fiure 16--The lower surface of the as-recovered lower stop assembly with arrows at damage locations. Note the fastened and inplace clamp bolt and the heavy safety wire.



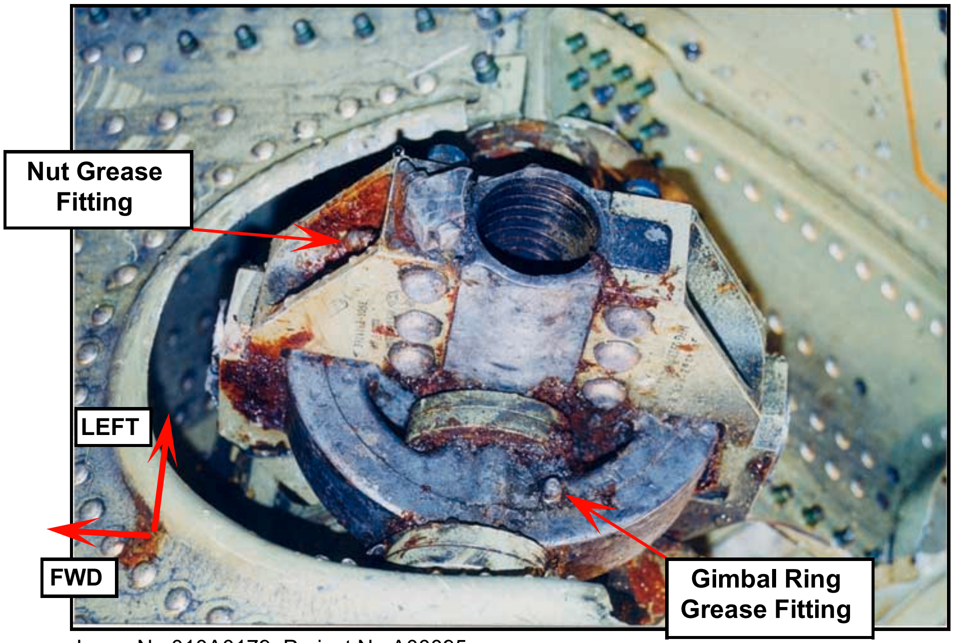
ImageNo:010A0177, Project No:A00095

Figure 17--The as-recovered Acme nut assembly in the structure of the vertical fin.



ImageNo: 010A0178, Project No:A00095

Figure 18--A close view of the as-recovered Acme nut assembly looking down and right. Note the visible reddish grease on the exterior of the nut and the black grease on the structure below.

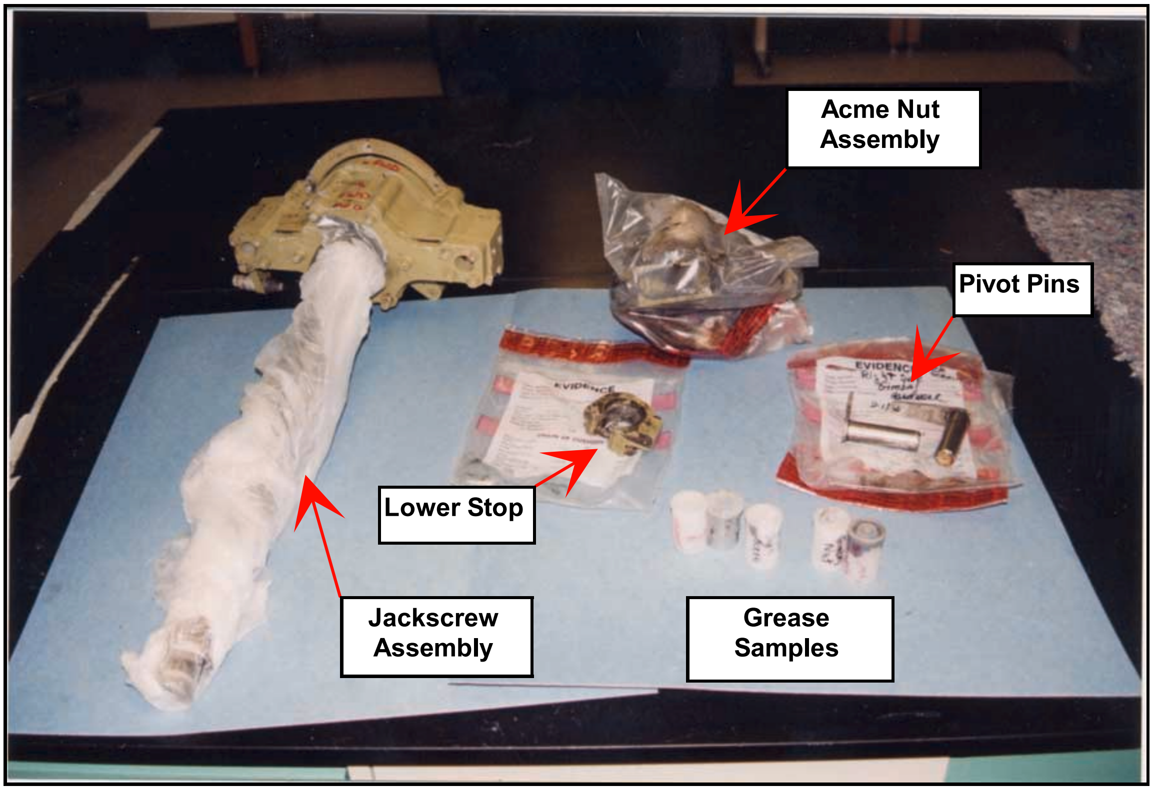


ImageNo:010A0179, Project No:A00095

Figure 19--A closer view of the Acme Nut assembly showing the grease on the exterior surface and the grease fittings. The spiral pattern on the nut interior is also visible.

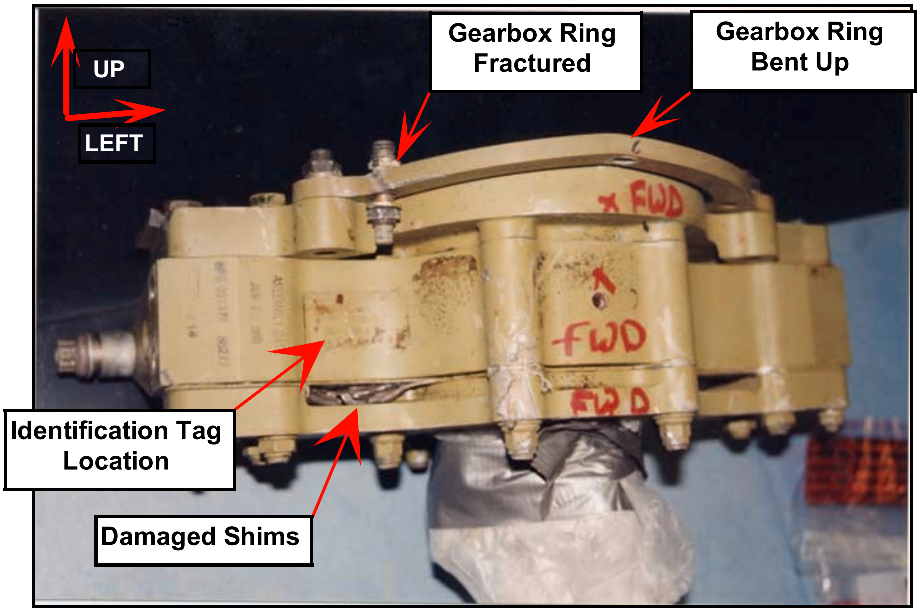
ImageNo: 010A0181, Project No:A00095

Figure 20--A view of the Acme nut assembly with the jackscrew assembly positioned above.



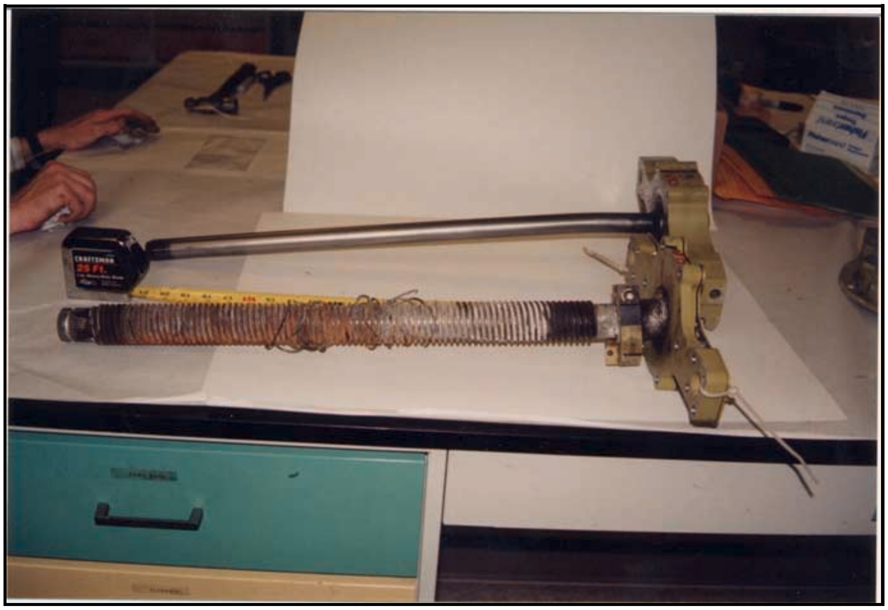
ImageNo: 010A0182, Project No:A00095

Figure 21--Components received for examination. Jackscrew assembly, lower stop, Acme nut assembly, pivot pins and 5 grease samples.



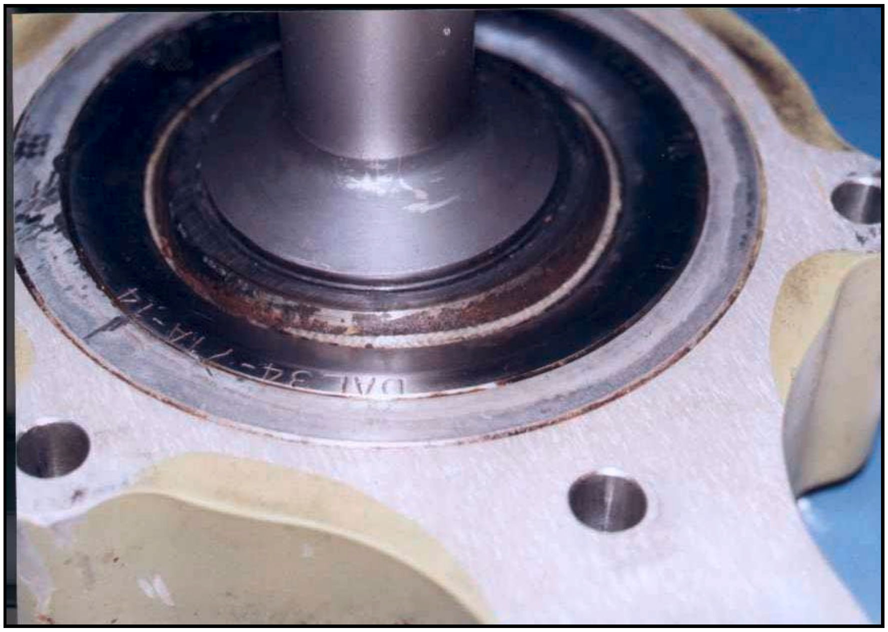
ImageNo:010A0183, Project No:A00095

Figure 22--The forward face of the gearbox support assembly showing the remnants of adhesive at the ID tag location. The damaged lower shim pack and the location of the fractured pivot bearing grease fitting are also visible.



ImageNo: 010A0184, Project No:A00095

Figure 23--Side view of the Acme screw and torque tube after separation.



ImageNo:010A0203, Project No:A00095

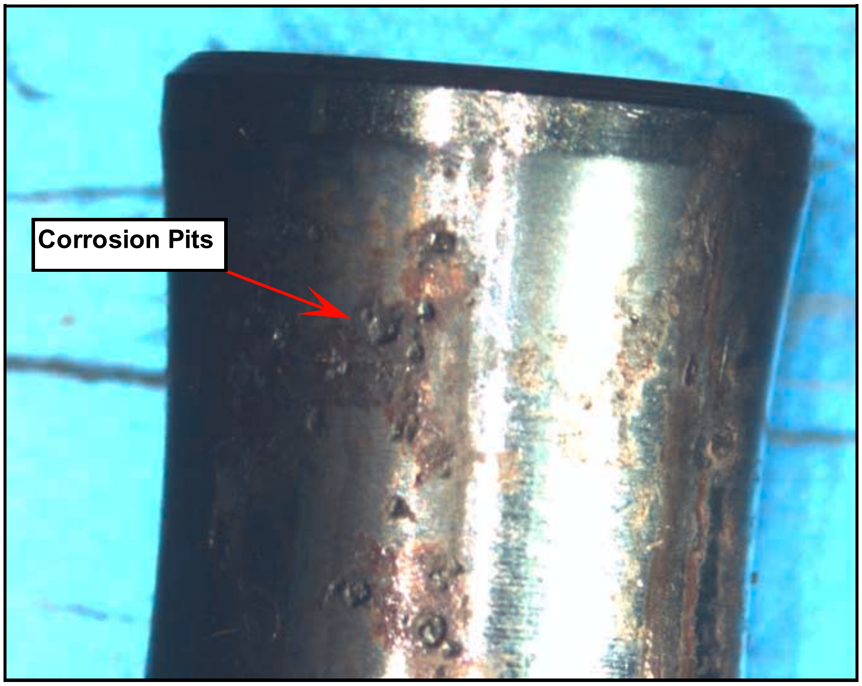
Figure 24--Close view showing the corrosion on the lower surface of the pivot bearing. Shown with torque tube installed.

ImageNo: 010A0204, Project No:A00095

Figure 25--The interior of the pivot bearing after removal from the gearbox support assembly and sectioning showing the black grease.

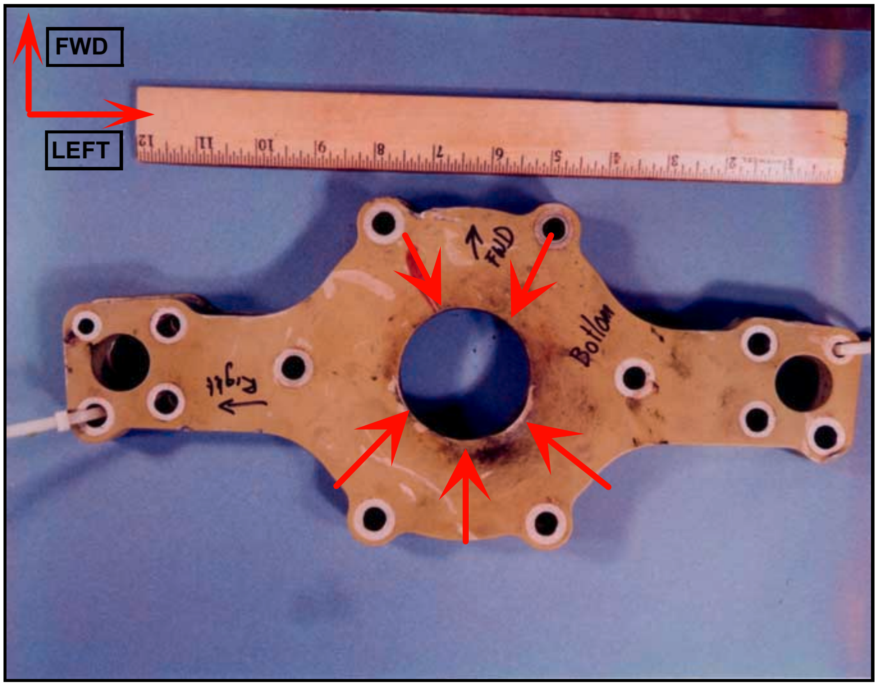
ImageNo:010A0205, Project No:A00095

Figure 26--Left corrosion visible on the inner shperical race of the pivot bearing after cleaning. A similarly opened bearing from another jackscrew assembly is shown at right for comparison.



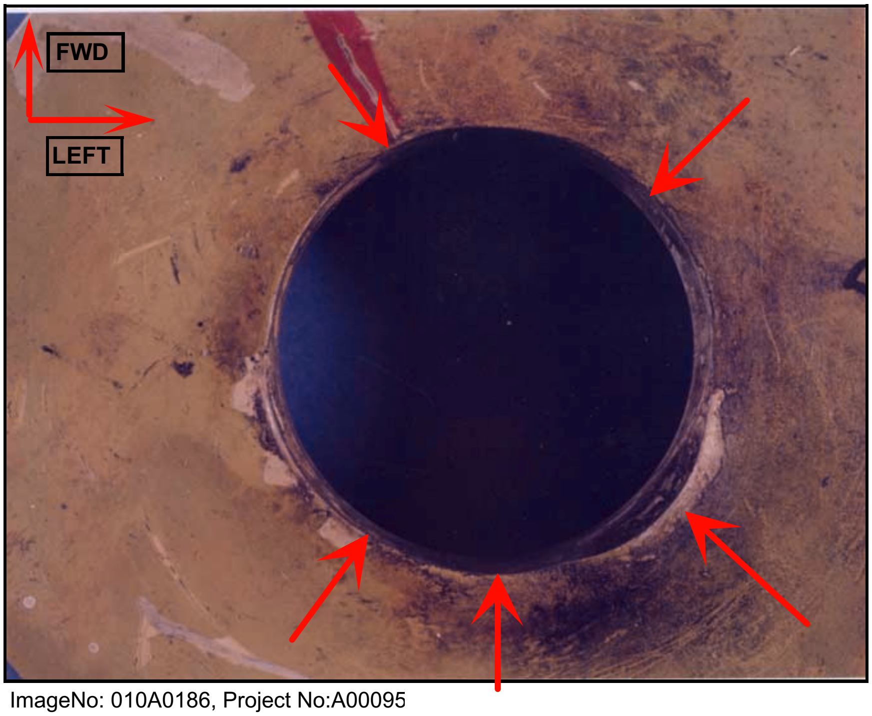
ImageNo: 010A0206, Project No:A00095

Figure 27--A typical rolling element from the pivot bearing with severe pitting corrosion.



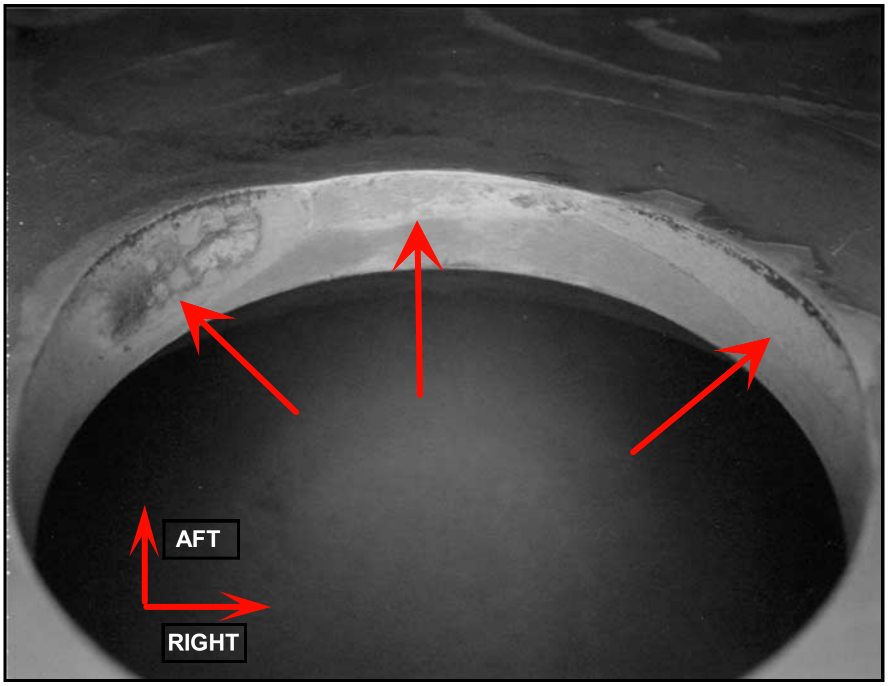
ImageNo:010A0185, Project No:A00095

Figure 28--The lower surface of the lower support plate with dents (arrows) in the edges of the pass through hole from contact with the Acme Screw.



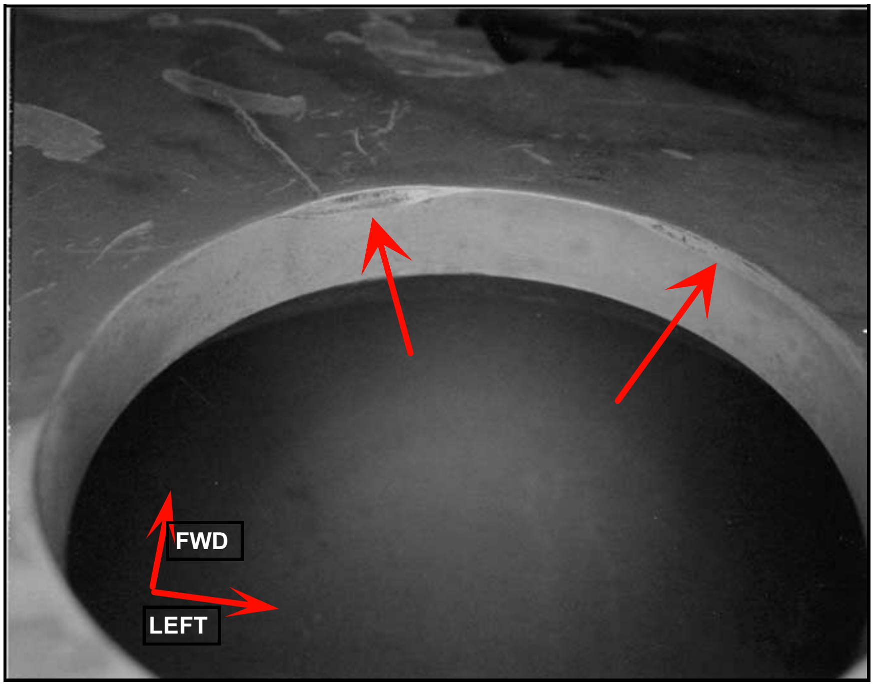
ImageNo: 010A0186, Project No:A00095

Figure 29--Closer view of the pass through hole showing the damage locations (arrows).



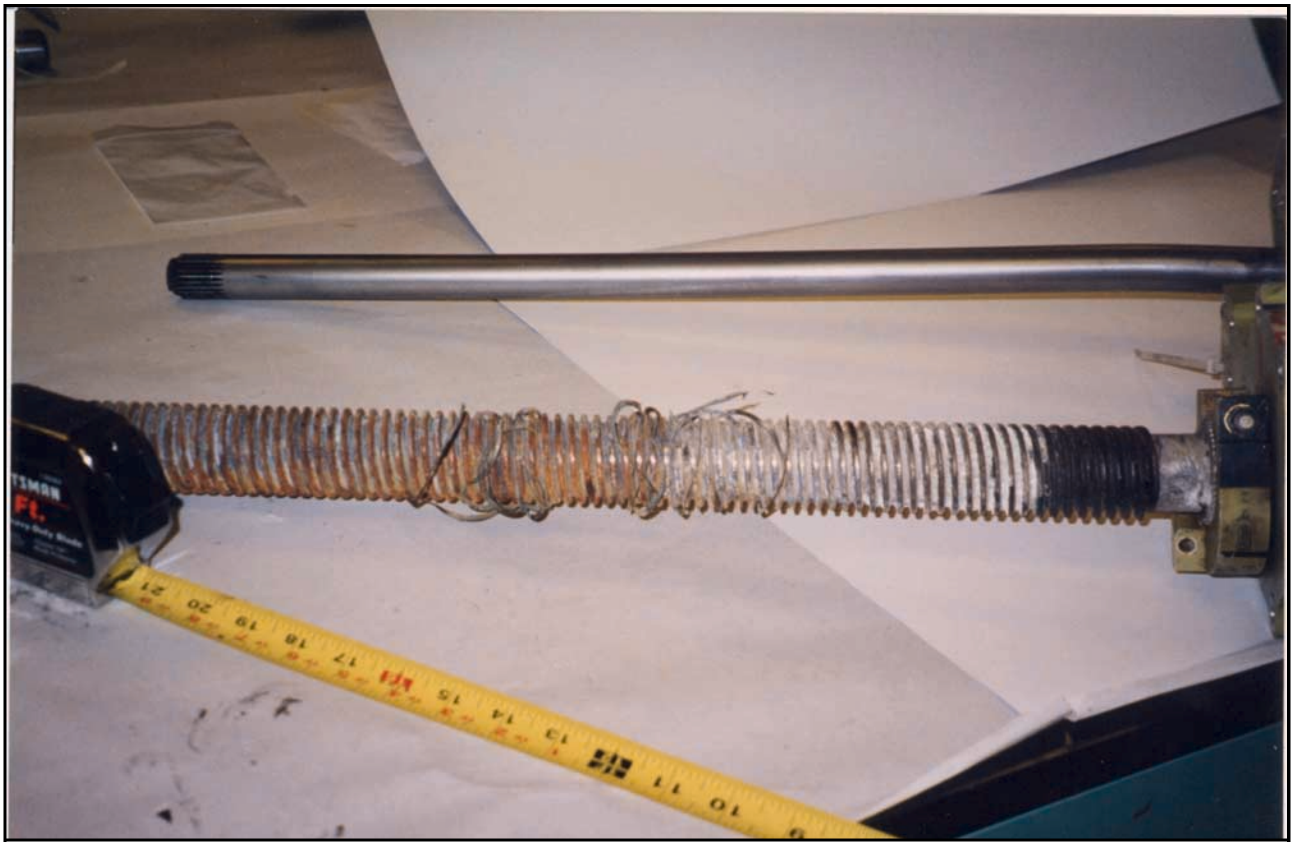
ImageNo:010A0188, Project No:A00095

Figure 30--Oblique view of the pass through hole showing the three major dents (arrows) in the half side of the hole.



ImageNo: 010A0189, Project No:A00095

Figure 31--A closer view of the pass through hole showing the two minor dents (arrows) in the forward half.



ImageNo:010A0202, Project No:A00095

Figure 32--Side view of the screw showing the thread remnants coiled around the Acme screw. Also note the white deposits and the red rust.

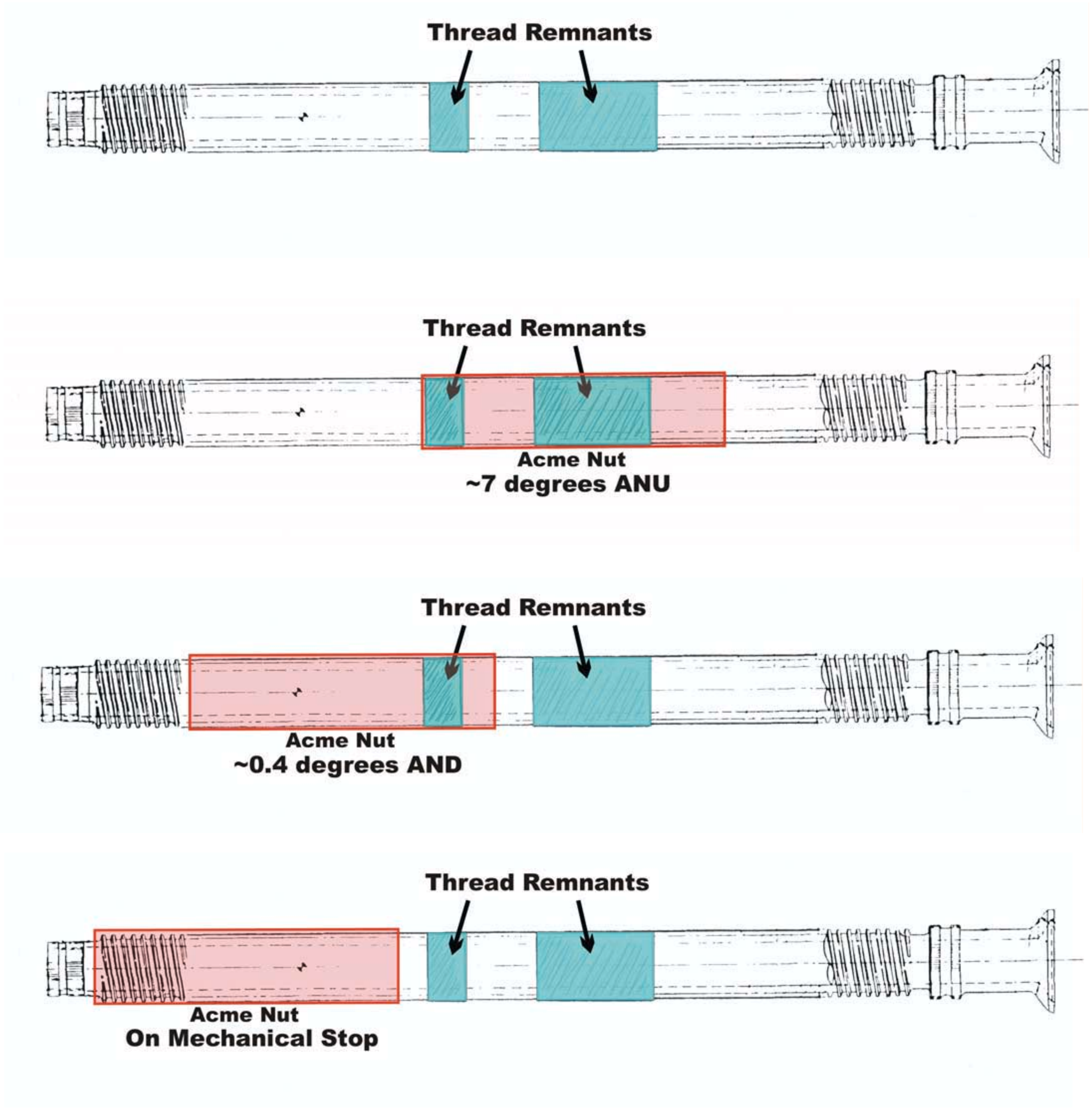
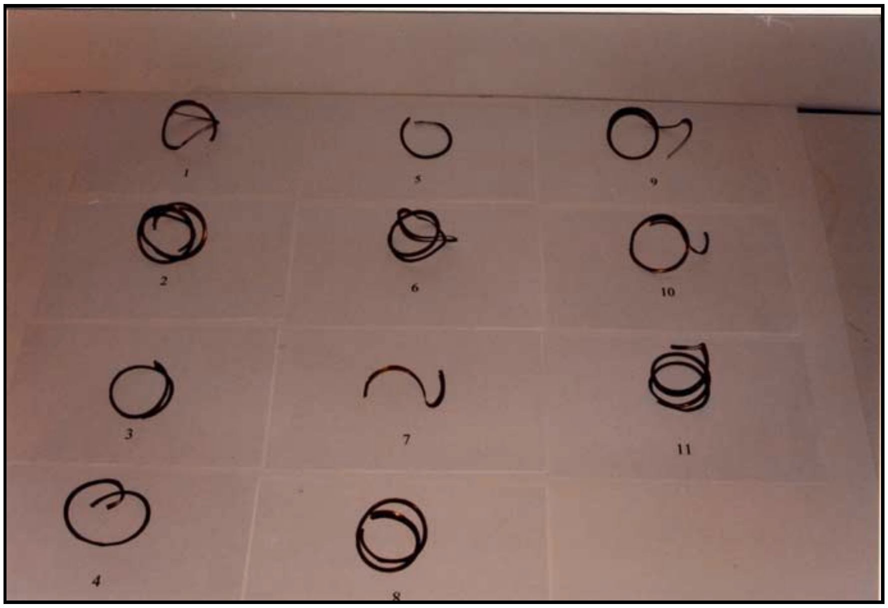
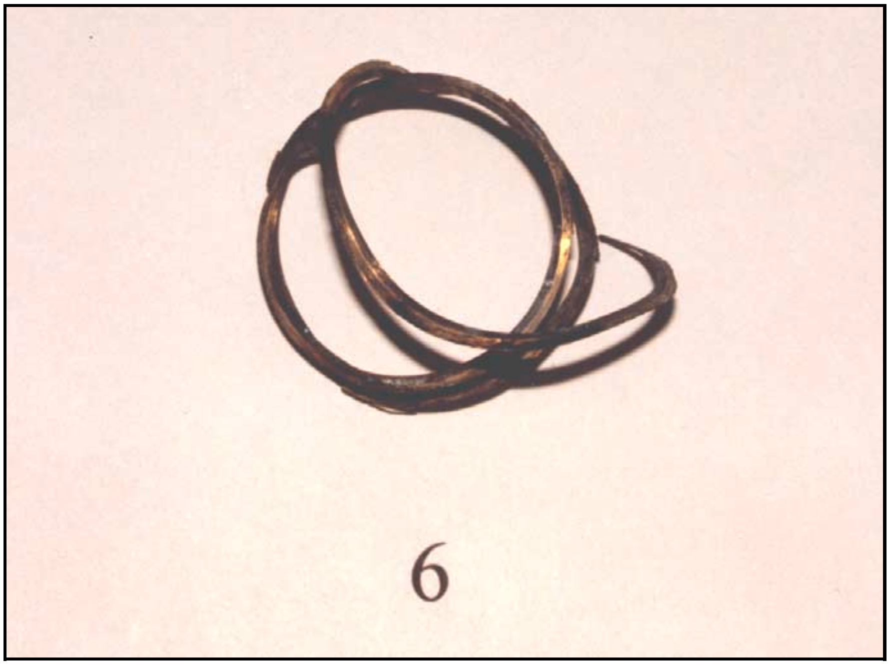


Figure 33--Four drawings illustrating the as-recovered position of the thread remnants on the screw and the relative position of the Acme nut at three different trim setting. From top to bottom, as-recovered, 7 degrees ANU, 0.4 degrees AND and with the nut contacting the upper surface of the lower stop assembly.

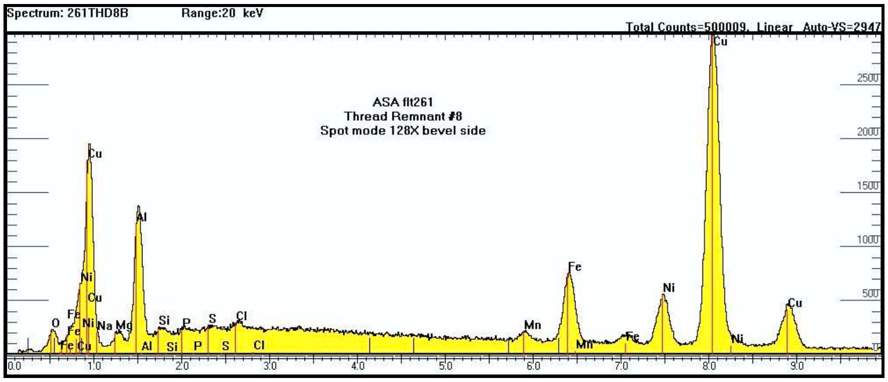


ImageNo:010A0190, Project No:A00095

Figure 34--An overall view of the eleven removed thread remnants, above. Below, remnant #6 showing typical features.

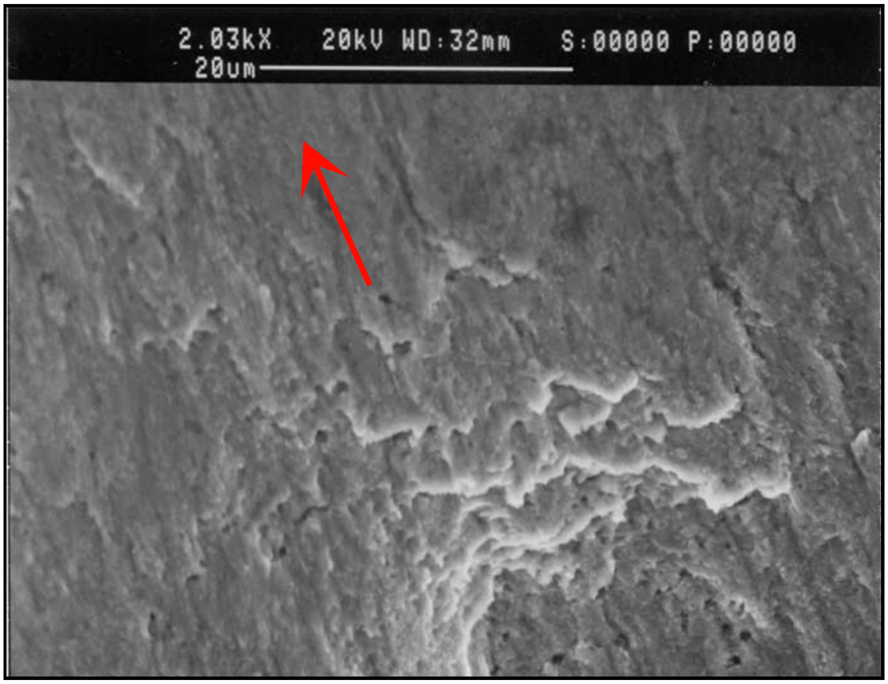


ImageNo: 010A0213, Project No:A00095



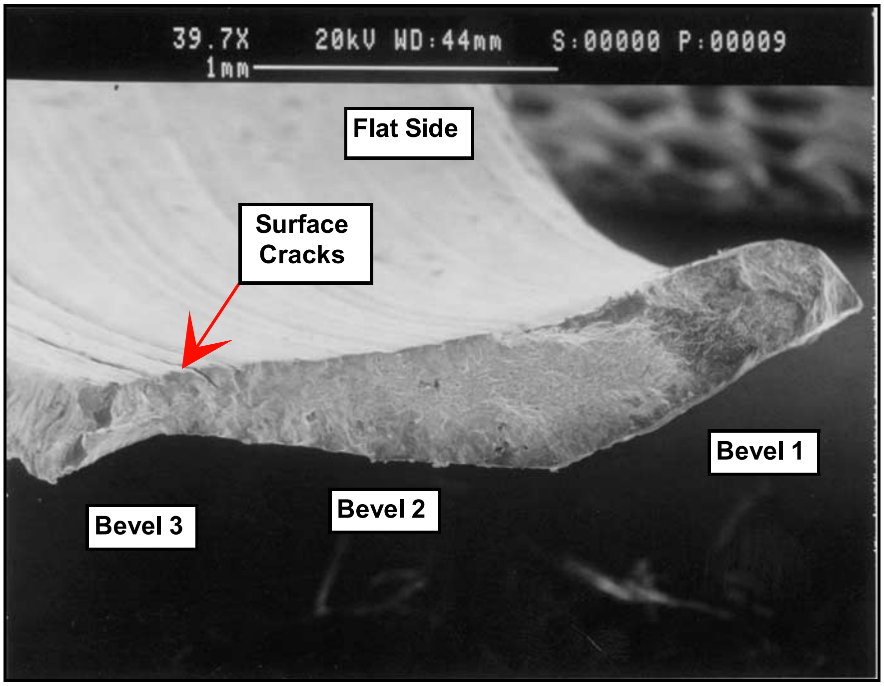
ImageNo:010A0352, Project No:A00095

Figure 35-- EDS of thread remnant #8 showing constituents of nickel aluminum bronze (Cu, Ni, Fe, Al, Mn) along with other contaminants (Cl, S, P, Si, Mg, O).



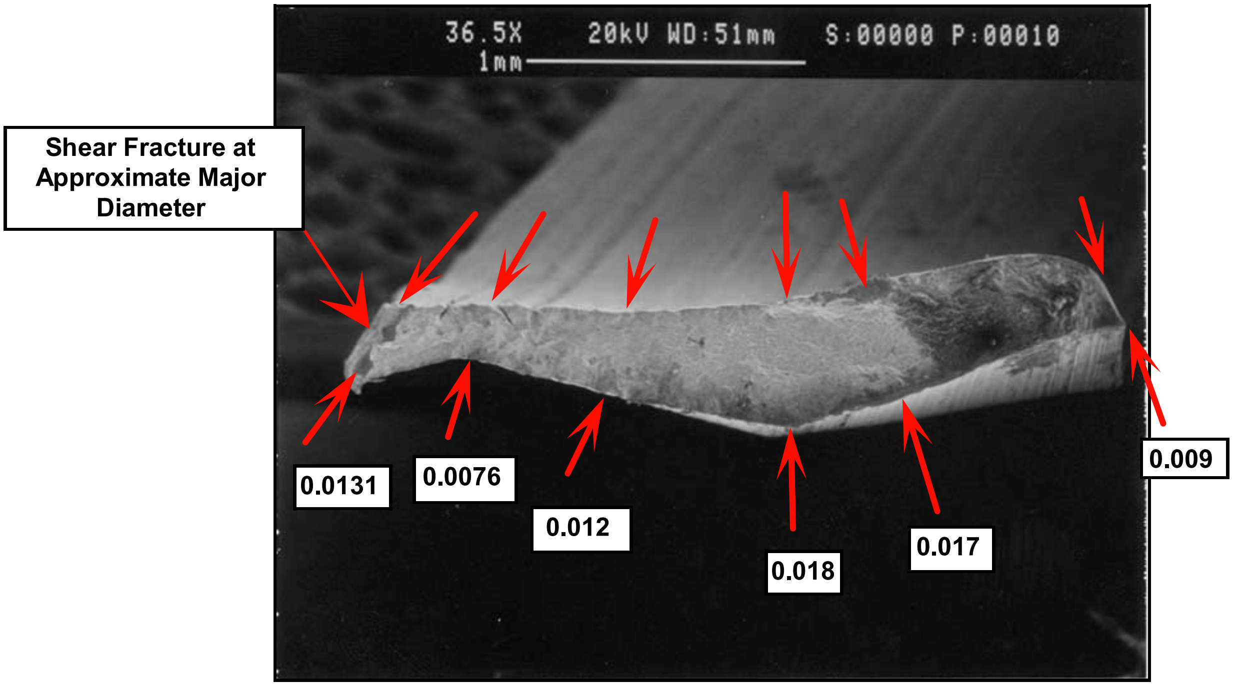
ImageNo: 010A0191, Project No:A00095

Figure 36--SEM view of typical shear dimple found on the outer edges of the thread remnants. Dimples indicate remnant moving up (arrow).



ImageNo:010A0192, Project No:A00095

Figure 37--Two SEM views of a radial fracture on remnant #4 showing typical features seen on other remnants. The upper suface is flat while the lower surface is beveled, labeled Bevel 1, 2 and 3. The outer diameter edge fracture is at left in both views. Flat surface cracks near the rim fracture are labeled. Lower view is annotated with local thickness dimensions.



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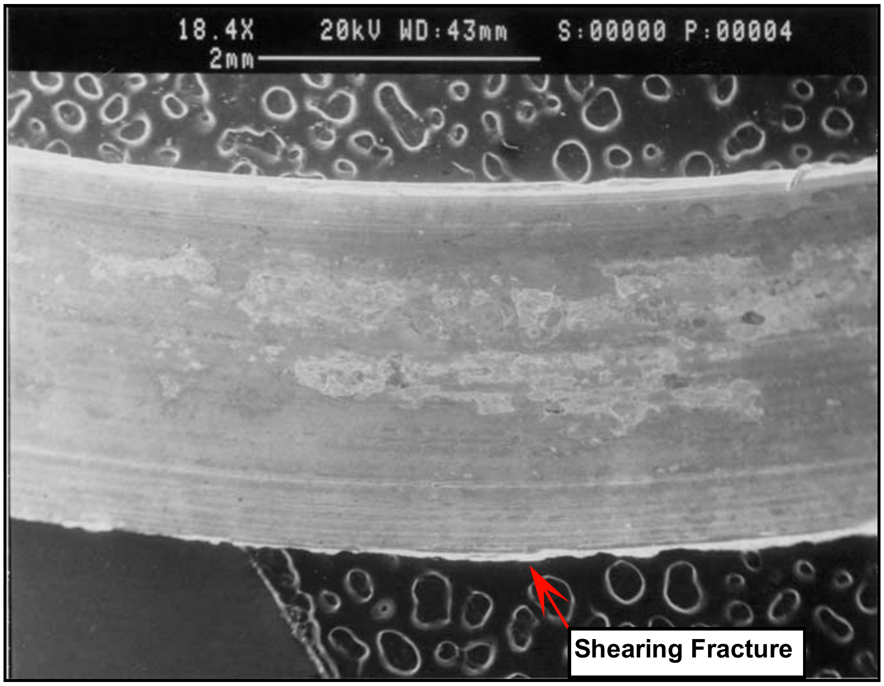
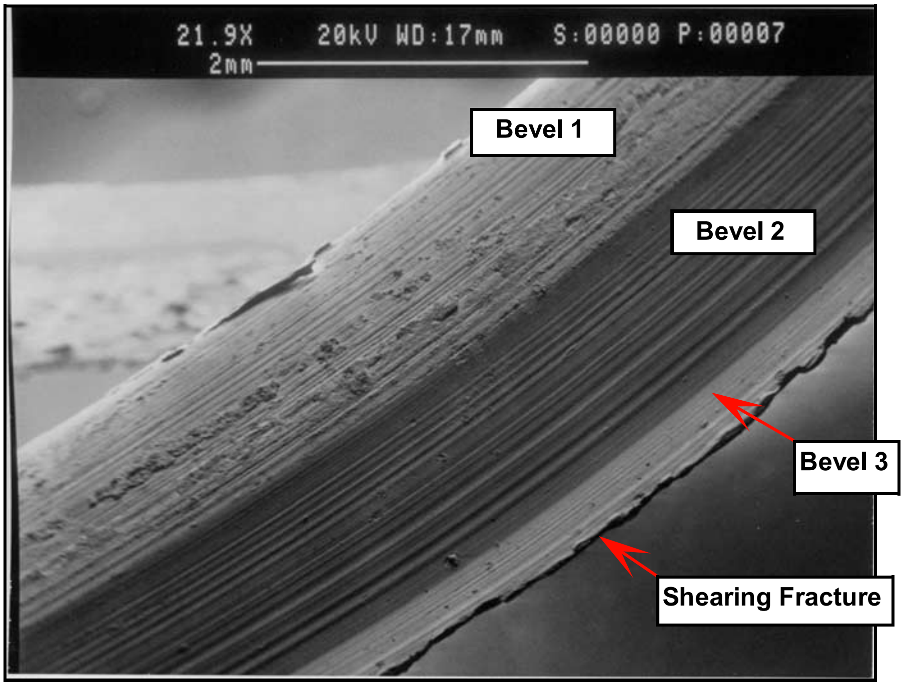


ImageNo:010A0194, Project No:A00095

Figure 38--Two SEM views showing the flat side of the thread remnant above and the beveled side below.



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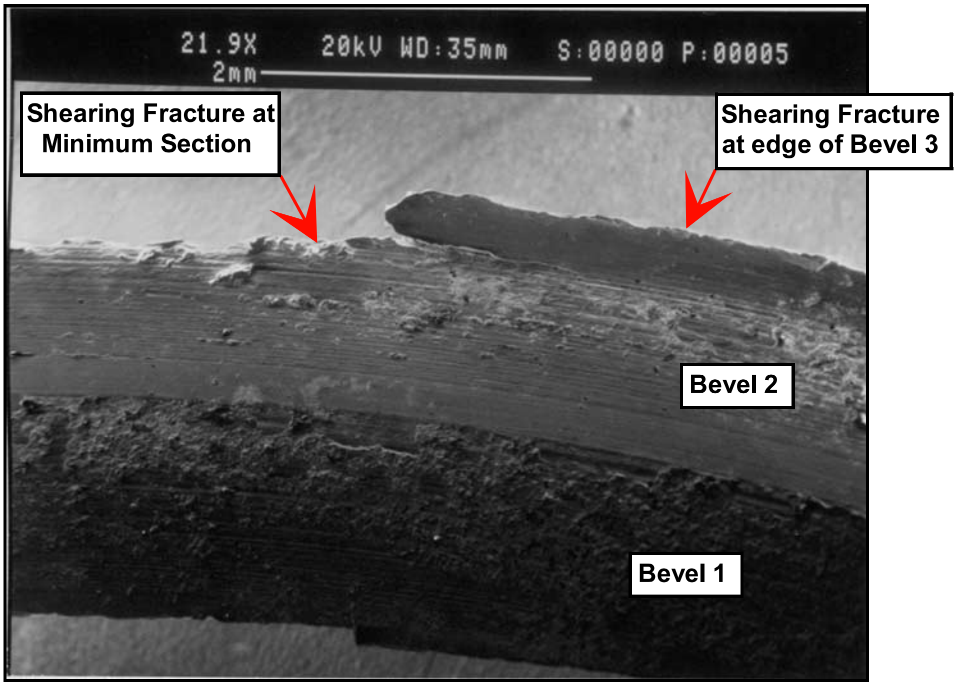
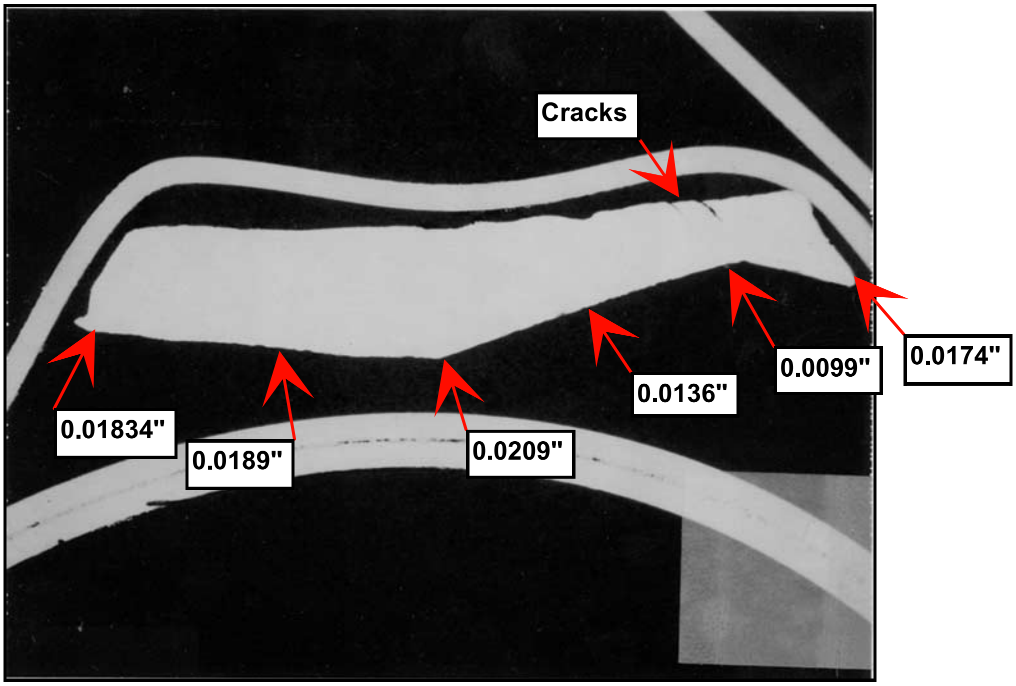


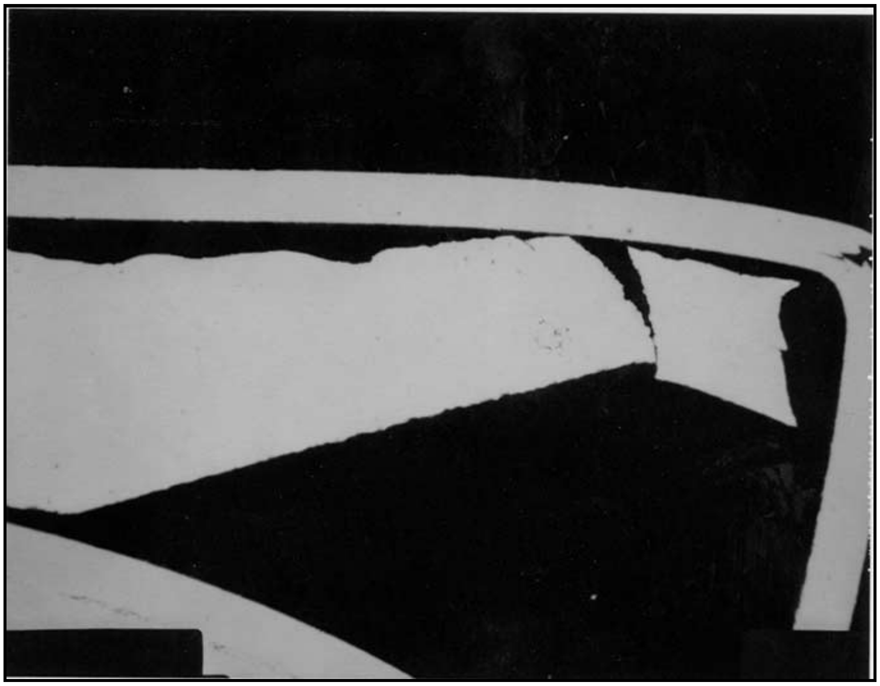
ImageNo:010A0232, Project No:A00095

Figure 39--SEM view of fracturing at both the minimum section line and at the free edge of bevel 3.



ImageNo: 010A0196, Project No:A00095

Figure 40--Radial metallographic cross section through remnant #6 showing a similar cross section as that seen during SEM examinations. Note the slight curvature of the flat surface (top). View is reversed with shear fracture at right. Thickness dimensions are noted at selected locations.

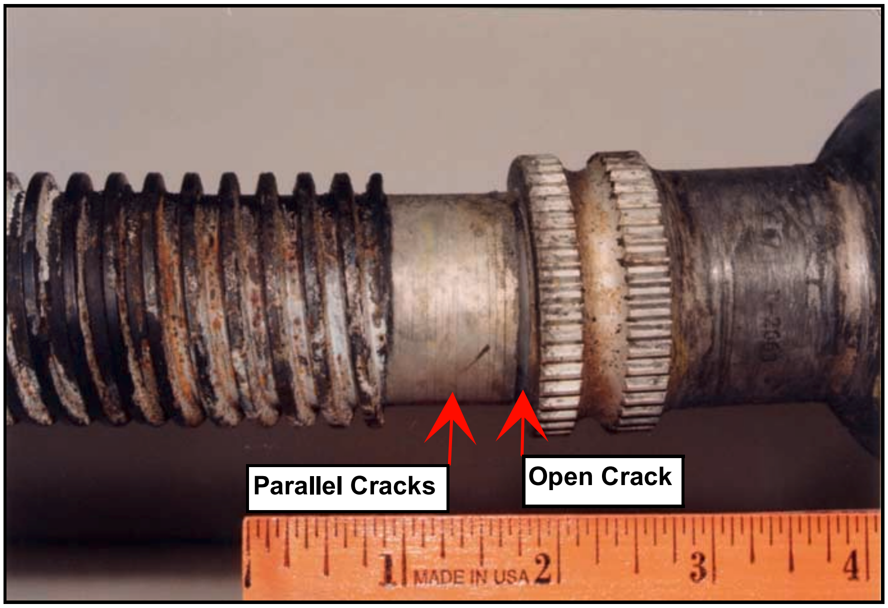


ImageNo:010A0198, Project No:A00095

Figure 41--Another mellographic section through #6 showing where the crack broke through the minimum section during mounting.

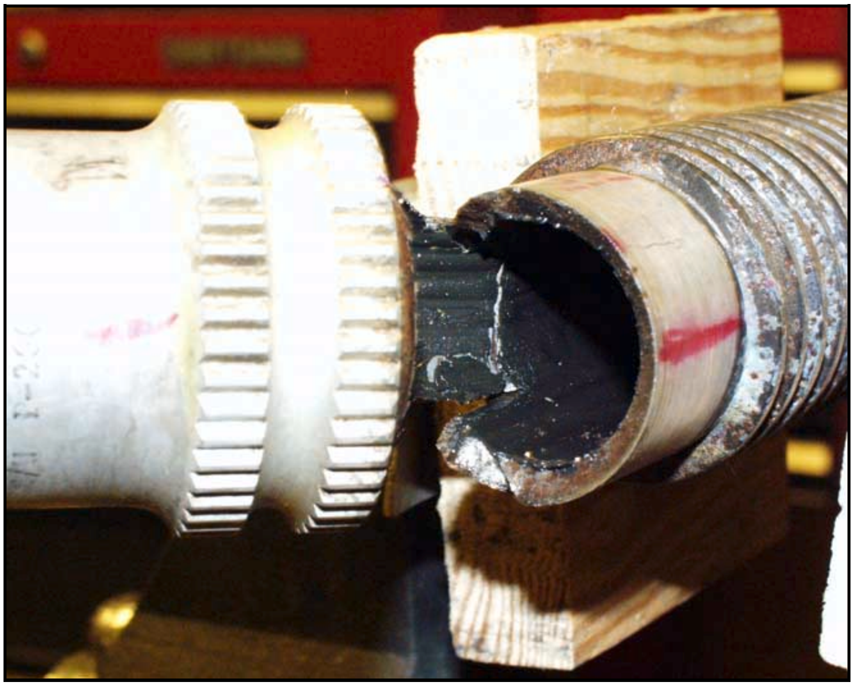
ImageNo: 010A0215, Project No:A00095

Figure 42--A view of the Acme screw showing the extent of the bending.



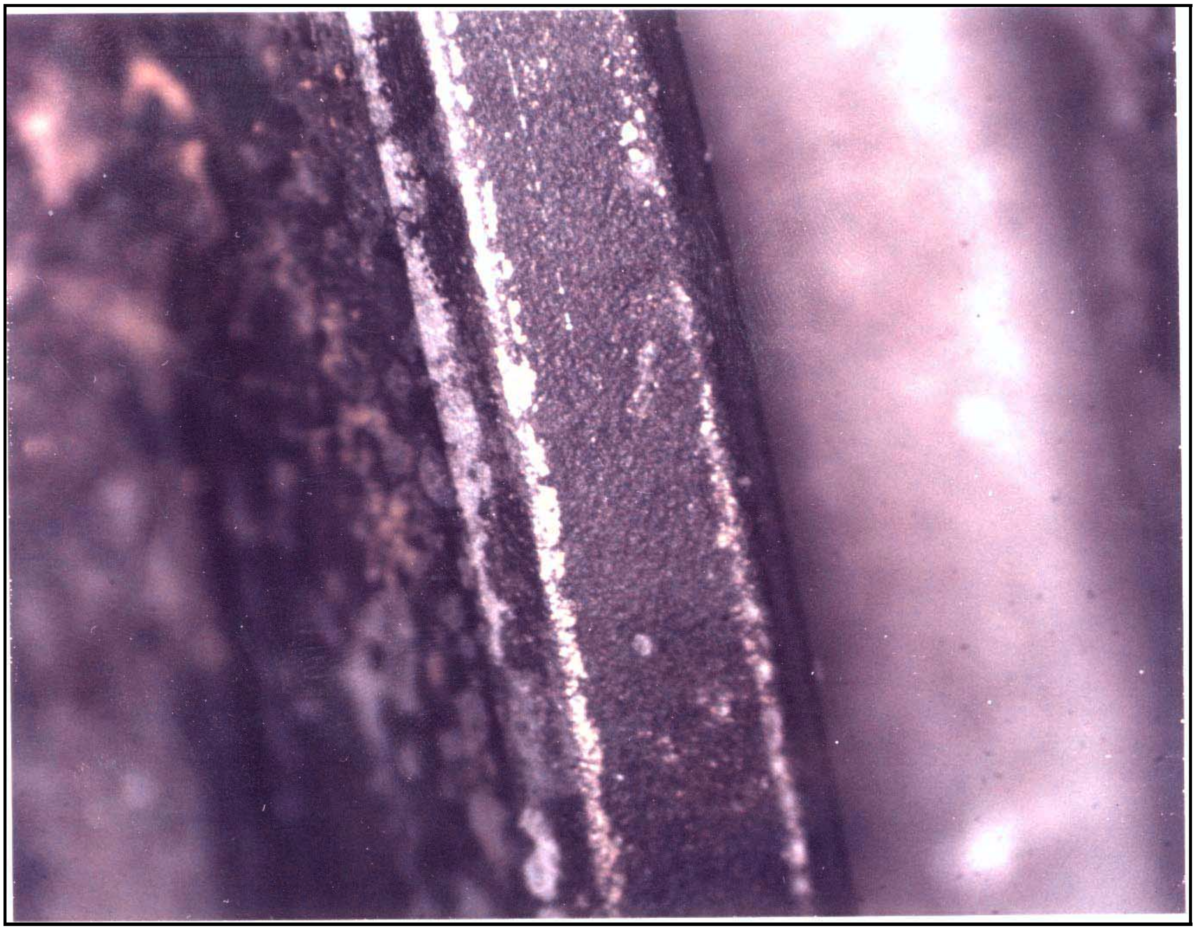
ImageNo:010A0216, Project No:A00095

Figure 43--A side view of the Acme screw showing the gaped open crack and the adjacent parallel surface cracks.



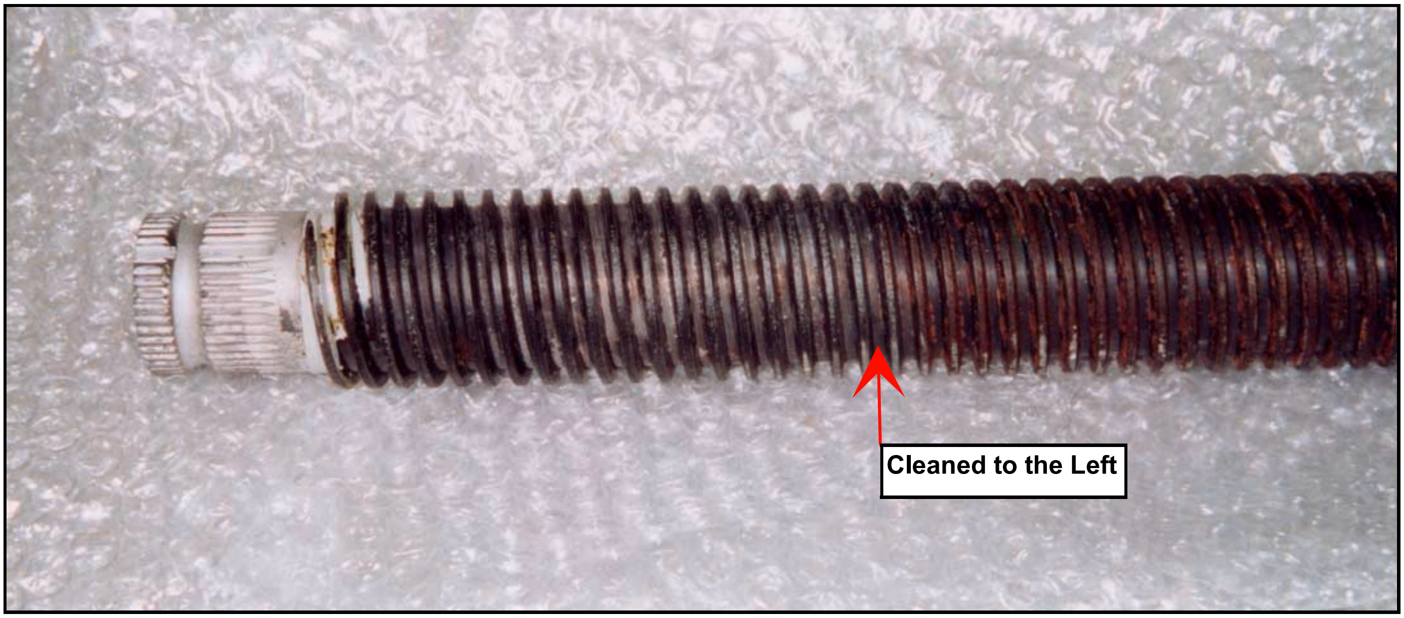
ImageNo: 010A0353, Project No:A00095

Figure 44--The opened crack at the upper end of the Acme screw. Fracture features typical of an overstress.



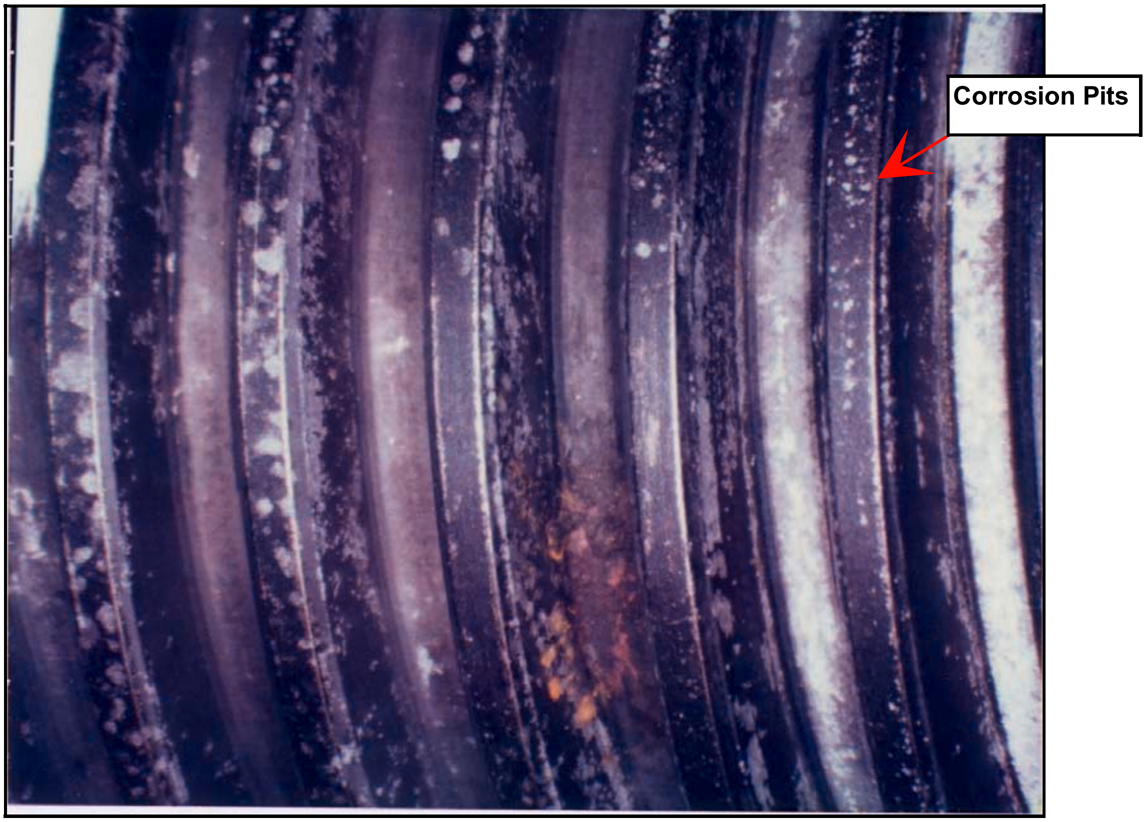
ImageNo:010A0217, Project No:A00095

Figure 45--Typical glass bead surface finish on the threads of the Acme screw.



ImageNo:010A0218, Project No:A00095

Figure 46--Two views of the Acme screw after electrolytic cleaning the lower end of the screw. Below is a higher magnification view showing the cleaned but pitted surface. Some small areas of corrosion products remained.



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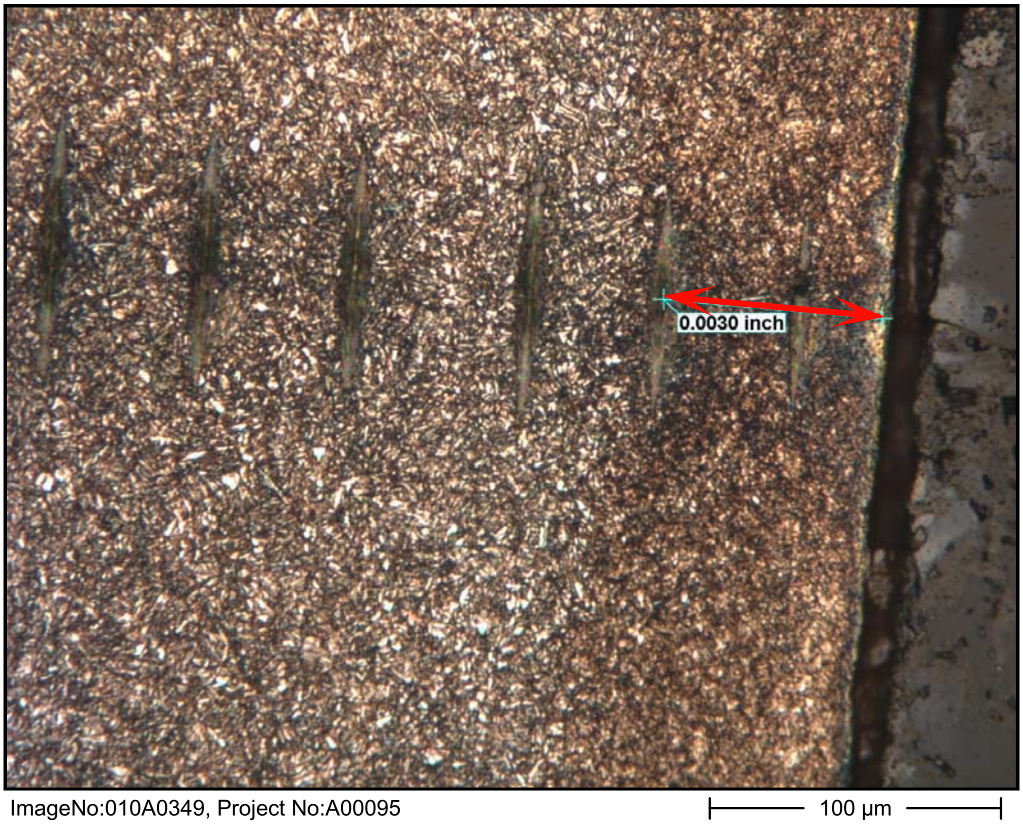
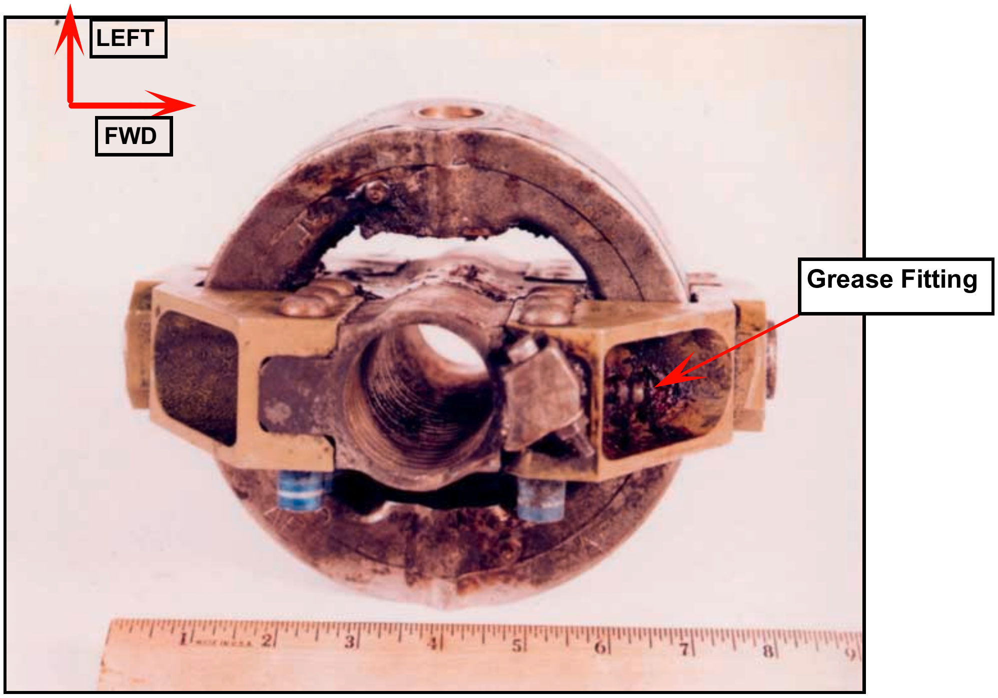


Figure 47--Typical nitride case on tooth flank of Acme screw with hardness impression visible. 2% Nital etch. The double arrow represents 0.030 inch.



ImageNo:010A0220, Project No:A00095

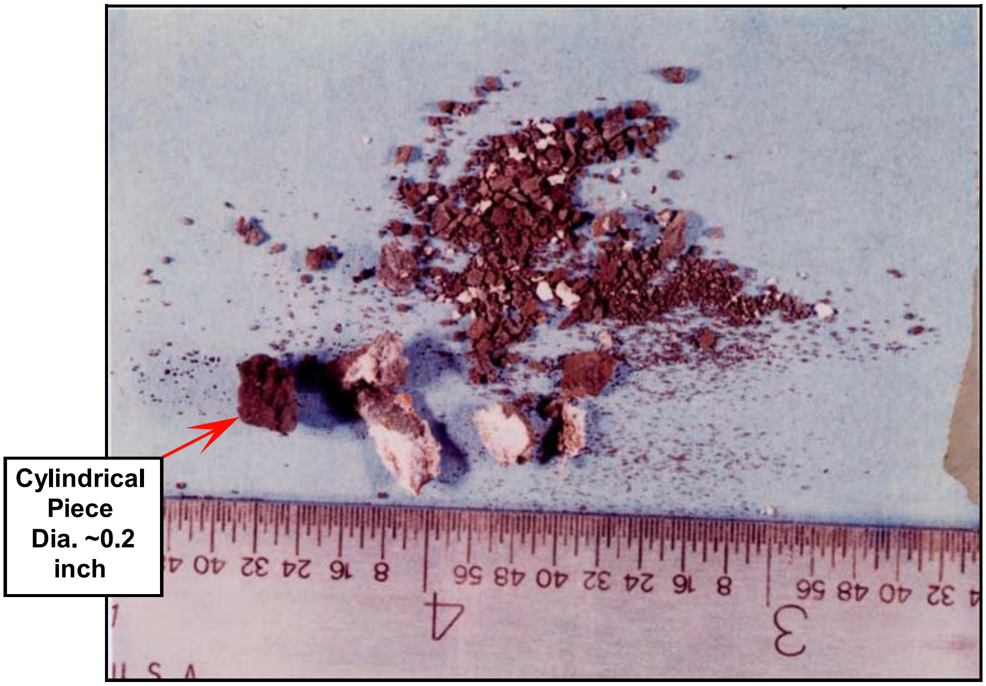
Figure 48--Above, an overall view of the as-received Acme nut assembly. A closer view into the interior showing the lack of threads is shown below.

ImageNo: 010A0221, Project No:A00095

ImageNo:010A0222, Project No:A00095

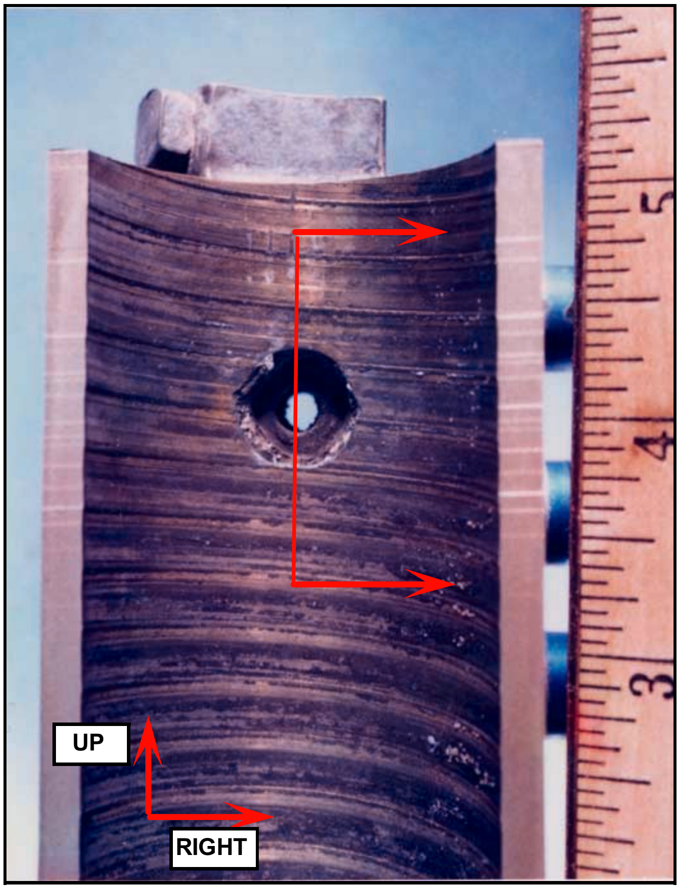
ImageNo:011A0436 , Project No:A0009

Figure 49--Side view (left) showing the reddish grease on the exterior of the grease fitting removed from the Acme nut. End view (right) looking into the orifice of the grease fitting.



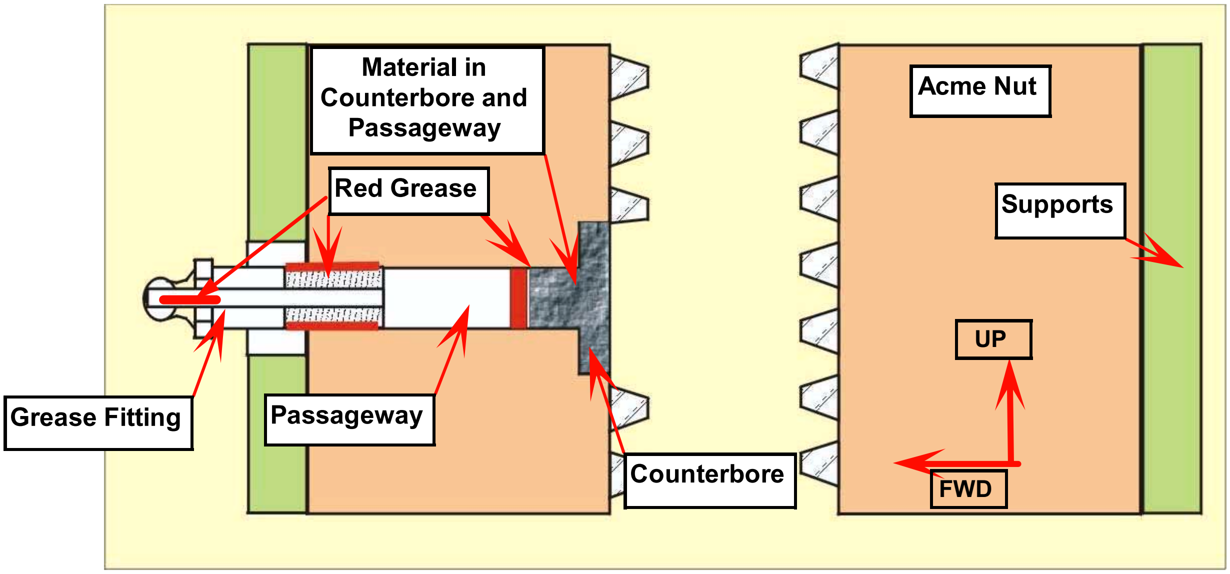
ImageNo: 010A0223, Project No:A00095

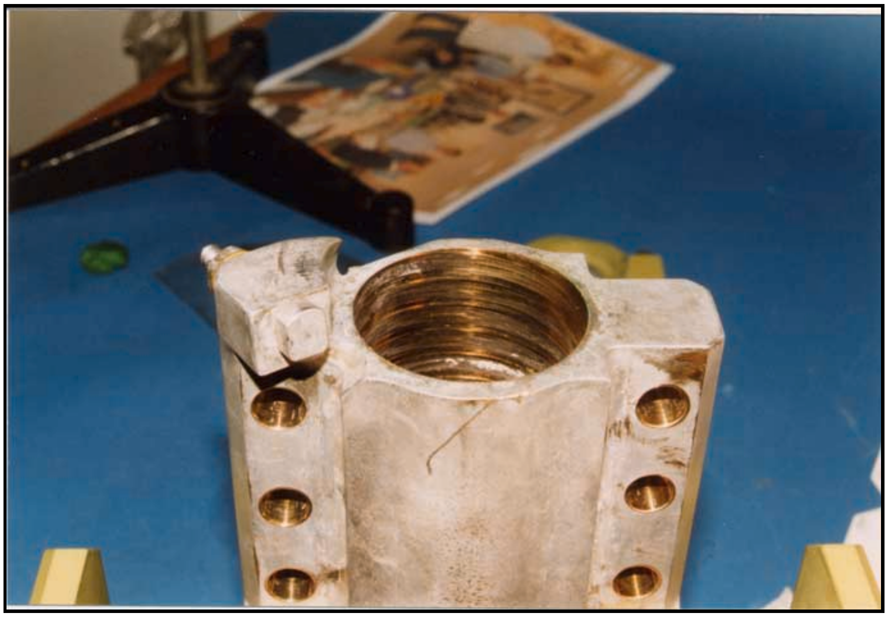
Figure 50--The residue removed from the Acme nut grease passageway and counterbore. The cylindrical piece has the approximate diameter of the passageway.



ImageNo:010A0224, Project No:A00095

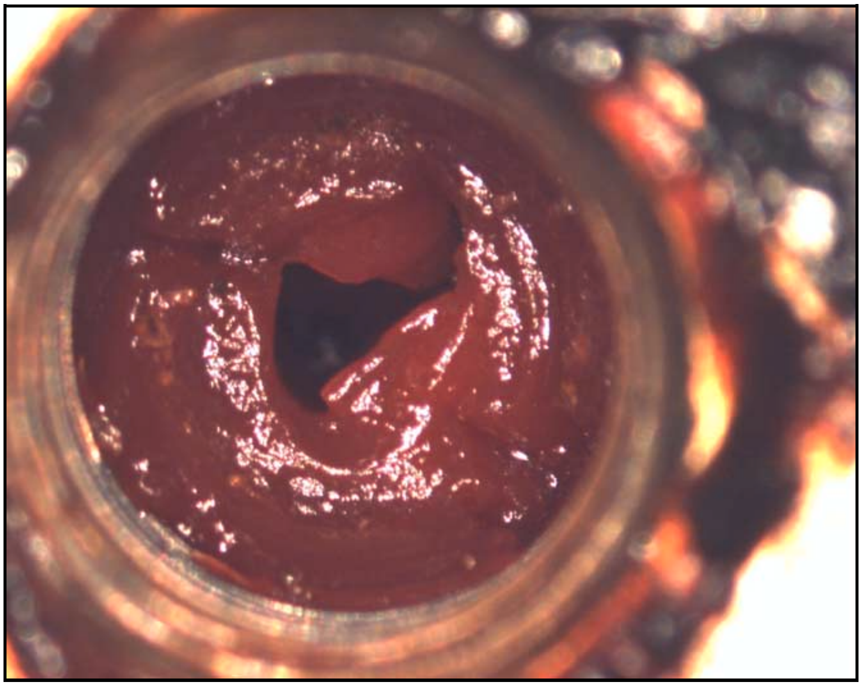
Figure 51--Upper view is looking forward into the grease passageway and counterbore, after sectioning the nut. The lower view is an illustration of a cross section (at section lines in upper view) through the passageway and grease fitting showing the approximate location and extent of the blockage in the passage. Red areas denote locations where red grease was found. (not to scale)





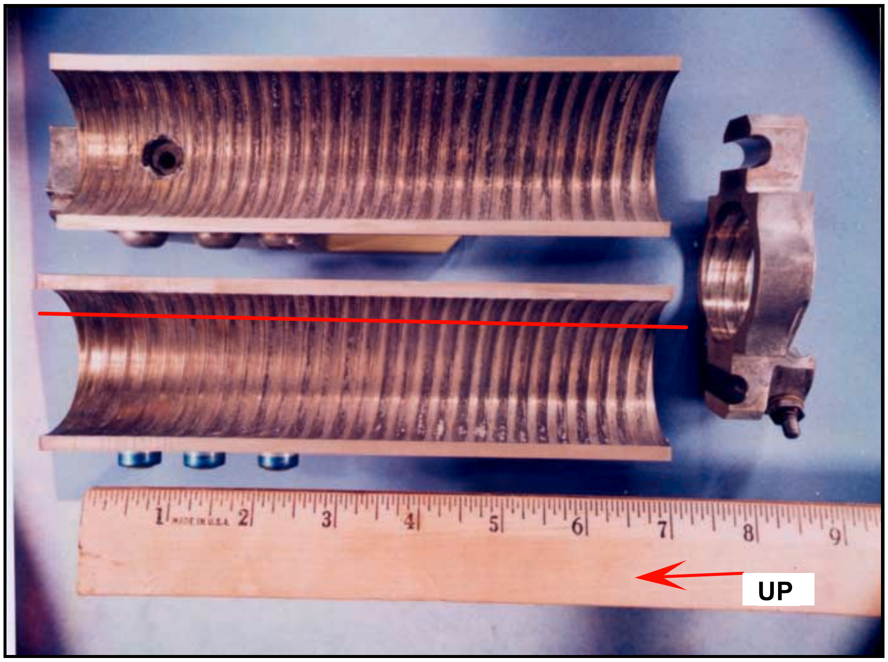
ImageNo:010A0226, Project No:A00095

Figure 52--The lower end of the Acme nut after partial disassembly showing the spiral pattern on the interior.



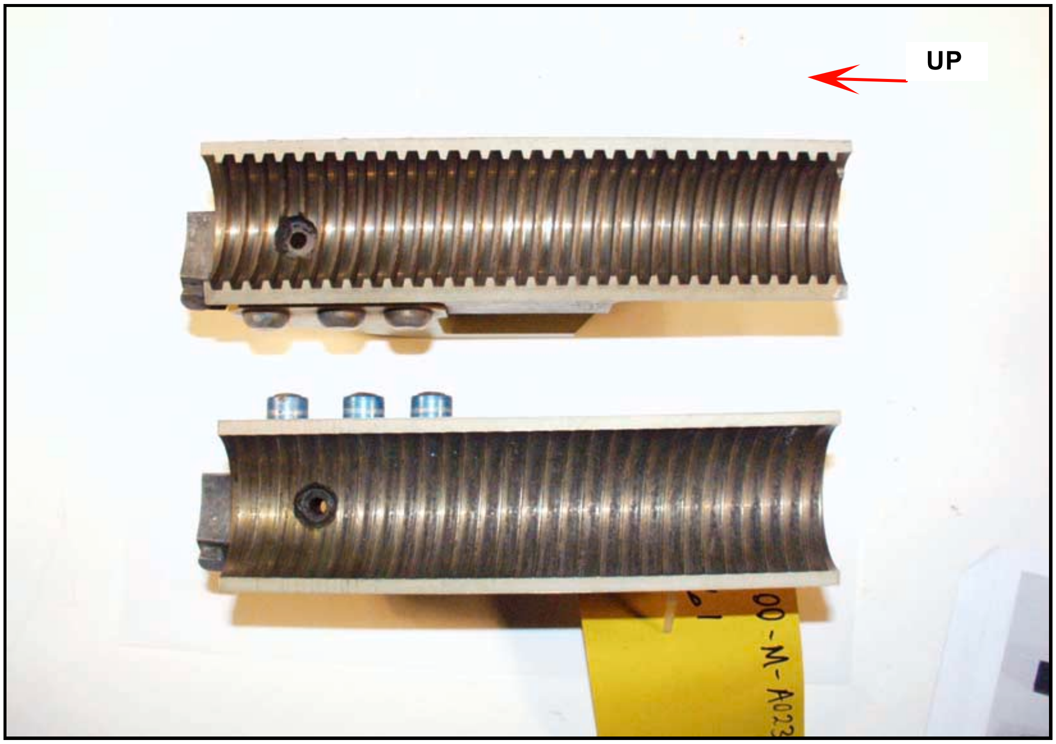
ImageNo: 010A0354, Project No:A00095

Figure 53--Red grease in left grease fitting passageway in the gimbal ring.



ImageNo:010A0227, Project No:A00095

Figure 54--The interior surfaces of the Acme nut after it was cut showing the repeating pattern. The line on the lower half of the nut denotes the location of an additional cut to remove additional nut samples.



ImageNo: 010A0259, Project No:A00095

Figure 55--Comparison of accident acme nut thread profile (Top) to a similarly sectioned exemplar nut 2264 (below).

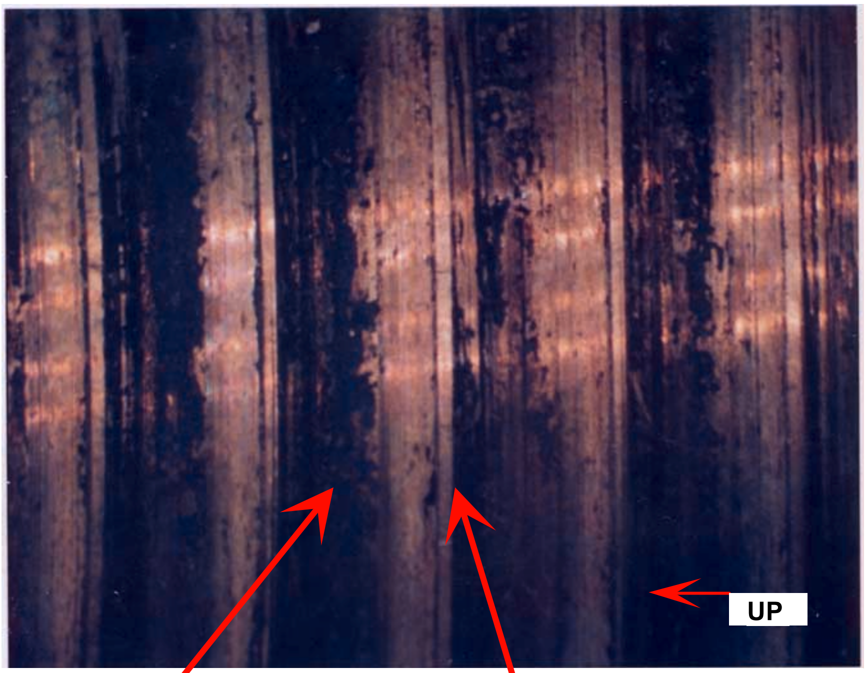
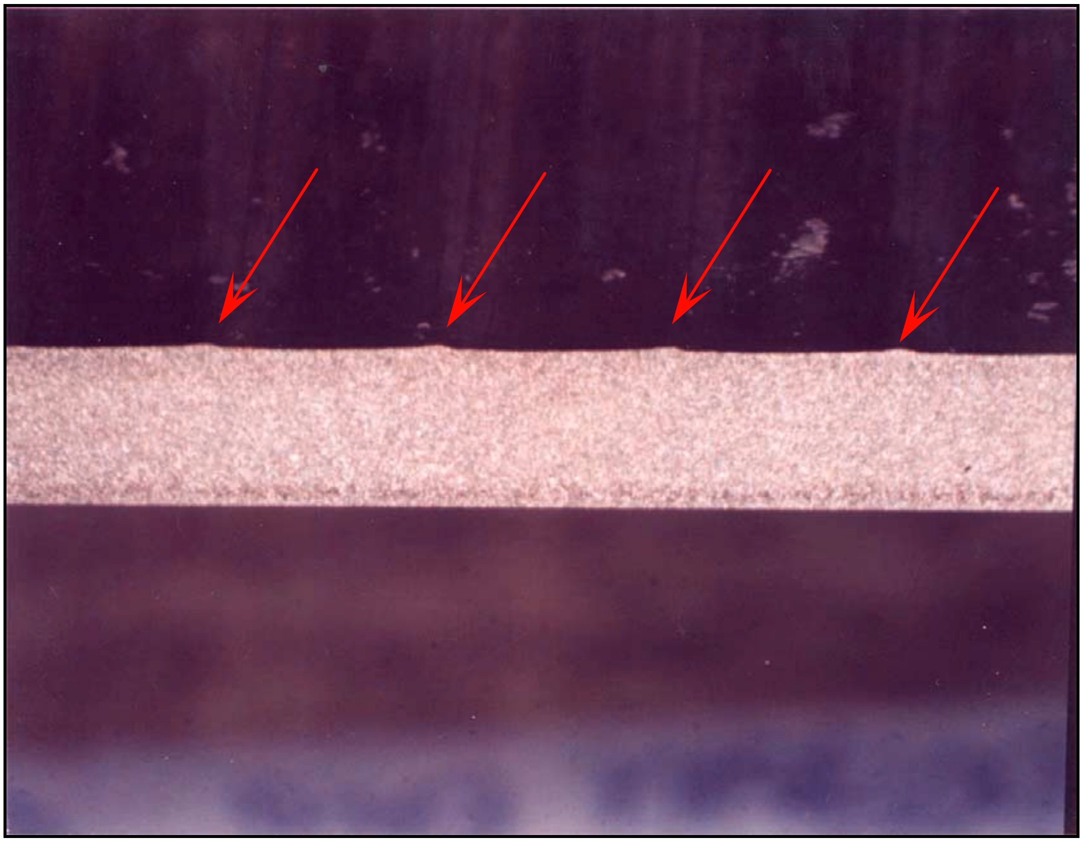


Image No. 010A0228 Project No. A00095 10 mm

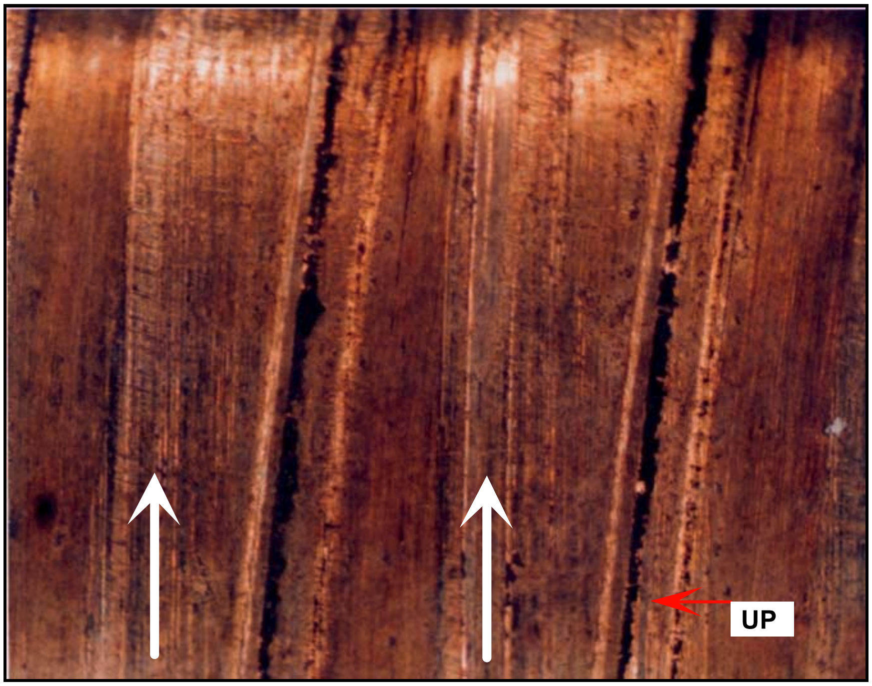
Image No. 010A0229 Project No. A00095 200 µm

Figure 56--Two views of the interior of the nut showing the pattern of damage. Upper view shows several threads with the raised ridges and the black deposits. Lower view is an enlargement of a single thread area with corresponding feature indicated and the approximate original thread width indicated by vertical lines.



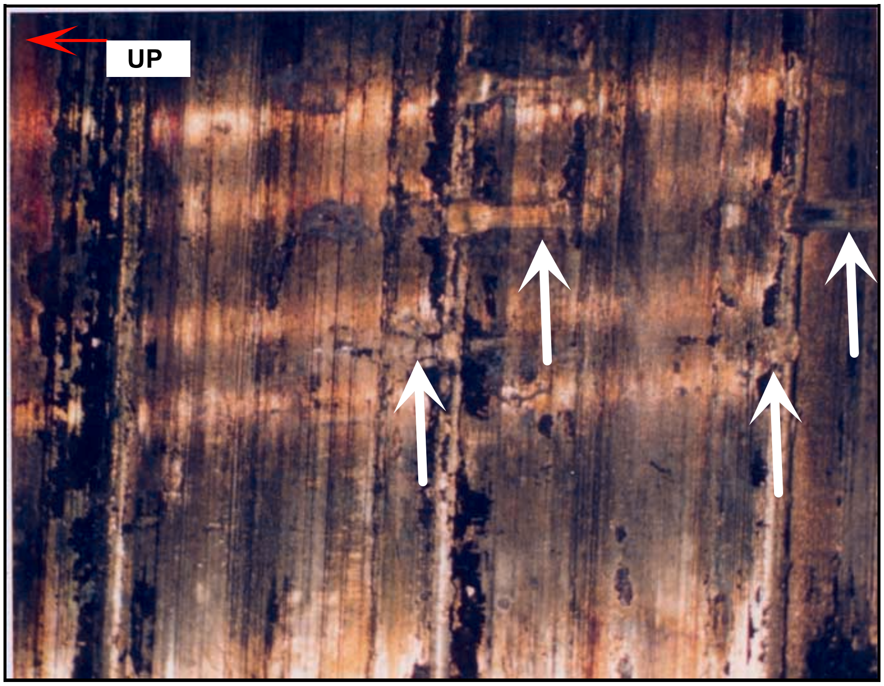
ImageNo:011A0056, Project No:A00095

Figure 57--A cross sectional view of the nut at the longitudinal cut. The raised ridges are indicated by the arrows.



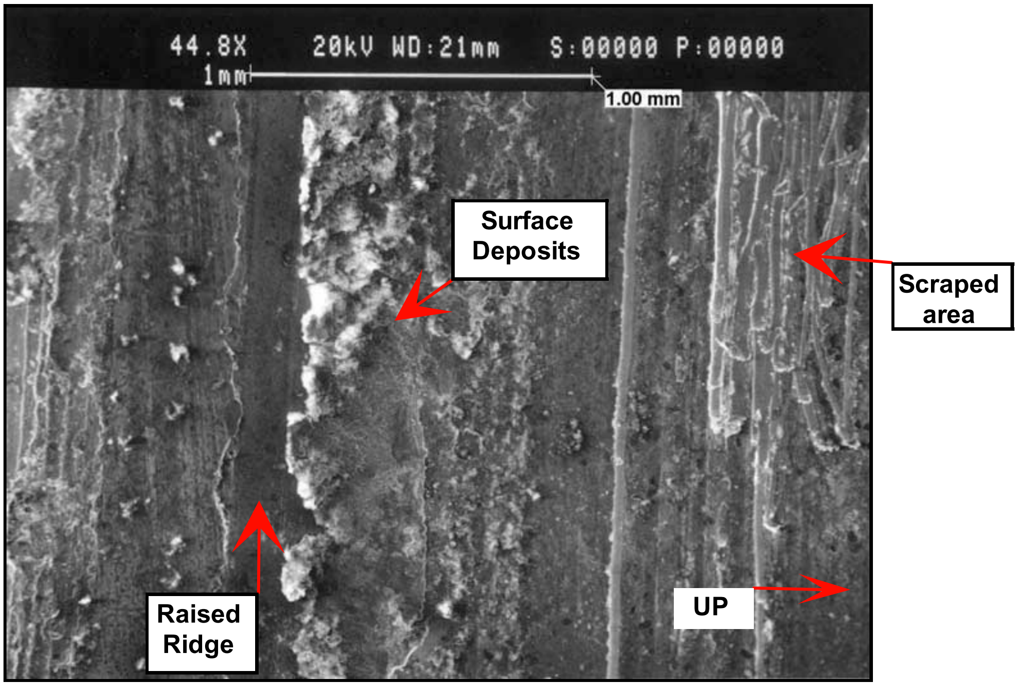
ImageNo:010A0230, Project No:A00095

Figure 58--Two circumferential bands of scratches (arrows) overlaying the spiral pattern.



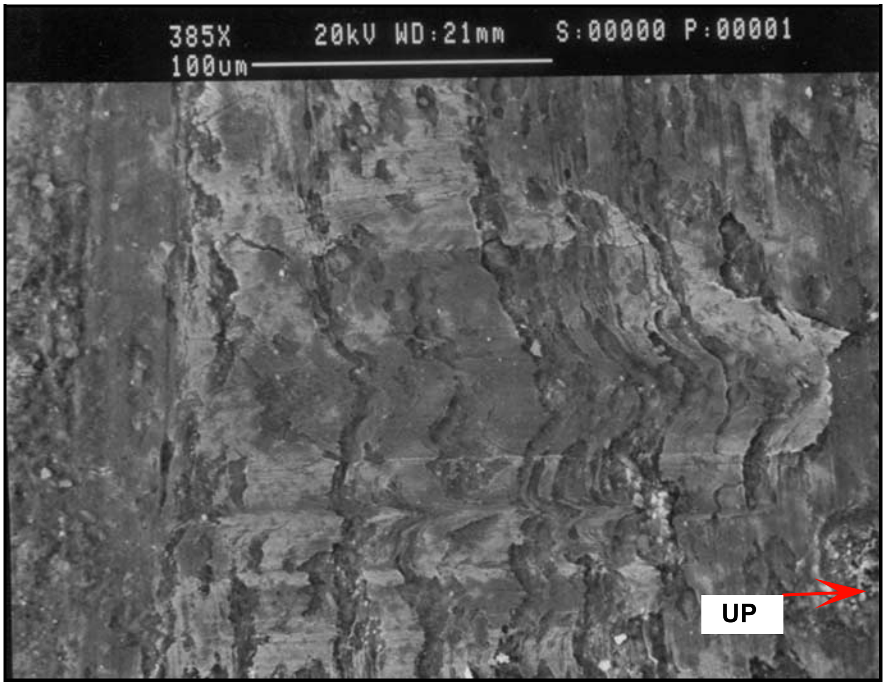
ImageNo: 010A0214, Project No:A00095

Figure 59--Longitudinal scuff marks (arrows) overlaying the spiral pattern.



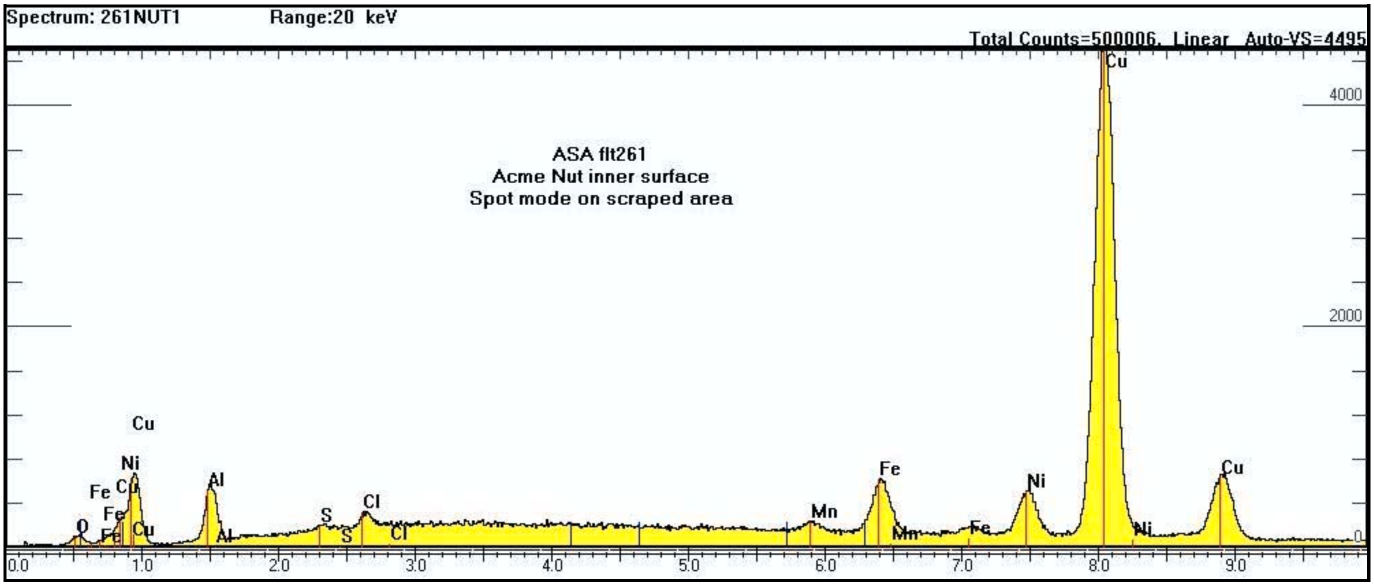
ImageNo:010A0376, Project No:A00095

Figure 60--An SEM view of a typical area on the nut interior showing the raised ridge and surface deposits. The scraped area used for base metal EDS is at the upper right.



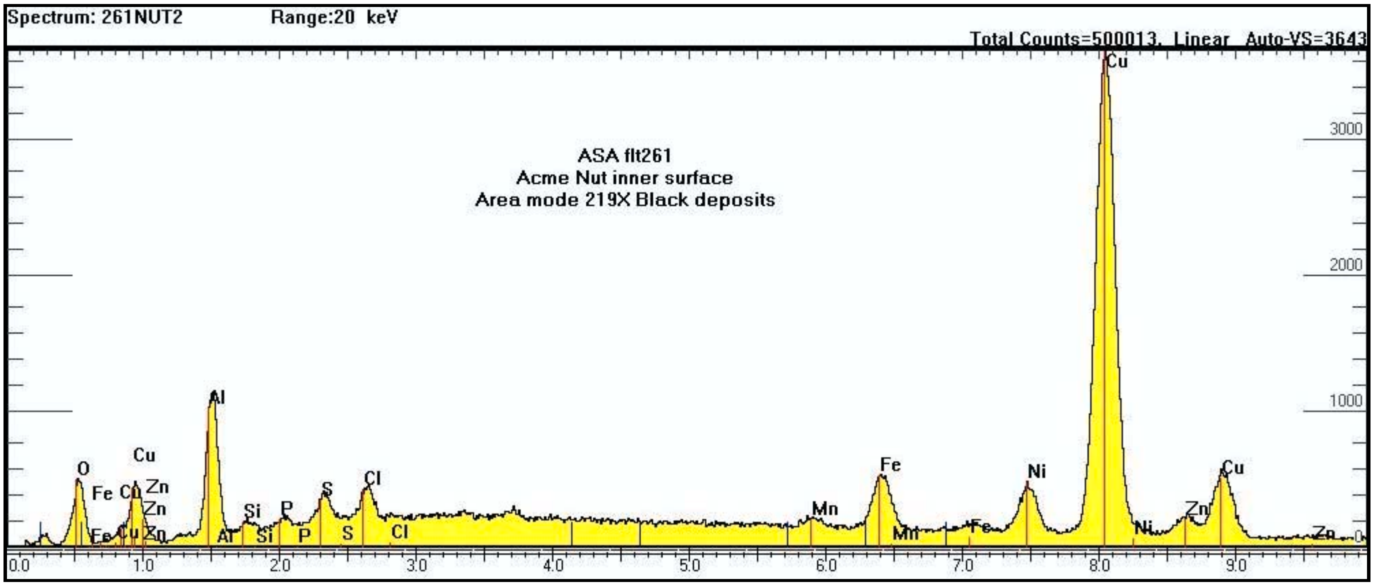
ImageNo: 010A0370, Project No:A00095

Figure 61--High magnification SEM view of the raised ridge showing smearing to the right (up).



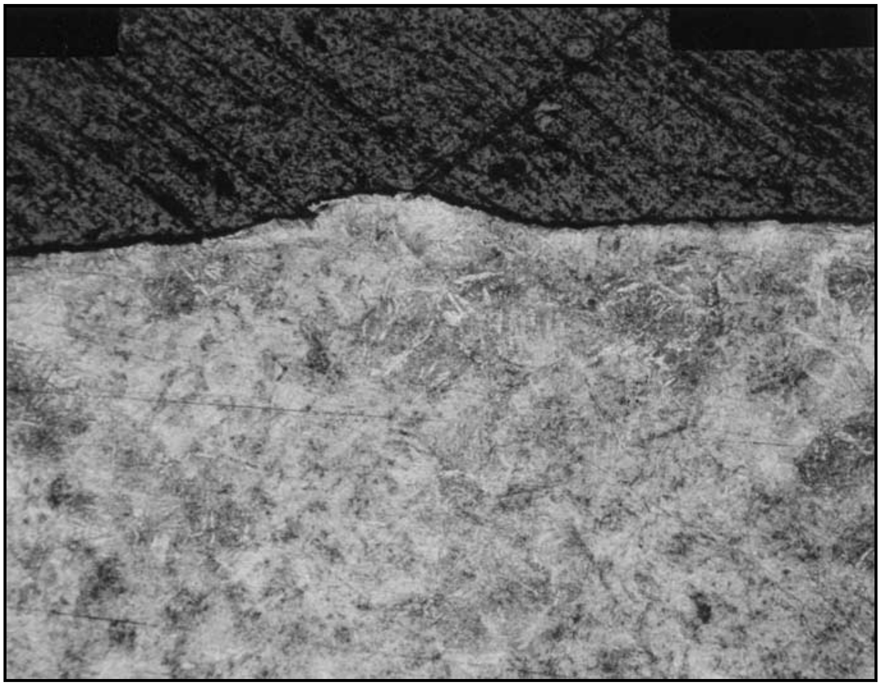
ImageNo:010A0256, Project No:A00095

Figure 62--EDS spectrum of the acme nut inner surface at the scraped area.



ImageNo: 010A0257, Project No:A00095

Figure 62-- EDS Spectra of the surface depositson the acme nut inner surface.



ImageNo:010A0371, Project No:A00095

ImageNo: 010A0372, Project No:A00095

Figure 63-- Two micrographs showing a raised ridge in profile and the surrounding microstructure. The height of the ridge measured 0.006 inches. Etch 50% Nitric in water. Original magnifications 40X and 200X

ImageNo:010A0355, Project No:A00095

Figure 64--Overall view of the torque tube removed from the Acme screw showing the bend near the upper end.

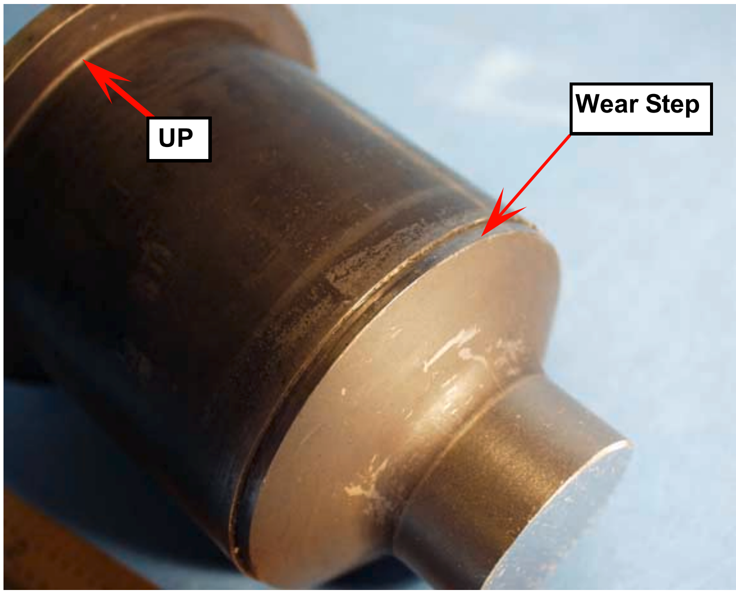
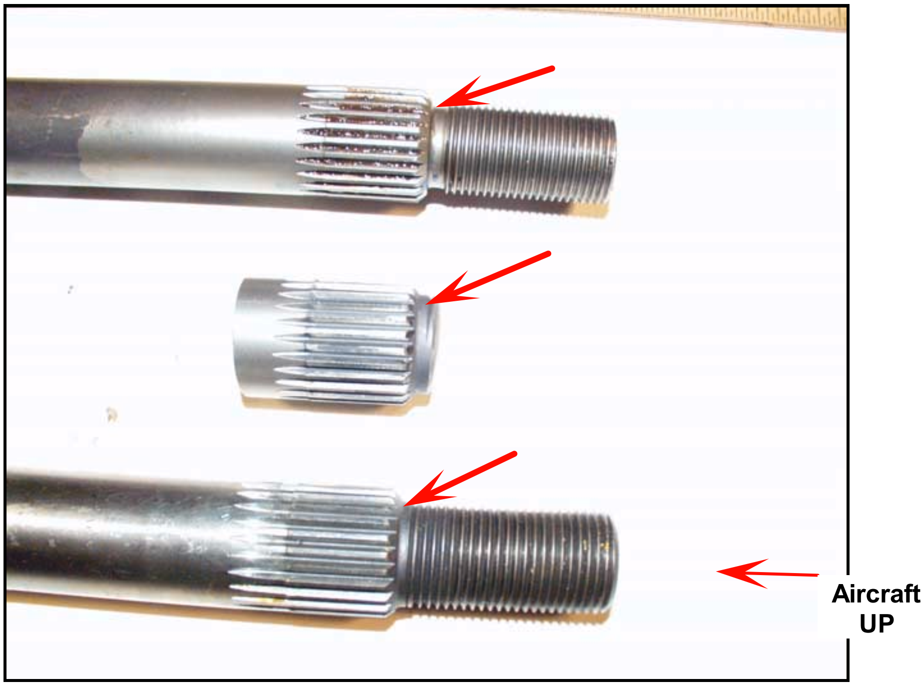
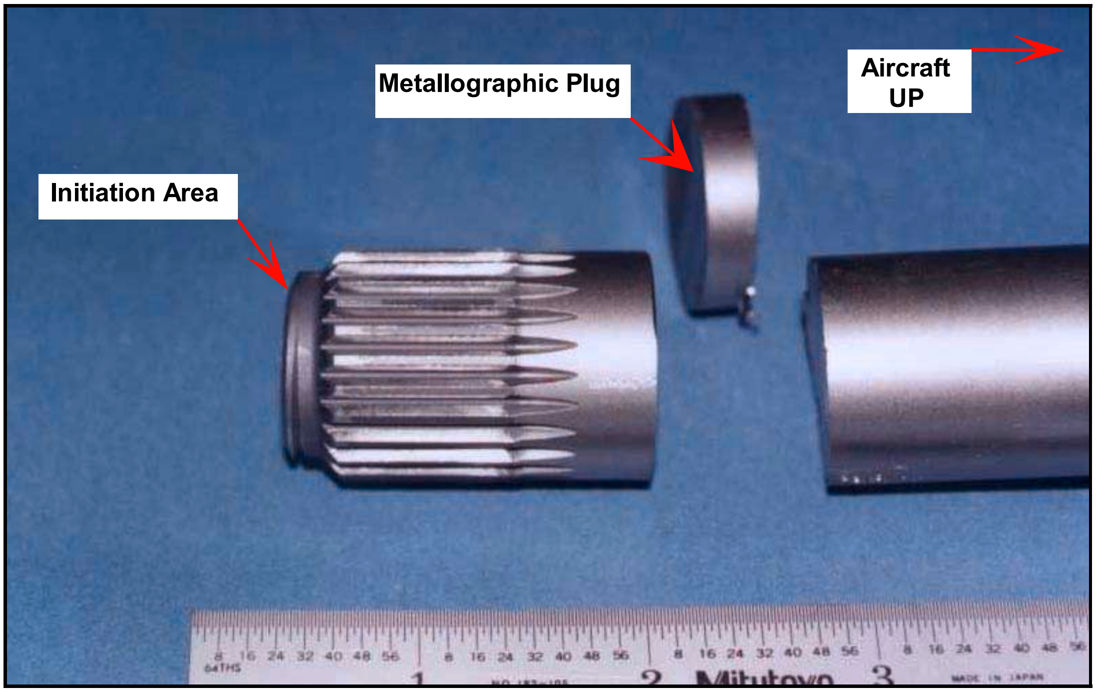


Figure 65--A view of the wear step in the large diameter section of the torque tube.



ImageNo:010A0356, Project No:A00095

Figure 66--Comparision of the lower end of the accident torque tube (middle) to exemplar torque tubes showing the different thread relief radius details (arrows). The upper tube has the optional relief while the accident tube and lower one do not.



ImageNo: 010A0357, Project No:A00095

50 mm

Figure 67--A side view of the torque tube after cutting off the fractured end and the metallograph plug. The initiation area is denoted in the first full thread.

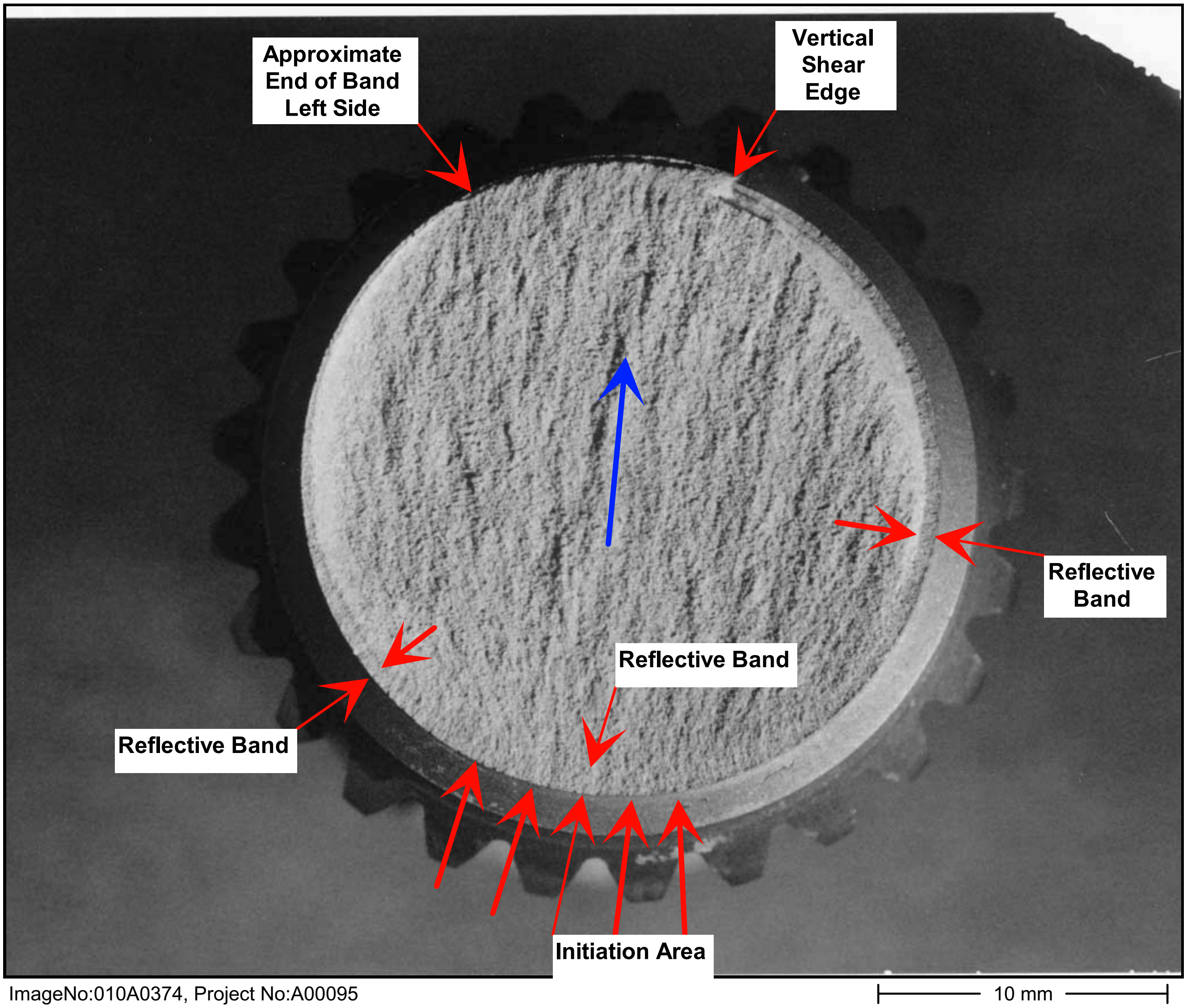
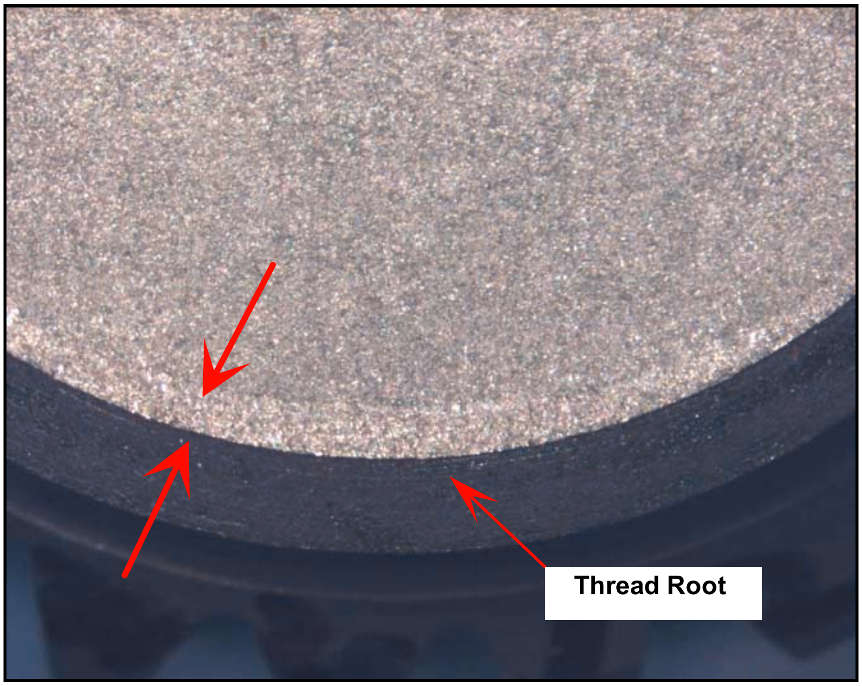
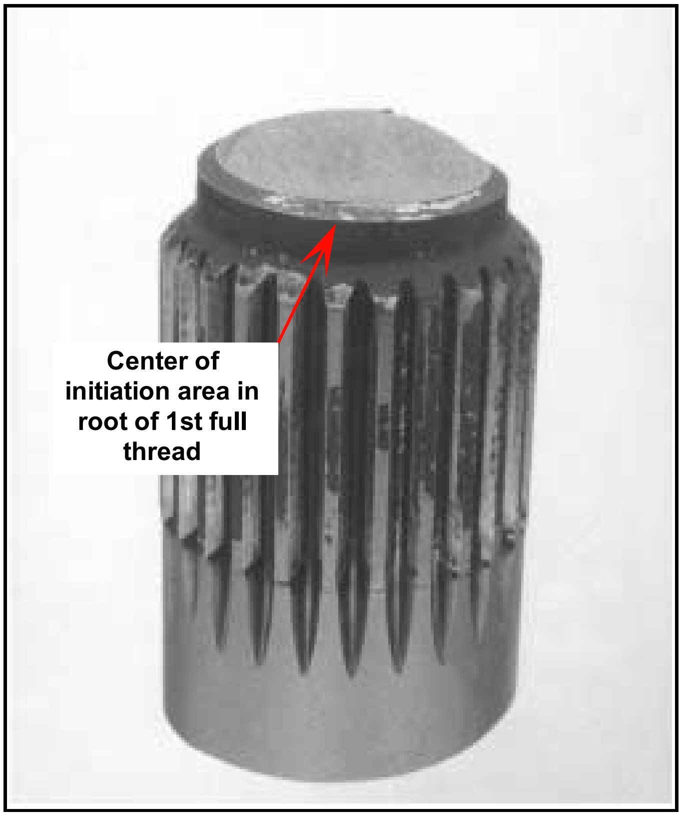


Figure 68--Direct view looking up at the torque tube fracture showing the initiation area, (arrows at lower edge) and the approximate widths of the circumferential band (between arrows) at the thread root. Large blue arrow denotes overall fracturing direction.



ImageNo:010A0358, Project No:A00095

Figure 69--Closer view of the torgue tube fracture initiation area showing the reflective band (between arrows) adjacent to the thread root.



ImageNo: 010A0360, Project No:A00095

Figure 70--Oblique view of the torque tube fracture showing the thread and fracture. The thread is left-handed and spirals upward to the left in this view.

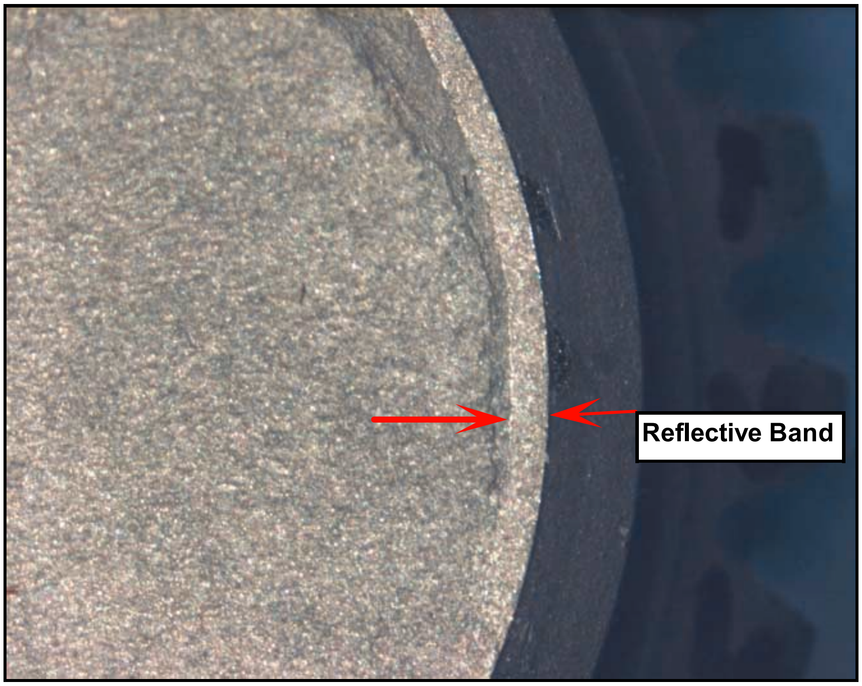


Figure 71--View looking upward onto the torque tube fracture showing the reflective band 90 degrees to the right of the initiation area.

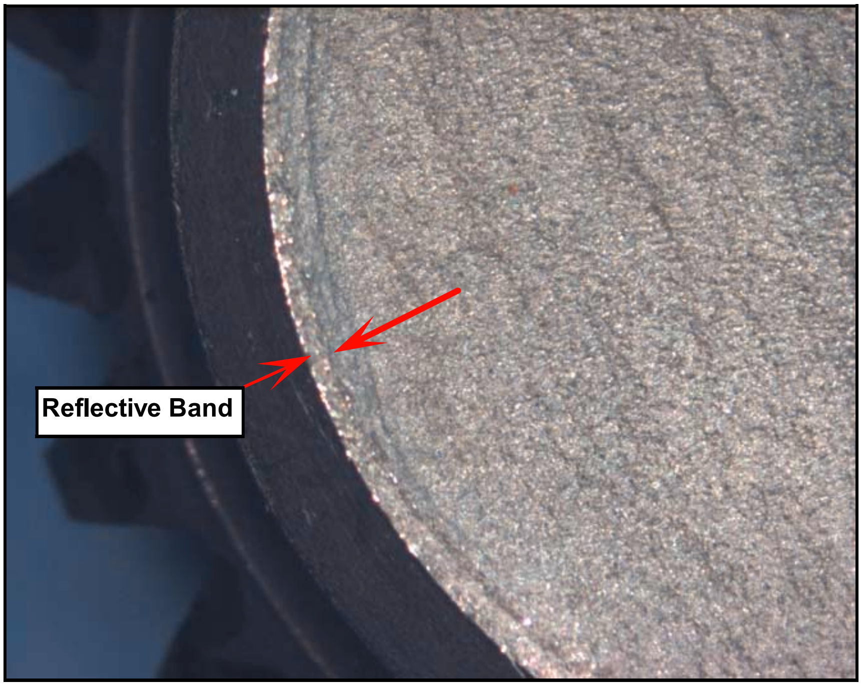
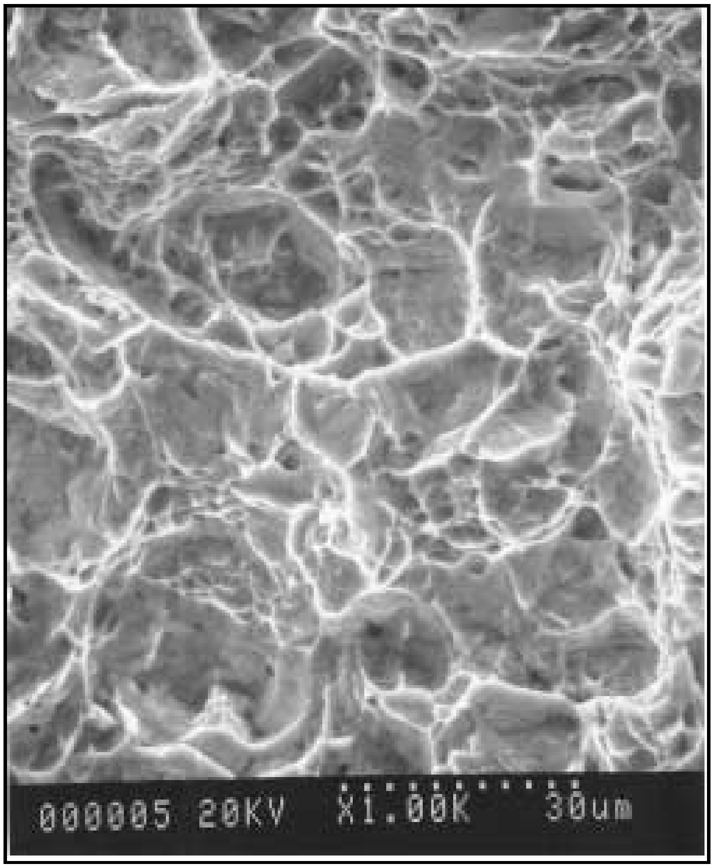
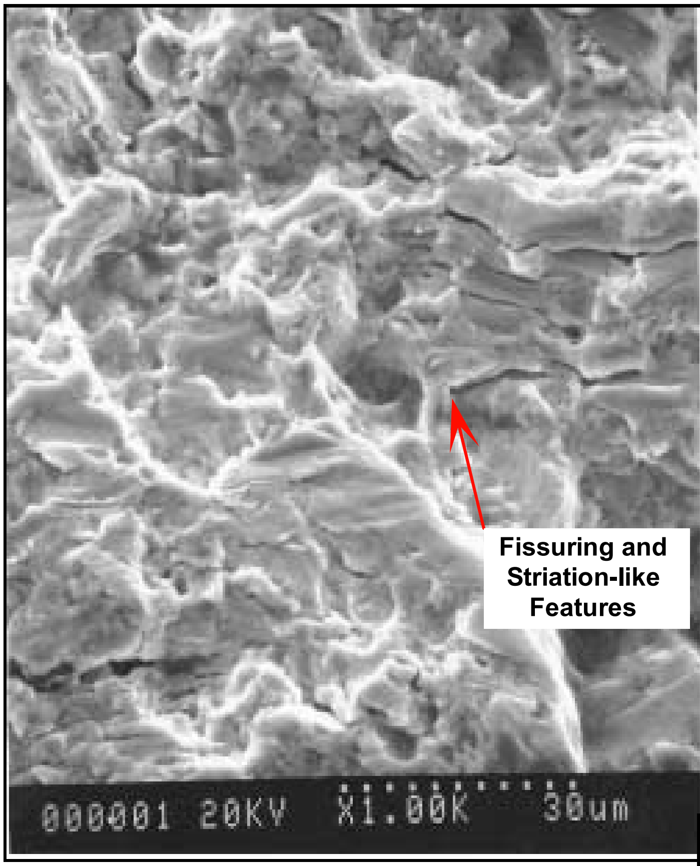


Figure 72--View looking upward onto the torque tube fracture showing the reflective band to the left of the initiation area.



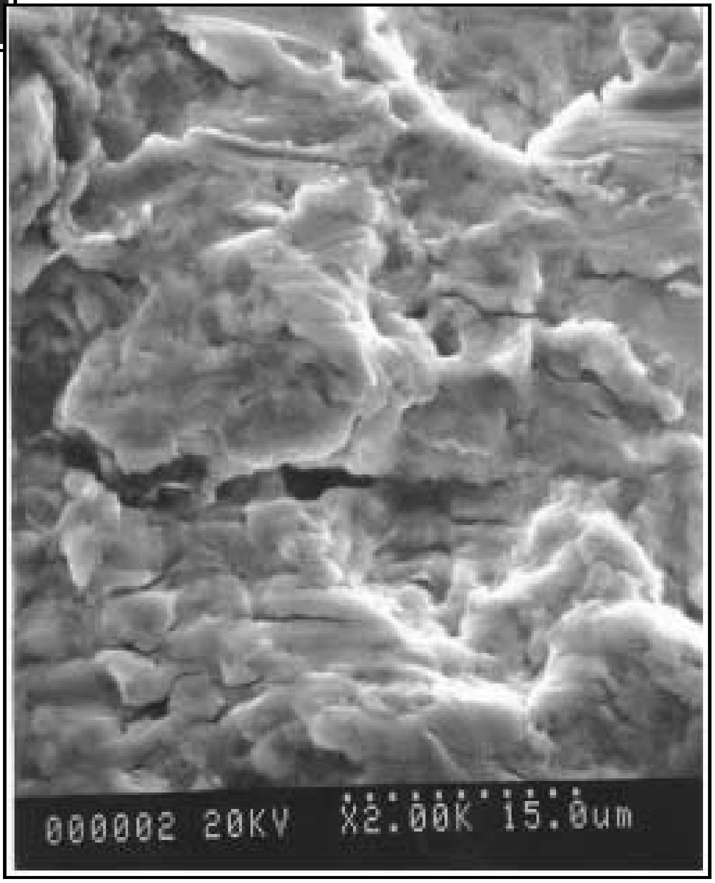
ImageNo:010A0361, Project No:A00095

Figure 73--SEM view showing typical overstress ductile dimples present on the majority of the fracture.

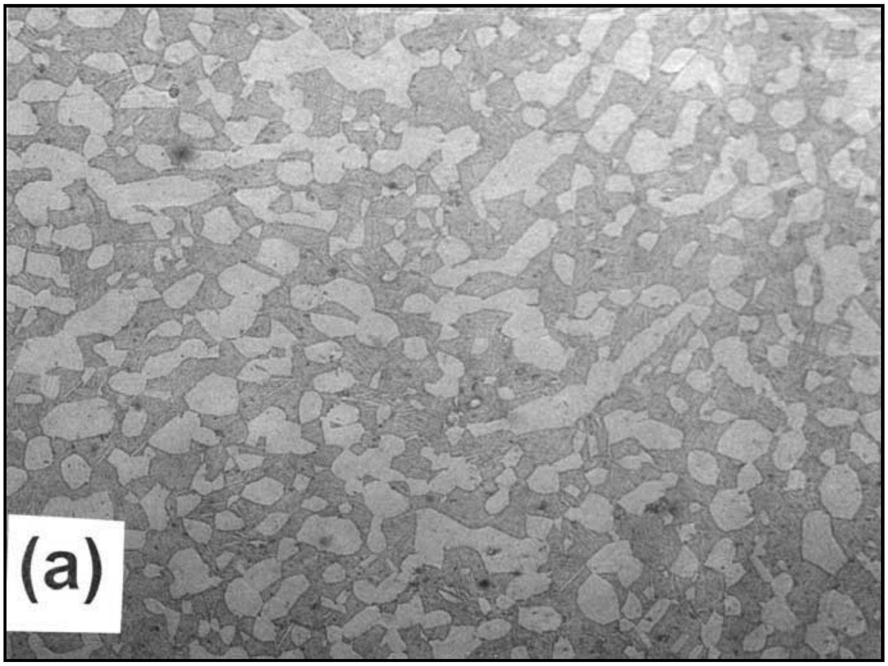


ImageNo:010A0362, Project No:A00095

Figure 74--SEM views showing typical fracture features in the reflective band. Note the fissures and striation-like features.

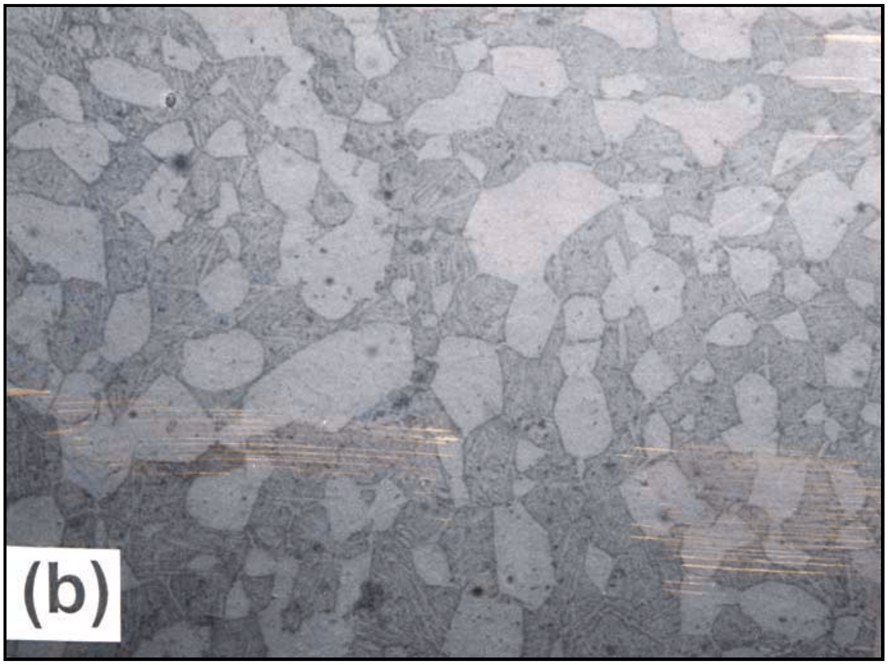


ImageNo: 010A0363, Project No:A00095

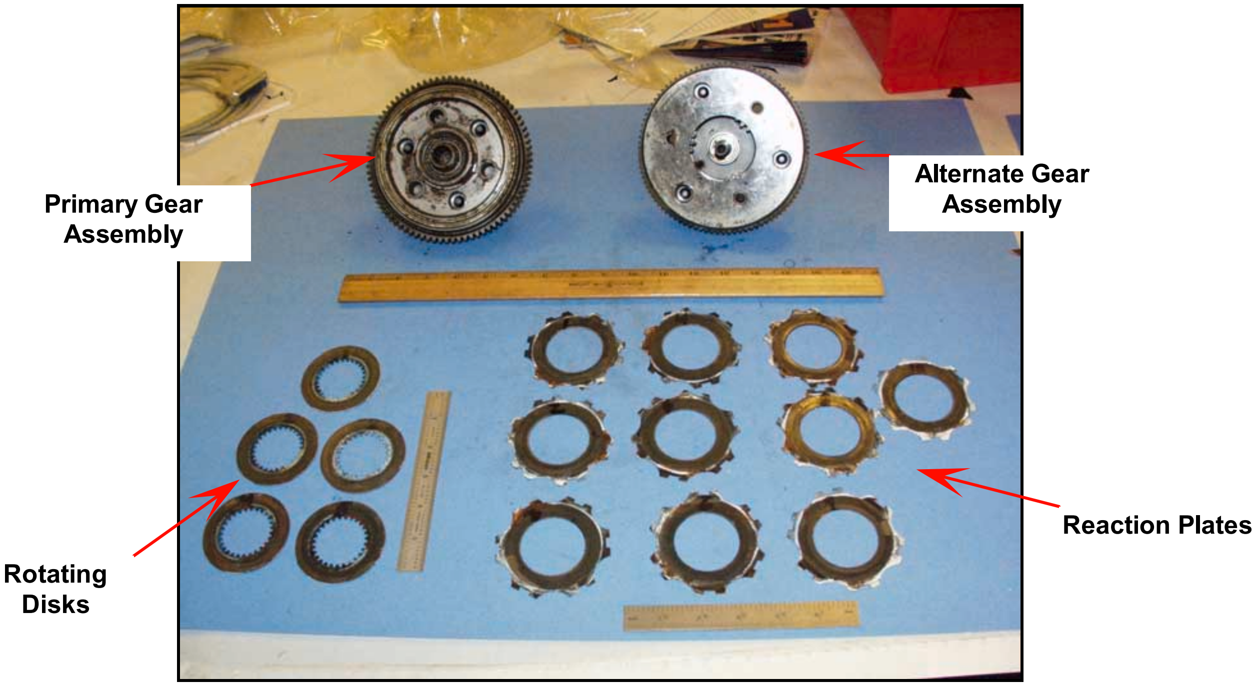


ImageNo:010A0375, Project No:A00095

Figure 75--The torque tube transverse microstructure showing alpha islands (light etching) in a fine alpha plus beta matrix (darker areas). Upper view at 800X, lower at 1600X original Magnifications. Etchant Kroll's

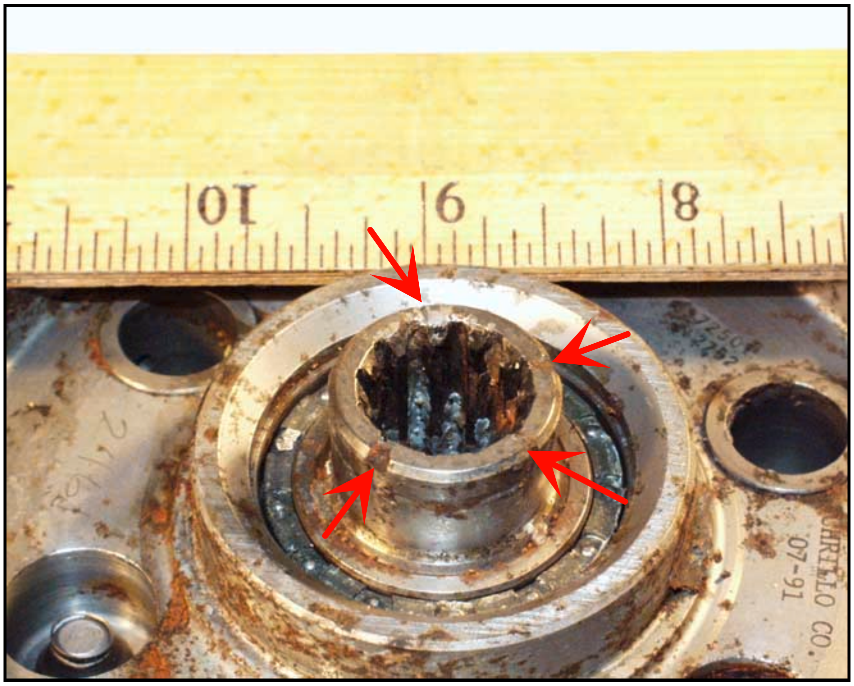


ImageNo: 010A0369, Project No:A00095



ImageNo:010A0367, Project No:A00095 ⊢ 100 mm ⊣

Figure 76--An overall view of the gearbox and trim motor components.



ImageNo: 010A0368, Project No:A00095 ⊢ 20 mm ⊣

Figure 77--Longitudinal cracks (arrows) in the input socket for the primary gear assembly.

List of for Materials Report 00-145

System Description, Mechanical and Metallurgical

Boeing Report

Summary Listing of Grease Samples taken by Materials Group

Part Numbers and Nomenclature

Shear Calculations

Durkee Testing Laboratories Reports

Vendor Information Request Summary

Summary of Engineering Drawing Changes

Brief Jackscrew Operational Description

The jackscrew assembly is the mechanism for adjusting the angle of incidence of the horizontal stabilizer to change the horizontal trim of the airplane. In addition, the jackscrew assembly is one of the three structural attachment points between the horizontal and vertical stabilizers. The other two are hinge points located well behind the jackscrew. The major components of jackscrew assembly are the motors and associated gearboxes (primary and alternate), a gearbox support assembly, an Acme screw and mating Acme nut, a torque tube (inside the ACME screw) and the hardware to connect the components to the airplane.

Figure 5 in Factual Report 00-145 illustrates these components. The ACME nut (nickel aluminum bronze) assembly is attached to the structure of the vertical fin by pivot pins and a gimbal ring. As such, the nut and supports can gimbal while they remain “fixed” in place. The Acme screw (nitrided steel) along with the torque tube, motors and gearboxes are attached to the structure of the horizontal stabilizer through the gearbox support assembly. They move with the horizontal stabilizer.

In operation, the motors supply rotation to the titanium torque tube through the gearbox and spherical spline adapter. The torque tube then drives the Acme screw through splines at the lower end of each. The torque tube is not, in actuality, a tube but rather a solid shaft and is many times referred to as the “quill shaft”. Rotation of the Acme screw is translated into vertical movement of the horizontal stabilizer through the fixed Acme nut via mating Acme threads in each.

In addition to supplying torque to the Acme screw, the torque tube is also the structural connection between the Acme nut and horizontal stabilizer. Normal in-flight and on ground loads on the horizontal stabilizer place the jackscrew assembly in tension. These loads in turn place tension loads on the torque tube that are transferred as compression loads to the length of the Acme screw extending below the Acme nut. The Acme threads then load the Acme Nut assembly and attachments upward.

Because of the one directional loading through the Acme threads, only one side of the threads is normally contacting, the upper sides of the Acme screw threads and the lower sides of Acme nut threads. To reduce wear and friction, the Acme threads are normally lubricated during maintenance with grease.

The limits of travel of the jackscrew assembly are primarily defined by electrical stops in the trim control system. Secondarily, “mechanical” stop assemblies are fixed to the Acme screw and Acme nut. These are intended to stop rotation of the screw should the electrical stop limits be exceeded.

Both the Acme screw and nut are gimbaled to accommodate the angular changes between the fixed ends of the jackscrew assembly during operation. A spherical bearing is employed at the upper end of the torque tube to allow in-plane angular misalignments along with rotary motion. The Acme nut can gimbal in all directions from the combination of a gimbal ring and four pivot points used to attach it to the vertical stabilizer.

SEM\METALLURGY LABORATORY RECORD

Lab Record No.: 00-14-0026
Requested by: T. Posten
Title: Fractographic Analysis: MD-83 Jackscrew Nut Thread, P/N 5914405-3
Material: C95500 Aluminum Bronze

Date: 2/10/00
CCN: DL5P84A1

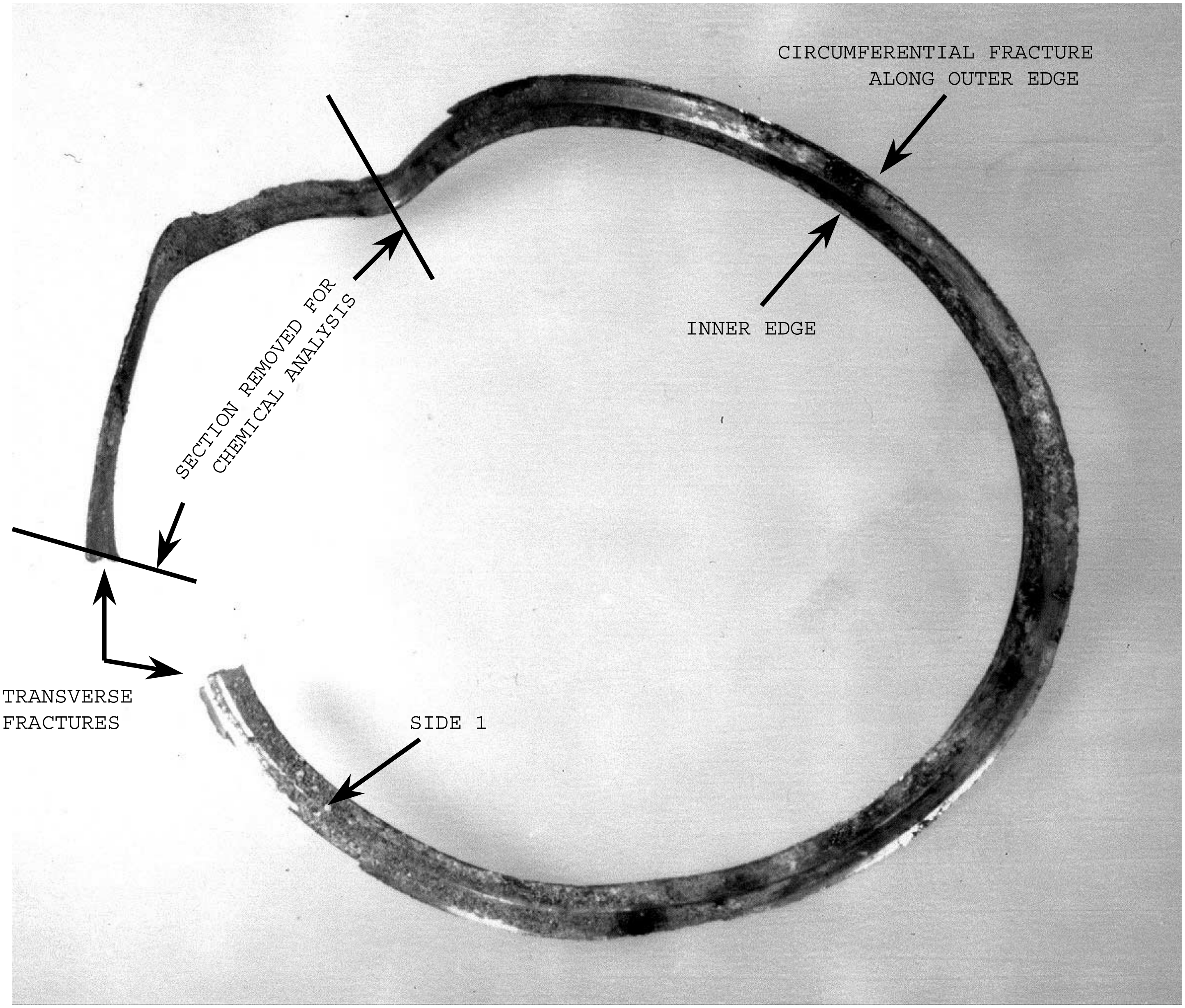
Macroscopic Examination

A small, metallic shaving/sliver, approximately 6.3 inches in length, was submitted for SEM evaluation (Figure 1). The sliver was measured to be 0.125 inch in width and 0.025 inch thick. The sliver exhibited a light, copper color and was partially masked by bluish-green corrosion byproducts. The sliver was ultrasonically cleaned in acetone, and a small section at one end was excised for chemical analysis of the base material prior to SEM examination. The cleaning technique removed a portion of the corrosion byproducts.

SEM Evaluation

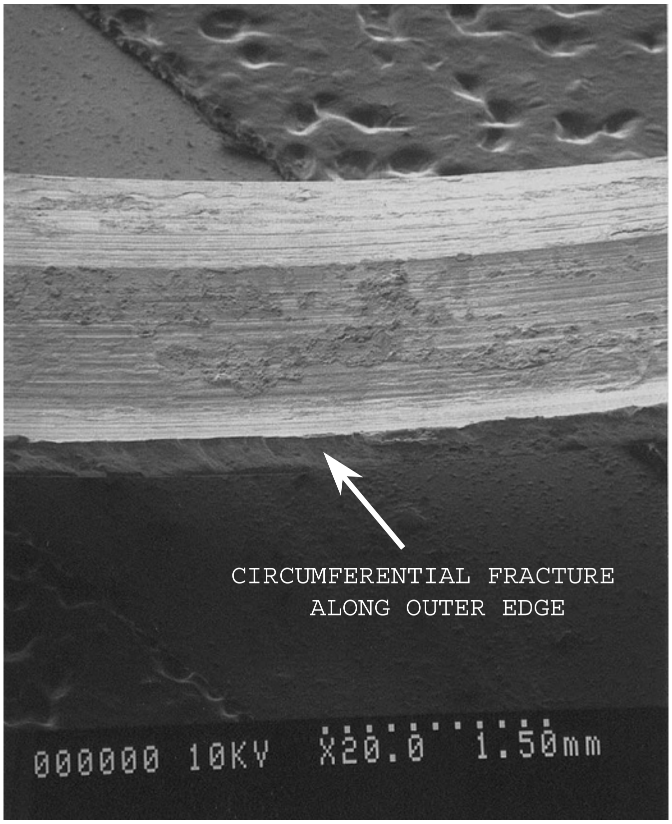
Both sides of the sliver exhibited circumferential grooves (Figures 2 to 5). No evidence of a failure mechanism was observed along either of these two surfaces. The sides were identified as Side 1 and Side 2 in the lab (Figure 1). Side 1 exhibited a bevel. Side 2 was relatively flat. A small circumferential fracture was observed along the outer edge of the sliver (Figure 6). The fracture surface appeared smooth and smeared, typical of shear overload. The direction of smearing appeared to extend from Side 2 towards Side 1. SEM analysis of this fracture surface revealed a predominant dimple mode of rupture, indicative of ductile overload (Figure 8). The sliver also exhibited two transverse fractures (Figure 1). One was excised with the section that was sent out for chemical analysis. The other fracture exhibited a smooth, smeared topography, similar to the circumferential fracture (Figure 7). SEM analysis of this transverse fracture also revealed a predominant dimple mode of rupture.

METAL SHAVING
(LR: 00-14-0026)

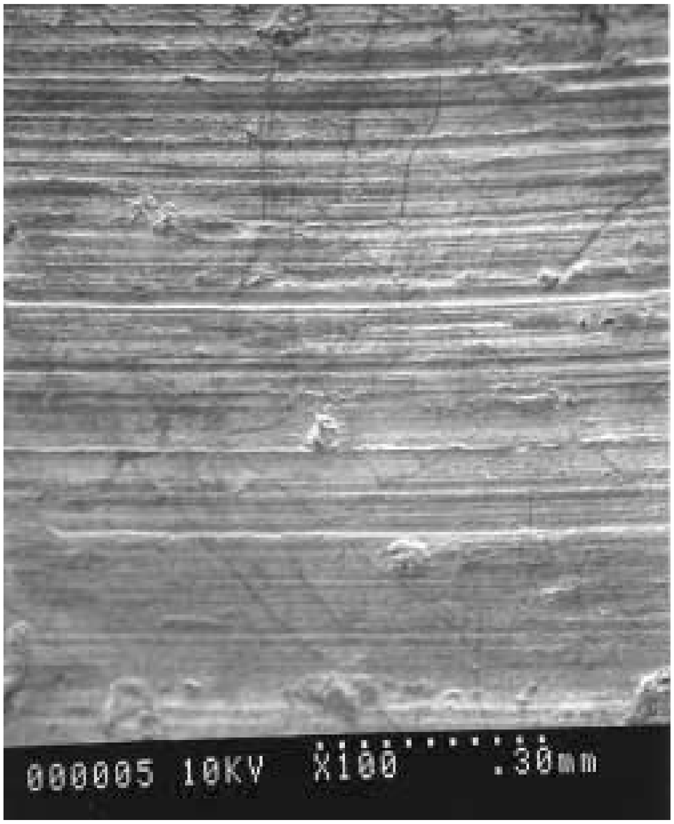


OVERALL OF METAL SHAVING
(NEG: 00-N0069)

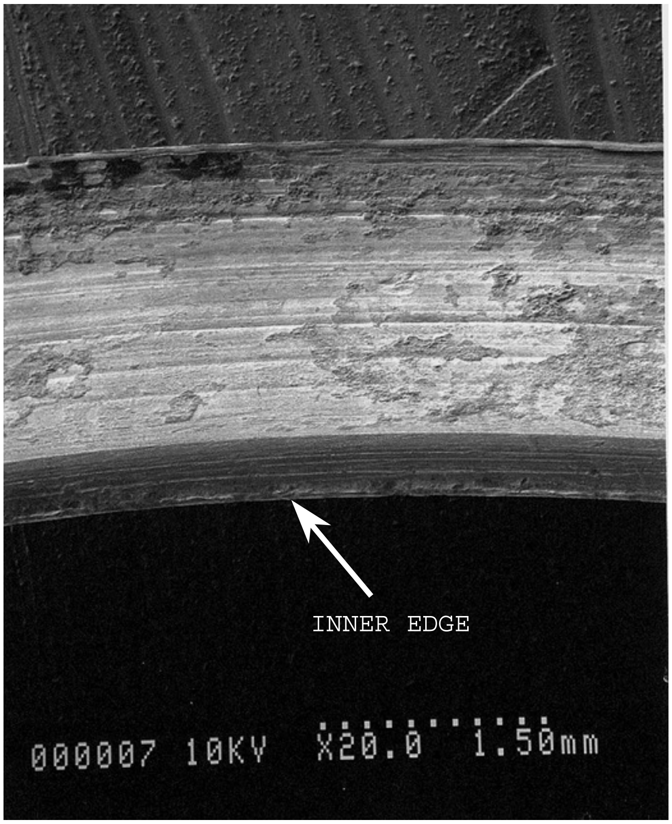
METAL SHAVING
(LR: 00-14-0026)



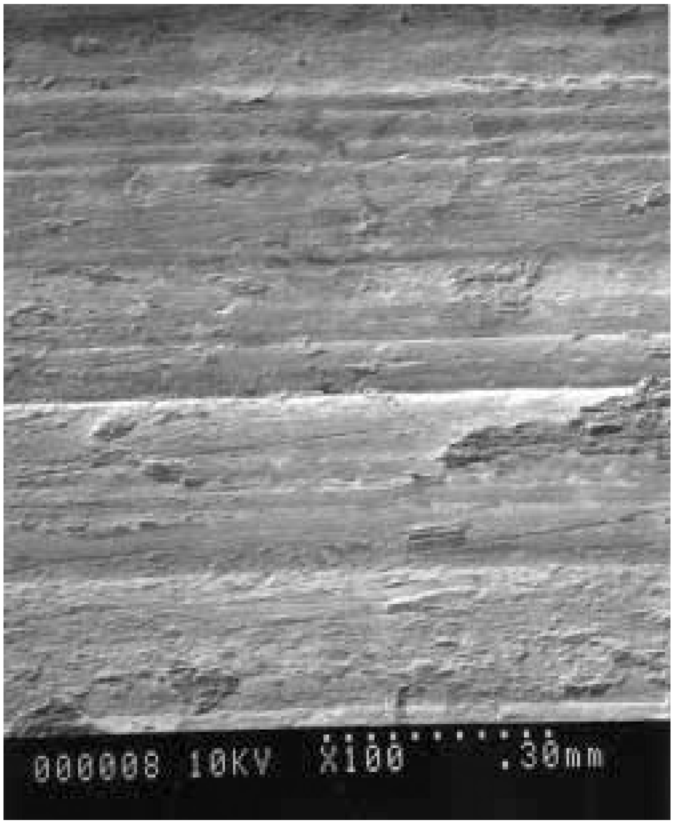
CLOSE-UP OF SIDE 1
(NEG: 00-S0066)



CLOSE-UP OF SIDE 1
(NEG: 00-S0067)

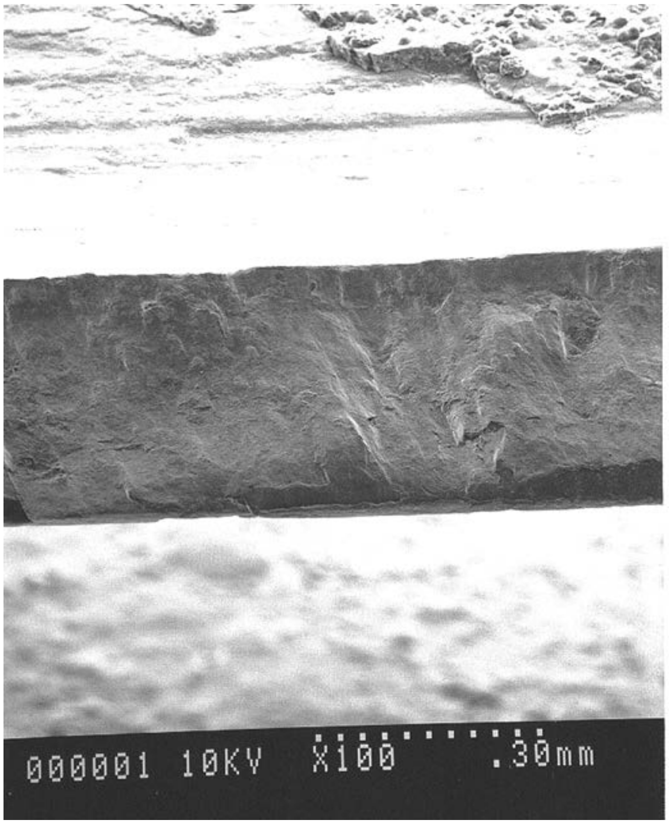


CLOSE-UP OF SIDE 2
(NEG: 00-S0068)

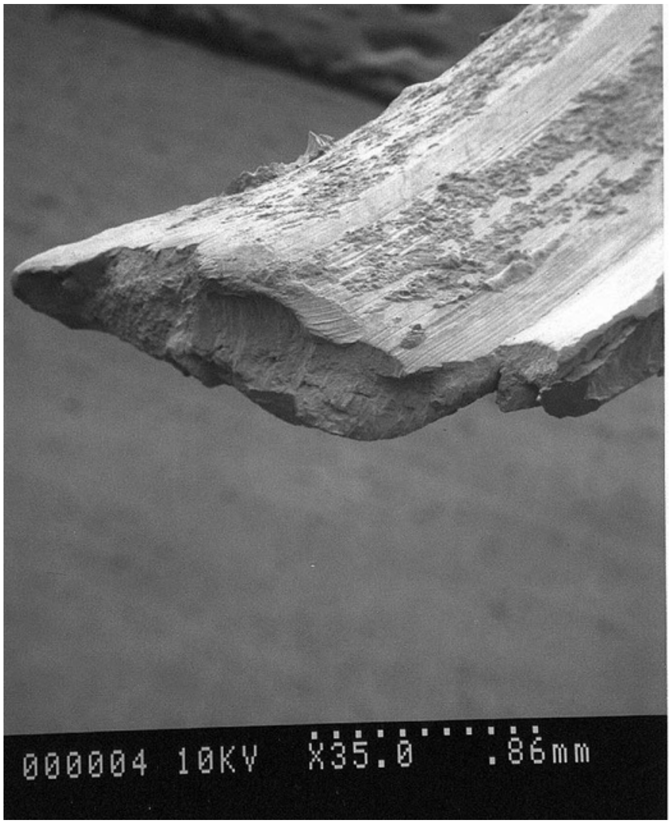


CLOSE-UP OF SIDE 2
(NEG: 00-S0069)

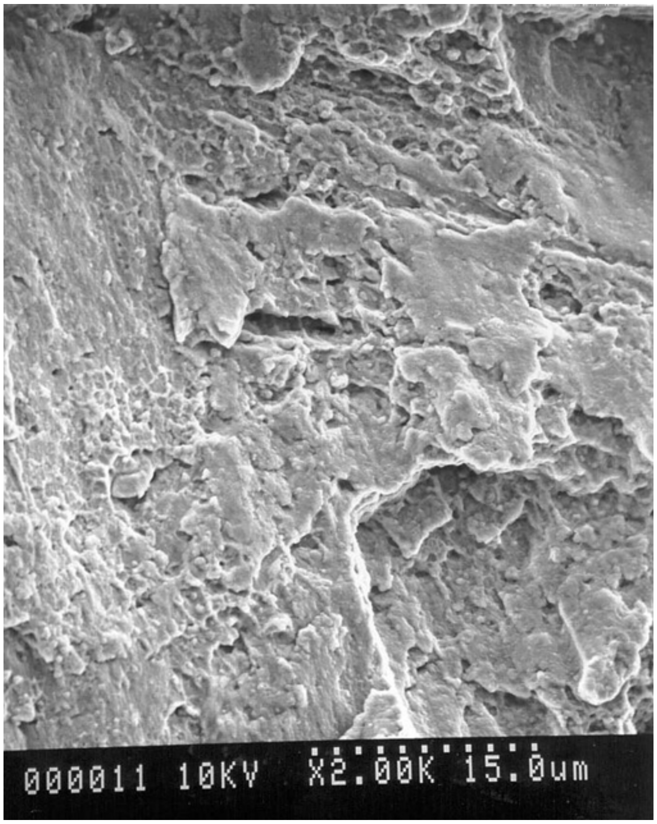
METAL SHAVING
(LR: 00-14-0026)



CLOSE-UP OF FRACTURE ALONG OUTER EDGE.
(NEG: 00-S0070)



CLOSE-UP OF TRANSVERSE FRACTURE.
(NEG: 00-S0072)



RAPID FRACTURE - DIMPLE RUPTURE.
(NEG: 00-S0071)

Summary Listing of Grease Samples taken by Materials Group

On-scene
(recovered in film containers)

Sample between lower screw threads -Sandy grease
Sample lower stop upper surface- black
2 Samples from exterior of Acme nut assembly
1 Sample from structure below nut assembly

5 total samples

Lab
(Most Samples placed in petri dishes)

Sample from grease passage at ID bore of gearbox support plate after bearing pressed out.
Sample between rollers of spherical bearing during disassembly
Grease flakes from thread remnants 1-6
Grease flakes from thread remnant 7-11
Between Lower stop splines on acme screw
Acme nut grease fitting passageway and counter bore black crumbly
Additional samples from exterior of Acme nut assembly
Gimbal ring grease fittings right and left samples from each reddish translucent
9 total samples.

Part Numbers and Nomenclature

The following is a listing of part numbers and other identifying marks found on components from the jackscrew assembly from Alaska Airlines flight 261. Component names are taken from engineering drawing or Illustrated Parts Catalogs.

Numbers or letters surrounded by parenthesis () were not illegible or were questionable. Parts are generally listed from the top down on the assembly.

Name	P/N	S/N	Other Markings
Jackscrew Assembly	59()()962-17	DCA-2064	AP()ED1()
Spherical Spline Adapter			
Gearbox Adapter Ring			
Upper Support Plate Assembly	5914180-1H		
Gearbox Support Assembly	5914181-1D		Jun 28, 1990
Lower Support Plate	5914182-1B		
Upper “Mechanical” Stop Assembly	3914179-501M		12/12/()()
Acme Screw	5914168-505M	P-2663	77288
Acme Nut Assembly	5914169-507H	P-2663	APR 06 1990
Acme Nut			
Gimbal Ring Assembly	3914163-1E		JUN 8, 1990 MFR 091379
Acme Nut Support, Upper Forward	3914162-505E		OCT 9 19(7)9 MFR 091379
Acme Nut Support, Upper Aft	3914162-503E		DEC 2, 1989
Acme Nut Support, Lower Forward	3914162-1E		OCT 31, 1989 MFR 091379
Acme Nut, Support Lower Aft	3914162-501E		DEC 4, 1989 MFR 091379
Lower Stop Assembly	3927223-1C		NOV 11, ()()()()
Nut, Torque Tube			
Torque Tube-Drive Acme screw			
Washer, Torque Tube			
Crank Assembly, Cable Indicator			

Durkee Testing Laboratories, Inc.

P.O. BOX 1401•15700 Texaco Street•Paramount, CA 90723 • (562) 531-7111

CHEMICAL ANALYSIS REPORT

ENT BY GM

CUSTOMER

BOEING / H B
ATTN: LOU SZELIGA
MAIL CODE H021-F116
5301 BOLSA AVENUE
HUNTINGTON BEACH, CA 92647

CUST P.O. 181084

SHIPPER / W.O.

LAB NO. S5737

LOG NO. 58118N

SPECS DMS 1583F AMS 4928P

DATE REC. 09/19/00

DATE COMP. 10/03/00

Item	Quantity	Cust Item	Test	Description	Material
1-01	1	1	CHEM-ALLOY	W/GASES	

Desc.: ONE (1) TEST SPECIMEN, SUBMITTED AS FOR:
WORK ORDER NO. 181084, SHOP ORDER NO. FP8755VG,
1-ASA 261 #ASW963AS

Alloy: 6-4 TITANIUM

	Carbon	Vanadium	Titanium	Aluminum	Iron
	0.01%	4.11%	REMAINDER	6.39%	0.21%
Min: Max:	0.08	3.50 4.50	REMAINDER	5.50 6.75	0.30
	Yttrium	Hydrogen	Nitrogen	Oxygen	OEE
	<.005%	123 PPM	0.01%	0.15%	<.10%
Min: Max:	0.005	125 PPM	0.05	0.20	0.10
	OET				
	<.40%				
Min: Max:	0.40				
Min: Max:					

By:GDL

Material(s) conform to specifications
ANALYSIS BY EMISSION SPECTROSCOPY AND INERT GAS FUSION METHOD.

NADCAP
PERFORMANCE REVIEW INSTITUTE
Accredited

Respectfully Submitted,

By: [redacted]

SHARON KIRKPATRICK
Q.A. MANAGER

Durkee Testing Laboratories, Inc.
P.O. BOX 1401•15700 Texaco Street•Paramount, CA 90723 • (562) 531-7111

MECHANICAL PROPERTIES REPORT

ENT BY GM

Page 1

CUSTOMER	CUST P.O.	SHIPPER / W.O.	LAB NO.	LOG NO.
BOEING / H B ATTN: LOU SZELIGA MAIL CODE H021-F116 5301 BOLSA AVENUE HUNTINGTON BEACH, CA 92647	181084		S5743	58364N
	SPECS	1. DMS 1583F	2. ENGINEERING DRAWING	DATE REC. 09/22/00 DATE COMP. 10/03/00

Item	Quantity	Cust Item	Test	Description	Material
1-01	2	1	MECHANICAL	TENSILE	6-4 TITANIUM

(2) TEST SPECIMENS, SUBMITTED AS 261-T1, W.O.: 181084,
SHOP ORDER NO.: FP8755VG, LOCATION: A3, DEPT.: NO46

Reqs.	ID	Actual Size	Actual Area	Yield Load @ .2%	Yield PSI @ .2%	Tensile Load @ max	Tensile PSI @ max	Elong Inch 1.00	Elong (%)	Reduced Dimension	R/A (%)	Note
1,2	T1	0.2500	.04909	7040	143400	8030	163600	0.170	17.000	0.1780	49.317	
1,2	T1-RETEST	0.2520	.04988	7580	152000	8110	162600	0.160	16.000	0.1730	52.866	

WITNESSED BY: JOE EPPERSON [redacted]
NTSB

DAN HO [redacted]
ALASKA AIRLINES

JIM DART [redacted]
ALASKA AIRLINES

TOM POSTEN [redacted]
BOEING - LONG BEACH

TERRY KHALED [redacted]
FAA

DAVE EISENBREY [redacted]
ALPA

SHARON KIRKPATRICK [redacted]
DURKEETESTING LABORATORIES, INC.

	Yield PSI @ .2%	Tensile PSI @ max	Elong (%)	R/A (%)
Minimum Requirements: 1	~~120000~~ 140,000 JE	~~130000~~ 150,000 JE	~~10.000~~ 8 JE	JE ~~25.000~~ 20
Minimum Requirements: 2	0	140000	0.000	0.000

By: ET

Material(s) conform to specifications

NOTE: RETEST PERFORMED ON SAMPLE DUE TO ANOMOLY IN STRESS-STRAIN CURVE, POSSIBLY DUE TO ALIGNMENT PROBLEM AND/OR EXTENSOMETER SLIPPAGE.

NADCAP
PERFORMANCE REVIEW INSTITUTE
Accredited

Respectfully Submitted,

By: [redacted]
KENNETH R. JOHN

Durkee Testing Laboratories, Inc.

P.O. BOX 1401•15700 Texaco Street•Paramount, CA 90723 • (562) 531-7111

MECHANICAL PROPERTIES REPORT

ENT BY GM

Page 1

C U S T O M E R

BOEING / H B
ATTN: LOU SZELIGA
MAIL CODE H021-F116
5301 BOLSA AVENUE
HUNTINGTON BEACH, CA 92647

CUST P.O.	SHIPPER / W.O.	LAB NO.	LOG NO.
181084		S5744	58364N

SPECS: 1. DMS 1583F 2. ENGINEERING DRAWING

DATE REC. 09/22/00

DATE COMP. 10/03/00

Item	Quantity	Cust Item	Test	Description	Material
2-01	2	2	MECHANICAL	TENSILE	6-4 TITANIUM

(2) TEST SPECIMENS, SUBMITTED AS 261-T2, W.O.: 181084, SHOP ORDER NO.: FP8755VG, LOCATION: A3, DEPT.: NO46

Reqs.	ID	Actual Size	Actual Area	Yield Load @ .2%	Yield PSI @ .2%	Tensile Load @ max	Tensile PSI @ max	Elong Inch 1.00	Elong (%)	Reduced Dimension	R/A (%)	Note
1,2	T2	0.2500	.04909	7470	152200	8020	163400	0.170	17.000	0.1810	47.586	
1,2	T2-RETEST	0.2500	.04909	7490	152600	8000	163000	0.160	16.000	0.1680	54.838	

WITNESSED BY:

JOE EPPERSON [redacted]
NTSB

DAN HO [redacted]
ALASKA AIRLINES

JIM DART [redacted]
ALASKA AIRLINES

TOM POSTEN [redacted]
BOEING - LONG BEACH

TERRY KHALED [redacted]
FAA

DAVE EISENBREY [redacted]
ALPA

SHARON KIRKPATRICK [redacted]
DURKEE TESTING LABORATORIES, INC.

Minimum Requirements: 1	140,000 ~~120000~~ JE	150,000 ~~130000~~ JE	8 ~~10.000~~ JE	10 JE ~~15.000~~
Minimum Requirements: 2	0	140000	0.000	0.000

By:ET /

Material(s) conform to specifications

NOTE: RETEST PERFORMED ON SAMPLE DUE TO ANOMOLY IN STRESS-STRAIN CURVE, POSSIBLY DUE TO ALIGNMENT PROBLEM AND/OR EXTENSOMETER SLIPPAGE.

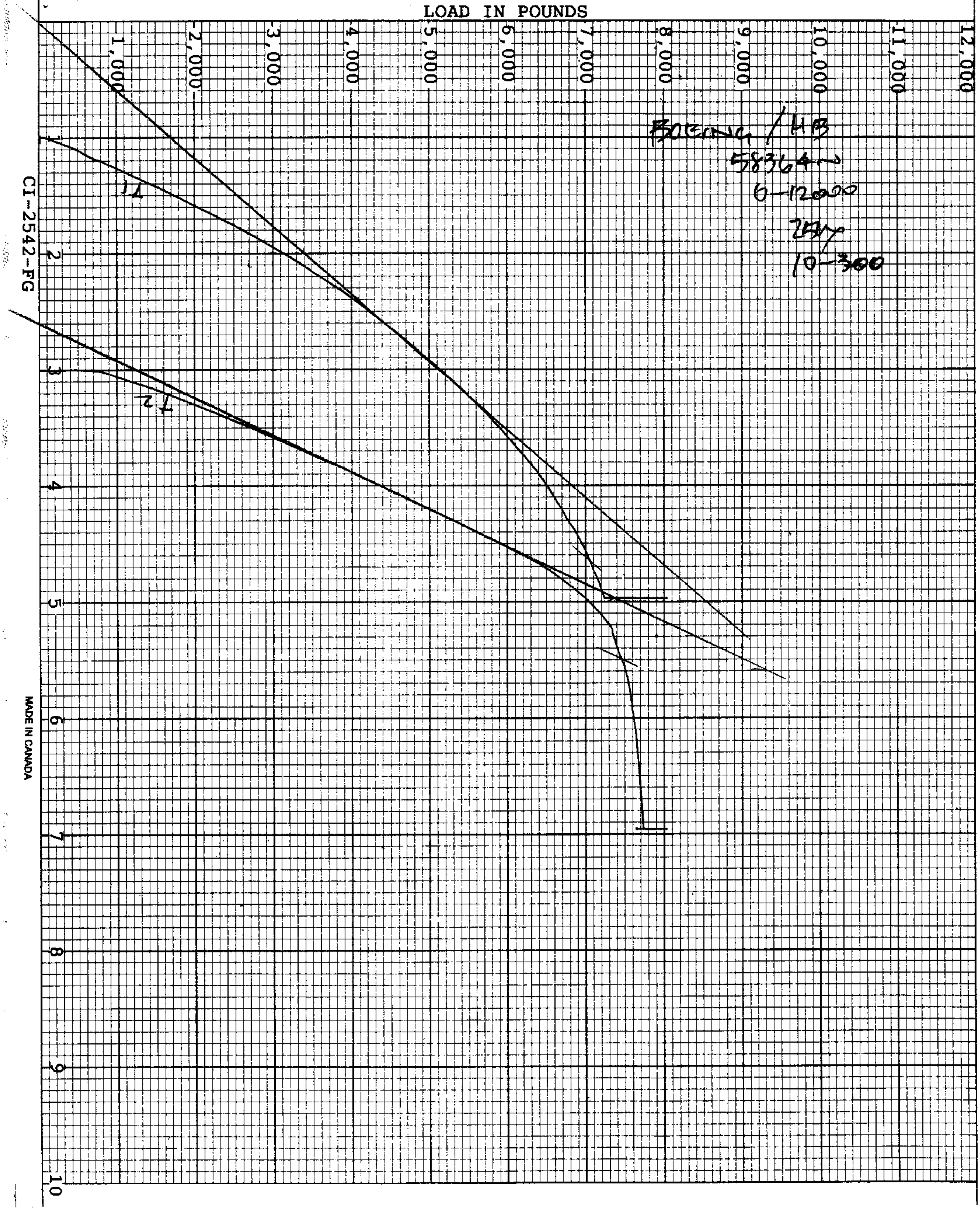
NADCAP
PERFORMANCE REVIEW INSTITUTE
Accredited

Respectfully Submitted,

By: [redacted]

KENNETH R. JOHN
GENERAL MANAGER

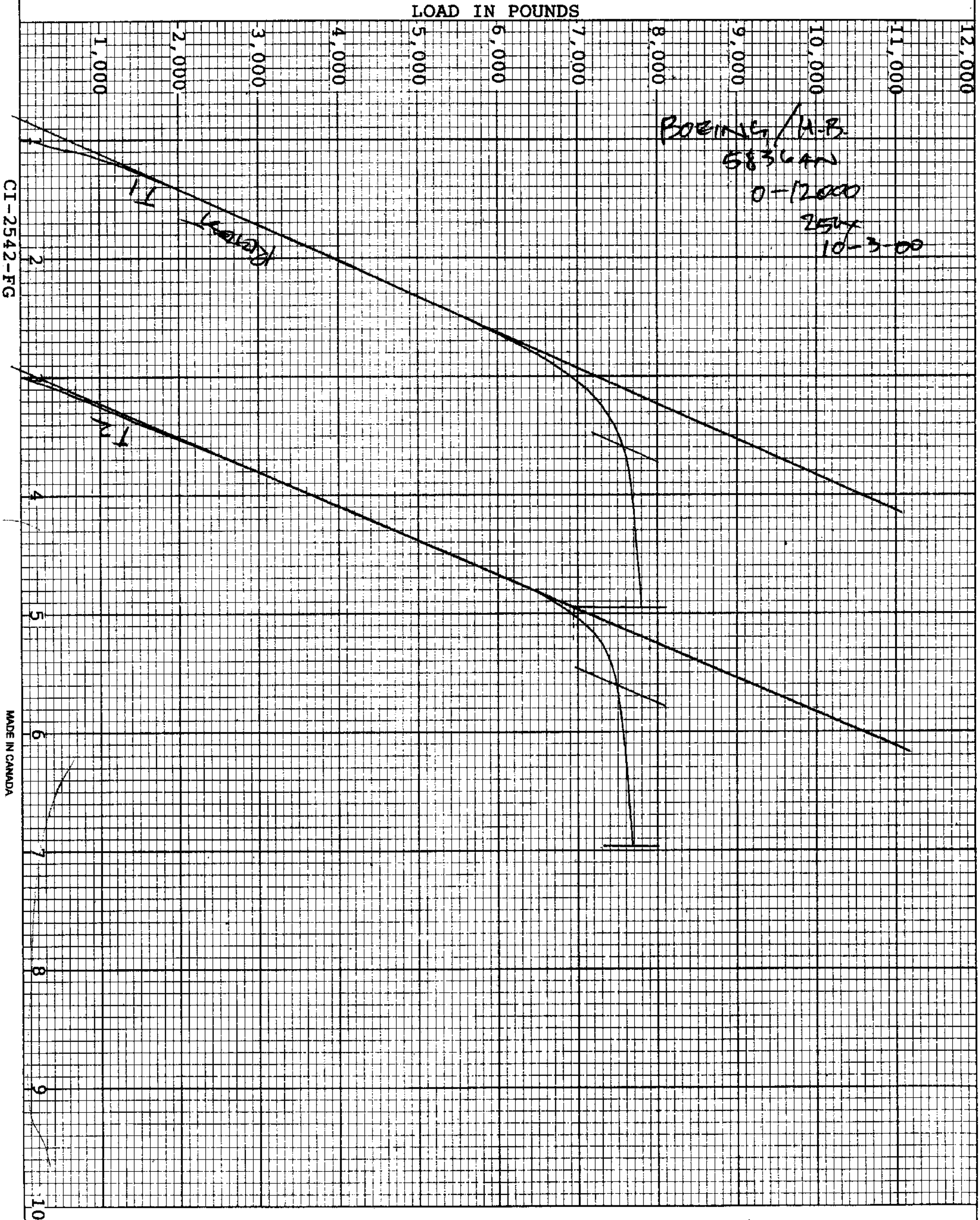
DURKEE TESTING



CI-2542-FG

MADE IN CANADA

DURKEE TESTING



BOEING / H-B
5836 AN
0-12000
254x
10-3-00

Vendor Information Requests Summary

Vendor Information Request (VIR)

NOTE: DCA2064 was shipped from "Peacock" on 6/28/90.

VIR Number	VIR Date	SUPPLIER	PART #	DETAIL P/N	PART NAME	DWG CHG	MODEL	1st FSN	COMMENTS
13123	4/13/95	DERLAN	5914168-509	N/A	SCREW-ACME	NO	MD80	2099	Requested to electroless nickle plate spline per DPS 9.76 to meet spline requirement. Disposition: Submitted to QA for waiver.
13196	5/17/95	DERLAN	5914168-509	N/A	SCREW-ACME	NO	MD90	2099	Variance for grinding wheel grade & grinding speed was accepted provided nital etched, and PI, and cad plate per DPS 9.28. Purchase order number is the same as VIR # 13123. However, this applies to 6 pcs of MD90 model.
13217	5/25/95	DERLAN	5914168-509	N/A	SCREW-ACME	NO	MD90	N/A	Conflicts between E.O. "R" and dwg callout (1.140/1.150 vs 1.160/1.170 dia). Disposition: Dia callout on dwg is correct.
13241	6/6/95	DERLAN	5940560-3	N/A	SCREW & SUPPORT ASSY	YES	MD90	2099	1. Add callout to reflect proper hardware usage on dwg 5940560. 2. Blueprint calls for MS21042L4 nut but not listed on parts list. 3. Bolts NAS6606-60 and NAS1204-60 are too long. Suggest using a -58 bolt. Disposition: 1. DAC engineering will add hardware callout on dwg. 2. MS21042L4 nut will be added on parts list. 3. Request denied. -60 bolt is required with laminated shims under max material condition.
13274	6/15/95	DERLAN	5914168-509	N/A	SCREW-ACME	NO	MD90	2099	Request deviation on wheel grade A100 R 9BH. Parts are nital etched inspected per DPS 4.715. Disposition: Acceptable. Revision of spec will be made by M & PE.
13298	6/21/95	DERLAN	5940560-3	N/A	NUT	NO	MD90	2117	Request usage of 2 1/8" dia round bar 4340 mil-s-5000 condition E4. This permits flat to be machined to remove surface defects 100%. Disposition: Acceptable to design to use substitute material.
13385	8/2/95	DERLAN	5914168-509	N/A	SCREW-ACME	NO	MD90	2117	Request deviation on wheel grade A100 R 9BH. Parts are nital etched inspected per DPS 4.715. Disposition: Acceptable. Revision of spec will be made by M & PE. Disapproved. Supplier planning is frozen and must be change prior to approval of VIR.
13561	10/9/95	DERLAN	5940560-3	5914168-509	SCREW-ACME	NO	MD90	2125	Request that oven number 55968 be added to DPS 4.804 SPEO # DE001 in addition to oven S/N 7315. Disposition: Acceptable.
13588	10/16/95	DERLAN	5910962-71	3914163-1	RING ASSY	NO	MD80	2128	Request permission to use P/N 3914163-1 Ring assy in lieu of P/N 3914163-501 to use existing stocks of the aforementioned Ring assy. Disposition: Acceptable.
VIR Number	**VIR Date**	**SUPPLIER**	**PART #**	**DETAIL P/N**	**PART NAME**	**DWG CHG**	**MODEL**	**1st FSN**	**COMMENTS**

13589	10/16/95	DERLAN	5910962-71	N/A	BEARING	NO	MD80	2128	Request permission to use P/N DAL34-71A-14 Bearing in lieu of P/N DAL 34-71A1-503 to use existing stock of the aforementioned bearing. Disposition: No engineering action required. 5914181E change was released with a HI NO. “O” which means that either bearing could be used.
13675	11/17/95	DERLAN	55940560-3	3927223-1	LOWER STOP	YES	MD90	2140	Request B/P change to allow scribe line to be filled in with non specular black paint DN 2590 as opposed to DPM 1447 dri-marquette and remove requirement of painting over line with DPM 2232FR primer. Disposition: Approved. VIR cancelled on 12/20/95
13677	11/17/95	DERLAN	5940560-3	3914179-501	UPPER STOP	YES	MD90	2136	Request B/P change to allow scribe line to be filled in with non specular black paint DN 2590 as opposed to DPM 1447 dri-marquette and remove requirement of painting over line with DPM 2232FR primer. Disposition: Approved.
13787	1/18/96	DERLAN	5910962-71	5914168-505	FORGING, SCREW	NO	MD80	2135	Request permission to use P/N 5914168-5 upset forging in lieu of -3. Disposition: Acceptable.
13935	2/20/96	DERLAN	AJH-7349-503	AJH7155-3	SCREW	NO	MD11	603	Request that the 0.003 - 0.005 case depth per b/p note 15 be changed to 0.003 - 0.010 case depth. Disposition: Acceptable.
14396	7/26/96	DERLAN	5910962-71	3914163-1	RING	NO	MD80	2204	Request permission to use P/N 3914163-1 Ring Assy in lieu of P/N 3914163-501 to use existing stocks of the aforementioned Ring Assy. Disposition: Acceptable.
14441	8/14/96	ELECTROL	5940560-3	5914168-509 REV “R”	JACKSCREW	NO	MD80	2209	Blue print face Rev “R” calls for I.D. to be 1.160 /1.170 dia for BN-509. “R” change E.O. calls BN-509 I.D. to be 1.140 / 1.150 dia which is correct. Disposition: I.D. of -509 should be made to dwg call out of 1.160 / 1.170 dia. Part should be built per face of dwg
14737	11/27/96	DERLAN	5940560-3	5914168-509	SCREW-ACME	NO	MD90	2175	Request clarification on chamfer dimension. Derlan interpret dimension as being break out point for each end of one chamfer. Disposition: Engineering concurred with Derlan interpretation.
15292	5/14/97	DERLAN	5940560-3	N/A	ACTUATOR ASSY	YES	MD90	2198	Request the DPS 4.999 be removed from the blue print parts list and be replaced with DPS 9.05 which is called out on the APO. Disposition: Acceptable.
15293	5/14/97	DERLAN	5910962-71	N/A	ACTUATOR ASSY	YES	MD80	2201	Request DPS 4.999 be removed from B/P parts list and the APO and replace with a more suitable spec. Disposition: Acceptable to M & PE. See E.O. 5914168 “U” change.
15294	5/14/97	DERLAN	5914169-505	N/A	NUT ASSY	YES	MD80	SPARES	Request DPS 4.999 be removed from B/P parts list and the APO and replace with a more suitable spec. Disposition: Acceptable to M & PE. See E.O. 5914168 “U” change.
15448	6/20/97	DERLAN	5910962-71	3914163-1	JACKSCREW ASSY	NO	MD80	2206	Request permission to use P/N 3914163-1 Ring Assy in lieu of P/N

									3914163-501 to use existing stock of the aforementioned Ring Assy. Disposition: Acceptable

VIR Number	VIR Date	SUPPLIER	PART #	DETAIL P/N	PART NAME	DWG CHG	MODEL	1st FSN	COMMENTS
15549	7/23/97	DERLAN	5910962-71	5914168-505	ACTUATOR ASSY	NO	MD80	2206	Request blue print change to blue print note 20 of subject part to “nitride” screw per DPS 5.00-3 in lieu of “malcomize” screw per DPS 5.00-3. Disposition: Acceptable to MPS + TL. “Malcomizing” only applicable to stainless steel parts. -503, -505 and -507 are made from 4140. VIR Cancelled.
15757	9/11/98	DERLAN	5910962-71	3914162-1	ACTUATOR ASSY	NO	MD80	N/A	The following material was used to manufacture subject P/N: 2024-T351 Alum plate per QQ-A-225/6E. The blue print calls out for this material on subject P/N is 2024-T351 alum plate per QQ-A-250/4. Is this an acceptable substitute? Disposition: Rejected.
15758	9/11/98	DERLAN	5910962-71	3914162-501	ACTUATOR ASSY	NO	MD80	N/A	The following material was used to manufacture subject P/N: 2024-T351 Alum plate per QQ-A-225/6E. The blue print calls out for this material on subject P/N is 2024-T351 alum plate per QQ-A-250/4. Is this an acceptable substitute? Disposition: Rejected.
15759	9/11/98	DERLAN	5910962-71	3914162-503	ACTUATOR ASSY	NO	MD80	N/A	The following material was used to manufacture subject P/N: 2024-T351 Alum plate per QQ-A-225/6E. The blue print calls out for this material on subject P/N is 2024-T351 alum plate per QQ-A-250/4. Is this an acceptable substitute? Disposition: Rejected.
15760	9/11/98	DERLAN	5910962-71	3914162-505	ACTUATOR ASSY	NO	MD80	N/A	The following material was used to manufacture subject P/N: 2024-T351 Alum plate per QQ-A-225/6E. The blue print calls out for this material on subject P/N is 2024-T351 alum plate per QQ-A-250/4. Is this an acceptable substitute? Disposition: Rejected.
16116	12/1/97	DERLAN	5940560-3	5914168-509	ACTUATOR ASSY	YES	MD90	2221	Request the following ultimate materials to be added to the PSAMSL or issue an E.O. authorizing the ultimate substitute material as follows: current blue print alternate material; 3” dia 4340 steel per DMS 1555 “Grade A” condition annealed and cold finished. Request ultimate substitute material; 3” dia 4340 steel per DMS 1555 “Grade B” condition normalized and tempered. Disposition: Acceptable
16410	2/26/98	DERLAN	5940560-3	N/A	SCREW ASSY	NO	MD90	2203	Disposition: Returned to buyer.
16413	2/26/98	DERLAN	5910962-71	N/A	SCREW & SUPPORT ASSY	NO	MD80	2220	Disposition: Returned to buyer.
16549	3/19/98	DERLAN	5910962-71	5914168-505	SCREW & SUPPORT ASSY	YES	MD80	2239	Request that the 0.003- 0.007 case depth per blue print note 20 be changed to 0.003 - 0.010 case depth. Disposition: Acceptable.
16949	9/17/98	DERLAN	5910962-71	5914405-501	SCREW &	NO	MD80	2254	Request using certs showing spec QQ-C-390B, C95500 type II HT.

					SUPPORT ASSY				Disposition: VIR not required.
VIR Number	**VIR Date**	**SUPPLIER**	**PART #**	**DETAIL P/N**	**PART NAME**	**DWG CHG**	**MODEL**	**1st FSN**	**COMMENTS**
OM80359	6/24/91	PEACOCK	5914169-1/-501/-503/-505	N/A	SUPPORT	YES	DC9	N/A	Request substitution of the following material: From Al plate 2024-T351 per QQ-A-355 To Al plate 2024-T351 per QQ-A-250/4 for all part numbers: 3914162-1,501,503,505 Disposition: Acceptable.
OM80381	9/24/91	PEACOCK	5914169-503	N/A	SCREW, ACME	YES	DC9	N/A	Request dwg be revised to a case depth of 0.003 to 0.007 Disposition: Acceptable.
OM80533	10/2/92	PEACOCK	5940560-3	N/A	SCREW ASSY	NO	MD90	N/A	Supplier requests substitution of Nas6206-60 and alternate part NAS1306-58 Disposition: Acceptable for purchase order 2CB018584-9 for 5 pcs only.
61563	**4/11/73**	**PEACOCK**	**5914169-503**	**5914168-503**	**NUT ASSY**	**NO**	**DC9**	**N/A**	**Request permission to vibra-pencil S/N on the 1.625 dia of the jackscrew P/N 5914168-501 for in-process control during heat treat, glass bead cleaning and cad plate operations.** **Disposition: Approved.**
16950	9/28/98	DERLAN	3924229-1	N/A	SPLINE-DRIVE, ACME SCREW, SPHEROIDAL	UNK	MD90	UNK	Request permission to replace bar, steel, 4340, per DMS 1555, hot rolled & annealed with bar, steel, 4340 per AMS 6415 1.75” dia Disposition: Approved.

Changes are "highlited"

HORIZONTAL STABILIZER
Jackscrew Assy History

4/26/2000

Effectivity	EWO WRO	5914169	Chg Ltr #	Serial'd Set 2919145	Chg Ltr #	Serial'd 5914168 Screw	Chg Ltr #	Serial'd 5914405 Nut	Chg Ltr #	Component	Variables	
DC-9		-1	new	-1	new	-1	new	-1	new	**Nut**	Material	Alum Bronze Centrifugal Casting per QQ-B-671, Typ 2, Cl 4, Cond HT TR
										Screw	Material	4140 Steel Bar, Hot Rolled/Normalized per Mil-S-5626, Cond D1
											Ht Tr	125,000 - 145,000 PSI
											Finish	8 Grind & Lap
											Length	22.806 / 22.786
DC-9, 717,MD80, MD-87, MD-90		-501	E #1	-501	A #1	-1		**-501**	**F # 1**	**Nut**	**Add stress relief radius in "stop" area**	
(All aircraft)	**SC 795**		11/66		9/66				9/66			
DC-9		-501		-501		-1	cde	-501		Screw	**Major Dia**	**1.7169 / 1.7149**
											Pitch Dia	**1.5698 / 1.5591**
											Minor Dia	**1.4353 / 1.4192**
DC-9	**95073**	-503	F#2	-503	C #3	**-501**	**H #1**	-501		**Screw**	Material	4140 Steel Bar, Hot Rolled/Normalized per Mil-S-5626, Cond D1
	4484		3/67		3/67		3/67			(wear rate)	**Ht Tr**	**180,000 - 200,000 PSI**
											Finish	**Grind 12 finish, Glass Bead 32 finish**
											Length	22.806 / 22.786
	SC 933									**Re-work -1**	**into -501**	**Rework -1 into -501 by Malcomize or reheat treat**
Standard for all aircraft created after this change						**-501**	**J**			Screw	**Major Dia**	**1.7769 / 1.7149**
							7/70				**Pitch Dia**	**1.5629 / 1.5591**
											Minor Dia	**1.4353 / 1.4192**
DC-9, B717	**94048**	-505	G	-505	D#5	**-503**	**K #3**	-501		**Screw**	Material	4140 Steel Bar, Hot Rolled/Normalized per Mil-S-5626, Cond D1
(637 & Subs(?))	**8646**		10/70		11/70		10/70			(wear rate)	**Ht Tr**	**160,000 -180,000 PSI**
	(SC 1849)											**Malcomize .003-.005 case depth, hardness Rockwell 15N-85 min.(250,000psi)**
											Finish	Grind 12 Finish, Glass Bead 32 finish
											Length	22.806 / 22.786
MD-80		-507	H #5	-507	E #6	**-505**	**M #4**	-501		**Screw**	Material	4140 Steel Bar, Hot Rolled/Normalized per Mil-S-5626, Cond D1
909 & Subs			5/78		5/78		5/78			(MD80 new)	Ht Tr	160,000 -180,000 PSI
												Malcomize .003-.005 case depth, hardness Rockwell 15N-85 min.
											Finish	Grind 12 Finish, Glass Bead 32 finish
											Length	**24.249 / 24.229**
MD-87		-509	J #6	-509	F #7	**-507**	**N #5**	-501		**Screw**	Material	4140 Steel Bar, Hot Rolled/Normalized per Mil-S-5626, Cond D1
1326 & Subs			4/85		4/85		4/85			(MD87 new)	Ht Tr	160,000 -180,000 PSI
												Malcomize .003-.005 case depth, hardness Rockwell 15N-85 min.
											Finish	Grind 12 Finish, Glass Bead 32 finish
											Length	**24.792 / 24.772**
MD-90		-511	K #7	-511	G #8	**-509**	**R #6**	-501		**Screw**	**Material**	**4340 Steel Bar per DMS 1555, Grade A, Normalized, Temperized, Cold Finished**
			2/92		2/92		8/91			(MD90 new)	**Ht Tr**	**260,000 - 280,000 PSI**
												"NO" Malcomize
											Finish	**Grind 12 finish**
											Length	**24.792 / 24.772**
DC-9, B717, MD80, MD87						-503,505,507	S	12/91		Screw		**Malcomize .003-.007 case depth, hardness Rockwell 15N-85 min.(250,000psi)**
MD-90						-509	U	6/97		Screw		**Glass Bead clean per DPS 9.05, 32 Finish after Glass Bead**
DC-9, B717, MD80, MD87						-503,505,507	W	6/98		Screw		**Malcomize .003-.010 case depth, hardness Rockwell 15N-85 min. (250,000psi)**