NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

September 24, 2001

MATERIALS LABORATORY FACTUAL REPORT Report No. 01-082

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. COMPONENTS EXAMINED

Horizontal Stabilizer Acme Nut Assembly (nut and screw only) p/n 5914169-505, s/n DCA110 from jackscrew assembly s/n DCA110 removed from Hawaiian Airlines, DC-9-51, N601AP fuselage 790, HWI a/c 59.

Horizontal Stabilizer Jackscrew Assembly (complete), p/n 5910962-35 CHG LTR AP, s/n DCA110 with Acme Nut assembly s/n D-3351 also removed from Hawaiian Airlines, DC-9-51, N601AP.

Horizontal stabilizer jackscrew assembly (complete) p/n 5940560-3 CHG LTR D ED 6, s/n DGA-0024, from a China Northern Airlines MD-90, fuselage no. 2143, s/n 53523. The unit contained Acme nut assembly D-3053.

Acme Nut (reported s/n 470) from Spirit Airlines removed from jackscrew assembly s/n DCA302.

C. INTRODUCTION

This report contains details of examinations of Acme nut assemblies and jackscrew assemblies from airplanes not involved in the subject accident. These components were brought to the attention of the Safety Board because of reported endplay amounts, as measured by operators in the field.

For the purposes of this report, a matched Acme screw and Acme nut along with the nut supports and fastening hardware constitutes an Acme nut assembly and will be referred to as such. A jackscrew assembly is the next higher assembly and contains the Acme nut assembly along with the torque tube, mechanical stops, gearbox support plates, and miscellaneous other hardware, but not the gearbox or motors. This entire assembly will be referred to as the jackscrew assembly in this report.

Because of the possible confusion between the initially received Hawaiian Acme nut assembly s/n DCA110 and the Hawaiian jackscrew assembly having the same serial number but received later, the following convention will be used in this report to distinguish among the various components.

Jackscrew assembly s/n DCA110 will refer to the assembly when the serial number of the Acme nut assembly associated with the jackscrew is unknown.

Jackscrew assembly s/n DCA110(a) will refer to the assembly when Acme nut assembly s/n DCA 110 is installed. An "(a)" will also be added after the serial number of this Acme nut assembly [s/n DCA110(a)] to further associate it with jackscrew assembly s/n DCA110(a)

Jackscrew assembly s/n DCA110(b) will refer to the assembly when Acme nut assembly s/n D-3351 is installed.

The following members of the Materials Group participated in examinations and measurements of Hawaiian Airlines Acme nut assembly s/n DCA110 from February 21 to 23, 2001; Joe Epperson (NTSB, Group Chairman), Dan Ho (Alaska Airlines), Terry Khaled (FAA) Joe Bracken (ALPA), Jim Dart (AMFA Alaska Airlines), and Tom Posten (Boeing, Long Beach).

The initial examination of jackscrew assembly s/n DCA110 occurred on June 12, 2001 and was witnessed by NTSB and FAA personnel only. Further examinations of the Acme nut and screw followed the components return from Trig Aerospace.

The China Northern jackscrew was examined June 4 to 7, 2001, by NTSB personnel only.

NTSB personnel examined the Spirit Airlines Acme nut during August 2001.

D. DETAILS OF THE EXAMINATION

Hawaiian Airlines

History Of Jackscrew Assembly S/N DCA110 and Related Aircraft

The following history of jackscrew assembly DCA110 and its related components and aircraft was compiled from several sources including airline records, Integrated Aerospace documents, FAA communications and in person documentation.

- February 25, 1967 — Integrated Aerospace records indicated that a jackscrew assembly (p/n 5910362-411) with serial number DCA110 was initially shipped to Douglas Aircraft along with 17 others. The original s/n of the Acme nut assembly is unknown.

- March 15, 1967 — Engineering Order "H" of Acme screw drawing 5914168, creates "Malcolmized" screws. Released with rework instructions to reharden or "Malcolmize" –1 screw to –501.
- December 3, 1977 — Original manufacture of N674MC, Fuselage 869.
- March 16, 1984 — Jackscrew assembly s/n DCA110 overhauled and installed on A/C N674MC at A/C total time of 24,878 hours. Serial number of Acme nut assembly associated with jackscrew assembly s/n DCA110 not known.
- July 29, 1988 — Hawaiian Airlines (HWI) acquires N674MC (HWI aircraft number 63) with jackscrew assembly DCA110 installed.
- January 1996 — During C-check of N674MC, jackscrew DCA110 reported endplay 0.035 inch, time unknown.
- September 1996 — D-check of N674MC unknown endplay and times.
- July 9, 1997 — Jackscrew assembly s/n DCA110 removed from N674MC after 17,544 hours on the aircraft because of excessive endplay (greater than 0.040 inch) at A/C total time of 42,442 hours. Serial number of Acme nut assembly associated with jackscrew assembly s/n DCA110 not known.
- September 10, 1997 — Jackscrew assembly DCA110, now referred to as s/n DCA110(a), overhauled by Derlan (Trig Aerospace) with Acme nut assembly s/n DCA110(a), released with endplay of 0.010 inch, shipped to HWI.
- June 22, 1998 — During C-check, HWI installs jackscrew assembly DCA110(a) on N601AP, fuselage 790 (HWI a/c 59). Aircraft total time 43,417 hours and 61,240 cycles. Replaces jackscrew assembly "0110", due to "zero" endplay. Trig Aerospace measures 0.031 inch endplay on "0110".
- April 3 1999 — Acme nut assembly D-3351 (manufactured 1998) delivered new to Boeing with an initial endplay of 0.006 inch.
- December 4, 1999 — During C-check, "Grit blast" found in vertical fin and removed from N601AP.
- February 2000 — During same C-check, no shavings were detected during the AD mandated visual inspection of jackscrew DCA110(a) in N601AP.
- February 17, 2000 — While on N601AP, Acme nut assembly s/n DCA110(a) removed from jackscrew assembly s/n DCA110(a) because of excessive endplay, measured as 0.043 inch. Jackscrew assembly s/n

DCA110(a) had accumulated 2,582 hours and 6,377 cycles since installed on N601AP.

- February 20, 2000 — Jackscrew assembly DCA110, now referred to as s/n DCA110(b), reassembled with new (from Boeing) Acme nut assembly s/n D-3351. Aircraft total time 46,009 hours 67,650 cycles.
- March 1, 2000 — DCA110(a) Acme nut assembly scraped by Trig during overhaul due to excessive endplay, 0.048 inch, forwarded to NTSB.
- January 22, 2001 — N601AP with DCA110(b) visually inspected by NTSB. Grease samples removed from vertical fin.
- February 2001 — N601AP with DCA110(b) endplay check measured 0.025 inch at aircraft time of 47,988 hours.
- June 18, 2001 — Jackscrew assembly s/n DCA110(b), with Acme nut D-3351, was removed from N601AP because of excessive endplay (0.036 inch) after 2,514 hours and 6,071 cycles. Replaced with jackscrew assembly s/n DCA987 containing Acme nut assembly P-1065, initial endplay 0.008 inches. Aircraft time 48,514 hours and 73,696 cycles.
- August 2001 — N601AP with jackscrew assembly s/n DCA987, visually inspected by NTSB along with N662HA and N709HA. Grease samples removed from all aircraft.

Examination of Acme Nut Assembly DCA110(a)

As shown in figure 1, only the Acme screw and Acme nut were received from jackscrew assembly s/n DCA110(a). An attached Integrated Aerospace tag indicated the components as a p/n 5914169-505 Acme nut assembly. In addition to the screw and nut, 8 grease samples, 7 swab samples and a small quantity of glass bead blasting media were received[1]. Two additional grease samples were removed from the internal counter bore area of the Acme nut grease-fitting passageway after disassembly in the Materials laboratory, see figure 2. (See Hawaiian Grease Section below for details)

Assembly

Because the entire jackscrew assembly was not received, endplay measurements on the nut assembly were performed using hand pressure. These measurements averaged 0.040 inches. The assembly was then taken apart and the individual components inspected as detailed below.

[1] Grease samples removed from N601AP on January 22, 2001, by NTSB personnel.

Screw

The screw was marked in the cadmium-plated area above the upper stop splines with the following annotations.

5914168-5?? (remaining dash numbers not legible)
MFR O (remainder not legible)
SEP-(remainder of date not legible)
S/N DCA110
EP 010
Serial number DCA-110 was also found in another nearby location.

Following disassembly and cleaning, several dimensional measurements were performed on the Acme screw. These measurements are listed in the Table A below. Prior to receipt of the screw in the Materials Lab, Integrated Aerospace also made several measurements of the screw in preparation for overhaul. Where available, the Integrated measurements are also presented in Table A.

The central portion of the Acme screw had visible wear steps in both the upper and lower flanks of the threads. The step in the upper flank (normal screw pressure face) had a measurable depth over a length of about 15.5 inches in the central region of the thread (between 2.5 and 18 inches from the top thread). At it's maximum, the step was 0.0068 inch deep below the projected original surface of the thread. Figure 3 shows two views of the screw and the wear step in the upper flank. Figure 4 shows a typical wear step in the upper thread flank as seen on an optical comparator. On the lower flank the step was visible and measurable between 7 and 14 inches from the top thread and had a maximum depth of 0.0029 inch. The depth of wear on the thread flanks was measured with an optical comparator.

A longitudinal microsection was later cut through the heavily worn area near the center of the screw. Figure 5 shows a thread tooth profile showing the wear step.

The major diameter surfaces of the screw threads also displayed circumferential wear that removed the black oxide and grit blasted surface finish around the major diameter surfaces in the central region of the threads. The finish was completely removed on the thread diameters located between 6 and 18 inches from the top thread. Partial removal of the finish extended slightly above and below this area.

Except for the above noted wear, no other mechanical or corrosion damage was noted on the Acme screw.

The upper portion of the Acme screw (in the plated region) was marked with part number 5914168-5__ (dash number partially illegible). The length of the threaded area was consistent with either a –1, a –501 or a –503 screw. The engineering drawing indicates that -1 and –501 screws are through hardened to ultimate strength levels of 125 to 145 KSI and 180 to 200 KSI respectively. The –503 screw along with the longer –505 and –507 screws are to be nitrided (Malcolmized) with a minimum specified surface hardness of 15N-85.

Superficial hardness indentations performed on the major diameters of the threads varied between 78 and 83 on the 15N superficial scale and did not meet the minimum drawing requirement of 15N-85 minimum for the nitrided screws (-503, -505, -507). Direct HRC scale indentations both in the threaded and nonthreaded areas averaged 40 HRC (182 KSI) and meet the core strength requirements for either –501 (180-200 KSI) or –503 (160 to 180 KSI) screws.

Longitudinal microsections were cut from the worn central portion of the threads and from the lower unworn threads. Extensive microhardness[2] traverses on the unworn section did not indicate the presence of a nitrided case on the screw. The hardness traverses indicated an average hardness of about 42 HRC, which is approximately equivalent to an ultimate strength of 195 KSI consistent with a –501 screw.

Etching the sections with 2% Nital[3] revealed a tempered martensite microstructure consistent with a quench and tempered steel but no indications of nitrided case on the threads.

The engineering order (drawing change letter “H”) that created the –501 screw configuration was issued March 15, 1967, almost one month after the initial delivery of jackscrew assembly DCA110 to Boeing (Douglas at the time). The stated reason for the change was “to provide increased service life for horiz(ontal) stab(ilizer) jackscrew”. The engineering order (EO) also provided rework instructions to convert a –1 screw to a –501 screw. The EO allowed rework by either through hardening (re-heat treating) the screw to 180 to 200 KSI or by nitriding the threads. The EO also instructed that the “marked”[4] thread was to be identified by an additional chamfer at the end of the threads. On the –1 screws the “marked” thread was identified by a punch mark in the outer diameter of the screw, this type of marking was expressly forbidden by note **III** in the EO. On screw DCA110(a) the “marked” thread was identified by the additional chamfer. In addition, there were blended areas in the locations noted for the punch marks for a –1 screw.

Acme Nut

Serial number “DCA110” and an initial endplay reading of “0.010” were visible on exterior of the nut along with the basic nut part number “5914405-50?H”. Markings also indicated that the nut was manufactured on January 14, 1997. However, the assembly part number and manufacturing date of the assembly were not legible.

Initial examinations of the nut showed that both flanks of the nut threads were lustrous with circumferential marks consistent with wear (see figure 6). The major diameter of the threads (root area) was also worn and lustrous. The widths of the thread crests (minor diameter) appeared to be significantly reduced from as-new dimensions but for the

[2] Knoop hardness indenter with a 500 kg load.
[3] 2% concentrated nitric acid in alcohol.
[4] Because the threads on the screw have two individual threads one is “marked” to provide a reference orientation with a matching “marked” thread on the nut during assembly.

most part retained their original machined and grit blasted appearance. The edges of the thread flanks at the thread crests were sharp with no significant burrs visible on any of the threads. Figure 7 is an as-received view showing the wear on the lower flank and major diameter surfaces of threads near the bottom of the nut.

To further examine the threads, the Acme nut was longitudinally sectioned into two halves. A smaller, approximately 0.25 inch wide longitudinal section was then removed from one of the halves. The sectioning was performed with a wire electrical discharge machine[5] (EDM) that, unfortunately, caused corrosion and pitting to the surfaces of the nut due to abnormal cutting conditions during the 6 hours of cutting time. The previously bright and lustrous surfaces were also tarnished and darkened. During further examinations, the corrosion pits were readily visible at low magnification as shown in figure 8. At high magnifications a light surface film was also present. Energy dispersive x-ray spectrographic analysis (EDS) indicated a high oxygen content in the film.

Scanning electron microscope (SEM) examinations of the nut thread surfaces uncovered a fine pattern of parallel scratches on both the upper and lower thread flank surfaces, as shown in figure 8. The parallel scratch pattern ran circumferentially around the thread flanks. The transitions from the thread flanks to the crests were sharp lines with no indications of material flow or the formation of burrs, as shown in figure 9 and the upper view of figure 10.

As a comparison, a section was saw cut from Acme nut D-3145[6] and examined both visually and with a SEM. Macroscopically, the thread appearance of this nut appeared typical of others examined at the NTSB materials laboratory and reported in Materials Laboratory Factual Report No. 00-146. Even at low magnifications, raised burrs were visually apparent at the intersections of the lower thread flanks and the crests, compare burrs on the upper and lower views of figure 10. Figure 11 shows two views of typical burrs seen during SEM examination of the section from D-3145.

The thread crest widths of DCA110(a) were measured on one of the nut halves using a computer assisted optical measurement system. The range and average width results are presented in Table A and are also shown graphically along with those from Acme nuts D-3351 (DCA110(b)) and 470 (DCA302, Spirit Airlines) in figure 27.

Close examination of the thread roots and flanks of Acme nut DCA110(a) showed that the lower root radius area of the threads had taken the shape of the chamfer on the crest of the screw thread (see upper view of figure 10). In comparison, the upper root radius was very small consistent with original manufacture (see upper view of figure 10). This was also evident on D-3145, lower view of figure 10, and on others reported in 00-146.

[5] Machining process that cuts metal using controlled spark discharges between the work piece and a moving brass wire. The work piece is submerged in water during the cut.
[6] Previously installed in jackscrew assembly DCA3000 removed from N982AS. Condition reported in Materials report 00-146.

The major diameter surfaces of Acme nut s/n DCA110(a) also showed heavy localized wear that enlarged the diameter in some areas of the nut. Close inspection found that the wear was nonuniform both in the circumferential and vertical directions. As seen on the transverse cut surfaces of the nut, the heaviest wear and enlargement of the major diameter occurred in the upper right quadrant of the nut. Wear on the major diameter was also present but to a lesser extent in the lower left quadrant. The major diameter was not significantly worn diametrically opposite these locations. Figure 12 shows profiles of the major diameter and adjacent thread surfaces at the cut surfaces near the four lateral corners of the nut. The wear had removed approximately 0.009 inches of material from the major diameter at the upper right cut surface and about 0.001 inch from the lower left portion of the nut. The major diameter wear patterns are consistent with an angular misalignment of the screw axis to the nut axis with the upper end of the screw relatively displaced to the right and the lower end to the left. The transitions (transition ramps) from the original major diameters to the worn diameters were at angles to the nut axis indicating that the angular misalignment had increased with nut wear (endplay). For comparison, the approximate original shape of the thread is shown in the upper left quadrant view of figure 12.

The two views in figure 13 show cross sections of the nut and screw mated together as if installed. The mated sections show the corresponding nature of the previously noted wear areas on each component and also the internal clearances at this stage of wear.

Table A	**Measurement Results**		
Measurement	Drawing Requirement	NTSB	Integrated
SCREW			
Thread Straightness	0.005 inch max	0.002 inch max	0.002 inch
Counterbore Runout	0.005 inch max	**0.008** inch max	**0.011** inch
Major Diameter	1.7149-1.7169 inch	**1.71307**-1.71571 inch min-max	
Pitch Diameter	1.5591-1.5629 inch	Not measured	
SCREW (cont)			
Minor Diameter	1.4192-1.4353 inch	1.42067-1.42504 inch min-max	
Surface Finish	32 RA max	**66.5 RA** Average of 5 readings	**44 RA**
Pitch	4 tpi 0.250 inch Nominal	.2490-.2500 inch unworn areas	
Wear Step	Upper Flank inch	0.0068 inch max	0.005 inch
Wear Step	Lower Flank inch	0.00295 inch max	
Nitrided Screw Surface Hardness	85 min HR15N	**78-83** HR15N	
Core Hardness	36-40 HRC (160-180 Ksi)	40.8 HRC avg	

Table A	**Measurement Results**		
Measurement	Drawing Requirement	NTSB	Integrated
NUT			
Hardness	93 HRB min	96.3 HRB avg	
Thread Crest Width	0.0927 inch Nominal	0.06020-0.06697 inch min-max 0.06426 inch avg 0.0020 inch Std Deviation	
ASSEMBLY			
Endplay	0.040 inch max (service limit)	0.040 inch	**0.048** inch
		Out of limits values are bolded.	

Examination of Jackscrew Assembly DCA110(b) with Acme Nut Assembly D-3351

As received the jackscrew assembly s/n DCA110(b) (figure 14) was very clean with no indications of lubrication except at the thread interface between the Acme nut and screw. The screw was reportedly solvent cleaned by Hawaiian Airlines prior to shipment. However, Hawaiian Airlines reportedly took grease samples prior to cleaning and shipment (see Hawaiian Grease Section below for details).

The jackscrew assembly was marked with a Derlan tag attached to the gearbox support plate identifying the assembly as p/n 5910962-35 CHG LTR AP, serial number DCA110. Few other markings were found on the assembly components but the following was found on the Acme nut and screw. This assembly is referred to as jackscrew assembly DCA110(b).

Screw
P/N 5914169-505W
S/N D-3351
OCT 29, 1998
EP .006

Nut
5914169-505
S/N D-33?? (Last digits illegible)
EP .006

During initial examinations of jackscrew assembly DCA110(b) it was also noted that the upper lug surface of the lower mechanical stop appeared to have been filed and the primer removed. An impression was apparent on the head of the lower stop bolt on the

Acme nut and the cadmium plating was missing from the adjacent surface of the nut. The shape of the impression on the lower stop bolt matches the overall shape and orientation of the stop bolt installed in the lower mechanical stop. Also, the upper mechanical stop had areas where the primer was missing and the stop scratched. See figure 15 for photographs of the damage areas. The torque tube nut safety wire had been cut, and only a small piece of the wire was received attached to the lower mechanical stop clamp bolt.

As received, the screw and nut appeared undamaged and no metal slivers were visible. Polishing was noted on the upper thread flanks and major diameter in the central portion of the screw. No noticeable steps in the thread flanks were apparent.

Acme screw / nut endplay measurements were performed with the assembly mounted to a fixture (see figure 14) and approximately 180 pounds applied in both directions to the nut. With the nut in the middle of the screw and the existing amounts of grease, the endplay consistently measured slightly greater than 0.028 inch. During the tests a noticeable snap or click movement of the nut was noted. Free play was not recorded.

After the endplay test, the torque tube nut, washer and lower mechanical stop were disassembled from the screw, and the Acme nut was unthreaded and internally inspected. Dark brown lubricant was readily apparent on the ID threads; however, it had a very liquid consistency. Grease was also found in the grease fitting counter bore. This had a much thicker consistency. Samples from the counter bore (sample 133) and the thread (swab sample 134) were removed for further examination by the Grease Working Group (see Hawaiian Grease Section below for details). Grease fittings from the gimbal ring and Acme nut were removed. Clean brownish red grease was apparent in both passageways.

The lower flanks of the Acme nut threads were worn with a circular pattern, and the shape of the screw thread major diameter chamfer was worn into the nut threads. A small continuous burr was present at the intersection between the lower thread flank and the thread crest (minor diameter) as shown in figure 16. The upper threads flanks also appeared slightly worn but no burr was present.

The Acme nut was rethreaded onto the screw, and the other removed components (bagged separately) along with the Acme nut assembly were forwarded to Integrated Aerospace for further examinations by the Systems Group. Following the System Group's teardown and examination of the assembly, the Acme nut was returned to the Materials Laboratory for further examinations.

The nut was longitudinally cut approximately along its transverse axis with a band saw. One side was then trimmed by wire EDM to produce a flat undisturbed profile of the threads.

Examinations of the profile and interior surfaces of the nut after sectioning found that all threads had a small burr extending from the lower thread flank into the minor diameter area. The burrs on all teeth projected less than 0.010 inch from the thread crests but every other thread profile exhibited a much smaller burr of less than 0.004 inch see

figure 17. In comparison the burr shown on Acme nut D-3145 in figure 10 measured 0.010 inch. Every other thread also showed an enlarged chamfer at the minor diameter intersection with the upper thread flank as shown in figure 18. The thread profiles with the enlarged chamfers correspond to the ones exhibiting the smaller burrs. The enlarged chamfer showed repetitive vertical marks consistent with tool chatter as shown in figure 18.

The as-manufactured major diameter surfaces of the nut displayed some localized contact damage but the diameter did not appear to have been enlarged at any location. Original manufacturing tooling marks were clearly evident over much of the major diameter. Consistent wear patterns in the thread flanks indicate that the major diameter clearance between the nut and screw were even from top to bottom with no indications of angular misalignment.

Measurements of the thread crest widths on the transverse profile averaged 0.0836 inch with very little deviation (standard deviation of 0.0008 inch). The thread crest measurement are show graphically in figure 27 along with those from DCA110(a) and DCA-302 (Spirit Airlines).

Hawaiian Grease Samples

Many grease samples were recovered from DCA110(a) and DCA110(b) and from N601AP between January and August 2001. These included samples from the vertical fin of N601AP removed on January 22, 2001. At this time DCA110(b) was installed. Samples were also removed from the grease fitting counterbore areas of DCA110(a) and DCA110(b) during disassembly in the Materials Laboratory and from an unknown exterior location[7] on DCA110(b). Several additional grease samples were removed during an on-site examination of N601AP during August 2001.

N601AP, January 2001 and DCA110(a) samples.

Acme nut assembly DCA110(a) was received along with eight samples of grease (99 thru 106[8])and seven swab samples (109 thru 115) removed from the vertical fin area of the aircraft. Also included was a sample of the glass beads used by Hawaiian Airlines reportedly for corrosion cleanup. A list of the as-received samples is presented in Table B below along with two additional samples, 107 and 108, that were removed from the grease fitting counterbore area of DCA110(a) during examinations in the Materials Laboratory. Sample 107 was the dark material removed from the counterbore of the grease fitting and sample 108 was the cleaner brownish red grease contained in the grease fitting passageway.

[7] A grease sample from the exterior of jackscrew assembly DCA110(b) was removed by Hawaiian Airlines following its removal from N601AP but prior to solvent cleaning. This sample was forwarded to Equilon for analysis. Subsequently, the Safety Board received the remaining portion of the sample from Shell. However, the original location on the jackscrew from which the sample was removed remains unknown.

[8] Sample number assigned by the Grease Working Group.

In conjunction with the Grease Group particles were extracted from portions of the grease and swab samples by dissolution in toluene and filtering through micron sized filter papers. Optical inspections were performed on the particle extractions and selected samples were further examined by scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS). Table B also provides a summary of the visual observations on each sample. At low magnifications each sample consisted of both larger individual particles and various amounts of fine particles (fines).

Of particular interest was the finding of many translucent pink particles visible in many of the extractions. Grease sample 103 contained a large number of the pink particles as shown in figure 19. The pink particles were fairly uniform in size and color and the majority had rounded edges. These appeared consistent with fine grains of a pink colored sand-like material. EDS chemically analyzed a selection of the pink particles from grease sample 103. Although some variations were apparent from grain to grain the overall compositions were mostly iron, silicon and aluminum with significant quantities of calcium, oxygen and magnesium, as shown by the EDS spectrum in figure 19. In sample 103, the sizes of the particle ranged from 266 microns to 751 microns with most in the 400-500 micron range. However, in other samples much smaller pieces of the pink sand were apparent.

Clear spherical beads were found in sample 108. These beads were very similar in size, shape, and color to a sample of glass beads reportedly used by Hawaiian to bean blast clean corrosion. EDS founds the beads in sample 108 to be composed predominately of silicon, oxygen and calcium and almost identical in peak heights and peak ratios to spectra acquired from a selection of the glass beads from Hawaiian Airline stock.

SEM samples were prepared of the fine material in sample 104 and 107. On sample 104, two types of particles were apparent during EDS analysis in the SEM. One type had a composition consistent with the pink sand grains analyzed from sample 103 (compare upper spectrum of figure 20 to spectrum in figure 19). The second type of particle was actually an agglomeration of much finer individual particles. Overall, these particles were copper based with the same elements as the base metal of the Acme nut (aluminum nickel bronze) with additional silicon, oxygen and calcium peaks, as shown in the lower spectrum in figure 20. Sample 107 was made up of very fine particles with an overall composition similar to the Acme nut base metal.

Table B	**Grease Samples, HWI January 2001**	
Grease Sample	**Location**	**Description**
99	Top layer of globule A, located 2 inches forward of the crease in the “hell hole”[9].	Heavy load of particles with a few large pink sand grains. The fines were gray / black with many fine shiny flakes.
100	Remains of globule A	Heavy load of particles with a few brass flakes. The fines were gray / black with many small brass

[9] The “hell hole” refers to the enclosed volume within the vertical fin immediately below the jackscrew. This volume is only accessible through small inspections covers on either side of the vertical fin.

Table B	Grease Samples, HWI January 2001	
Grease Sample	**Location**	**Description**
		particles.
101	Top layer of globule B, located about ½ inch aft of globule A.	Heavy load of particles with some large pink grains. Fines were white / gray.
102	Remains of globule B.	Heavy load of particles with some large pink grains and a few paint flakes. Fines were gray / white.
103	Remnants of all grease residues in crease of "hell hole".	Heavy load of particles with many large pink grains, some silver metallic flakes and some paint flakes. Fines were overall gray / black with a copper tint and very numerous multicolor particles. (SEM and EDS of pink particles)
104	Entire globule C located immediately above crease.	Very heavy load with many large rounded and smaller sharp pink grains with some brass flakes. Fines were brown with heavy copper tint containing small copper and glassy particles. (SEM and EDS of particles)
105	Entire globule D, located on web aft of crease, first stringer	Heavy load of particles with many large pink grains and some silver metallic slivers. Fines were gray / black
106	Entire globule E, on forward web, forward of crease	Light load with a few large pink particle and a few paint flakes. Fines were gray.
107	Removed from Grease fitting counterbore of Acme nut (Mat Lab).	Very heavy total load with larger brass flakes and some glassy particles. Fines were brass colored and numerous. (SEM and EDS of particles)
108	Sample removed from Grease fitting passageway of Acme nut cleaner grease than 9 (Mat Lab).	Heavy load with several large pink particles, 3 intact glass beads and a few metallic burrs some brass. Fines were gray and some very small pink particles. (EDS of glass beads)
Swabs		
109	Top portion of stringer located just above and aft of crease.	Heavy load with a few large and small pink particles some large paint flakes and a few large silver metallic particles. Fines were gray with many shiny metallic particles and a few copper clumps.
110	Top portion of 2nd stringer above and aft of crease	Light load with some large pink and black particles. Fine were shiny black with a few small pink particles.
111	Top portion of 2nd stringer above and aft of crease	Light load with a few pink and metallic particles. Fines were shiny black.
112	Top portion of stringer mounted along right side of "hell hole".	Light load with a few pink and metallic particles. Fines were shiny black.
113	Top portion of horizontal web immediately below bottom of jackscrew.	Light load with some small sharp pink particle, few metallic particles and a few paint flakes. Fines were gray / black with very small shiny particles
114	Top portion of ledge of right side access panel	Heavy load with large number of pink and clear particles and a few brass flakes.
115	Large grease globule from bottom of jackscrew.	Heavy load with a few large brass flakes. Fines were gray / black.

DCA110(b) Samples

During disassembly of jackscrew assembly DCA110(b), one grease sample (133) was removed from the grease fitting counterbore area and another swab sample was taken from the thread surfaces of the nut (134). Initial examination of the particle extractions from samples 133 and 134 found large amounts of very fine particulate with many shiny brass colored particles and a few larger brass flakes in both. An EDS spectrum acquired from a general area of the filtrate of sample 133 exhibited peaks consistent with the base metal of the nut and additional peaks for silicon, calcium and oxygen as shown in figure 21. The overall spectrum of the filtrate from sample 133 was very similar to that found for the second type of particle found in from sample 104 of nut assembly DCA110(a) (compare figure 21 to the lower spectrum in figure 20). The additional silicon, calcium and oxygen peaks were also constituents found in the pink sand particles and glass beads. Later analysis also found that silicon, calcium and oxygen were the main constituents left by particle extractions on virgin samples of Aeroshell 22 discussed below.

Extraction of particles from the grease sample (142) removed by Hawaiian Airlines from the exterior of DCA110(b) showed a heavy load of gray fines with many very small shiny brass colored flakes. In addition, many larger brass flakes were apparent, as were three small pink particles. A general area EDS spectrum of the fine material is shown in the upper view of figure 22 with elemental peaks consistent with the Acme nut base metal along with a large silicon peak and smaller calcium, oxygen and magnesium peaks. Spot EDS analysis of a pink particle found in sample 142 was also consistent with the pink particle analyzed in sample 103, see lower view of figure 22.

N601AP, August 2001 samples.

During another inspection of N607AP in August 2001, areas of the vertical fin were visually inspected and additional grease samples were taken. The visual inspections did not uncover visible pink particles in the “hell hole area” of the vertical fin as reported during the January 2001 inspection. However, small amounts of pink particles were found trapped in corrosion preventative compound on the upper surface of the vertical fin horizontal bulkhead located above the horizontal stabilizer and within the structure of the horizontal stabilizer.

As of the date of this report, particle extractions on the samples removed during August 2001 have not yet been performed. A virgin sample of Aeroshell 22 used by Hawaiian to lubricate jackscrews was also acquired. A particle extraction on a portion of the clean Aeroshell 22 resulted in a thick waxy film that mud cracked and turned white when dried, see upper view in figure 23. EDS spectra showed large elemental peaks for silicon, magnesium, calcium and oxygen and smaller peaks for other elements as displayed in figure 23.

During this inspection it was discovered that Hawaiian Airlines also used a garnet material[10] as blasting media for corrosion cleanup. Visual inspections found this material to be pink sand like material as shown in figure 24 and visually very similar to the previously noted pink sand found in grease sample 103 and others. EDS spectrum acquired from a sample of the garnet blasting material (lower view in figure 24) found elemental peaks and peak height ratios almost identical to that of the pink sand spectrum from sample 103 (figure 19).

China Northern Airline

Background

The jackscrew assembly, DGA-0024, was removed from the aircraft following an endplay measure on May 10, 2001 with a reported endplay of 0.10 inch. The identification tag on the received assembly indicated that the jackscrew was assembled on March 16, 1996. The assembly was reportedly installed new on aircraft fuselage number 2143 during the original manufacture of the aircraft, July 28, 1996 and had not been removed or overhauled since installation. As of the end of April 2001, the aircraft and jackscrew had accumulated 10,961 service hours and 5,929 cycles since new. The endplay of the jackscrew assembly had been previously checked March 6, 2000 at 7,740 service hours and September 25, 2000 at 9,390 hours and reported as 0.019 and 0.013 inch, respectively.

Examination

The complete as-removed jackscrew assembly was received on June 4, 2001 after being removed from the aircraft for reportedly high (0.10 inch) endplay measurements, see figure 25. Initial visual examinations found no visually apparent damage. No brass or other metal particles or flakes were noted anywhere on the assembly. The Acme screw showed localized polishing on the upper thread flanks in the central portion of the screw.

The following annotations were found on the various components of the assembly. All components except for the gimbal ring and the torque tube retaining nut contained manufacturing code OFPNO indicating manufacture by Derlan Inc, (now Integrated Aerospace Inc.).

Acme Screw
S/N in two nearby places D-3053 clear at one, D-305_ At another
EP 0.004
Partial part number __4168-509, FEB-09-199_

Acme Nut
No serial number visible

[10] Garnet is a naturally occurring mineral that among others is used as an abrasive or blasting material. At Hawaiian Airlines the material was contained in a bag that identified it as Australian Garnet 30-60 mesh from Barton Mining Company.

.00_
P/N 5941695_K, MAR-19?-199_

Upper support plate 5914180-3H, Jun-2-1995, s/n D-0015
Gearbox support plate 5914181-501F, AUG-17-1995, s/n D-0015
Lower support plate 5914182-1B, JUN-2-95, s/n D-0015
Upper stop 3914178?-30, FEB-5-19__
Lower stop 3927223-1M Rev c Jul-30-1994
Torque tube retaining nut MFG 38277 ASSY 3963290-1N? SEP-08-1995
Gimbal Ring Assembly 88277 Sub Assy
3914163-501HF Jan 30- 1996

Lubricating grease was apparent on the Acme screw and other components. In most instances the grease was dark colored consistent with being worked. However, fresh yellow tan grease was found filling the screw threads adjacent to the upper and lower mechanical stops. When the grease fitting for the gimbal ring and the Acme nut were removed, similar yellow tan grease was found inside the passageways. In addition, clumps of fresh red grease were found on the exterior surface of the gimbal ring. Samples of the grease were removed from several locations on the assembly and retained by the Grease Working Group for possible further analysis.

When turned by hand, the gimbal nut moved smoothly and freely but felt slightly stiff to rotate on the screw. No noticeable endplay was felt during these manipulations. However, with a dial position indicator was attached to the screw, relative longitudinal movement of about 0.025 inches was measured between the screw and nut.

Further tests of the Acme screw / nut endplay were performed with the assembly mounted to a fixture (see figure 25) and approximately 180 pounds applied in both directions to the nut. With the nut in the middle of the screw and the existing amounts of grease, the endplay measured at slightly greater than 0.024 inch and the free play measured less than 0.001 inch. A noticeable snap or click movement of the Acme nut was noted during load application. The Acme nut was then moved to the upper screw position and the grease was manually removed from the screw with cloths. It was again cleaned with the nut positioned at the lower end of the screw. With the Acme nut placed in the center of the “cleaned” screw, the endplay measured 0.033 inch. The snapping movement was again noted during load application.

The jackscrew assembly was forwarded to Integrated Aerospace on June 7, 2001 for further disassembly and inspection under the supervision of the Systems Working Group.

Spirit Airlines Nut

Background

Spirit Airlines removed jackscrew assembly s/n DCA-302 due to an excessive endplay measurement of 0.062 inch. At the time of removal, the aircraft had accumulated 60,738 hours and 52,470 cycles of service. Service time and cycles of the jackscrew assembly are not known. Following removal from the aircraft, the jackscrew assembly had been forwarded to Trig Aerospace (now Integrated Aerospace) for overhaul. Trig measured an as-received endplay of 0.062 inch during bench checks. Among other discrepant items, Trig reported that the screw contained steps in both the upper and lower thread flanks. Only the Acme nut, reported s/n 470, was forwarded to the Materials Lab for examination.

Examination

The Acme nut was received without supports as shown in figure 26 after sectioning. In contrast to most other received Acme nuts the exterior surfaces of the nut had a yellow gold coloration, consistent with a chromate conversion coat, except where the upper supports had been attached, see annotation in figure 26. In these areas, the surfaces had the appearance of cadmium plating consistent with engineering drawing specifications. The exterior of the nut contained vibro-peened markings 11788 and –51 but no other markings were visible.

The nut threads showed heavy wear from the lower flanks and some wear or contact patterns on the upper surfaces. Very small burrs were visible at the lower thread flank to minor diameter edges. The burrs were later measured to be 0.001 inches or less in height.

A thick dark grease sample was removed from the grease fitting counter bore revealing dark red in the fitting passageway. Dark red grease was also visible in the gimbal ring pin holes in the nut.

The Acme nut was split longitudinally as shown in figure 26 and one side wire EDM cut to expose an undisturbed profile of the threads. Examination of the profile showed a consistent wear pattern into the lower flanks of the threads with little or no indications of wear into the major diameter surfaces of the threads. The wear pattern was concentric and even from top to bottom.

The remaining thickness of the thread crests were measured from top to bottom and averaged 0.056 inches These are displayed in figure 27 along with similar measurements from DCA110(a) and DCA110(b).

Joe Epperson
Senior Metallurgist

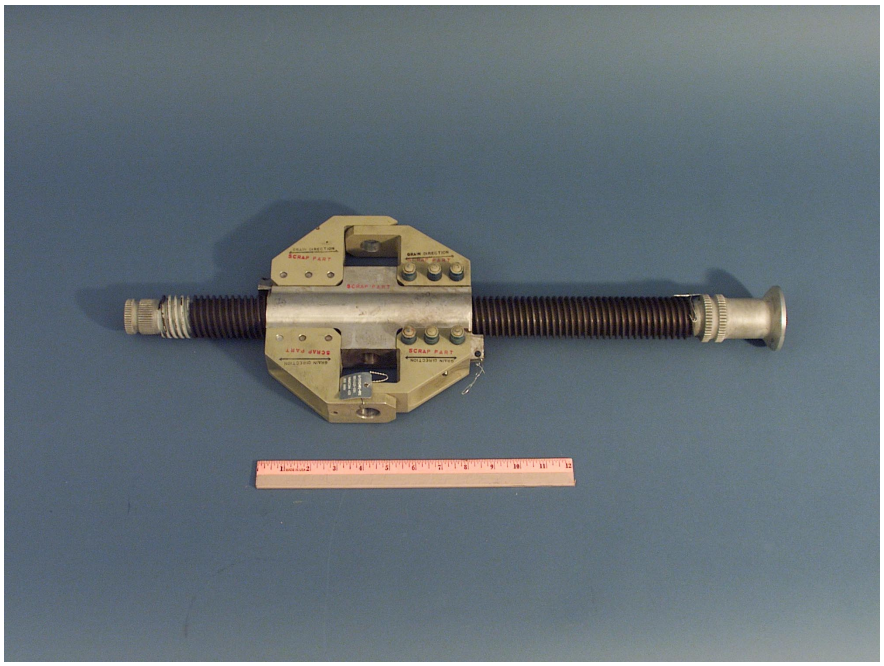


Figure 1--The as-received Acme nut asembly, s/n DCA110(a), from jackscrew assembly s/n DCA110.

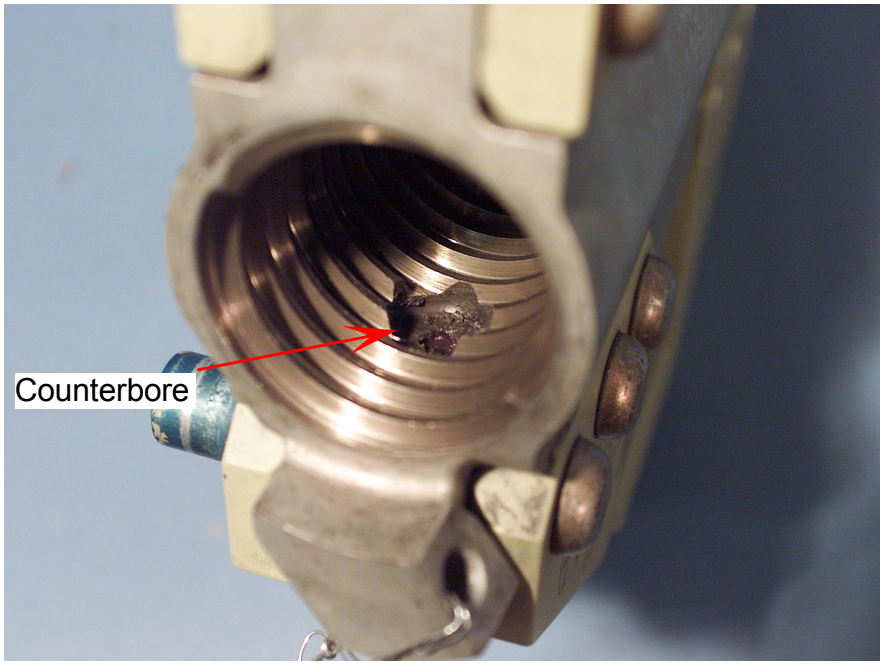
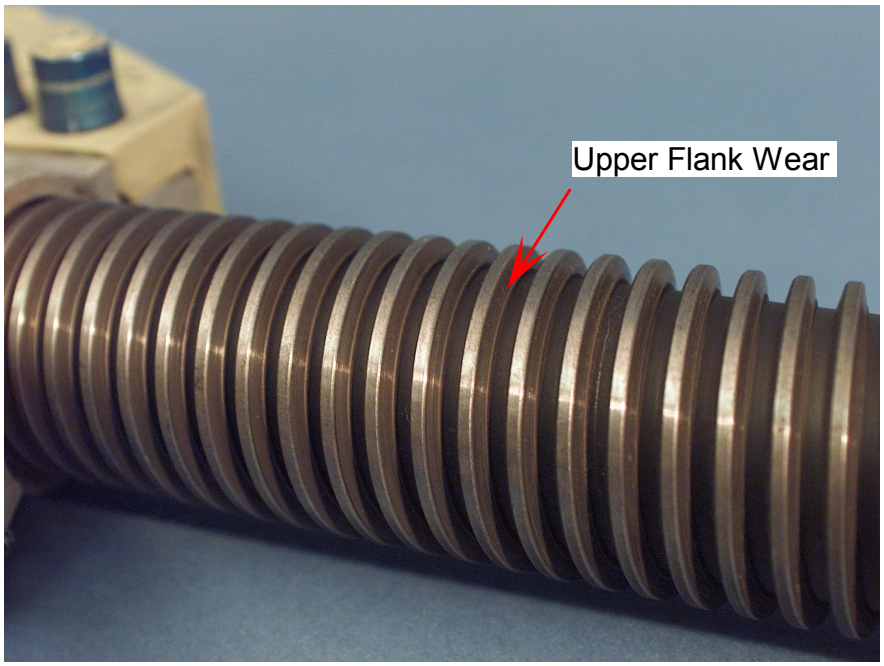


Figure 2--A view of the Acme nut grease fitting counterbore after additional samples were removed. (Nut s/n DCA110(a))



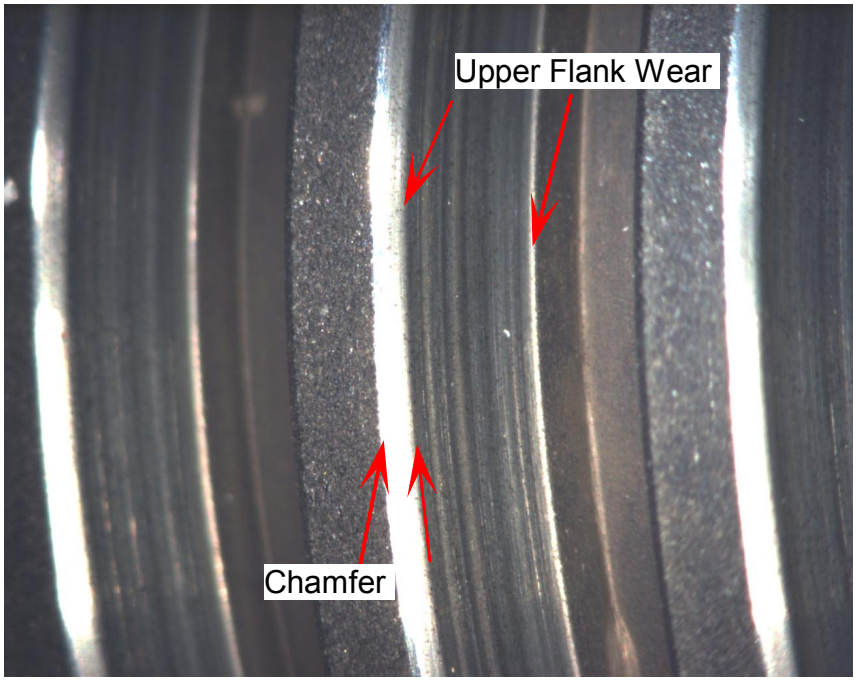


Figure 3--Two views of the wear step (shiny bands) in the upper flanks of the screw. (Screw s/n DCA110(a))

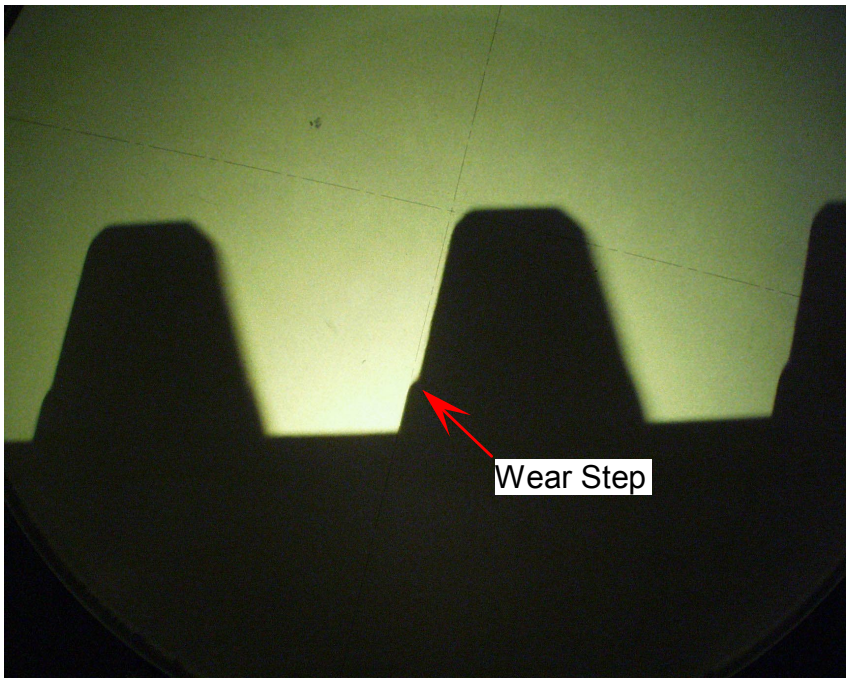


Figure 4--A optical comparator view of the step in the upper thread flank of the screw. Actual thread is dark. (Screw s/n DCA110(a))

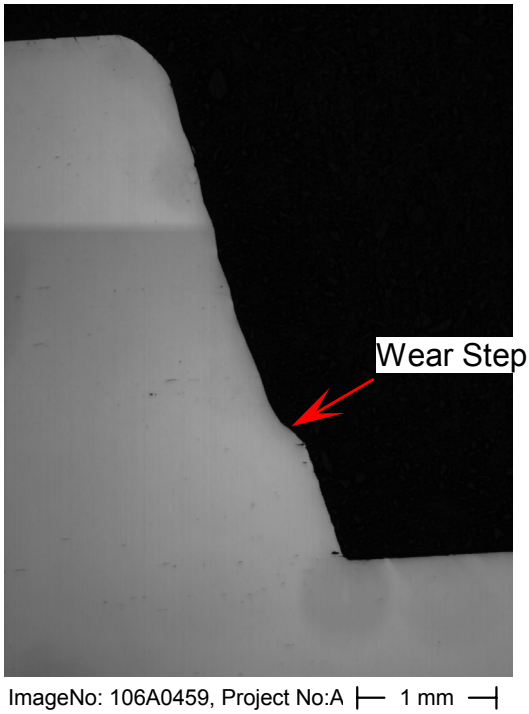


Figure 5--A montage of a section through one of the worn upper thread flanks. Actual thread is light-colored area at left. Mirror view of figure 4. (Screw s/n DCA110(a))

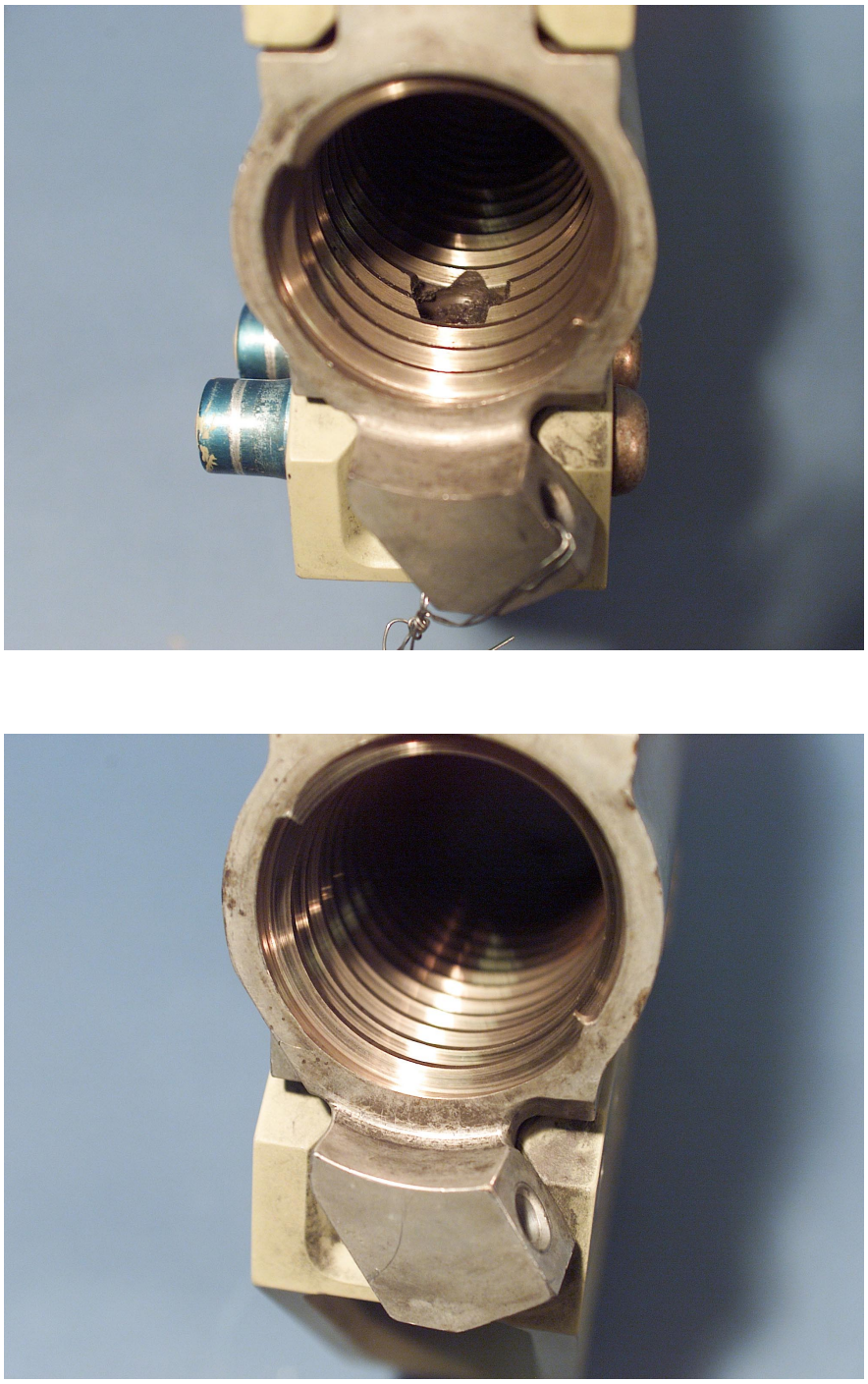


Figure 6--Top view looking at wear on the upper thread flanks of the Acme nut. Bottom view looking at wear on the lower flanks. (Nut s/n DCA110(a))

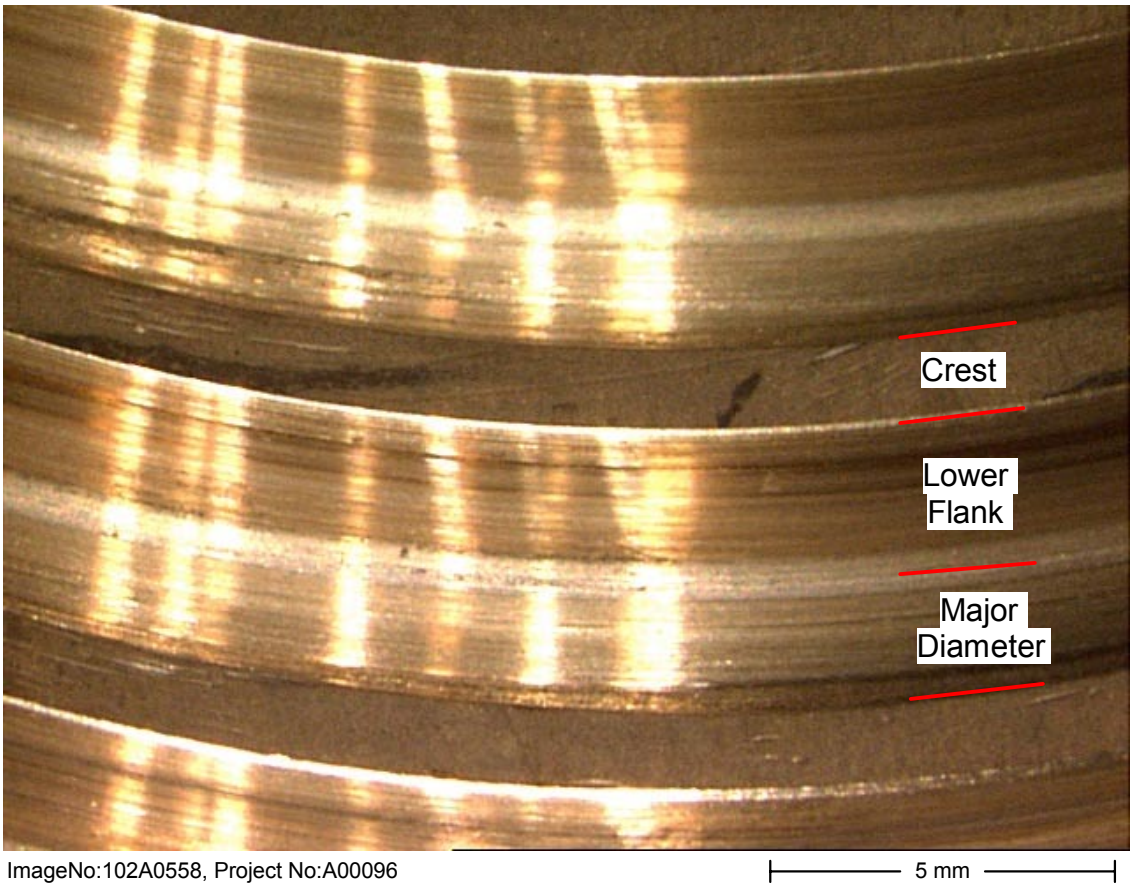


Figure 7--A closer view of the lower thread flanks of the Acme nut. Note the absence of a burr at the thread crest. The major areas of the thread are denoted at right. (Nut s/n DCA110(a))

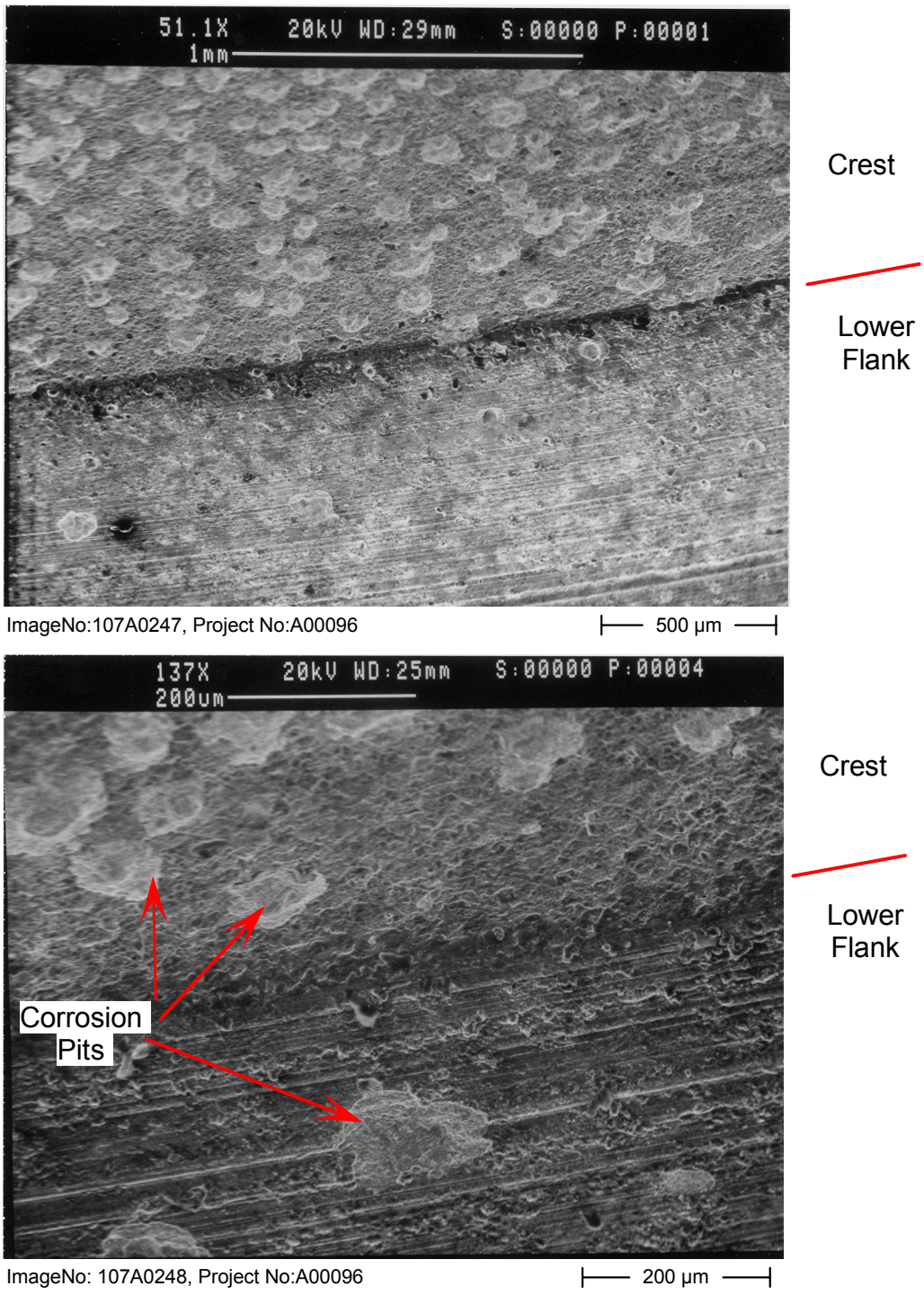


Figure 8--Two SEM views showing the pitting induced by EDM cutting and the lack of a burr at the lower thread flank to crest interface on the threads of nut DCA110(a).

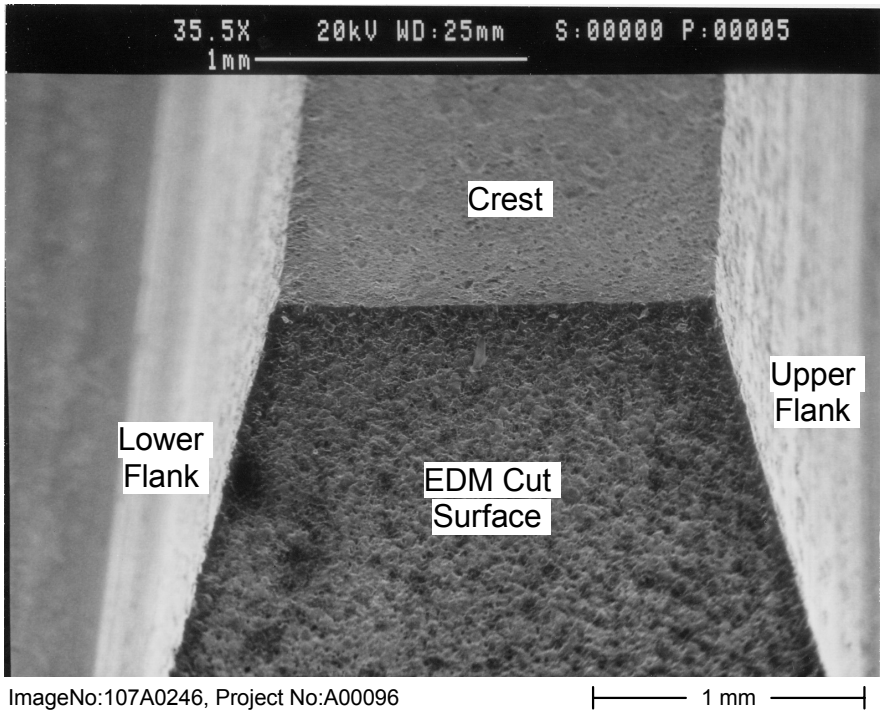


Figure 9--SEM profile view of a typical nut thread. Note the sharp corners at the crest to flank edges. Lower thread crest at left. (Nut s/n DCA110(a))

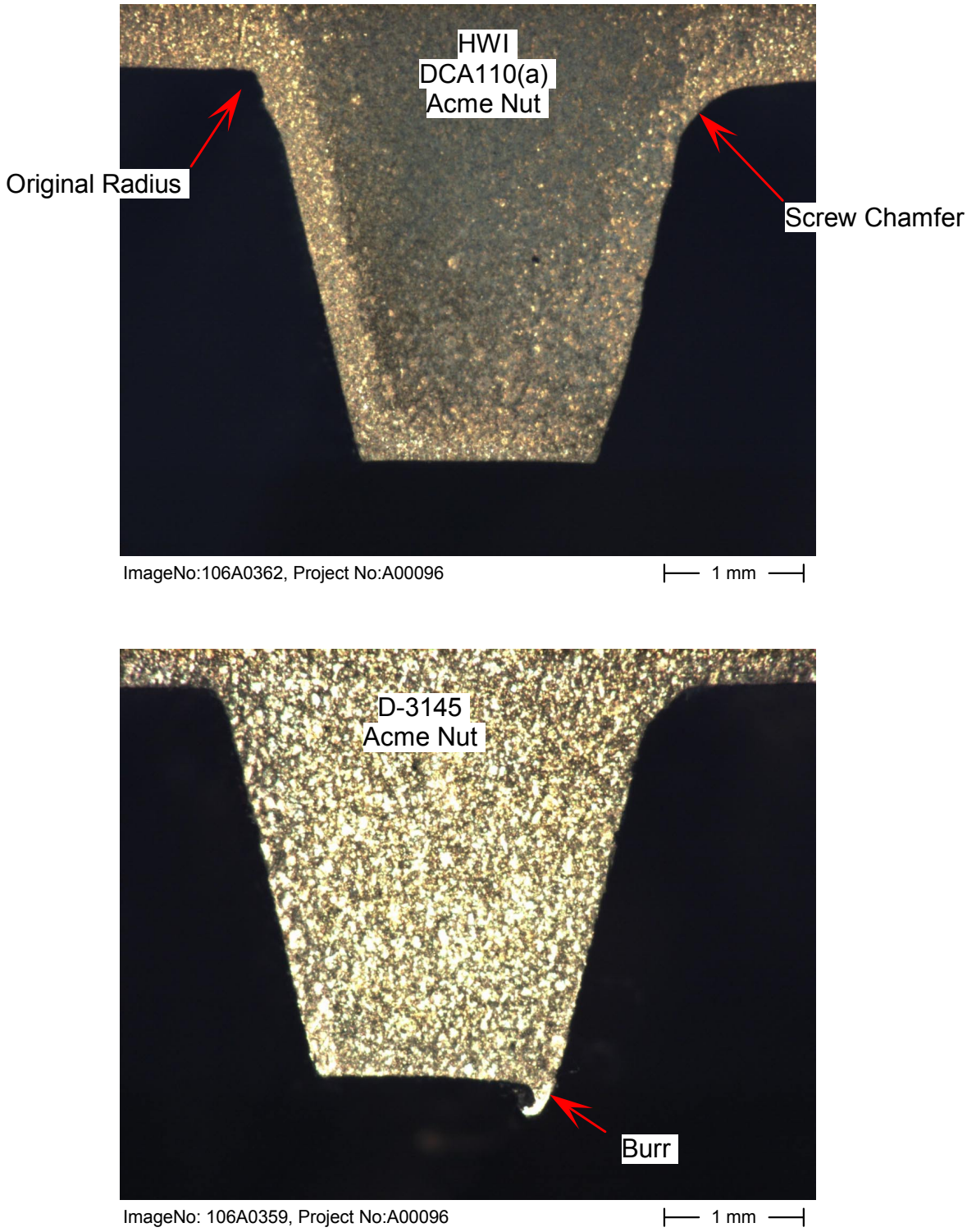
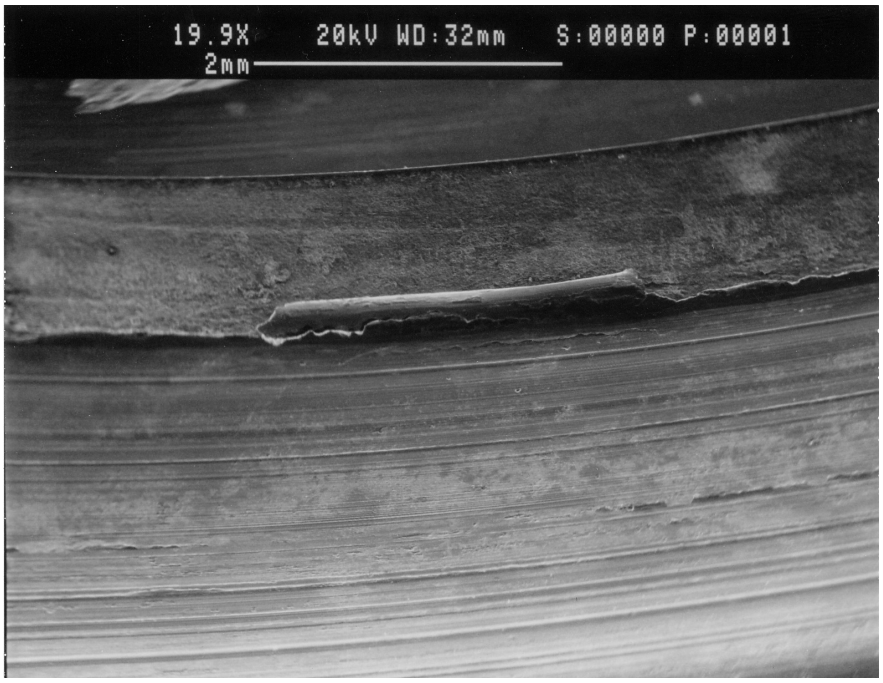


Figure 10--Two views showing the thread profiles from Acme nuts HWI DCA110(a) (top) and D-3145 (bottom). Note the prominent burr on the lower view at the lower thread flank to crest line.



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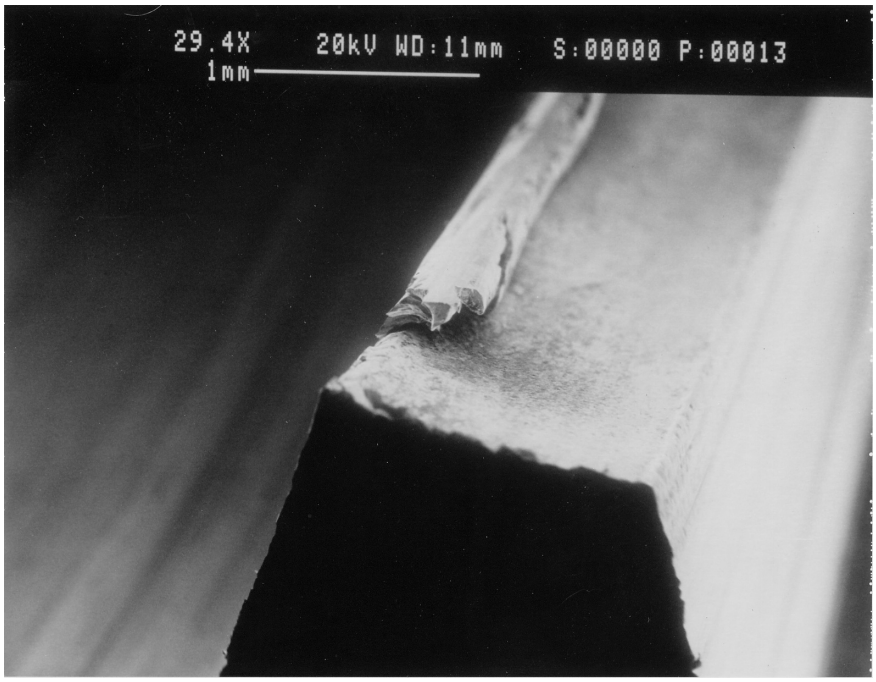

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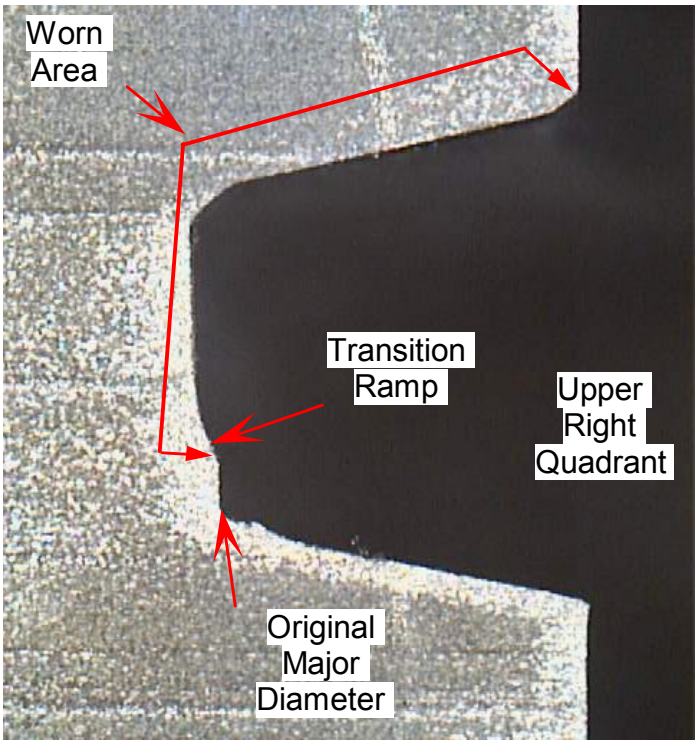
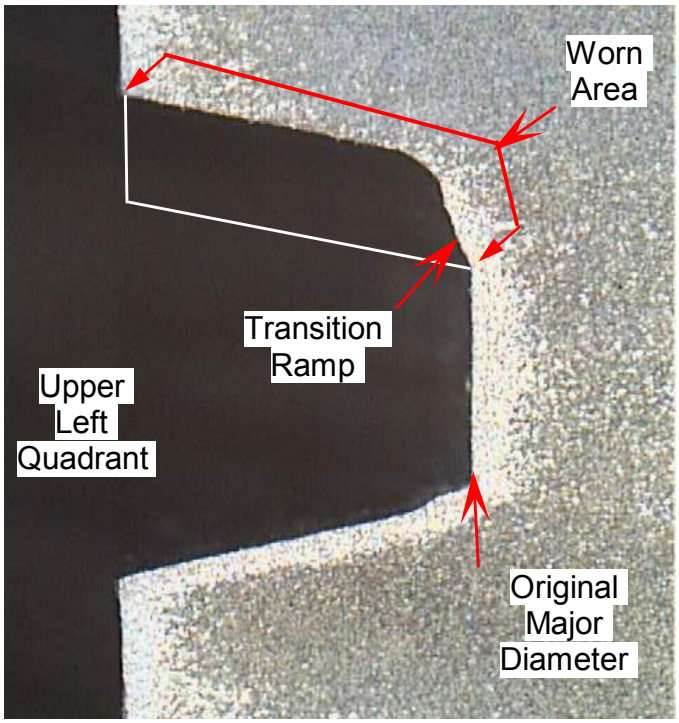
Figure 11--Two SEM views of typical burrs seen on Acme nut D-3145.





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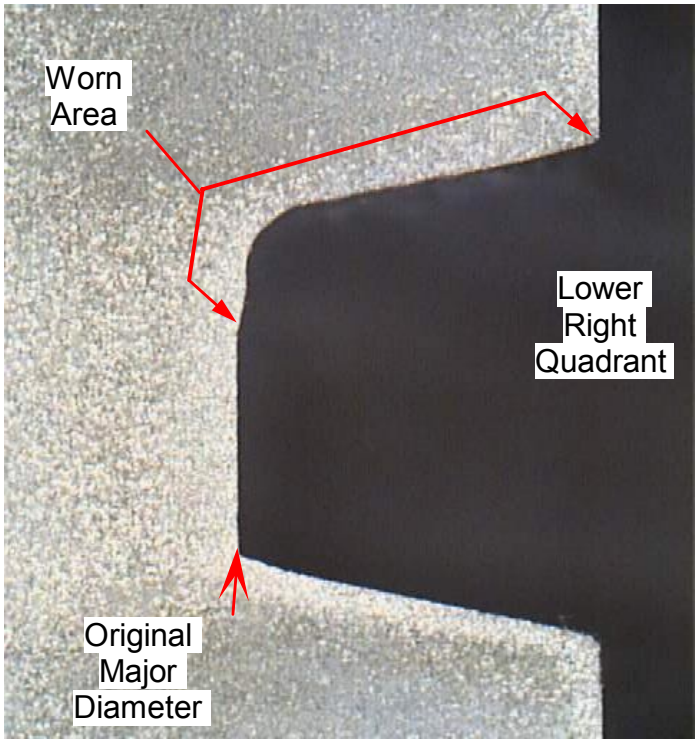

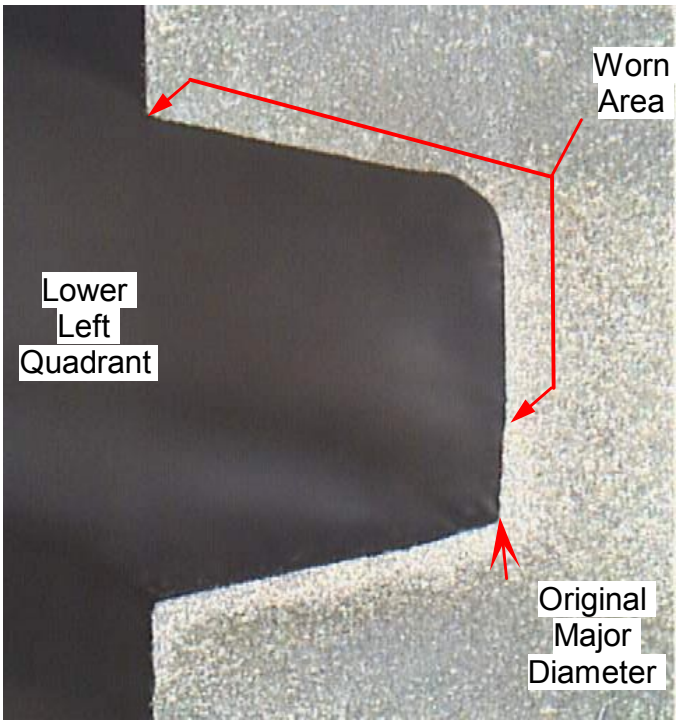

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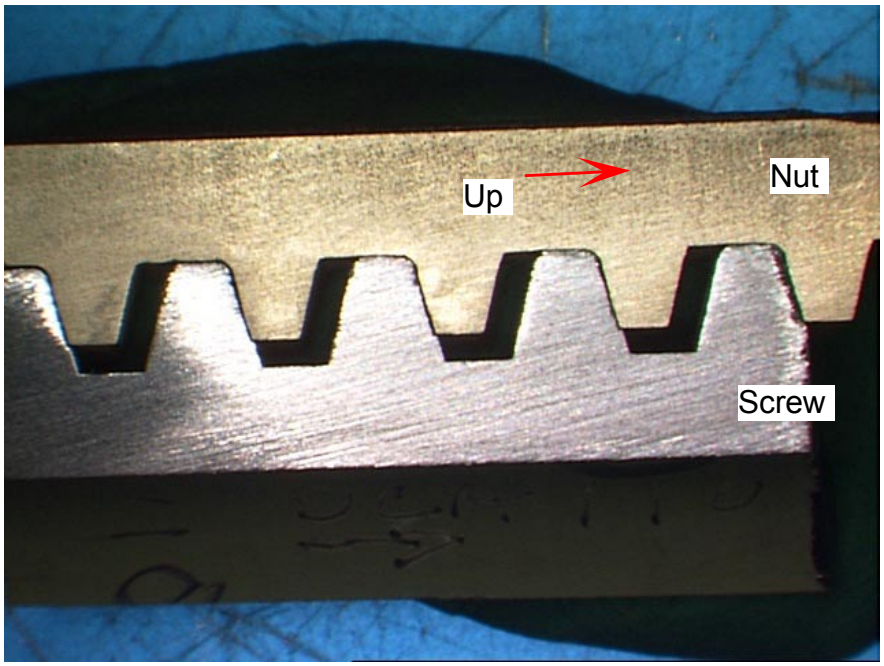
Figure 12--Four views showing the nonuniform wear of the major diameter on the Acme nut. Aircraft up is to the top of each view and each view is looking aft. Note the highly visible transition ramps in the upper views. The approximate original contour of the nut thread is depicted by the white line in the upper left quadrant view. (Nut DCA110(a))



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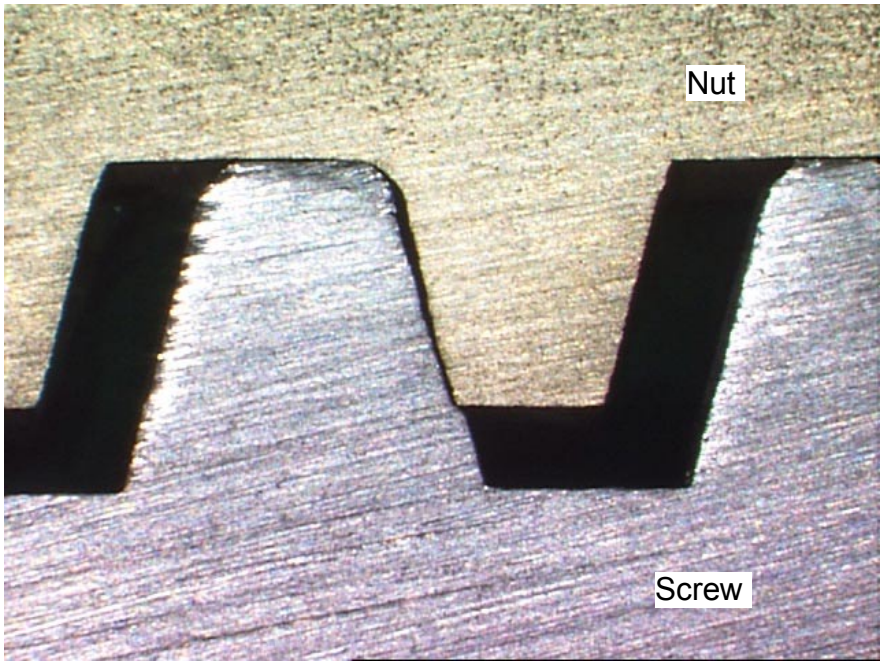


ImageNo: 106A0351, Project No:A00096 — 2 mm

Figure 13--Two views of sections cut from DCA110(a) screw (silver color) and nut (brass color) mated together as if in operation showing the corresponding nature of the wear. Aircraft up to the right.

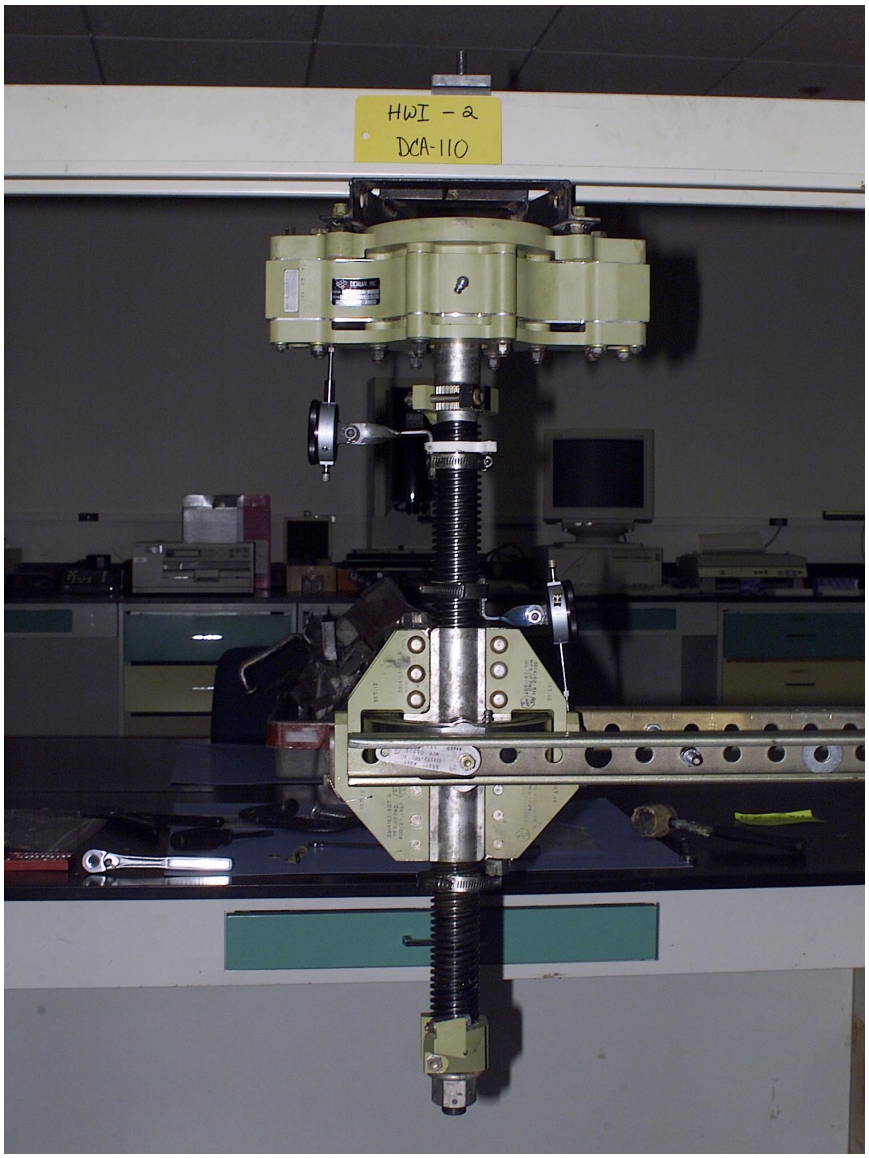


Figure 14--As-received jackscrew assembly DCA110(b) with Acme nut assembly D-3351 mounted in the endplay test fixture.

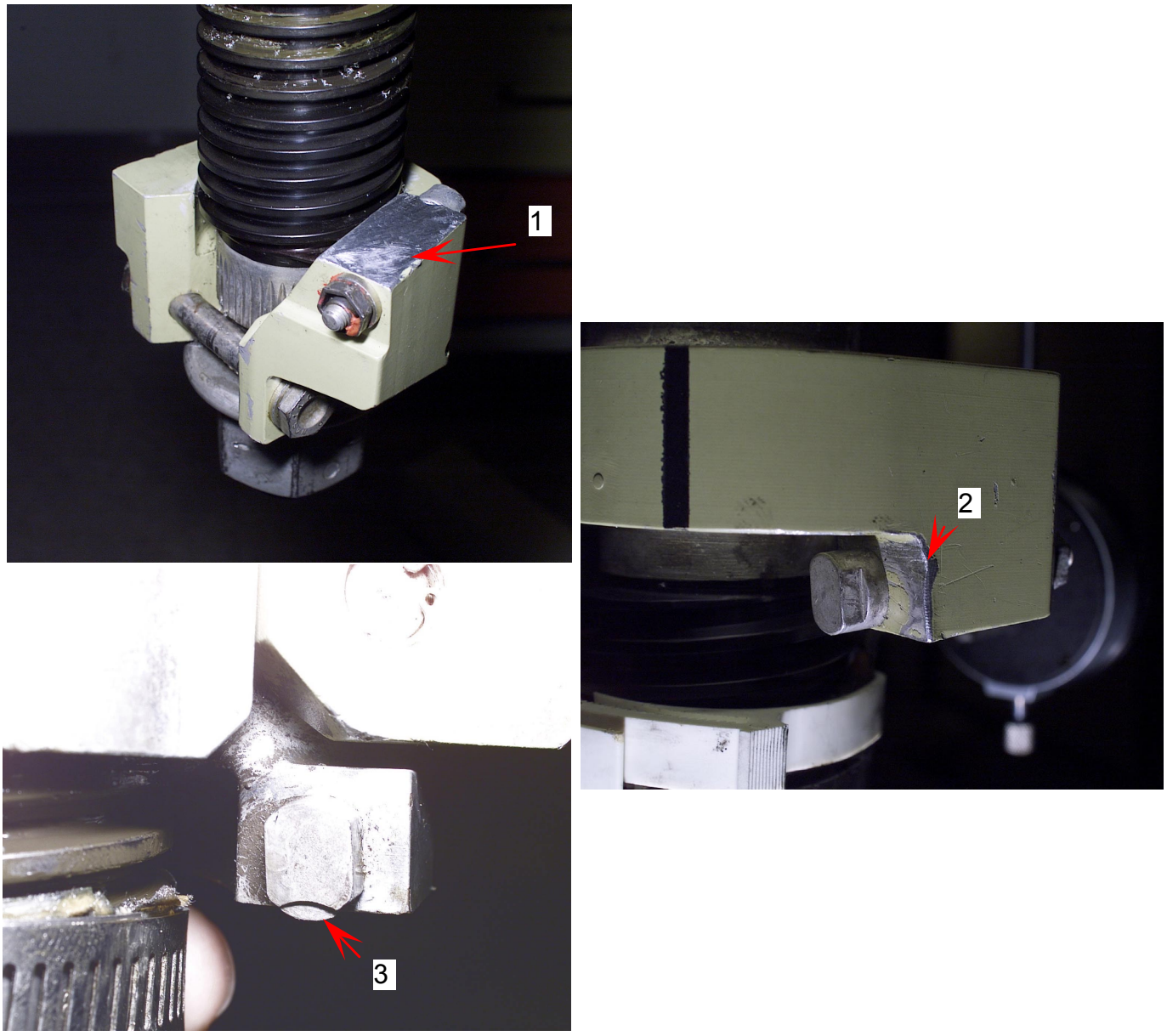


Figure 15--Three views, clockwise from upper left, showing the filing on the top of the lower mechanical stop lug, arrow 1, the missing primer from the upper mechanical stop, arrow 2 and the impression in the head of the acme nut lower stop bolt, arrow 3. (s/n DCA110(b))

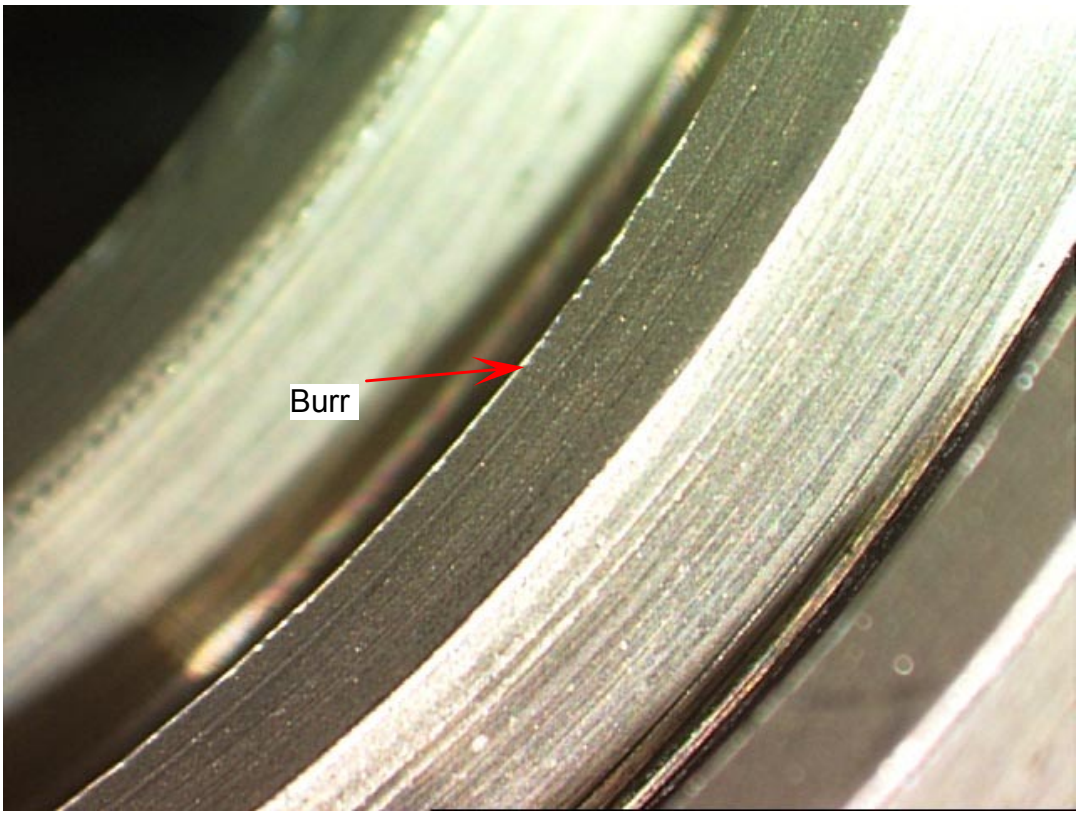
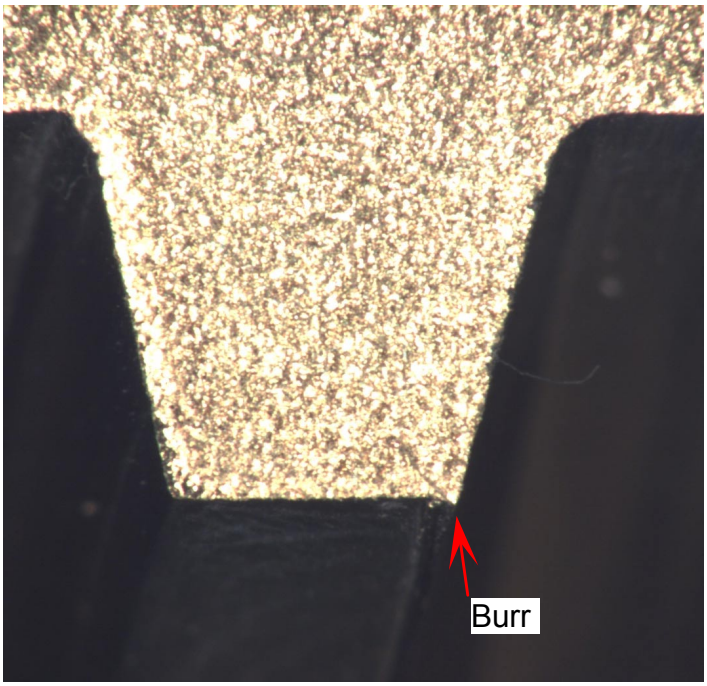


Figure 16--Looking into the interior of Acme nut D-3351 showing the burr at the minor diameter of the lower thread flank.



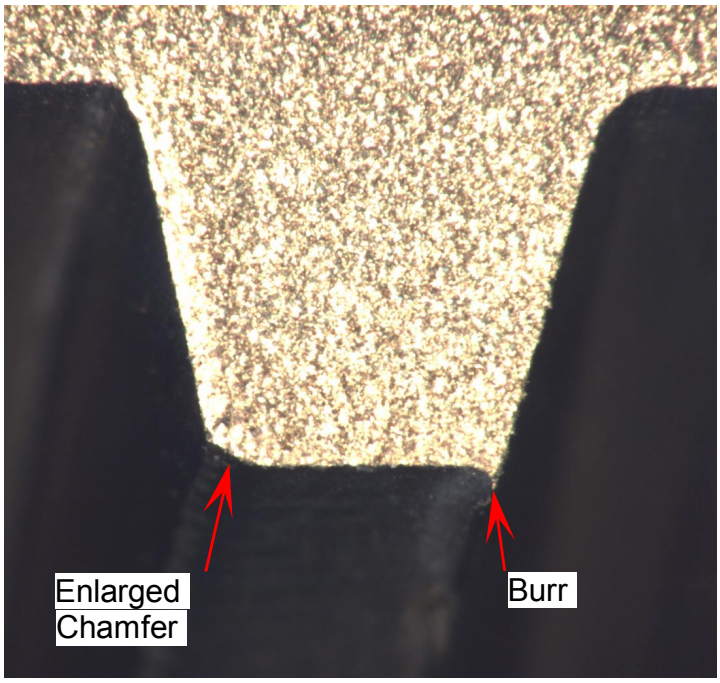


Figure 17--A comparison of the burr heights on adjacent threads of Acme nut D-3351, left measured ~0.004, right ~0.010 inch. Right thread also has an enlarged chamfer at the upper flank.

Figure 18--A view of the enlarged chamfer (right thread in figure 17) with repetitive marks on Acme nut D-3351.

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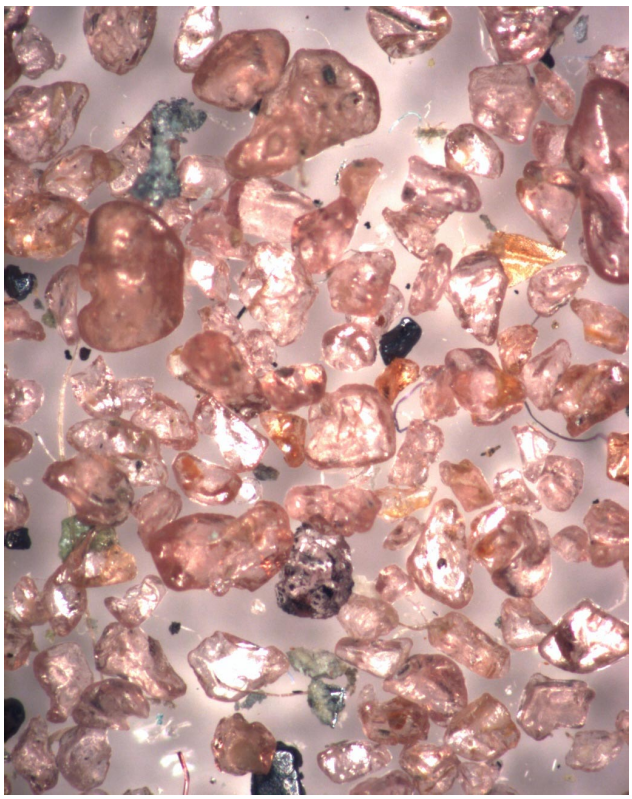
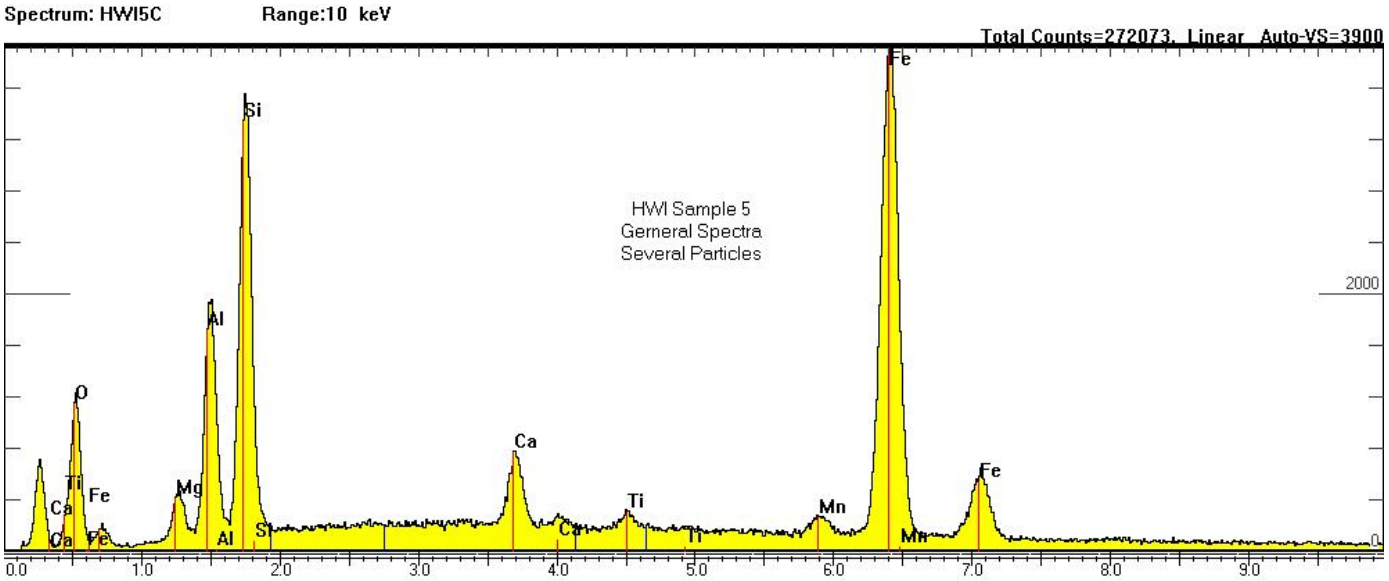


ImageNo: 102A0563, Project No:A00096 ⊢ 1 mm ⊣



ImageNo: 109A0035 , Project A00096

Figure 19--Upper two views show the pink sand found in the grease sample 103 removed from below the jackscrew in N601AP. EDS spectrum of pink particles shown at bottom.

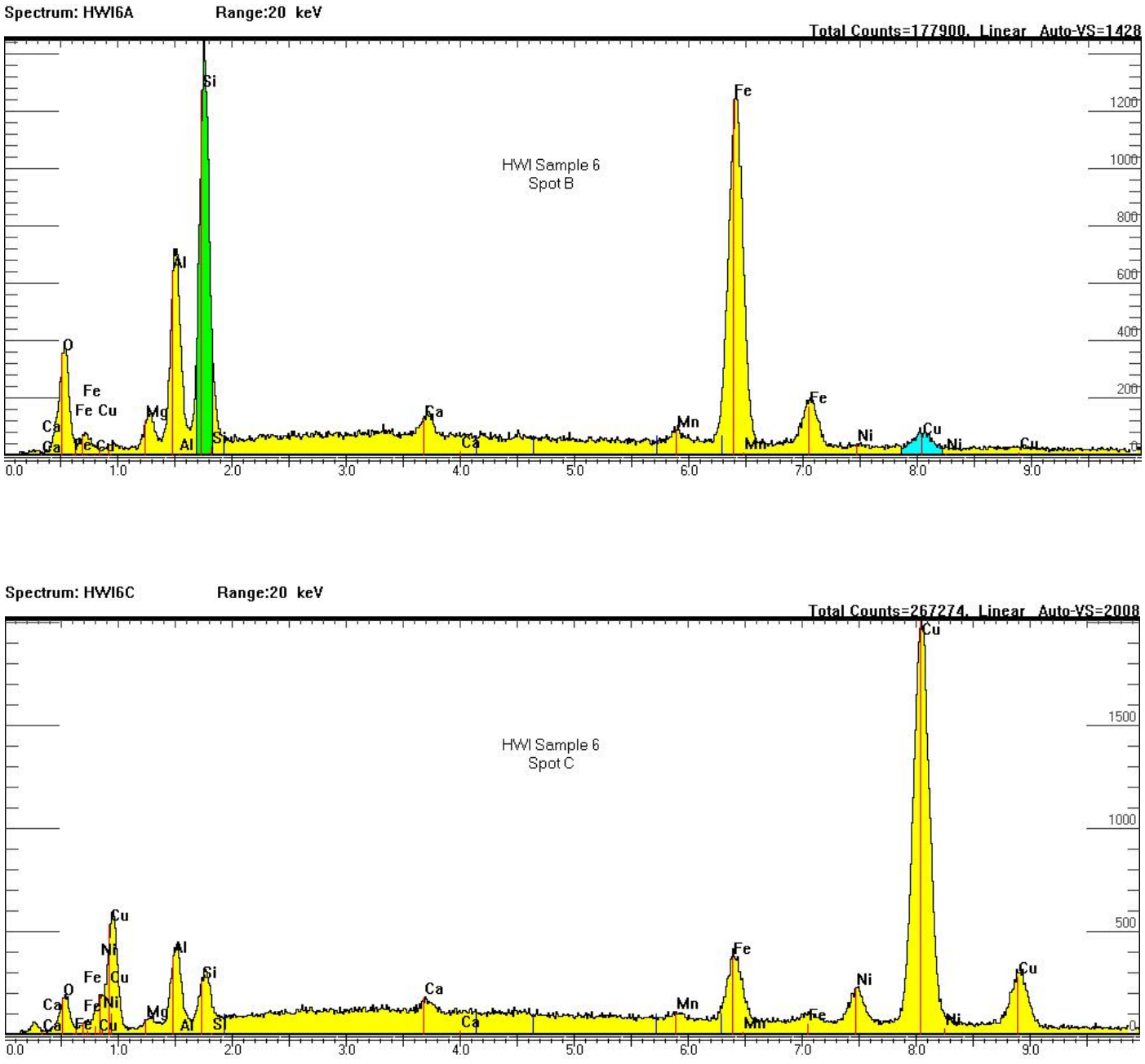


Figure 20--EDS Spectra from the two types of particle found in sample 104. Upper spectrum shows analysis of glassy particles similar to the pink particles in sample 103. Lower spectrum is from the fine aglomeration of particles in sample 104. Spectral peaks in the lower spectrum are consistent with the base metal of an Acme nut with additional peaks for silicon, oxygen and calcium.

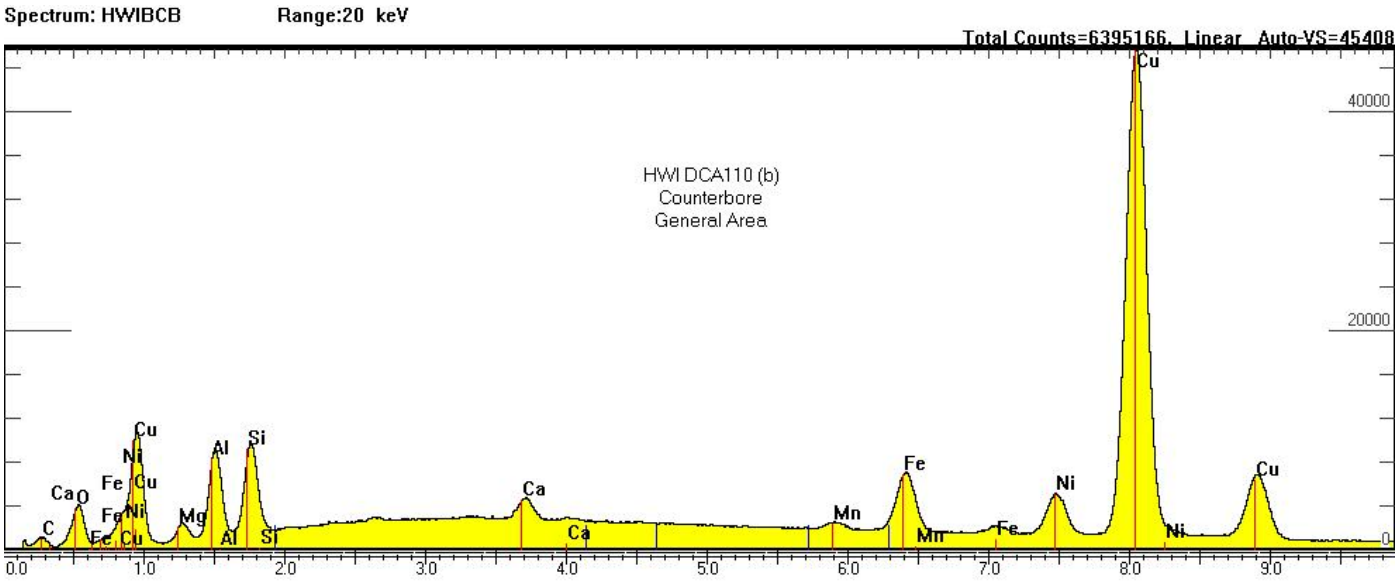


Figure 21--EDS spectrum of particles extracted from DCA110(b) Acme nut grease fitting counterbore (sample 133) showing the base metal constituents plus oxygen, silicon and calcium.

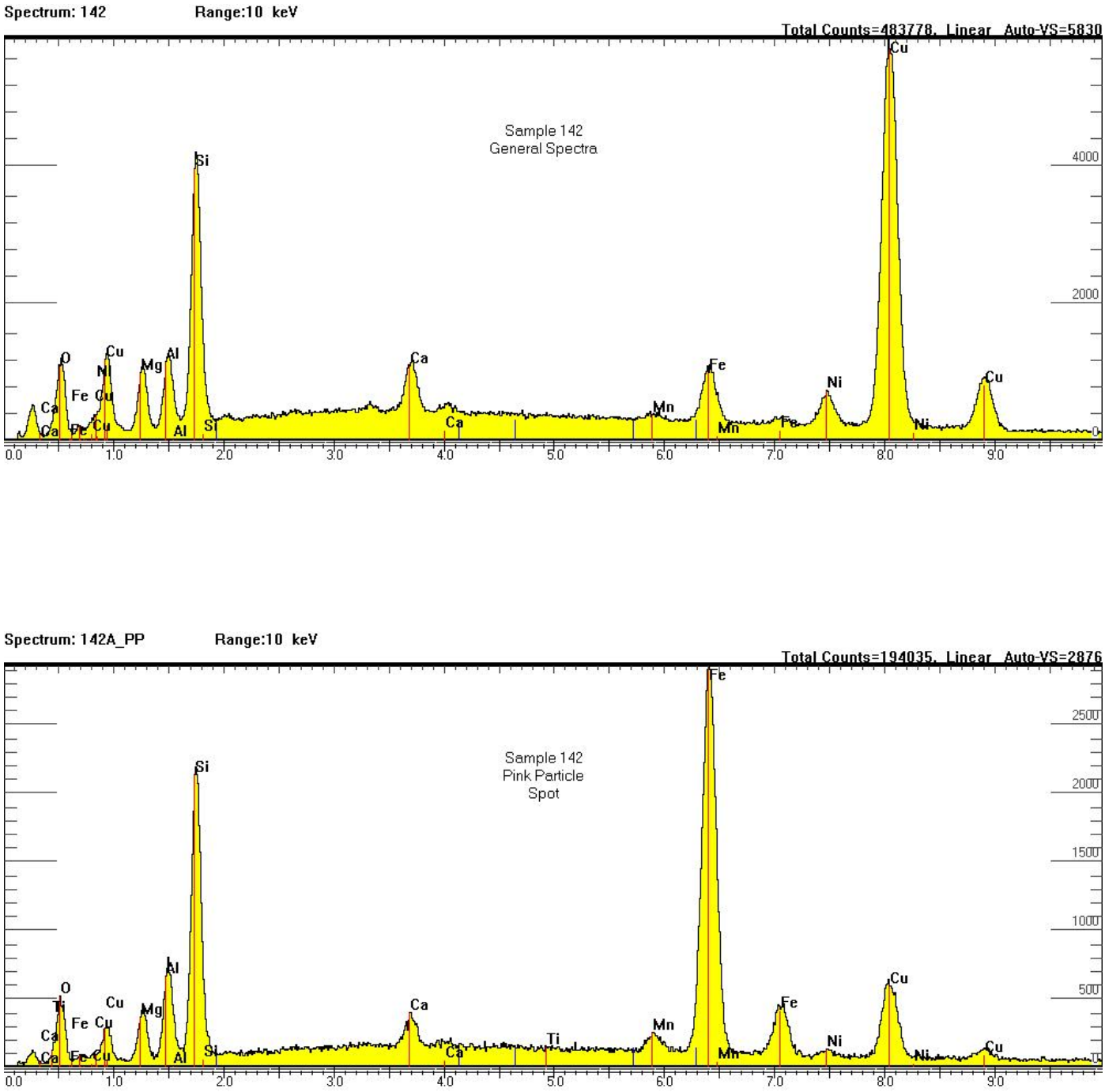
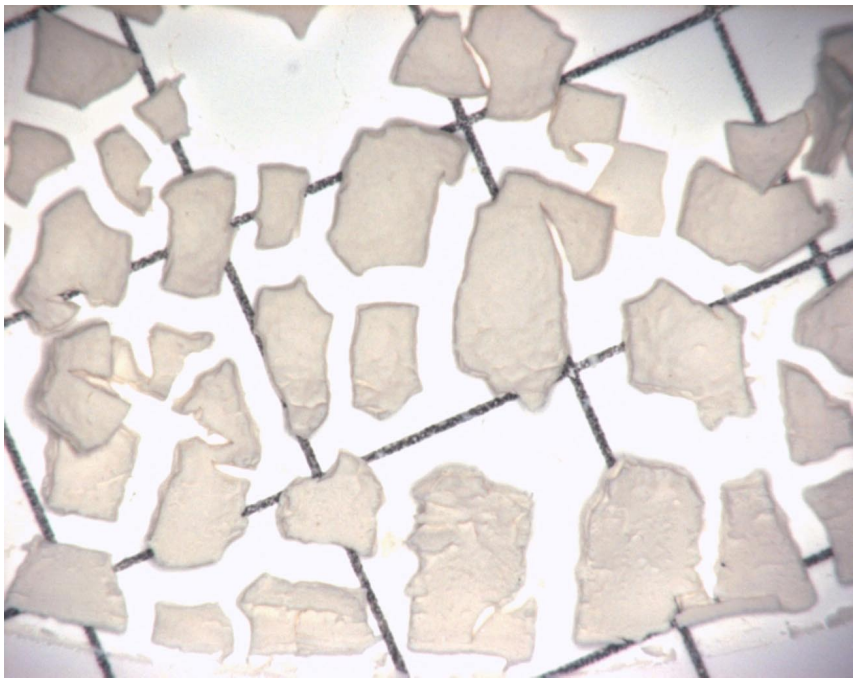


Figure 22--Two spectra from sample 142 removed by Hawaiian Airlines. Upper spectrum shows the elemental peaks from a general area of the sample. The lower peak is a spot spectrum from one of the pink particles in the sample.



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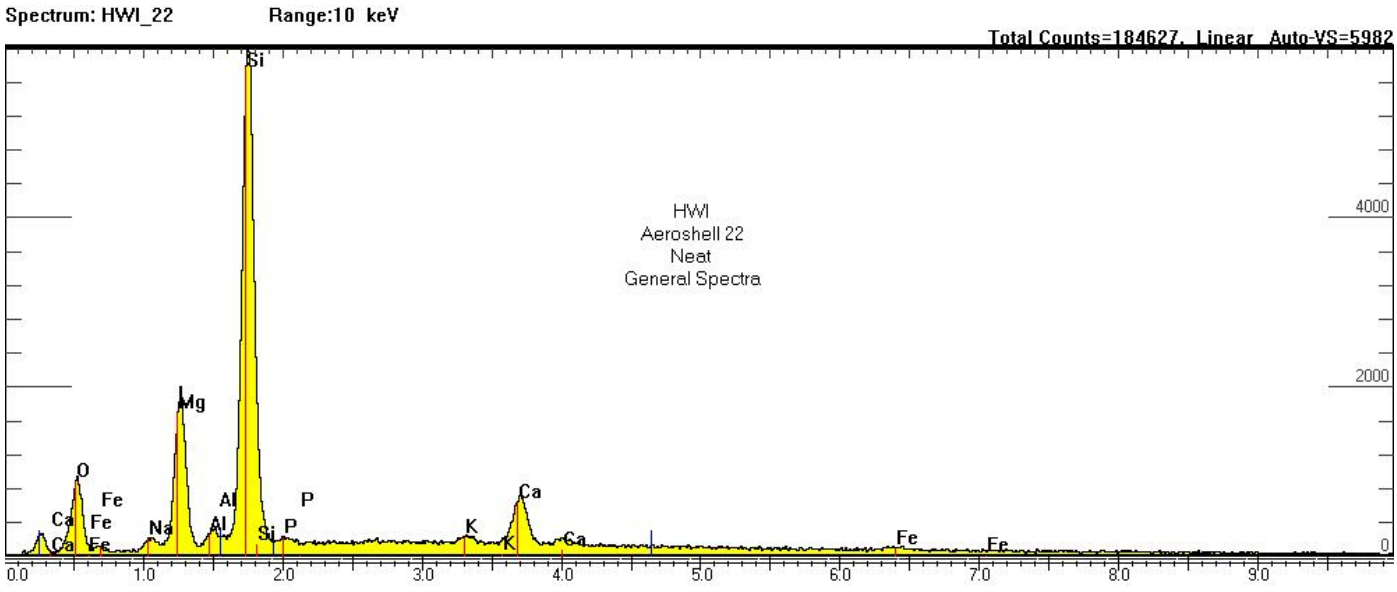
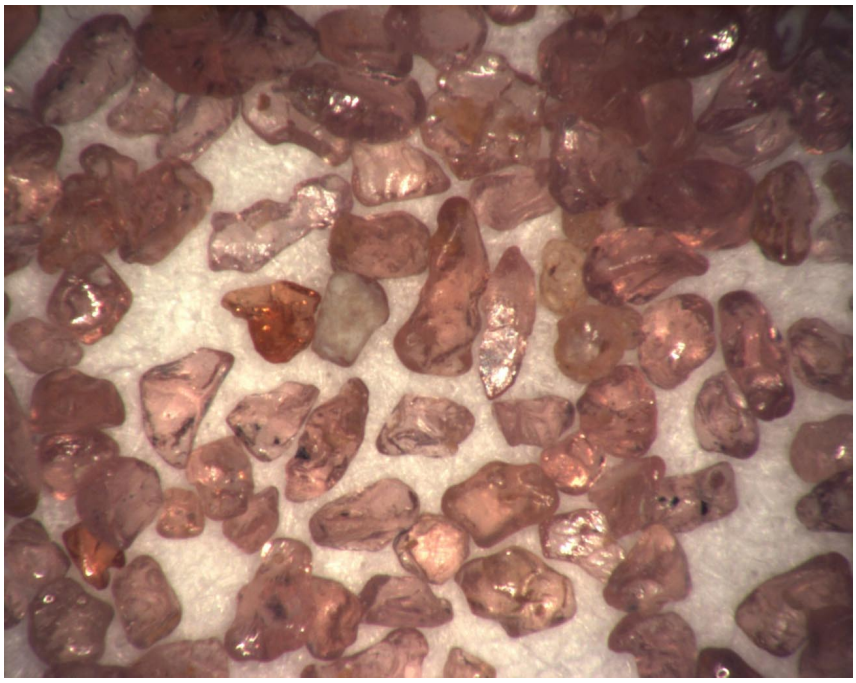


Figure 23--Upper view shows the results of a particle extraction on a sample of clean Aeroshell 22 grease. Spectrum below is the elemental make up of the resulting waxy material.



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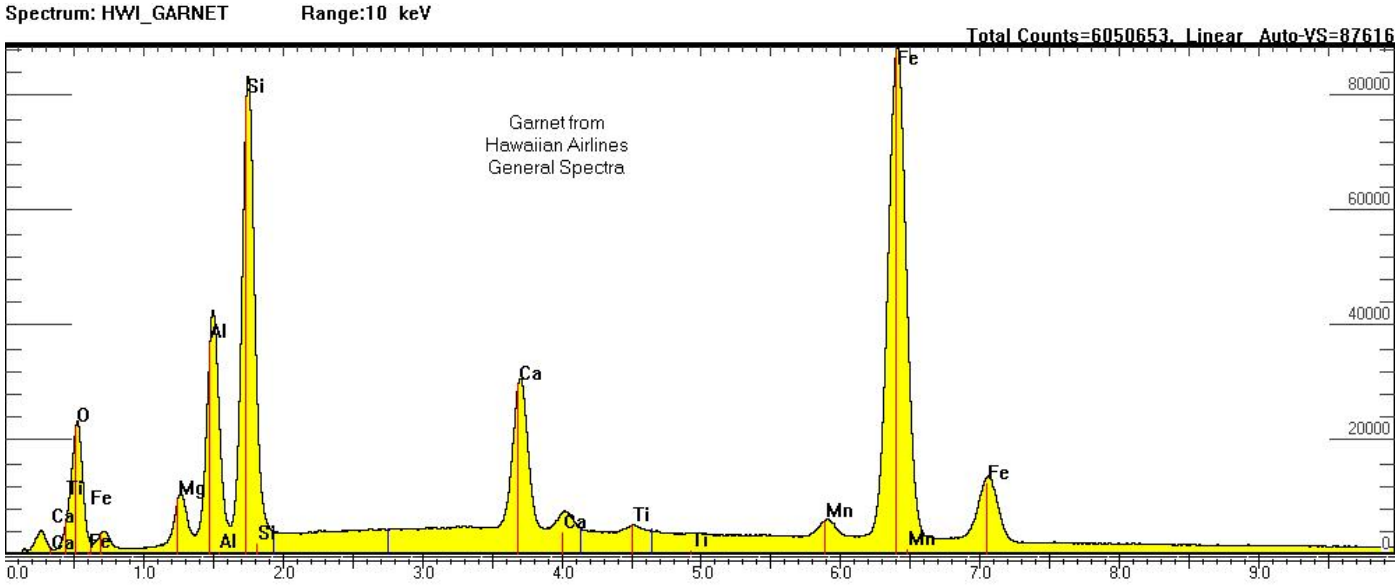

Figure 24--Upper view shows typical garnet blasting media from Hawaiian Airlines stock. EDS spectrum of the material is below. Compare both to the pink sand material found in sample 103 (figure 18), sample 104 (figure 19) and sample 142 (figure 21).

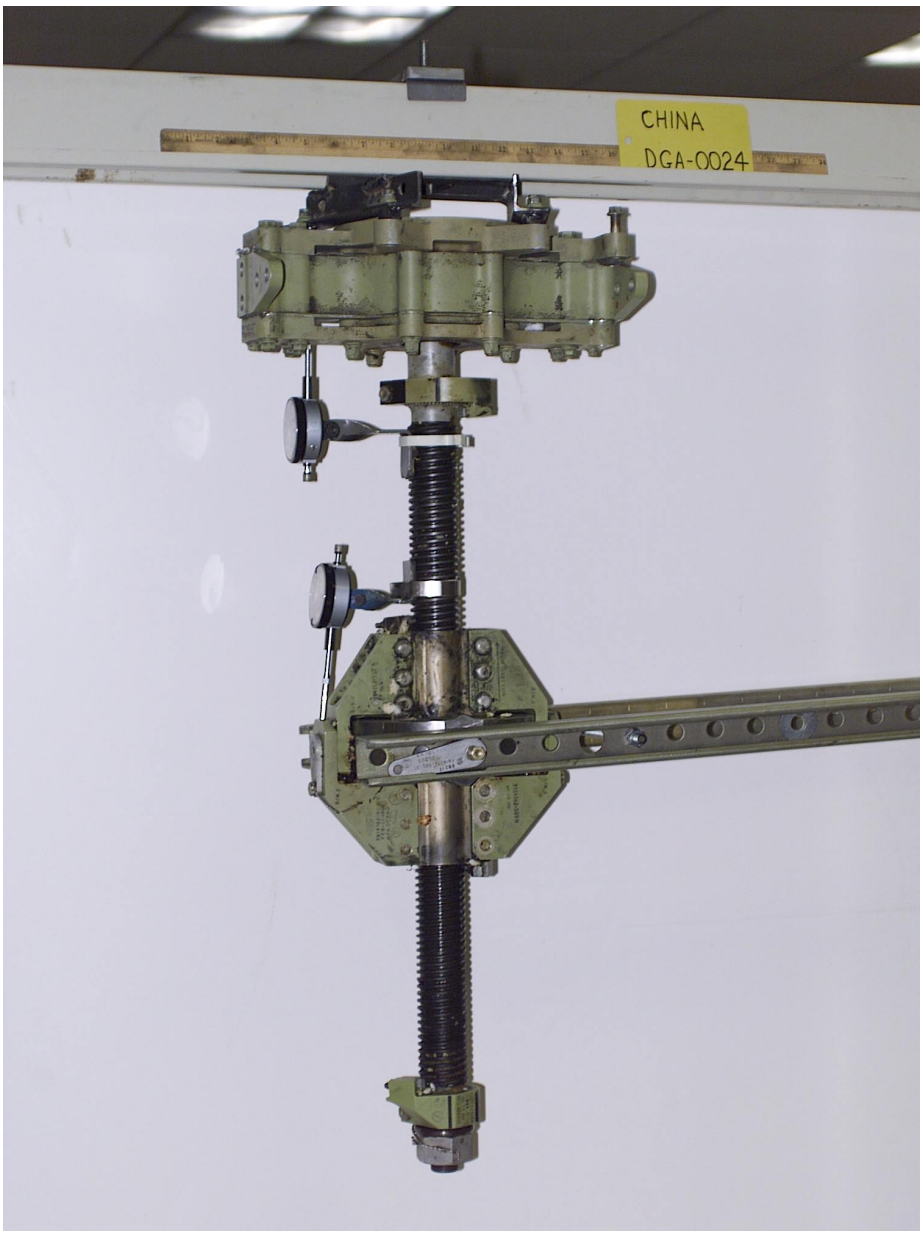

Figure 25--The China Northern Airlines jackscrew mounted in the endplay test fixture.

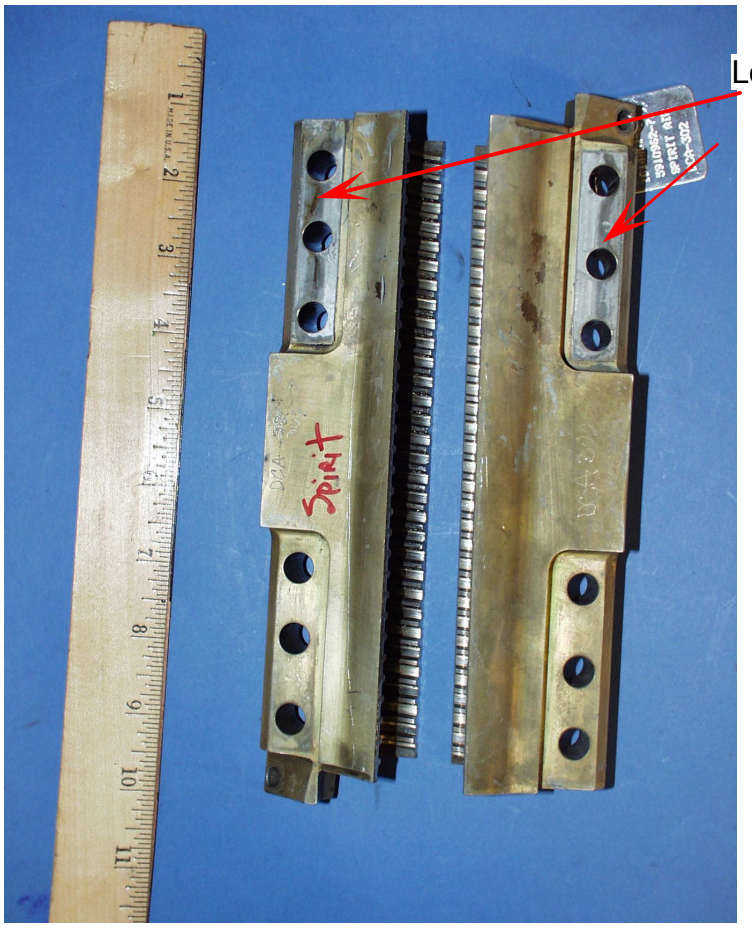

Figure 26--A view of the Spirit Airlines acme nut after cutting. Note the overall surface coloration versus that under the upper supports.

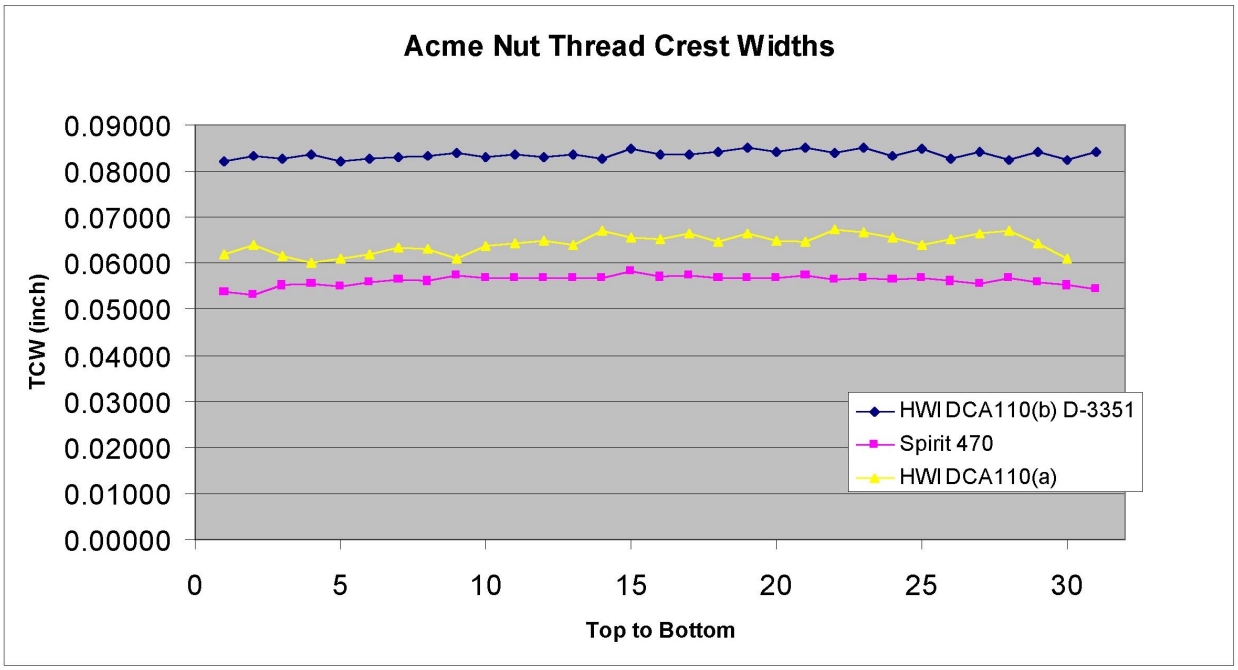

Figure 27--Graphical representation of the the remaining thread crest widths in the nuts from Spirit, and Hawaiian DCA110(a) and (b).