NATIONAL TRANSPORTATION SAFETY BOARD

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

October 10, 2001

MATERIALS LABORATORY FACTUAL REPORT Report No. 01-118

A. ACCIDENT

Place : Near Port Hueneme, CA
Date : January 31, 2000
Vehicle : McDonnell Douglas MD-83, N963AS
NTSB No. : DCA00-M-A023
Investigator : Jeff Guzzetti

B. COMPONENTS EXAMINED

Boeing stabilizer restraining fixture, s/n Boeing Rams #1.
Boeing stabilizer restraining fixture, s/n CE 9122.
Boeing stabilizer restraining fixture, s/n 2001.
Boeing stabilizer restraining fixture, s/n CE 79150.
Airline stabilizer restraining fixture, s/n 2018.
Airline stabilizer restraining fixture, s/n CE 0826.
Airline stabilizer restraining fixture, s/n CE 070811.
Airline stabilizer restraining fixture, s/n CE 070812

C. DOCUMENTS EXAMINED

Douglas (DAC) drawing 4916750, fixture-horizontal stabilizer restraining.
Douglas (DAC) parts list 4916750, fixture-horizontal stabilizer restraining.
Alaska Airlines drawing B-0-1301-0-0169, tooling drawing.
X-rays of fixtures.
Machinery's Handbook, 22nd Edition.

D. DETAILS OF THE EXAMINATION

The Boeing stabilizer restraining fixtures submitted for examination are illustrated in figure 1 and the Airline restraining fixtures submitted for examination are illustrated in figure 2. Although of two distinctly different designs, the fixtures consist of the center portion identified as a nut and the two end pieces (that screw into the nut) identified as screws. The screws have left hand and right hand threads that match the threads in the nut. The resulting fixture is essentially a turnbuckle.

Drawing examination.

Examination of Douglas drawing 4916750, first released in June 1965, revealed four sheets (C size) with dimensional details and notes for cadmium plating, painting and

identifying. The drawing revealed that there were three models of the fixture with the dash numbers below to follow the part number.

-1. Used on DC9 series 10 thru 50 and MD-80 to ship 1325.
-503. Used on MD-80's (except MD-87) ship 1326 and subs.
-505. Used on MD-87.

The screws on the –1 model have their clevis portion aligned with the threaded portion. The left hand threaded screws on the –503 model are offset 3 degrees to the clevis portion. The left hand threaded screws on the –505 model are offset 9 degrees and 37 minutes to the clevis portion. The offsets allow for the different locations of the attachment brackets in the horizontal stabilizer of the various aircraft models.

Examination of Douglas parts list 4916750 revealed that all three portions of the fixtures were to be manufactured from a bar steel designated as 4130 (a low alloy carbon steel) and subsequently heat-treated to a strength of 125 to 145 ksi (thousands of pounds per square inch).

Alaska drawing B-0-1301-0-0169 was a single sheet (B size) illustrating the fixture. The nut illustration had six dimensions and two thread designations namely 1/2-20 LH THREAD and 1/2-20 RH THREAD. The four illustrations for the screw had 11 dimensions and it appeared that the clevis portion was aligned with what would be the threaded portion (although it was not designated as such). The notes indicated that the fixture components were to be manufactured from 4130 (a low alloy carbon steel) or 17/4 PH (a precipitation hardening stainless steel) and both materials were to be heat treated to their "KSI/MIN". There was a reference to DAC TOOL #4916750-503. The tolerance on all dimensions was plus or minus 0.02 inches. The title block of the drawing indicated that the tool was effective for MD-80. There were no signatures or dates in the drafter, checker, engineer and approval blocks.

Boeing fixtures, visual examination.

Visual examination revealed that the unthreaded portions of three of the Boeing tools were painted red, per the Douglas drawing. The fourth tool, s/n 2001, was not painted.

Figure 3 illustrates a right hand screw in the nut that is typical of all the Boeing tools. The spring pin at the end of the threaded portion prevents the screw being removed and was found installed on fixtures s/n Boeing Rams #1 and s/n 2001 only.

Figure 4 illustrates a left hand screw with the threaded portion aligned with the clevis portion, consistent with DAC drawing 4916750-1 requirements.

Figure 5 illustrates a left hand screw with the clevis portion offset to the threaded portion. The center of the threaded portion is indicated by the blue line and the center of the clevis is indicated by the red line. The offset was measured and found to be consistent with DAC drawing 4916750-503 requirements. The only offset clevis was observed on fixture s/n Boeing Rams #1.

Figure 6 illustrates the left hand screw of fixture s/n CE 9150. The threaded portion was in alignment with the clevis portion, satisfying DAC drawing 4916750-1 requirements, but the threaded portion was not in alignment with the nut.

The screws of all the fixtures were screwed in and out of their respective nuts. When being screwed out, the left hand screw of fixture s/n 2001 came to a halt approximately 0.5 inches from the spring pin. Visual examination revealed that the root of a thread, in that approximate location, was packed with a hard gray material that appeared to consist of dirt particles embedded in a solidified lubricant. The gray deposit, located within the yellow box illustrated in figure 7, was removed and the screw then operated over its full length.

The following table indicates the identifications observed on the individual fixtures and the method used for the identification.

Serial Number	Identification	Method
Boeing Rams #1	Boeing Rams #1 TOOL 1 NEW BOEING TOOL 4916750-503 C AB06	Vibro-peened White label White paint Black paint
CE 9122	CE 9122 TOOL No 2 “BROKE” BOEING TOOL	Vibro-peened White label
2001	2001 TOOL #3 SILVER, OLD BOEING TOOL JA (on two sides)	Vibro-peened White label Vibro-peened
CE 79150	CE 9150 ? Airlines 079150 4916750-1 C AC 17 CE 79150 (with bar code)	Vibro-peened Polished label Black paint Black paint White label

On DAC drawing 4916750 note 7 states “Identify per DPS 3.02” and note 12 states “Impression stamp per DPS 3.02, .12 high letters, located approx as shown”.

Airline fixtures, visual examination.

Visual examination of the Airline tools revealed that some of the components exhibited a brown surface discoloration that would be consistent with a heat-treating process. The components that were not discolored were the left hand screw and nut of fixture s/n 2018 and the left hand screw of fixture s/n CE 0826.

Figures 8 and 9 illustrate typical right hand and left hand screws respectively. All screws and nuts were in alignment as suggested by the Airline drawing. All the nut ends were stamped, as illustrated, with the thread direction with the exception of fixture s/n 2018.

The screws of all the fixtures could be easily screwed in and out of their respective nuts with the exception of the left hand screws of fixtures s/n 2018 and s/n CE 070812 which could not be moved.

There was approximately 1 5/8 inches of the left hand screw of fixture s/n 2018 protruding from the nut. An x-ray, provided with the fixtures, revealed distortion of the mating threads, indicated by the red arrows in figure 10, approximately 1/8-inch from the end of the screw and 3/4-inch deep into the nut.

There was approximately 3/4-inch of the left hand screw of fixture s/n CE 070812 protruding from the nut. The same x-ray also revealed distortion to the mating threads, indicated by the red arrows in figure 11, approximately 1/4-inch from the end of the screw and 1 1/2 inch deep into the nut.

The following table indicates the identifications observed on the individual fixtures and the method used for the identification.

Serial Number	Identification	Method
2018	S/N 2018 (on two flats of the hexagon) TOOL No 4 ORIGINAL	Stamped White label
CE 0826	CE 0826 (on one flat of the hexagon) TOOL No 5 CLONE 0-1301-0-0169* (on a flat on the diameter) LH (on flat at left hand thread end) RH (on flat at right hand thread end)	Vibro-peened White label Stamped Stamped Stamped
CE 070811	CE 070811 (on one flat of the hexagon) TOOL No 6 CLONE 0-1301-0-0169* (on a flat on the diameter) LH (on flat at left hand thread end) RH (on flat at right hand thread end)	Vibro-peened White label Stamped Stamped Stamped
CE 070812	CE 070812 (on one flat of the hexagon) 0-1301-0-0169* (on a flat on the diameter) LH (on flat at left hand thread end) RH (on flat at right hand thread end)	Vibro-peened Stamped Stamped Stamped

*- Airline drawing B-0-1301-0-0169, note 3, states “Permanently identify as tool #0-01301-0-0169”.

Thread examination.

The threads utilized in the fixtures are 1/2-20-UNF (1/2 inch diameter, 20 threads per inc, Unified National Fine), left and right hand. For the screws, the Boeing drawing specifies the outside diameter, the thread size, the thread pitch, the thread type and a thread class of 2A. The Airline drawing does not specify any of these items. For the nuts, the Boeing drawing specifies the tapping hole inside diameter, the thread size and the thread class of 2B. The Airline drawing specifies the thread size, the thread pitch and the thread type only. The thread dimensions stated on the DAC drawing agreed with the standard dimensions

quoted in the Machinery's Handbook. As the Airline drawing also references drawing DAC 4916750-503 the threads were examined as class 2 threads.

The DAC drawing states that the threads should be "per MIL-S-7742". MIL-S-7742, section 1.1. (Purpose) states that it covers the requirements of standard Unified and Unified Miniature screw threads, class 3A and 3B although later in section 1.2.d. (Use) it states that FED-STD-H28 be used for new designs with class 2 threads.

The major diameter and the minor diameter of the screws was measured using an OGP Opticom Qualifyer, Model 14B, at 50X magnification. Measurements were taken on the thread adjacent to the clevis portion and are tabulated below. Measurements were also taken adjacent to the end of the threaded portion and are shown in parentheses.

Serial Number	RH or LH	Major Diameter (inches)	Minor Diameter (inches)
Boeing Rams #1	RH	0.4962 (0.4960)	0.4324 (0.4374)
	LH	0.4967 (0.4954)	0.4287 (0.4378
CE 9122	RH	0.4940 (0.4946)	0.4341 (0.4329)
	LH	0.4936 (0.4945)	0.4354 (0.4356)
2001	RH	0.4980 (0.4920)	0.4312 (0.4323)
	LH	0.4961 (0.4974)	0.4327 (0.4325)
CE 79150	RH	0.4941 (0.4944)	0.4350 (0.4356)
	LH	0.4917 (0.4957)	0.4351 (0.4360)
2018	RH	0.4955 (0.4989)	0.4244 (0.4314)
	LH	0.4960 (0.4986)	0.4331 (0.4330)
CE 0826	RH	0.4961 (0.4979)	0.4308 (0.4298)
	LH	0.4965 (0.4976)	0.4298 (0.4311)
CE 070811	RH	0.4858 (0.4916)	0.4263 (0.4272)
	LH	0.4927 (0.4935)	0.4215 (0.4289)
CE 070812	RH	0.4910 (0.4918)	0.4298 (0.4310)
	LH	0.4862 (*)	0.4196 (*)

* - Most of the threaded portion was retained in the nut.

The Machinery's Handbook quotes the following dimensions for a 1/2-20 UNF-2A thread.

Major diameter (max).....0.4987 inches.
(min).....0.4906 inches.
Minor diameter.....0.4374 inches.

Measuring the major and minor diameters on the Opticom Qualifyer also revealed some differences in thread forms. Most of the threads were similar in form to the profile illustrated in figure 12. The thread form observed on the left and right hand screws of fixture s/n CE 9122 displayed an increased root radius as indicated in figure 13. The thread form observed on the right hand screw of fixture s/n CE 070812 displayed a curvature on one flank as it approached the root. The flank curvature is indicated in figure 14.

The pitch diameter of the screws was measured using the 3-wire method. The pitch diameter was calculated using the formula below and the results are in the following table.

PD = M – (3W – 0.86602P) where PD = Pitch diameter
M = Measurement over the wires
W = Wire diameter (0.032)
P = Thread pitch (0.050)

Serial Number	RH or LH	Pitch Diameter (inches)
Boeing Rams #1	RH	0.4683
	LH	0.4673
CE 9122	RH	0.4646
	LH	0.4656
2001	RH	0.4628
	LH	0.4616
CE 79150	RH	0.4654
	LH	0.4663
2018	RH	0.4611
	LH	0.4671
CE 0826	RH	0.4649
	LH	0.4600*
CE 070811	RH	0.4637
	LH	0.4566**
CE 070812	RH	0.4641
	LH	0.4551

* - Measurement taken adjacent to the clevis portion of the screw. A measurement taken adjacent to the end of the threaded portion produced a PD of 0.4675 inches

** - Measurement taken adjacent to the clevis portion of the screw. A measurement taken adjacent to the end of the threaded portion produced a PD of 0.4659 inches

The Machinery's Handbook quotes the following dimensions for the pitch diameter of a 1/2-20 UNF-2A thread.

Pitch diameter (max) 0.4662 inches
(min) 0.4619 inches

The minor diameter of the nuts was measured using an internal micrometer and the results are tabulated below.

Serial Number	RH or LH	Minor Diameter (inches)
Boeing Rams #1	RH	0.454
	LH	0.454
CE 9122	RH	0.456
	LH	0.454
2001	RH	0.451

	LH	0.453
CE 79150	RH	0.455
	LH	0.455
2018	RH	0.460
	LH	*
CE 0826	RH	0.454
	LH	0.455
CE 070811	RH	0.452
	LH	0.456
CE 070812	RH	0.455
	LH	*

* - Threaded hole with the screw locked in place.

The Machinery's Handbook quotes the following dimensions for the minor diameter of a 1/2-20 UNF-2B thread.

Minor diameter (max).....0.446 inches.
(min).....0.457 inches.

All the fixture threads were checked, with the exception of the left hand threads of fixtures s/n 2018 and CE 070812, with certified class 2, "GO" and "NOGO" ring and plug thread gages.

Ring gages, both left hand and right hand, were used to check the screw threads. The "GO" ring gages had a pitch diameter of 0.4662 inches. Fixtures s/n 2001 right hand thread, CE 0826 right hand thread and CE 0826 left hand thread failed the "GO" test. The "NOGO" ring gages had a pitch diameter of 0.4619 inches. Fixture s/n 2018 failed the right hand "NO GO" test by allowing the gage to be screwed on.

Plug gages, both left hand and right hand, were used to check the nut threads. The "GO" plug gages had a pitch diameter of 0.4675 inches. The right hand threads of fixtures s/n BOEING RAMS #1 and s/n CE 070811 failed the "GO" test. Examination of the thread on fixture s/n BOEING RAMS #1 revealed only a small deformation on the thread crown in the vicinity where the plug gage was stopped. Rotation of the plug gage in fixture s/n CE 070811 was prevented after almost 1/2-inch of penetration into the nut. Rub marks observed on the flanks of the last thread suggested a localized change in thread pitch. The "NO GO" plug gage had a pitch diameter of 0.4431 inches. The gage screwed easily into the right hand thread of fixture s/n 2018.

As a compatibility test, all screws were successfully screwed into all nuts, with the exception of the left hand screws and nuts of fixtures s/n 2018 and s/n CE 070812, which were not be disassembled from each other because of the thread damage.

Hardness testing.

Parts list DAC 4916750 specifies that the fixture screws and nuts be manufactured from 4130 and heat treated to a strength of 125 to 145 Ksi (thousands of pounds per square inch) with a minimum core strength of 125 Ksi. The specified strength range

converts to a hardness of 27 – 32 HRC (Hardness Rockwell C Scale). Hardness readings were taken on the Boeing fixtures and the ranges, in HRC, are tabulated below.

Serial Number	Fixture Nut	Fixture RH Screw	Fixture LH Screw
Boeing Rams #1	21.6 – 24.1	23.9 – 24.4	25.3 – 28.2
CE 9122	19.5 –22.3	27.7 – 30.5	28.7 – 30.3
2001	22.8 – 24.3	26.1 – 29.0	25.7 – 26.4
CE 79150	21.9 – 24.7	27.1 – 29.5	27.9 – 30.0

The Airline drawing specifies that the screws and nuts be manufactured from 4130 or 17/4 PH and that they be heat treated to their "KSI/MIN" (normally the required range of strength is quoted). The American Society for Materials (ASM) Metals Handbook (Desk Edition) describes 4130 as a water hardening alloy steel of low to intermediate hardenability. When water quenched and tempered 4130 can achieve a tensile strength between 140, which converts to 31 HRC, and 356 Ksi and when oil quenched and tempered it can achieve a tensile strength between 120, which converts to 25 HRC, and 225 Ksi. The ASM Handbook also indicates that a minimum strength of 135 Ksi, which converts to 30 HRC, is achievable with 17/4 PH stainless steel. Hardness readings were taken on the Airline fixtures and the ranges, in HRC, are tabulated below. Circular correction was added.

Serial Number	Hardness (HRC) Fixture Nut	Hardness (HRC) Fixture RH Screw	Hardness (HRC) Fixture LH Screw
2018	<14*	43.4 – 43.8	<14*
CE 0826	40.6 – 44.1	41.4 – 44.0	<14*
CE 070811	41.7 – 43.1	38.5 – 39.1	40.8 – 41.6
CE 070812	38.4 – 39.6	38.9 – 39.3	42.9 – 43.2

* Although the minimum on the HRC scale is 20, the maximum, for these components, was recorded for consistency and comparison with the other readings.

Material examination.

All screws and nuts were placed in a scanning electron microscope and analyzed by an energy dispersive spectroscope. The spectra for all the Boeing fixtures displayed a major iron peak with minor peaks of chromium, manganese and silicon, consistent with the typical composition of 4130 steel. The spectra also indicated that the components were cadmium coated. The spectra for all the Airline fixtures displayed a major peak of iron with minor peaks of chromium, nickel, manganese, copper and silicon, consistent with the typical composition of 17/4 PH stainless steel.

Derek Nash
Mechanical Engineer

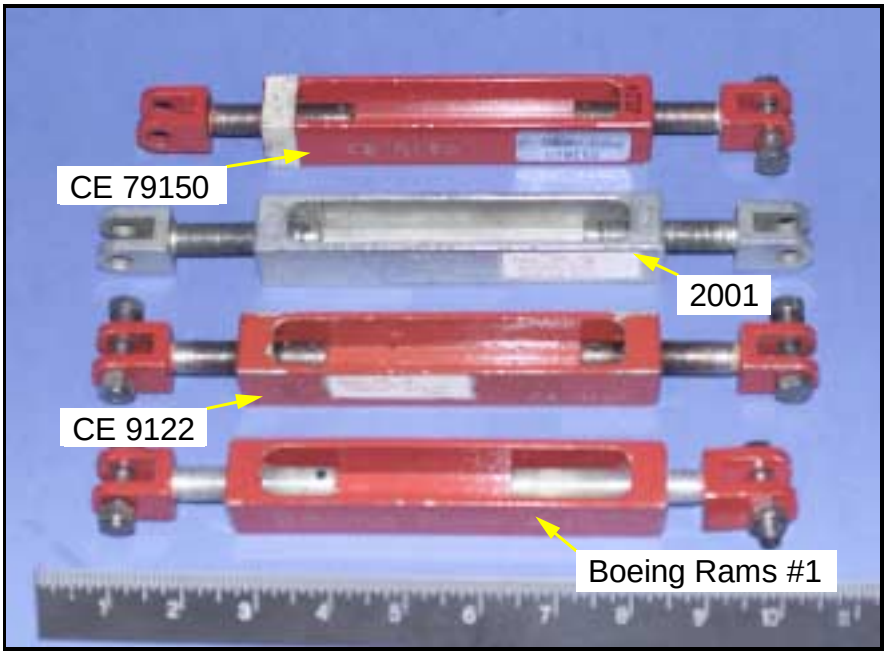

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Figure 1. The Boeing stabilizer restraining fixtures received for examination.

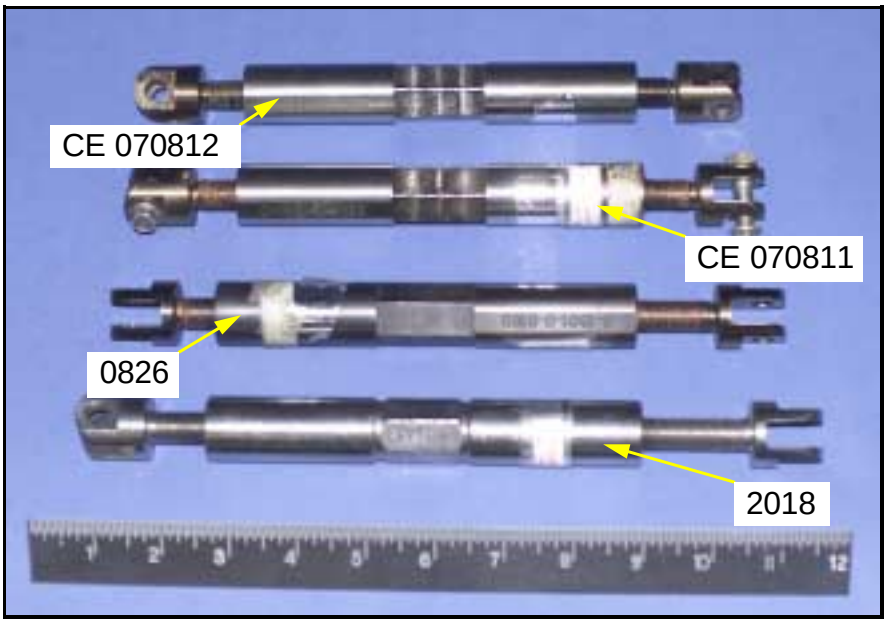

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Figure 2. The Airline stabilizer restraining fixtures submitted for examination.

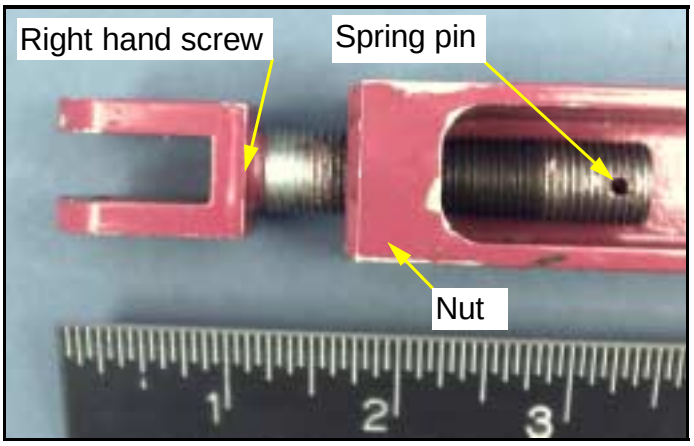

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Figure 3. A typical right hand screw in the Boeing stabilizer fixtures.

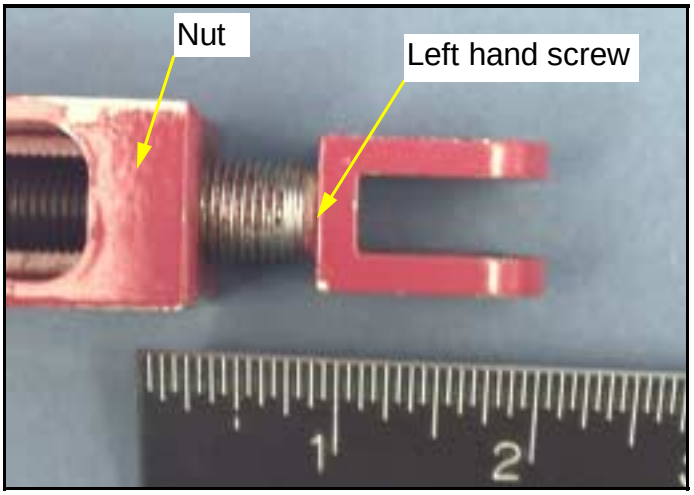

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Figure 4. A Boeing fixture left hand screw with the clevis portion aligned with the threaded portion.

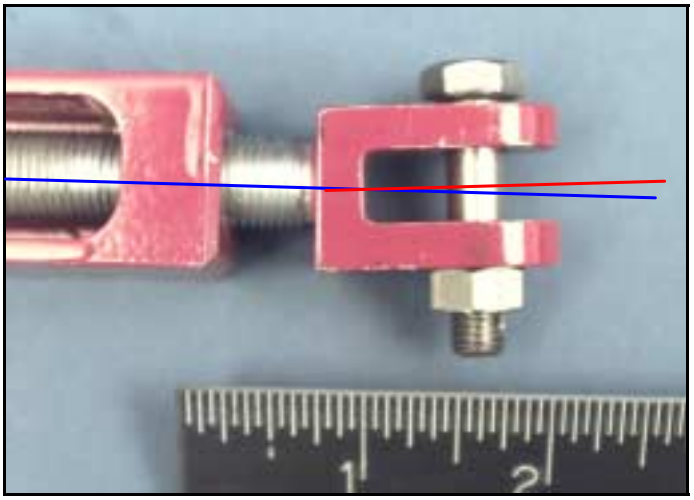

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Figure 5. A Boeing fixture left hand screw with the clevis portion offset to the threaded portion.

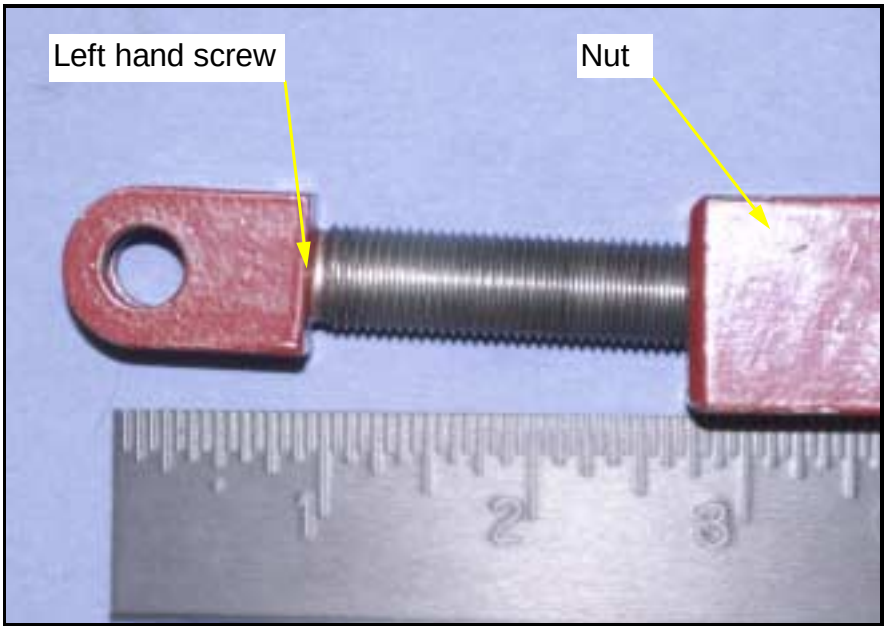

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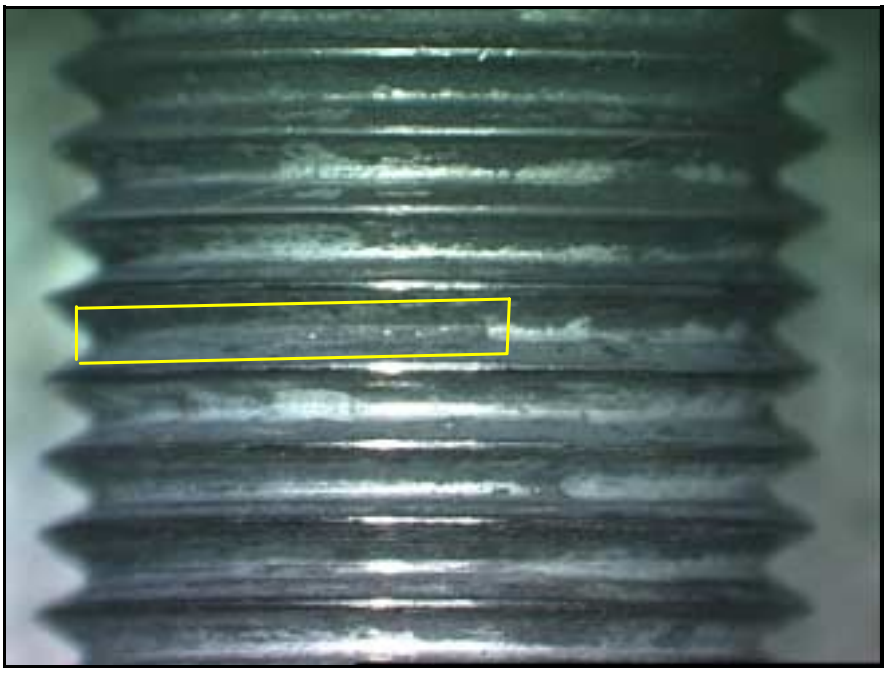
Figure 6. The left hand screw of Boeing fixture s/n CE 9150 illustrating the misalignment of the threaded portion with the nut.



ImageNo: 108A1127, Project No:A00194 ⊢ 2 mm ⊣

Figure 7. The deposit in the root of the left hand thread of fixture s/n 2001 that prevented full travel of the screw.

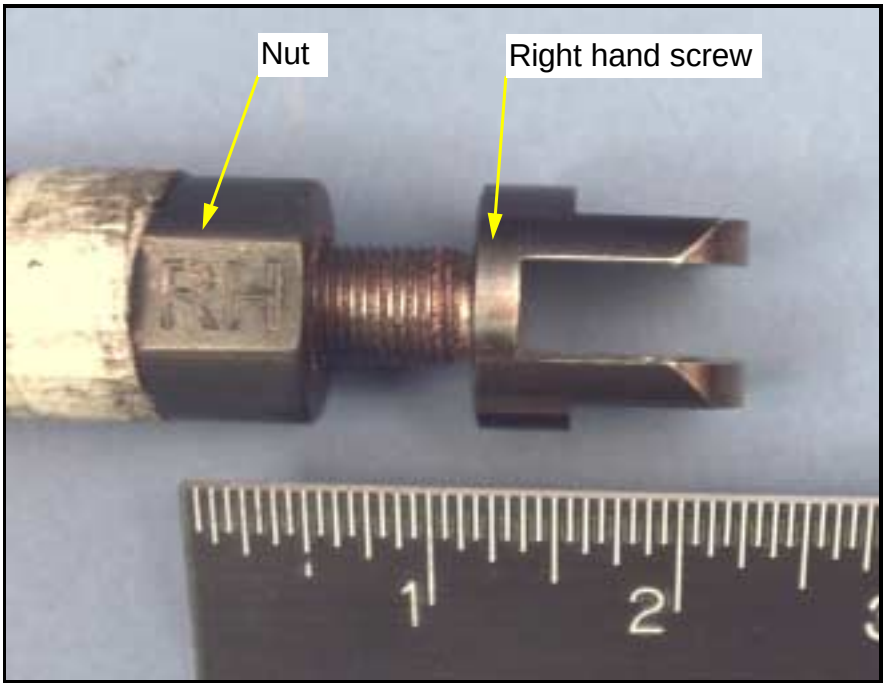


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Figure 8. A typical Airline fixture right hand screw in the appropriate end of the nut.

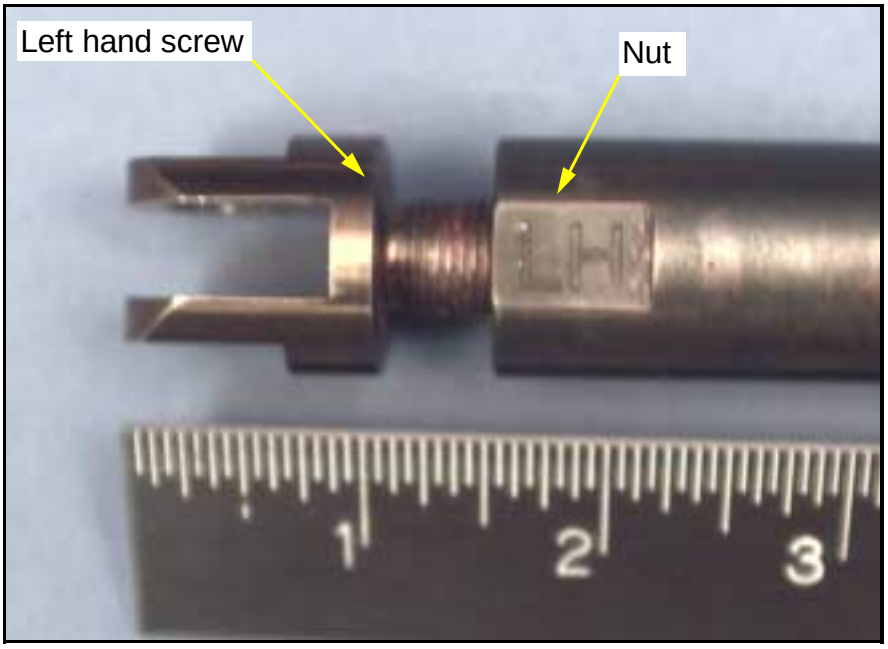

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Figure 9. A typical Airline fixture left hand screw in the appropriate end of the nut.

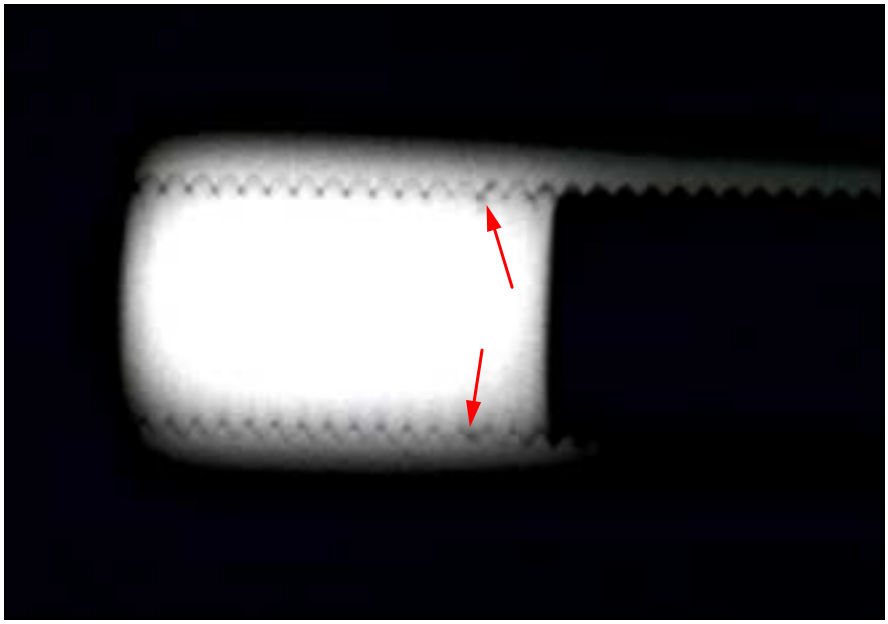

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Figure 10. An x-ray of the left hand screw of Airline fixture s/n 2018 in its nut with the deformed threads indicated by the red arrows.

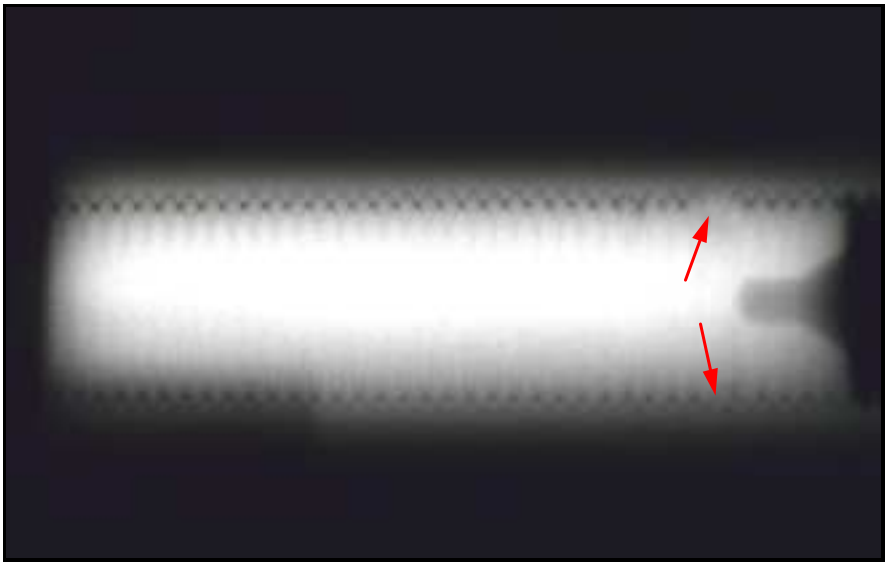

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Figure 11. An x-ray of the left hand screw of Airliine fixture s/n CE 070812 in its nut with the deformed threads indicated by the red arrows.

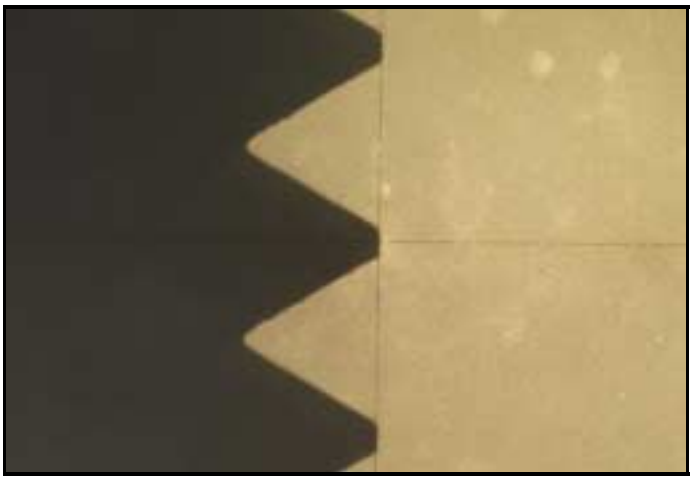

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Figure 12. Typical thread form observed on the stabilizer fixtures. The dark area is the thread profile.

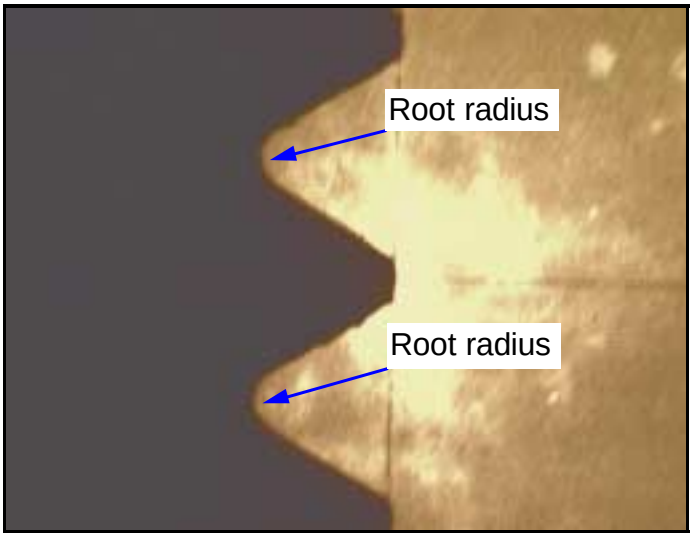

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Figure 13. The root radius observed on the left and right hand screws of Boeing fixture s/n CE 9122. The dark area is the thread profile.

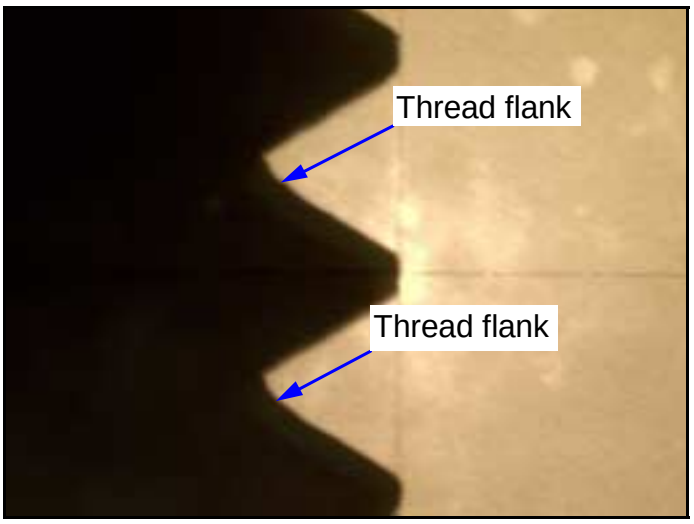

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Figure 14. The curvature on the flank of the right hand screw of Airline fixture s/n CE 070812. The dark area is the thread profile.