NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C. 20594

May 1, 2003

ADDENDUM NUMBER 2 TO THE SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION – RUDDER SERVO CONTROLS AND LINKAGE

DCA02MA001

A. ACCIDENT

Operator: American Airlines
Aircraft: A300-600R
Location: Belle Harbor, New York
Date: November 12, 2001
Time: 09:16 EDT

B. SYSTEMS GROUP

Chairman	Steven Magladry National Transportation Safety Board Washington, DC
Member	Robert Jones Federal Aviation Administration Seattle, Washington
Member	Gerald Gaubert Bureau Enquetes - Accidents Paris Le Bourget, France
Member	Albert Urdiroz Airbus France Toulouse Blagnac, France
Member	David Seratt American Airlines Tulsa, Oklahoma
Member	John David Allied Pilot's Association Fort Worth, Texas

C. SUMMARY

On November 12, 2001, American Airlines flight 587, an Airbus Industrie A-300-600R, N14053, crashed at Rockaway, New York, shortly after takeoff from John F. Kennedy International Airport (JFK), Jamaica, New York. The aircraft was equipped with General Electric CF6-80C2A5 engines. The airplane had taken off from runway 31 left and had turned southbound when it crashed. The aircraft was operated under the provisions of Title 14 of the U.S. Code of Federal Regulations Part 121 as a regularly scheduled international passenger flight from JFK to Santo Domingo, Dominican Republic. The 2 pilots, 7 flight attendants, and 246 passengers plus 5 lap children on board were killed.

The vertical stabilizer and rudder were found in Jamaica Bay, not at the main accident site, and these components were shipped to the NASA facility at Langley, Virginia. The systems group convened at NASA, between December 18 – 20, 2001 to document, remove, and examine the rudder control components still attached to the vertical stabilizer. The input springrods were tested and disassembled, and the rudder servos were sent to the Army Research Laboratory, Aberdeen Proving Grounds, Maryland, where computer aided tomography (CAT) scans were performed. The servos were then shipped to the Bureau Enquetes - Accidents (BEA) in France and held until the systems group convened at the TRW Aeronautical Systems SOA facility near Paris, France, between March 14 – 22, 2002 to examine, test and disassemble the three rudder servo controls.

The control rods and bell cranks were intact from the bottom of the vertical stabilizer to the rudder servo controls, and there was no noticeable freeplay in the linkage. Two of the springrods passed the compression test, but failed the extension test. The springrod for the upper servo was found to be bent and could not be tested. When disassembled all three had white deposits on the internal components, but no substantial corrosion. The evaluation of the rudder servos revealed some corrosion and superficial damage, however, all three servos functioned satisfactorily and no significant discrepancies were noted during the disassembly.

This report provides the details of the above activities. Included as Appendices are Photographs of Rudder Control Linkage (Appendix A), CAT Scan Images of Rudder Servo Controls (Appendix B), Rudder Servo Control Illustrated Parts List (Appendix C), Rudder Servo Control Functional Test Plan (Appendix D), Rudder Servo Control Functional Test Data Sheets (Appendix E), Rudder Servo Control Spring Test Results (Appendix F), Upper Rudder Servo Control Disassembly Photos (Appendix G), Middle Rudder Servo Control Disassembly Photos (Appendix H), Lower Rudder Servo Control Disassembly Photos (Appendix I), Rudder Servo Control Hydraulic Fluid Sample Analysis (Appendix J), Rudder Servo Control Attachment Hardware Dimensions (Appendix K).

D. DETAILS OF THE INVESTIGATION

1.0 Rudder Controls System Description (Figure 1.0)

There are three mechanically actuated rudder servo controls attached to the rear spar of the vertical stabilizer, and attached to the front spar of the rudder by hinge assemblies. Each servo is operated by an independent hydraulic power supply. At the input of each servo a springrod is attached, which allows the other actuators to operate in the event of a jam of its servo input mechanism. The springrods are connected to pushrods and bellcranks, which provide a dual load path down to the base of the vertical stabilizer to the rudder frame assembly.

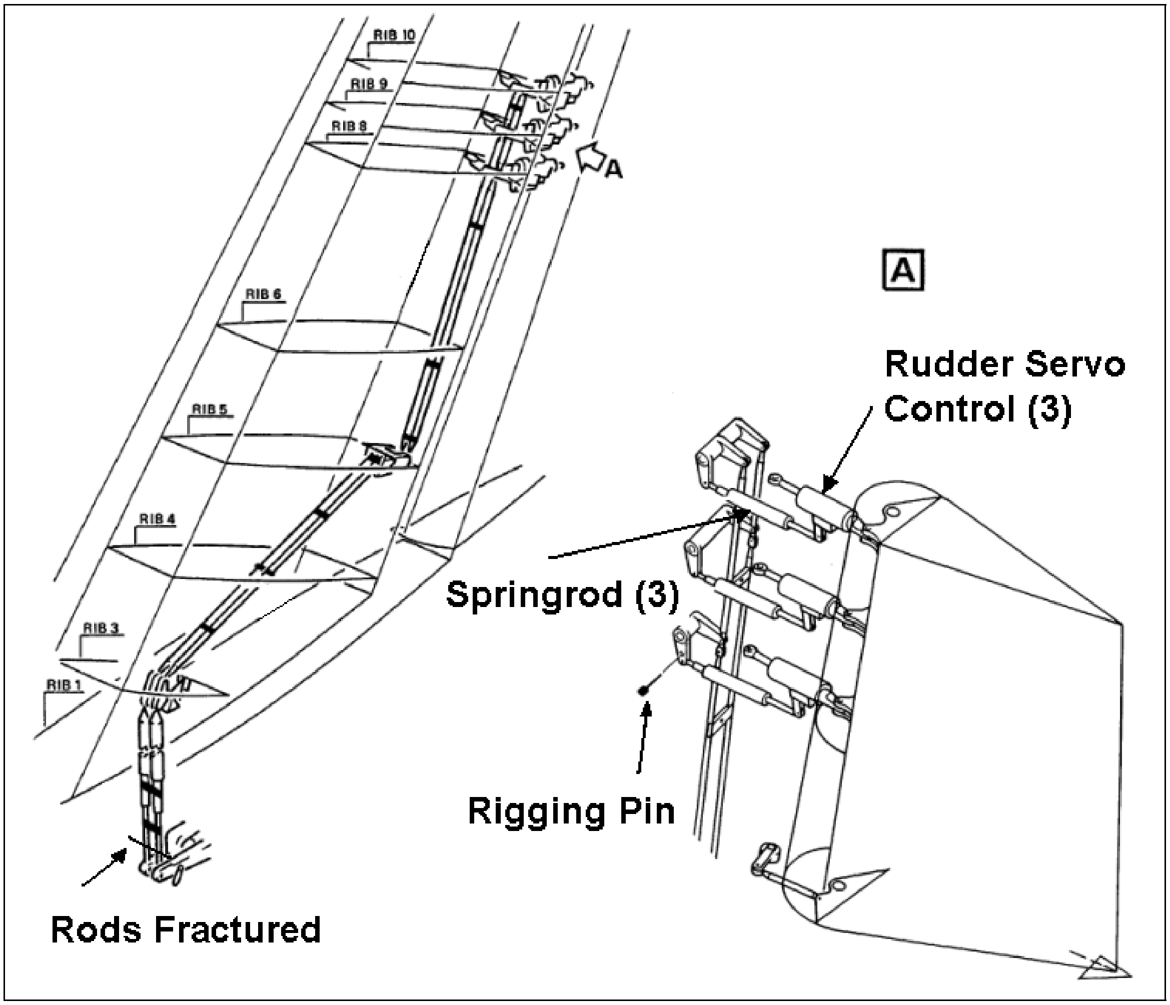


Figure 1.0. Rudder Controls

2.0 Condition of Accident Airplane Rudder Control Components

The rudder control components shown in Figure 1 remained with the vertical stabilizer when it departed from the empennage. The vertical stabilizer was recovered from Jamaica Bay, so all components were subjected to sea water.

2.1 Control Linkage

The control linkage was intact from the bellcranks at the rudder servo to the base of the vertical stabilizer (See Appendix A for photos). The control rods fractured at the location indicated in Figure 1, approximately six inches from the end of the rod. Figure 2.1A and 2.1B show the recovery of the vertical stabilizer from Jamaica Bay. The support straps were positioned in the same area where the control rods were fractured. The pushrod and bellcrank near rib 3 were damaged, as shown in Appendix A, Figure 10. The bearing from one of pushrods had been removed and bagged during shipping, so documentation of that bearing in situ was not possible. There did not appear to be any binding or measurable freeplay in the linkage.

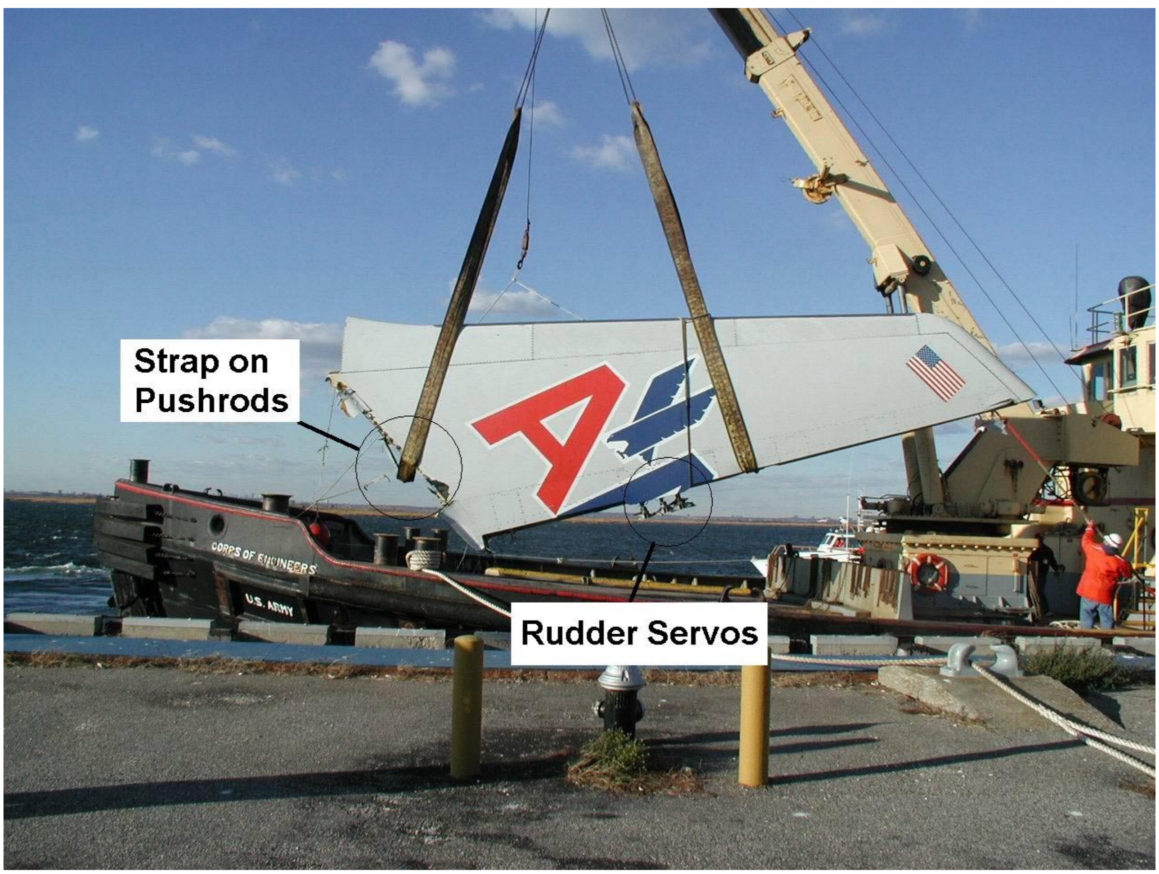


Figure 2.1A Recovery of Vertical Stabilizer from Jamaica Bay.

Figure 2.1B Recovery of Vertical Stabilizer from Jamaica Bay.

2.2 Input Springrods

The springrods were found connected to the input bellcranks and to the rudder servos (Figure 2.2A). The upper servo input springrod was observed to be bent.

The observations and measurements shown in Table 2.2 were made with the lower bellcrank rig pin installed. Dimensions are defined in Figure 2.2B.

Table 2.2. Springrod Observations and Measurements.

Springrod	S/N	P/N	Dimension A (inches)	Dimension D (inches) (1)
Upper	None	A272711 4900000	9.46 leftside	0.952 0.945
Middle	AA48	A272711 4900000	9.51 leftside	0.952 0.945
Lower	AA46	A272711 4900000	9.3 top 9.36 bottom 9.48 leftside	0.940 0.945

(1) Two independent measurements made

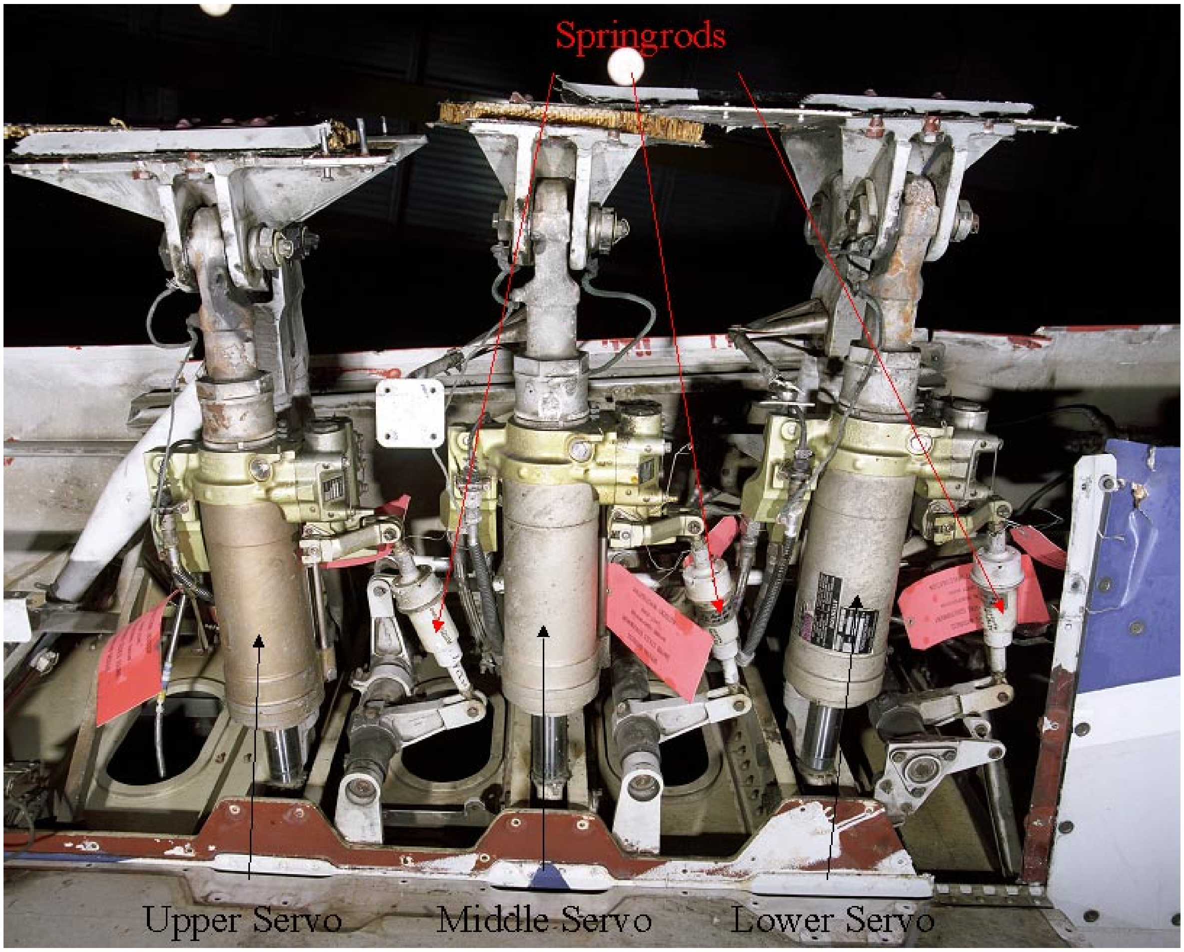


Figure 2.2A. Accident Airplane Rudder Servo Controls and Linkage

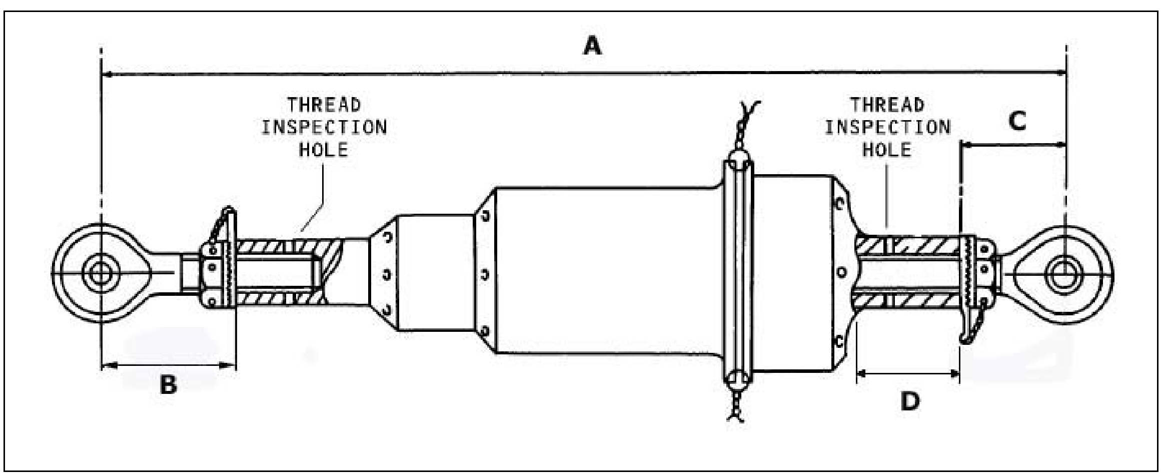


Figure 2.2B. Springrod Dimensions Defined

2.3 Rudder Servo Controls

All three rudder servo controls were attached to the rear spar of the vertical stabilizer and to the rudder hinge assemblies (Figure 2.2A). The rudder hinge assemblies were attached to separate pieces of the rudder front spar. This allowed the middle and lower servos free to swivel (left and right in Figure 2.2A) around their attachment points at the vertical stabilizer. The upper servo remained stationary along this axis due to an additional support rod for that servo only.

The observations and measurements shown in Table 2.3 were made with the lower crank rig pin installed. Dimensions are defined in Figure 2.3. It was observed that the fin was rested on the servos during the recovery process (Figure 2.1B). If sufficient force is applied to the rod end when hydraulics are not pressurized the piston can retract or extend.

Table 2.3. Rudder Servo Controls Observations and Measurements.

Rudder Servo Control	P/N	S/N	A, B (inches) (1)	Lever Position (inches) (1), (2)	Test Finger position (3)	Freedom motion Valve
Upper	Missing plate	Missing plate	3.438, 3.189	Aft 0.28 Fwd 0.32	Extended	Yes
Middle	31042-130	W487	3.906, 3.661	Aft 0.46 Fwd 0.14	Extended	Yes
Lower	31042-130	E9291	3.923, 3.701	Aft 0.10 Fwd 0.48	Extended	Yes

(1) Two independent measurements made
(2) Lever position documented by measuring the gap between the manifold stop on the servo housing and the valve input lever at the widest point. The gap was measured on the gap fwd of the valve lever and aft of the valve lever.
(3) Normal position with no hydraulic pressure is in the extended position.

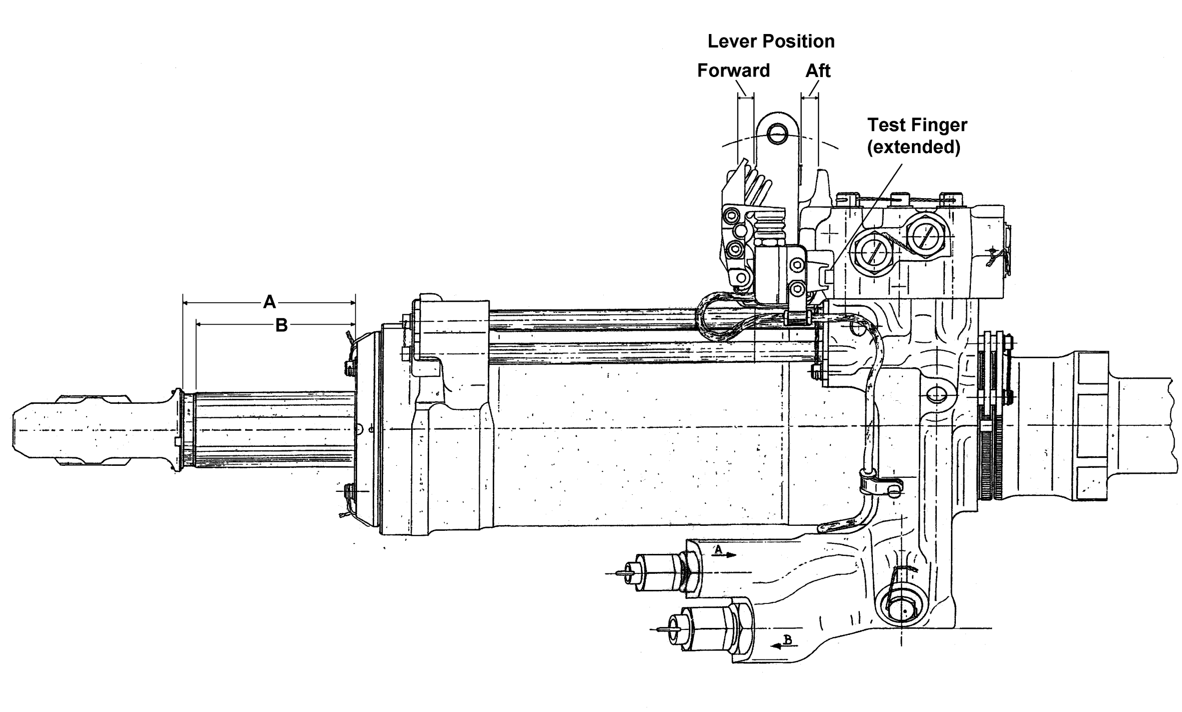


Figure 2.3. Rudder Servo Control Dimensions Defined.

3.0 Springrod Removal, Test, and Disassembly.

3.1 Springrod Removal

The springrods were removed from the actuators. All attachment hardware was removed and retained. Two x-ray's were taken of each rod. The x-ray's showed no evidence of defects. All draining holes visually inspected to be 4mm diameter and unclogged.

The observations and measurements are recorded in Table 3.1. The dimension are defined in Figure 2.2B

Table 3.1. Springrod Observations and Measurements.

Rudder Servo Control	Dimension A	Dimension B	Dimension C	Dimension D (1)	Inspection hole (2)
Upper	9.392	1.1315	1.128	0.967 0.959	ok
Middle	9.408	1.169	1.151	0.929 0.946	ok
Lower	9.377	1.199	1.081	0.945 0.948	ok

(1) Two independent measurements taken
(2) OK means thread inspection holes obscured by threads

3.2 Springrod Tests

The middle and lower springrods were tested in accordance with CMM 27-21-23, Revision 11. The upper rod was not tested because it was bent. The test setup and requirements are shown in Figure 3.2A. Results of the compression test, 27-21-23, page 101 are as follows (See also Figure 3.2B). In this test, force on the springrod was gradually increased until there was measureable compression. This was recorded as the breakout force. The springrod was then compressed by an amount (D) and the compression force (F) was recorded.

Middle Springrod:

Break out force = 29.91 lbf
D: 0.195 inch F: 37.25 lbf
D: +0.195 inch F: 34.60 lbf
D: +0.195 inch F: 40.05 lbf
D: +0.180 inch F: 43.35 lbf

Lower Springrod:

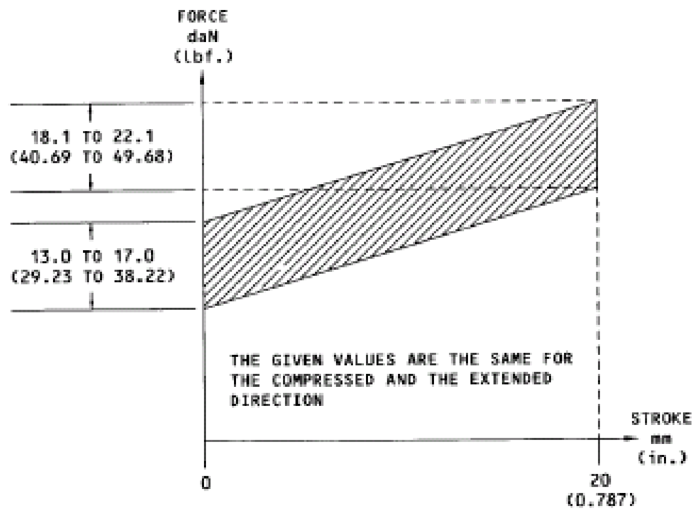
Break out force = 30.60 lbf
D: 0.195 inch L: 33.62 lbf
D: +0.195 inch L: 36.35 lbf
D: +0.195 inch L: 39.20 lbf
D: +0.195 inch L: 44.51 lbf

Full stroke reached without any abnormal friction on both springrods.

AIRBUS INDUSTRIE

COMPONENT MAINTENANCE MANUAL

A27270865, A27271149

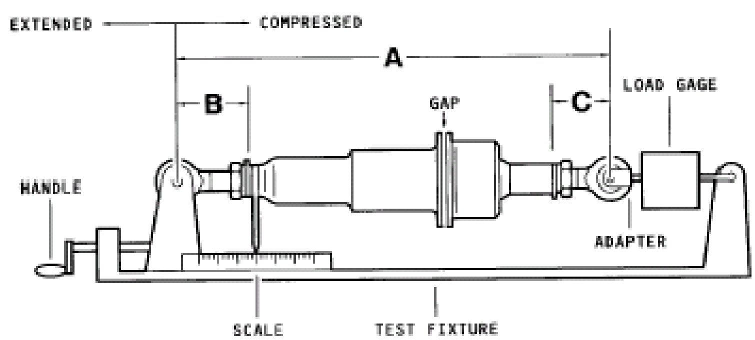


PRE MOD 44028D40372

DIMENSIONS		
A	239mm	9.41in.
B	33mm	1.30in.
C	26mm	1.02in.

POST MOD 44028D40372

DIMENSIONS		
A	239mm	9.41in.
B	38.5mm	1.52in.
C	30.5mm	1.20in.



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Spring Rod Test
Figure 101

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Figure 3.2A. Springrod Test Set-up and Requirements

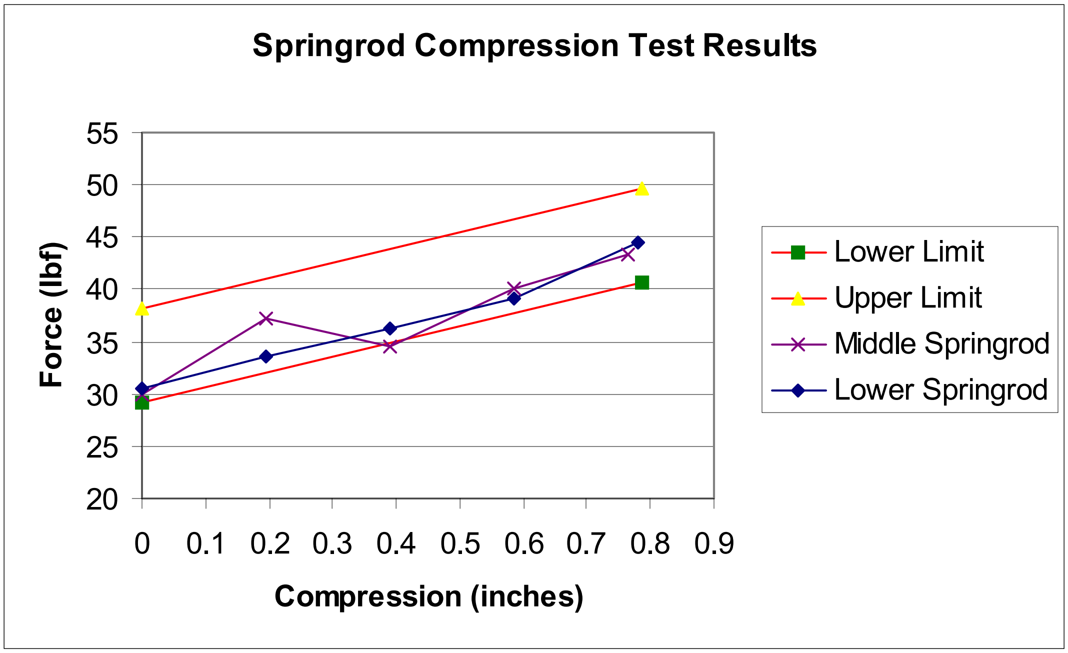

Figure 3.2B. Results of Extension Test.

The extension tests were performed by attaching one end to a spring scale and hanging weights to the other. The results are as follows:

Middle Springrod
Break out force between 50 and 55 lbf. The springrod went to full extension following breakout.

Lower Springrod
Break out force between 40 and 45 lbf. The springrod went to full extension following breakout.

A second test was performed on the lower springrod, and break out occurred between 35 and 40 lbf.

3.3 Springrod Dissassembly

3.3.1 Lower Springrod (Figure 3.3.1)

There were no difficulties removing the rod-ends, they were free to rotate when loosened.

There was a slight discoloration in the interior of the housing, item 140. White deposits and discoloration were observed, mostly on one side of the spring circumference. Item 120 nut side is rusted. Item 90 washer was not installed. There was significant friction between the item 110 retainer and the item 60 piston, near the shouldered face of the piston, but it was not stuck. Some friction was also noted when removing the item 110 retainer on the nut side. Numerous small spots of discoloration were observed on the piston operating surface. There were friction marks on the item 140 housing surface. On the retainer (piston shouldered face side) internal surface, there are significant blue spots located on 1/3 of the circumference.

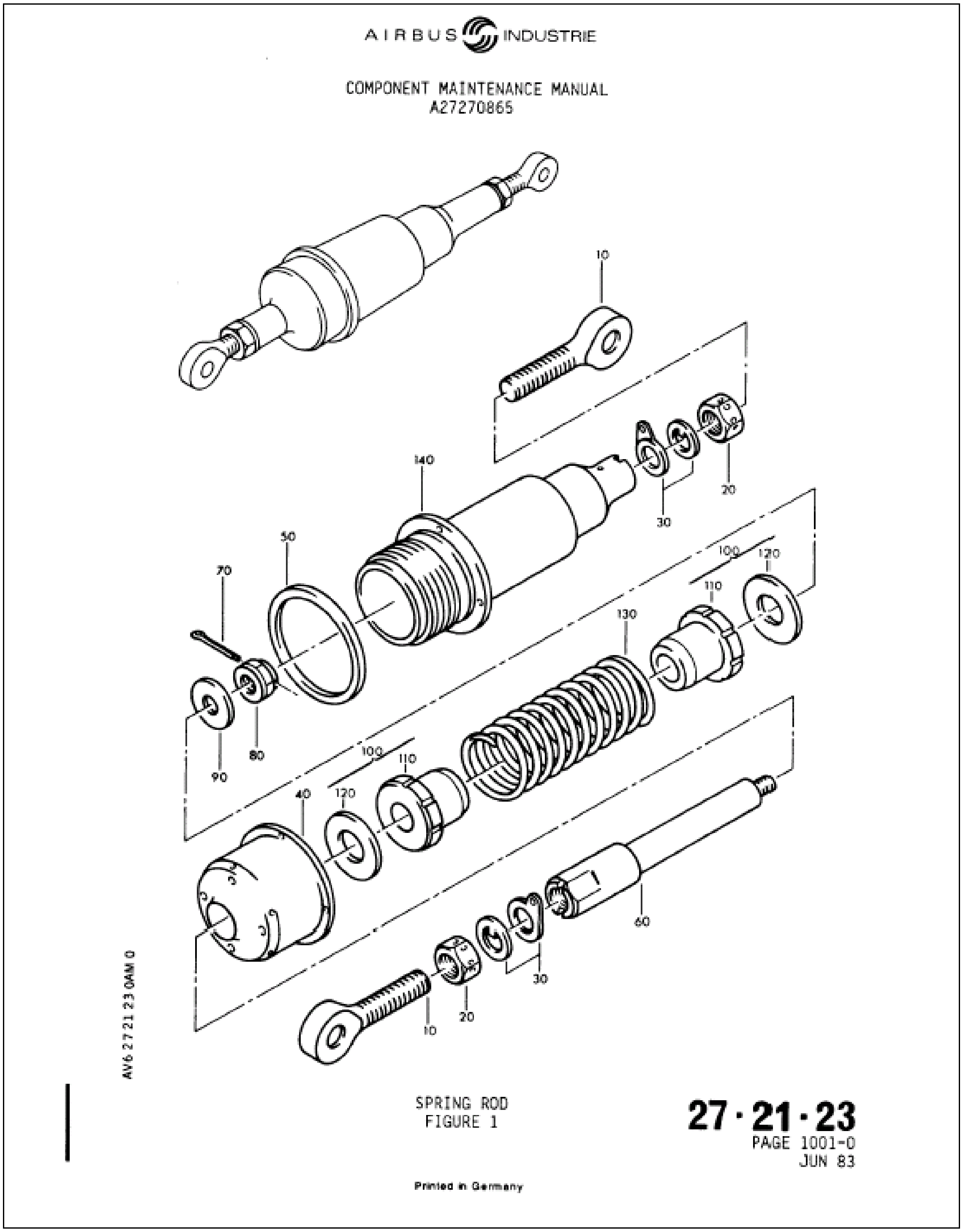

Figure 3.3.1A. Springrod Illustrated Parts List.

Figure 3.3.1B. Lower Springrod

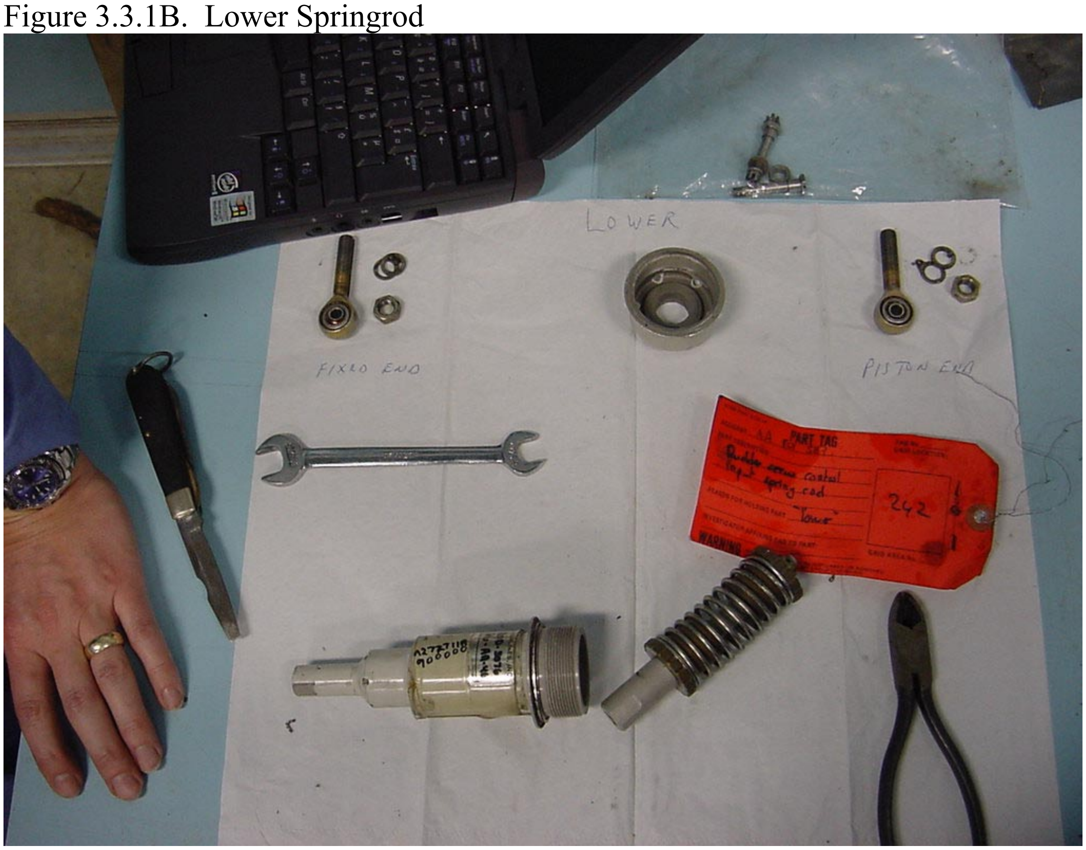

Figure 3.3.1C. Lower Springrod.

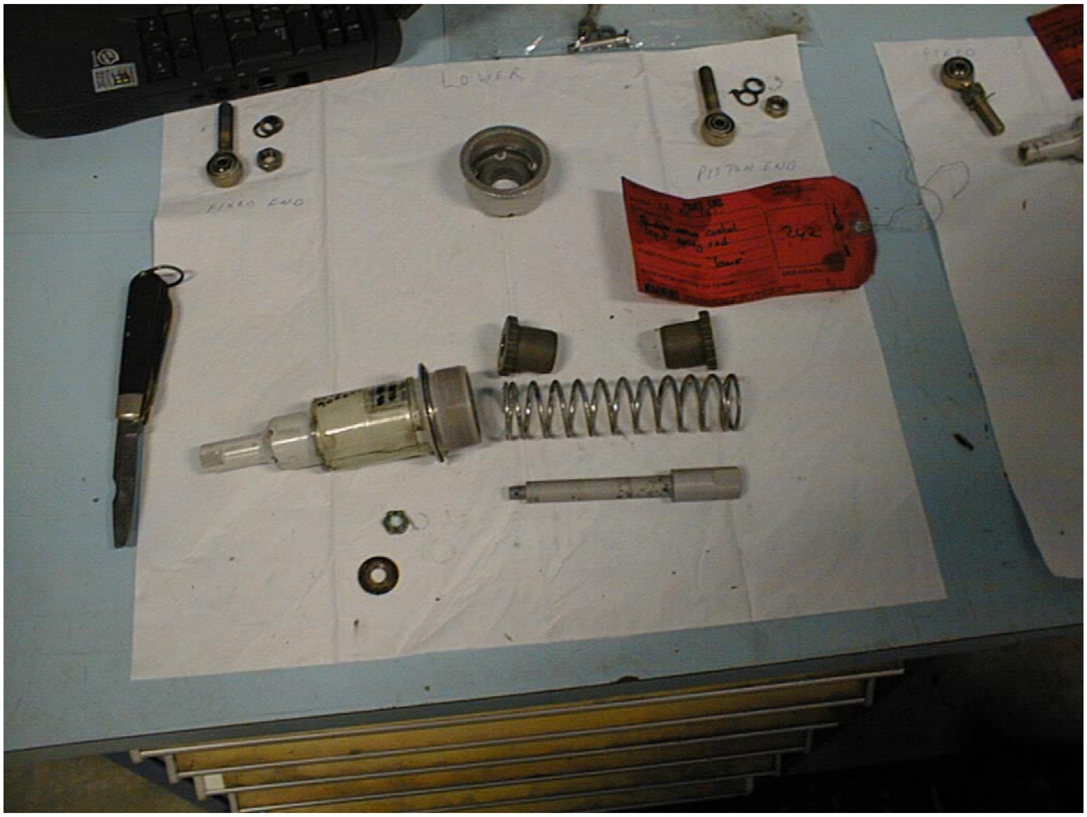

Figure 3.3.1D. Lower Springrod


Figure 3.3.1E. Lower Springrod

3.3.2 Middle Springrod (Figure 3.3.2)

There were no difficulties removing the rod ends, they were free to rotate when loosened.

White deposits and discoloration were observed, mostly on one side of the spring diameter. White deposits were noted on the internal face of the housings and retainers. There were light traces of corrosion (blue marks on bronze) on the retainers. The retainers were free to move on the piston, but some spots of white deposit induce some friction

Item 120 CMM washer was missing on the piston end.

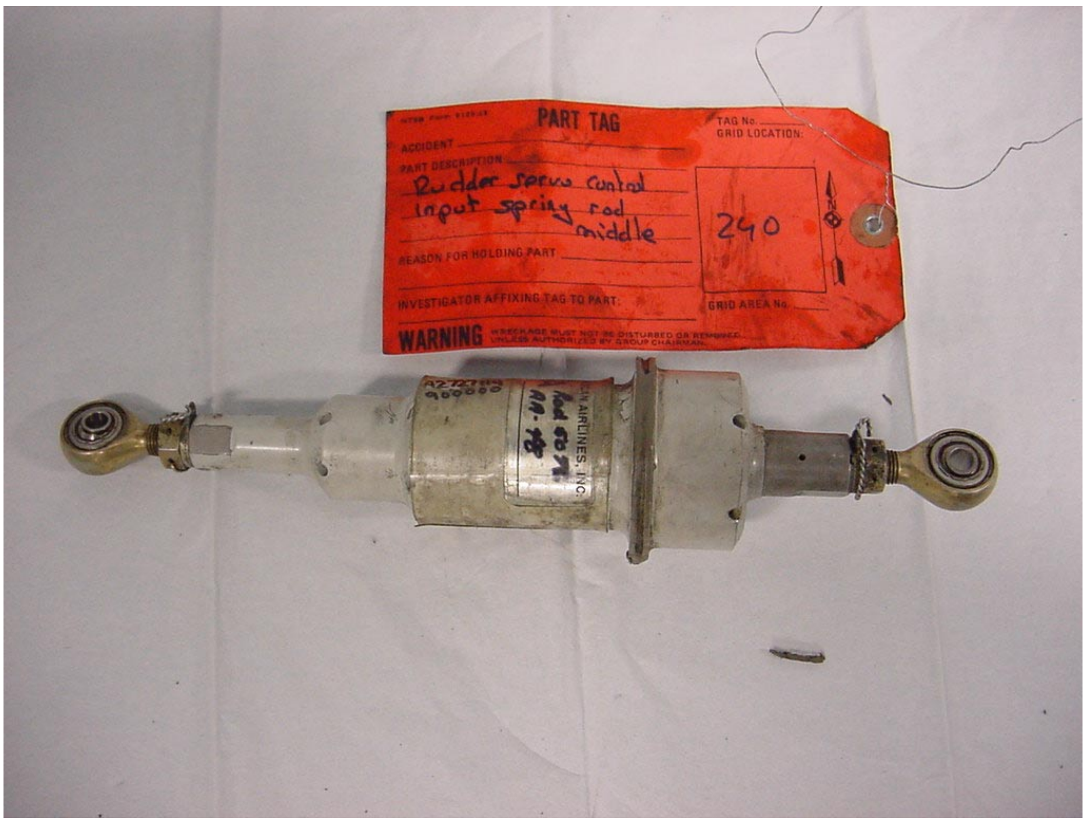

Figure 3.3.2A. Middle Springrod

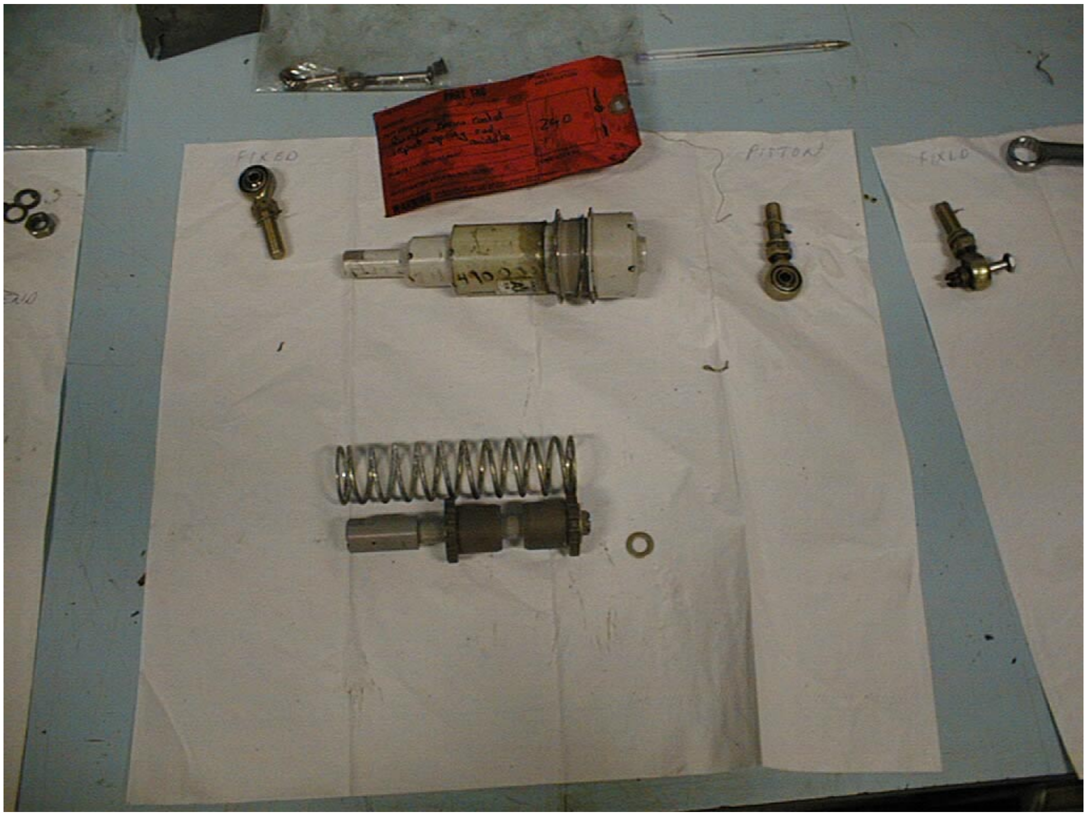

Figure 3.3.2B. Middle Springrod.

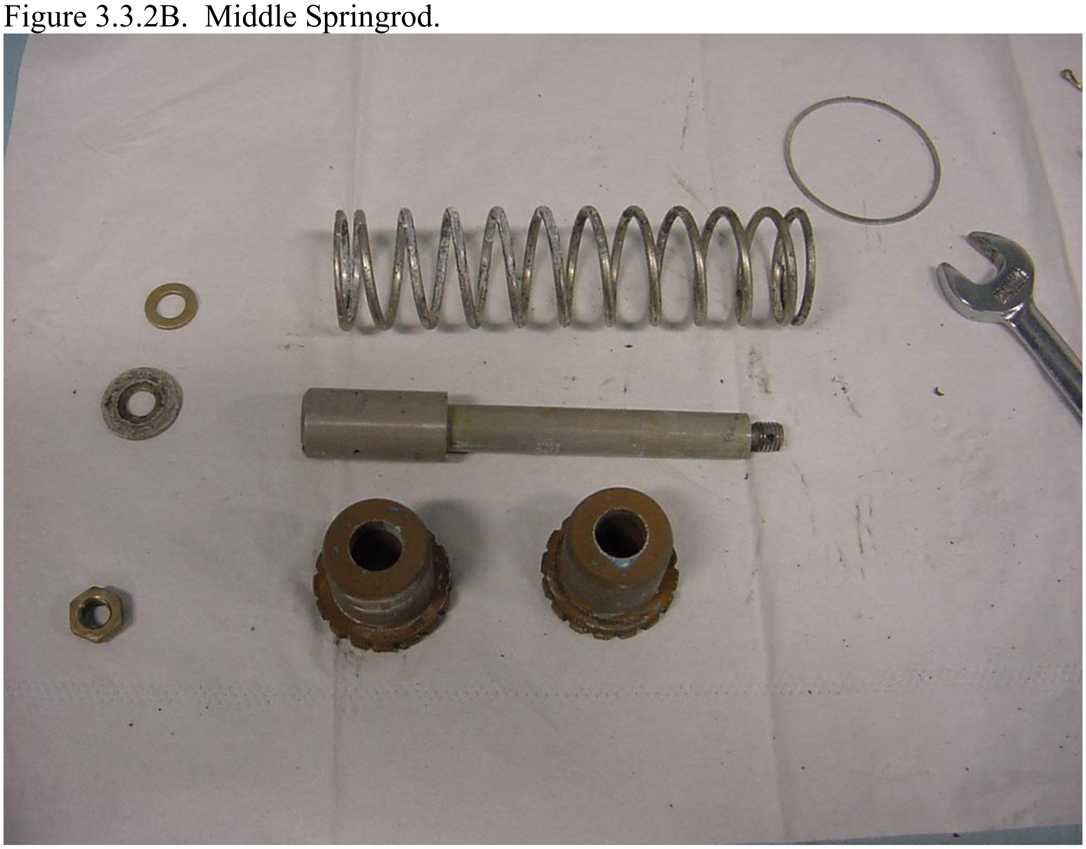
Figure 3.3.2C. Middle Springrod.

3.3.3 Upper Springrod (Figure 3.3.3)

There were no difficulties removing the rod ends.

Housing item 40 had to be rotated together with the piston to allow disassembly, due to the bent piston. This housing has one dent at a draining hole.

The item 90 washer was missing. There was no item 120 on the shouldered face of the piston. There was corrosion on item 120 on the nut side. Light blue deposits were noted on the exterior of the retainer nut side. There were white deposits on ½ of the diameter of the retainer internal surface.

White deposits and discoloration were present on 1/3rd of the spring circumference.

White deposits and numerous spots of discoloration were found on the operating surface of the piston, nut and retainer. There were light blue deposits on the exterior surface of the retainer piston shouldered face side. The shoulder side retainer was free to move with moderate friction. Several small spots of discoloration were noted under the retainer. Slight white deposits were observed on the interior face of this retainer.

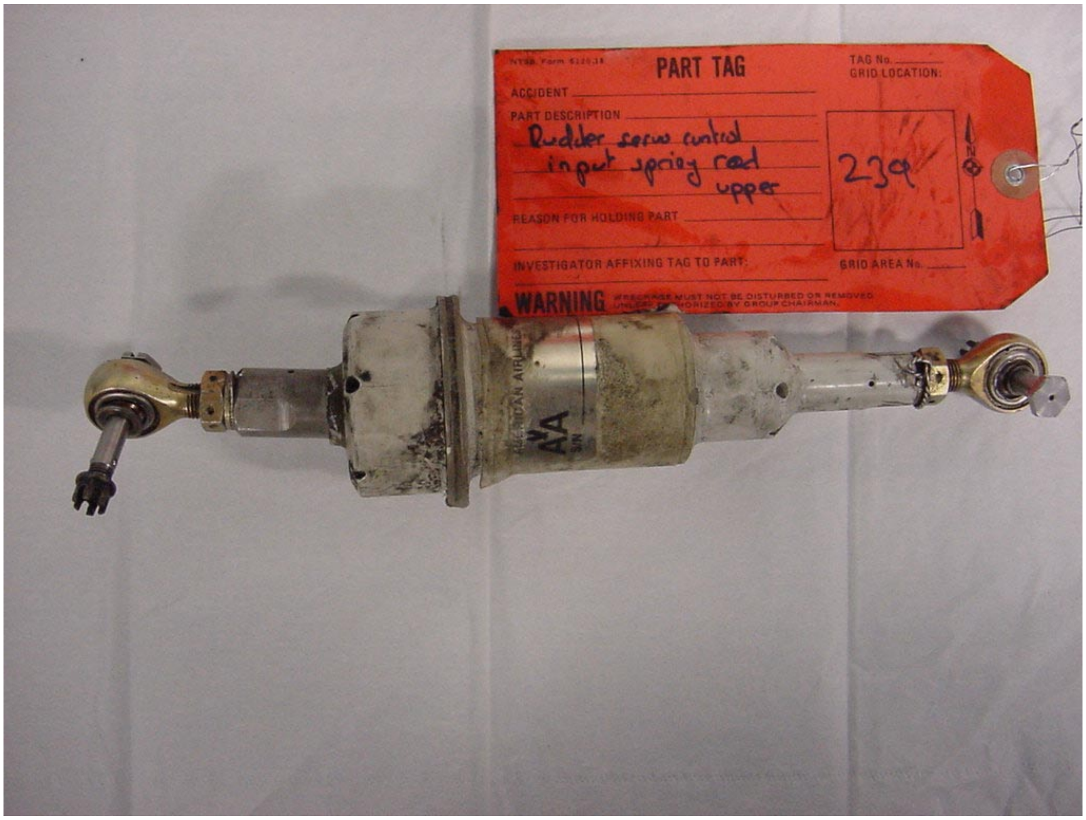

Figure 3.3.3A Upper Springrod.

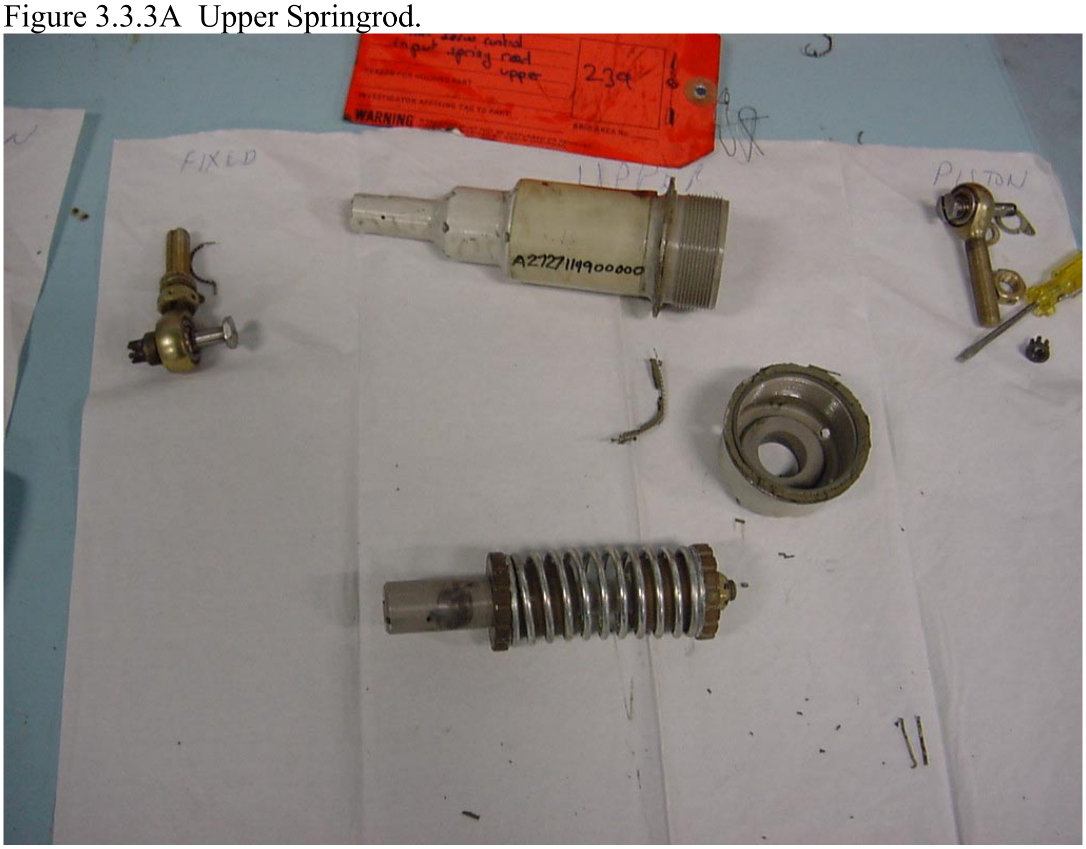

Figure 3.3.3B. Upper Springrod.

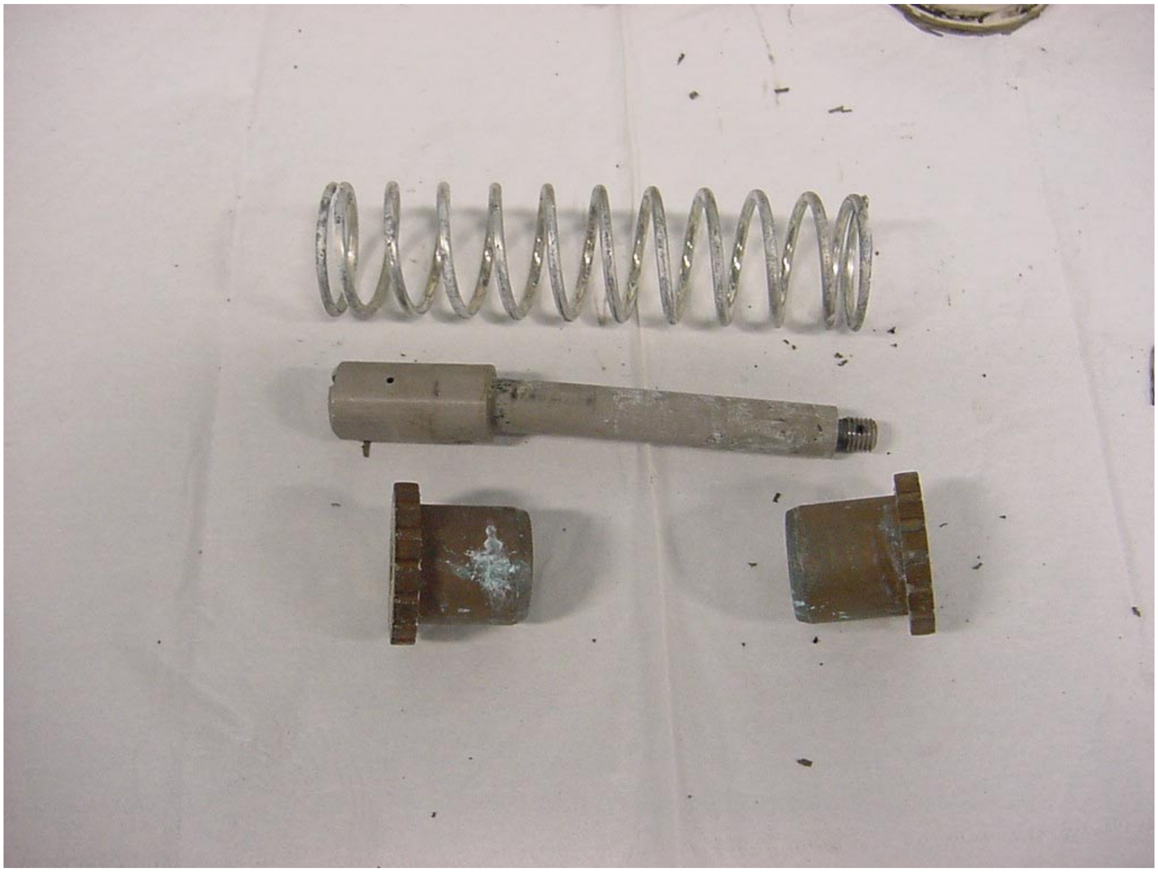
Figure 3.3.3C. Upper Springrod.

3.4 Upper Springrod, Examination of Bend

The upper springrod was bent as shown in Figure 3.4A. A dent was observed in the springrod cap as well as damage to the corner of the middle rudder servo hydraulic block. After disassembly the springrod was submitted to the NTSB lab for further examination. The results were provided in the Materials Laboratory 15 - Factual Report 02-091, dated October 11, 2002.

The springrod cap, and rudder servo hydraulic block are manufactured from aluminum alloys (2024 and 2618 respectively). The American Society for Metals, Metals Handbook, Volume 9, page 366, indicates that alloy 2618 contains insoluble particles of $FeNiAl_9$. Alloy 2024 is not known to have these constituents. The dent in the cap was inspected by scanning electron microscope (SEM) and energy dispersive spectroscopy (EDS). Figure 3.4B shows three areas of the dent which were sampled. Figure 3.4C is an enlargement of one of the areas. Many of the small bright spots in 3.4C were examined with EDS, and the results shown in Figure 3.3.4D were typical. Figure 3.4D showed the bright areas primarily contained Al, Fe, and Ni.

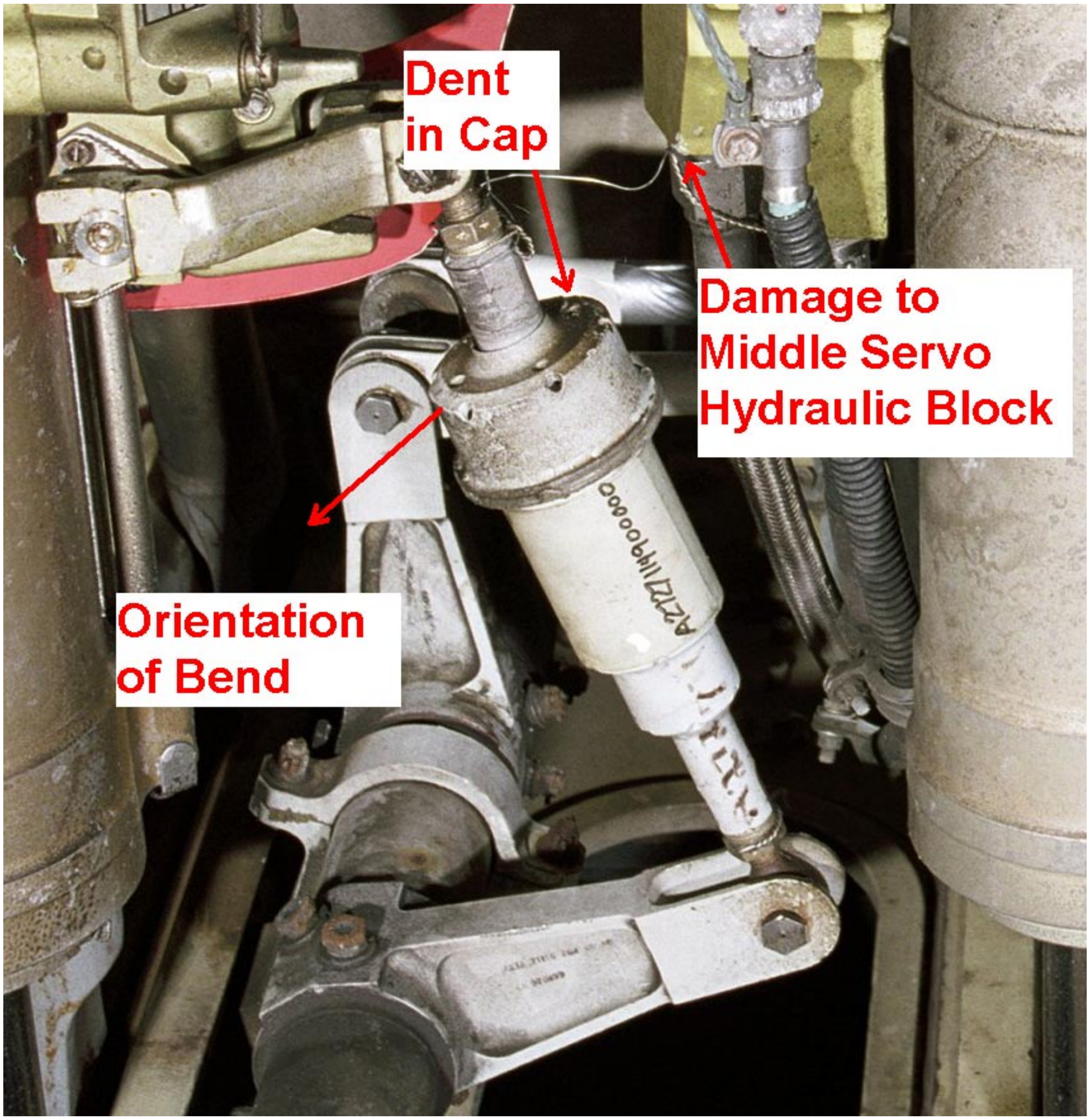

Figure 3.4A Upper Springrod as Installed Condition

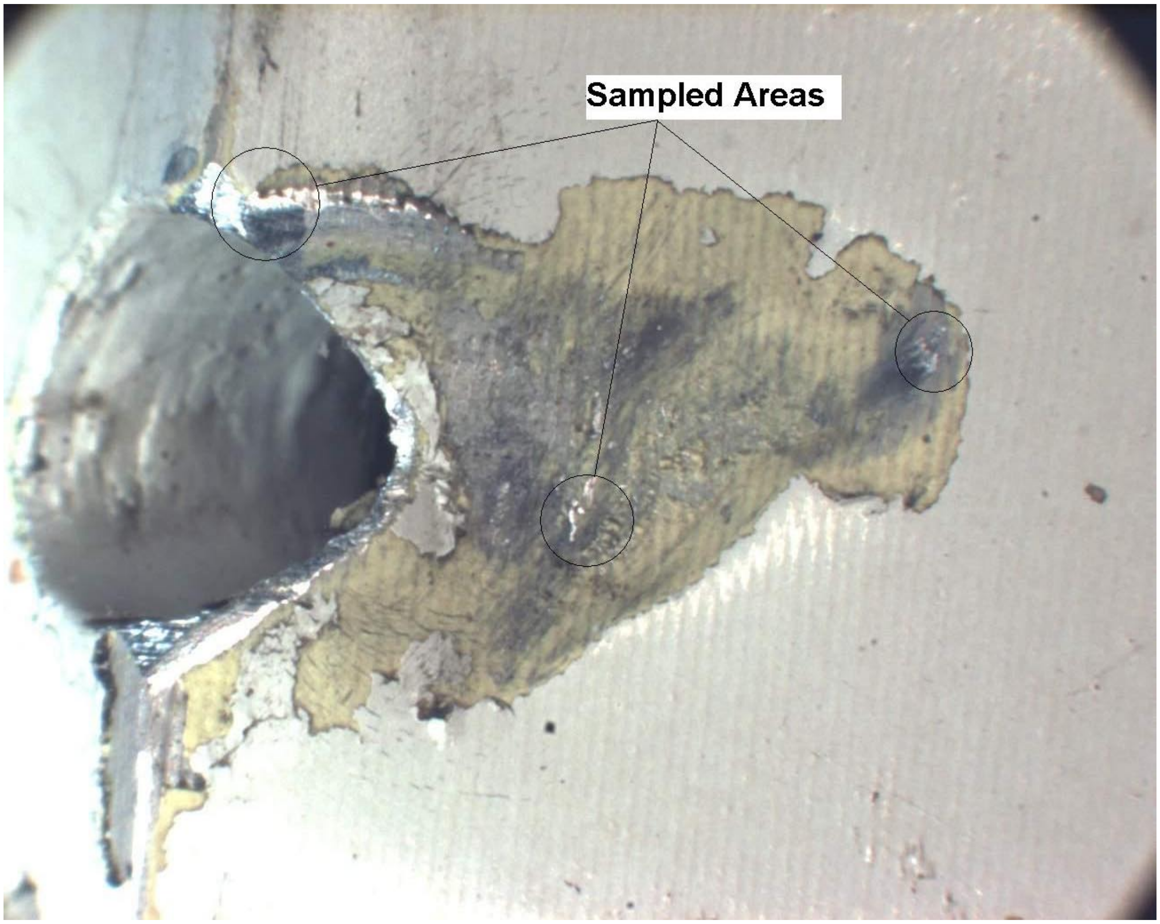

Figure 3.4B. Dent in Springrod Cap

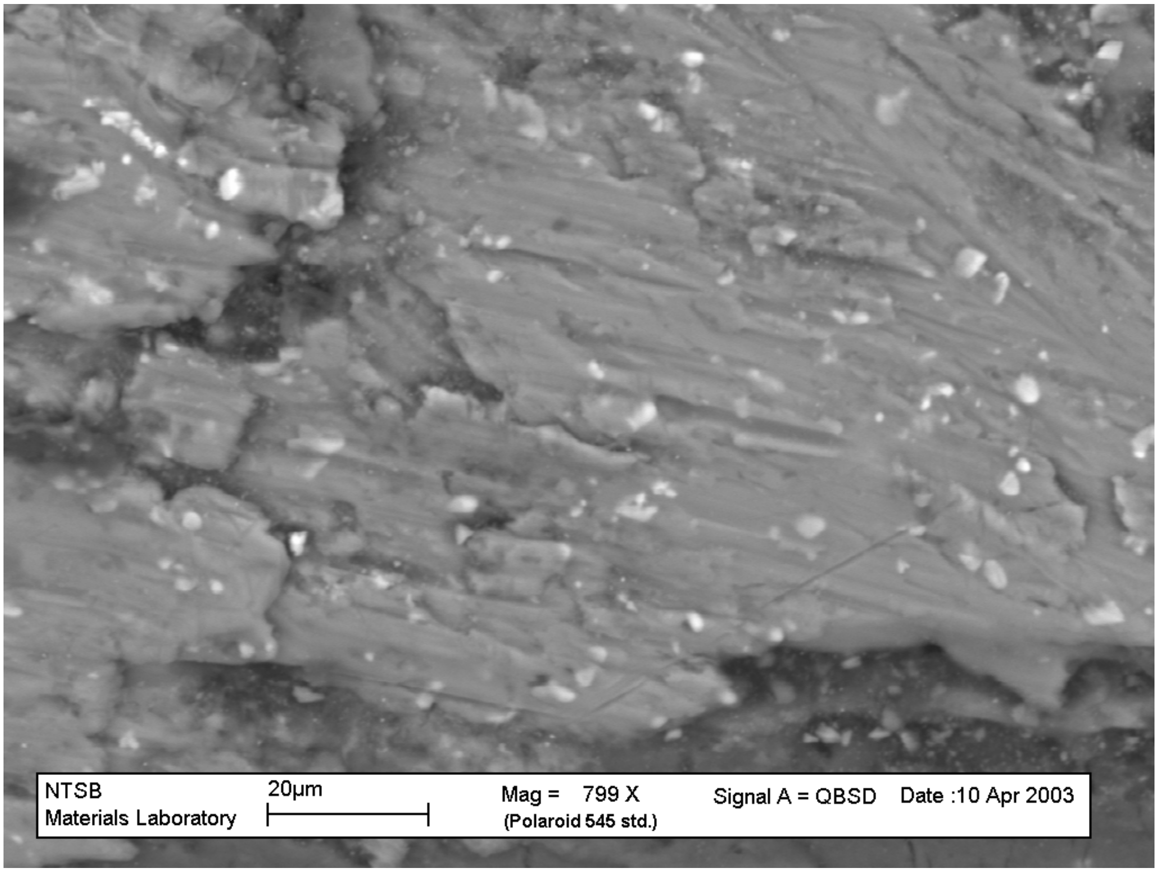

Figure 3.4C. Scanning Electron Microscope Image, Typical of the Areas Identified in Figure 3.4B.

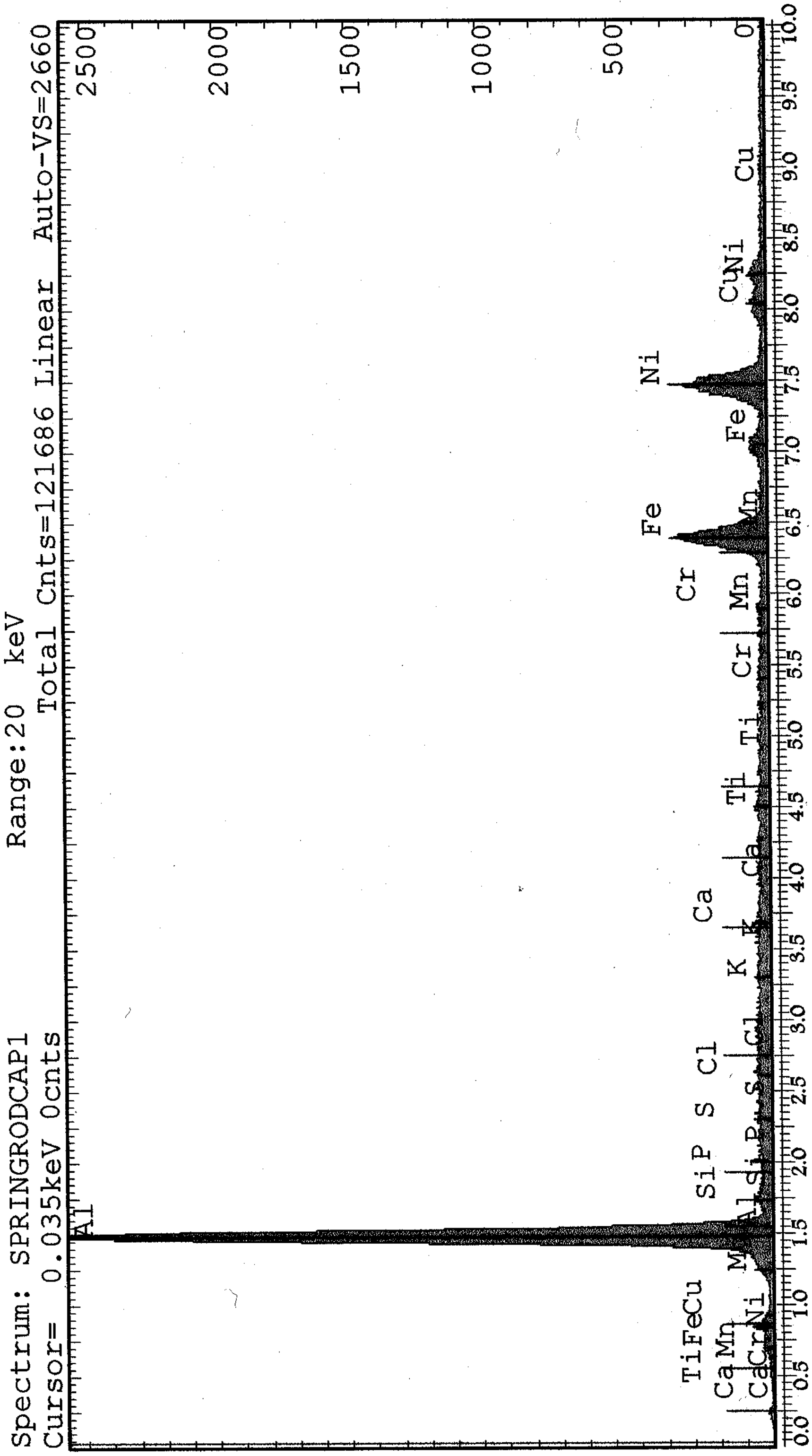

Figure 3.4D. Energy Dispersive Spectograph of Bright Particles.

4.0 Rudder Servo Controls Removal and Non-destructive tests.

The rudder servo controls were removed from the vertical stabilizer and sent to the Army Research Laboratory, Aberdeen Proving Grounds, Maryland, where computer aided tomography (CAT) was performed. The CAT scans were reviewed, and 3D reconstruction software was used to examine the internal state of the servo controls. Selected images are provided in Appendix B.

The servo controls were shipped to the Bureau Enquetes - Accidents (BEA) in France and held until the systems group convened at the TRW Aeronautical Systems SOA facility near Paris, France, between March 14 – 22, 2002 to inspect, test and disassemble the three rudder servo controls.

5.0 Rudder Servo Controls Inspection, Test and Disassembly.

5.1 Upper Rudder Servo Control

Table 5.1A provides all of the part numbers observed on the upper servo control.

Table 5.1A. Upper Rudder Servo Control Observations.

Nomenclature	Part Number	Serial Number	Forging Number
Servo Control	31042-130	W1063*	
Cylinder Body:	339784	W1128	
Valve Block forging:	339416	H0026	Matl AU2GN.B 328U
Body Attachment Fitting	339797-100	H0018	
Piston Rod	339786	W551	
Piston Rod End	339792	W1175	
Valve Block ID Plate	339531	E9351	
Hydraulic Block Forging Numbers	5.339794		AU2GN.B 031433A

* Obtained from historical records; as the ID plate was not found upon aircraft recovery.

See Table 5.1B for spherical bearing measurements. See Appendix K for attachment hardware dimensional check results.

Table 5.1B Spherical Bearing Measurements

Spherical Bearing	Diameter	Nutation Torque
Body end (IPL 4-320)	25.392mm	0
Piston end (IPL 4-10)	25.393mm	0.47 Meter Deca-Newtons (mdaN)

The general condition of the upper servo control was considered to be visually typical and satisfactory for an in-service unit, with the following observations. The Illustrated Parts List is provided in Appendix C. Images of the servo are provided in Appendix G.

- All of the lock-wires were intact, and taut.
- The servo control identification plate was missing.
- Surface corrosion at the rudder end ball joint union (attachment fitting, IPL 4-340) was evident, where Cadmium plating was absent.
- There were white deposits on piston-end of the jack body (IPL 4-510), and some, minor surface corrosion.
- There were traces of fluid around hydraulic connections (supply and return), but no evidence of leakage from other sealed joints and connections.
- The input lever (IPL 2-230) lower, outer edge (micro-switch side) of the servo control lever arm had been damaged, consistent with an impact (aluminum alloy edge had been “smeared”), with grease build-up in the fold of the damaged edge.
- There was evidence of light contact on the end-stop (machined body IPL 3-530) and input lever (IPL 2-230) in the extend direction.
- A pair of indentations were noted on the inner bush of the “top hat” bushing (IPL 2-200) of the servo control input lever opposite to the switch side. This would be consistent with an attempt to remove the spring rod retention bolt without retracting retention balls.
- The bushing diameter was measured: 6.35mm (switch side), 6.38mm (opposite). (Note: these sleeve bushes fit inside the TRW “top hat” bushes (IPL 2-190 & 2-200)). No sleeve bore ovality was observed.
- The switch side bushing needed to be removed to fit the standard test fixture (which provides a displacement measurement reference on rig). It was agreed to proceed with the removal, and the “top-hat” bushing (IPL 2-190) was lightly tapped out, together with the inner sleeve bushing. It was agreed that a new top-hat bush (IPL 2-190) would be used for the rig tests.
- Ball-joints: It was noted by the investigation team that at NASA the rudder end ball joint bolt had been difficult to remove. The bolt had to be pounded out.
- It was noted that the microswitch wiring was crushed.
- The test finger was extended.
- The microswitch connector 3 pins were intact and, relatively good condition.
- The body end fitting inner diameter of spherical bearing had black discoloration, grease and sawdust deposits.

- Scoring noticed on the body end spherical bearing.
- Black deposit marks were noted on the inner diameter of the spherical bearing. The mark was approximately 1 mm wide and 26.38 mm inside the bearing. Marks on the bolt corresponded with the spherical bearing. Two marks were 27 mm wide.
- Circumferential scoring was observed on the inner race of the body end spherical bearing.
- The force necessary to actuate the jamming detection switch was measured. Extention: 6.0/6.2 kgf, Retraction: 6.3/6.2 kgf
- Operation of the microswitch was confirmed by illumination of test box light.
- The right hand input lever bushing was removed with light pressure (tapped) for the installation of the test rig pin.

Electrical Measurements:

Pin to pin resistance and mega ohm insulation resistance tests were performed on the microswitch wiring and connector. Results are provided in Appendix E.

Hydraulic Fluid Samples:

Hydraulic fluid was taken from the four areas: Ca – extension chamber, Cb – retraction chamber, supply connection, and return connection. The Cb (retraction) plug contained chunks of debris that looked like white grease. Production assembly procedures allow the use of MCS352B Hydraulic Assembly Lube, L-AE: 9667-100 AFS, or 9652-600 grease. The fluid was drained into separate bottles, depending upon the collection point.

Observation: The fluid contained particles and was very dark in color.

NOTE: Axethane 212 solution was found in the sample bottles and was drained.

The fluid samples were sent to a lab for further analysis. The results are provided in Appendix J.

Functional Tests:

All tests were performed per the Servo Control Functional Test Procedure, Appendix D. The test results are provided in acceptance test report, Appendix E.

Functional Test Observations:
Leakage check – only minor wetting @ 15 bar witnessed.
Filter bowls were emptied into plastic tray boxes for visual inspection of contamination. Return filter bowl contained what appeared to be metallic particles, which broke up when attempts were made to extract them. No particles were observed in the supply side filter bowl fluid.
Measurements were taken at the highest edge of the fixed stop to lever, made with a digital readout caliper tool D111 10040 (next cal 08/02).

Disassembly:

Disassembly was performed per CMM 27-21-17, Revision 6, with the following observations.

NOTE: White substance refers to what appears to be assembly grease. Measurements of spring characteristics are provided in Appendix F.

- A white substance was observed on the microswitch boot interior.
- The bobbin on Cb was extremely difficult to remove.
- A white substance was observed on the non-return valve and body.
- There were no obvious deposits or damage on the split (mating) face of the valve body.
- All parts were bagged and identified.
- Item 470, Figure 3 – pin missing from servo control.
- Slight corrosion was observed on the valve block assembly bolts and threads.
- Due to the color of the perimeter (green), lee plugs in the valve block were noted to be original.
- No methylene chloride was available to dissolve the araldite seal – Step (4)(a). A small screwdriver was used to remove this epoxy type seal of the microswitch bracket assembly screws.
- The microswitch spring retainer pin looked good.
- The microswitch lever bearing was smooth; no observed freeplay.
- Slight dark deposits were noted on microswitch spring.
- The input lever was easily removed after the bobbins were removed.
- Test finger:
  The test finger valve, spring, and 3 part retainer came out relatively smoothly. There were deposits on the external part of the test finger.
- Bypass valve assembly:
  The bypass valve was removed. The pin and retainer washer was easily removed. Some corrosion was noted on port surfaces between the sealing lands. No apparent damage/deposits on the bypass valve internals (good condition). The spring was in good condition. There were white deposits on bypass piston cones. The bypass valve housing interior is in good condition (no deposits/corrosion noted).
  Item 3-250 – the bypass valve assembly pin, had plating missing in places. Some corrosion was observed on the bypass piston under the microscope.
- Spool Input Lever Assembly (Remote Control Lever):
  A white substance was found on the interior of the caps (Items 2-250 and 2-280).
  The needle bearing had a white substance and was in good condition (no noted damage).
  There was no damage or deposits on Items 2-420A and 2-340A.
  In the housing of the input lever, deposits of an unknown substance and black

particles were found.

- Spool Valve Assembly:
  Item 3-370 was removed.
  There was internal corrosion.
  Item 3-410 was removed. There was corrosion on part of the shaft.
  Item 3-400 was removed. There were some pitting and "rust" deposits noted. The housing had a gray foreign substance in the bottom of the slide shaft area and an indentation.
- The input lever fixed stop gap was 39.69 mm
- The inlet filter was removed and stored in a sample jar.
- The return filter was removed and stored in a sample jar.
- The supply and return plugs and packings were in good condition.
- The cylinder and attachment fitting end dimension was measured to be 541 mm. The width of the washer on the end of the cylinder body is 0.56 mm.
- Upon removal of the attachment fitting end, an unknown white substance was noted on the threads and inner surfaces of the cylinder and piston rod ends. A sample of the substance was taken from the threads of the attachment fitting end nut (IPL 4-310).
- Upon cylinder disassembly, a white substance was on all surfaces. Rust deposits were found on the chamber cylinder plugs. The valve block support was dirty, but no noticeable corrosion or damage.
- Item 4-240, piston had corrosion (corrosion or rust deposits) on the retraction chamber side. There were white deposits and corrosion on the shaft. A witness mark of the piston head position was observed on the extension chamber side.
- In the recessed areas of the cylinder near the retraction stop, corrosion was observed similar in height to the piston head witness mark. Measurement from the edge of the cylinder to the interior mark was 126.3 mm (first edge or top of the mark).
- To remove Item 4-370, the locating guide, some white substance was removed.
- Item 4-380, outer end was covered in a white substance. O'rings appearred undamaged, but had foreign deposits.

5.2 Middle Rudder Servo Control

Table 5.2A provides all of the part numbers observed on the middle servo control.

Table 5.2A Middle Rudder Servo Control Observations.

Nomenclature	Part Number	Serial Number	Forging Number
Servo Control	31042-130	W487	
Cylinder Body:	339784	W524	
Valve Block forging:	339416	W2224	Matl AU2GN.B
Body Attachment Fitting	339797-100	W560	
Valve Block ID Plate	339531	W454	
Piston Rod	339786	W475	
Piston Rod End	339792	W841	
Hydraulic Block Forging Numbers	5.339794		AU2GN.B 031433A

See Table 5.2B for spherical bearing measurements. See Appendix K for attachment hardware dimensional check results.

Table 5.2B Spherical Bearing Measurements

Spherical Bearing	Diameter	Nutation Torque
Body end	25.397 mm	0.184/0.2/0.3/0.088 mdaN
Piston end	25.395 mm	1.225/0.875/0.98/0.665 mdaN

The general condition of the middle servo-control was considered to be visually typical and satisfactory for an in-service unit, with the following observations. The Illustrated Parts List is provided in Appendix C. Images of the servo are provided in Appendix H.

- The lockwire above the part number placard was broken and the metal adjacent to the broken lockwire was gouged. All other lockwire was intact.
- Minor corrosion was noted only on the eye end.
- The input lever bushing diameter was measured on the switch side (sleeve installed). Two measurements were taken at different orientations:
  - 6.345 mm
  - 6.35 mm
- Input lever bushing diameter on opposite side. Two measurements were taken at different orientations:
  - 6.345 mm
  - 6.34 mm
- There was no freeplay detected in the rod end spherical bearings.
- The input lever did not have any binding, it moved freely.
- The jamming detection switch was tested under zero hydraulic pressure:
  - Extension force: 6.6 kgf
  - Retraction force: 6.0 kgf

- Operation of microswitch was confirmed by illumination of the test box light.

Electrical Measurements:

Pin to pin resistance and mega ohm insulation resistance tests were performed on the microswitch wiring and connector. Results are provided in Appendix E.

Hydraulic Fluid Samples:

Hydraulic fluid was taken from two areas using special plugs provided by TRW: Ca – extension chamber and Cb – retraction chamber. Production assembly allows the use of MCS352B Hydraulic Assembly Lube, L-AE: 9667-100 AFS, or 9652-600 grease. The fluid was drained into separate bottles, depending upon the collection point.

NOTE: Axethane 212 solution was found in the sample bottles and was drained.

The fluid samples were sent to a lab for further analysis. The results are provided in Appendix J.

Functional Test:

All tests performed per the Servo Control Functional Test Procedure, Appendix D. The test results are provided in acceptance test report, Appendix E.

Functional Test Observations:
Additional measurement of gap between neutral position and fixed stop on piston side at 206 bars. Measurement made with gage blocks: 7.80 mm

Disassembly:

Disassembly was performed per CMM 27-21-17, Revision 6, with the following observations.

NOTE: White substance refers to what appears to be assembly grease.
Measurements of spring characteristics are provided in Appendix F.

- The input lever and intermediate lever assembly were removed:
  Input lever width – 23.98 mm
  Valve body manifold stops – 39.61 mm
- The valve block was removed:
  Alignment pin present.
  Bobbins removed
  O-rings removed
  Lee plugs were green type (original)
- The bypass valve was removed:

Corrosion deposits seen between lands; not on the lands.
No corrosion on the spring to bypass valve pistons.

- The spool input lever assembly (Remote Control Lever) was removed:
  Small amounts of white substance noted
  Uniform distribution of wear on shaft.
  NOTE: Component completely disassembled; including drive pin.
- The slide and spool valve was removed:
  Minor corrosion seen in cap and between lands of the spool. Slide appeared okay.
  No spots of corrosion seen inside spool (inspect by borescope)
- The filter was removed (supply and heating):
  Placed in specimen jars.
- The piston was removed:
  Corrosion on 'flat' side.
  Machined side only had spots of corrosion.
- The cylinder was examined:
  Measurement to piston witness mark (very faint) – 129.88 mm

5.3 Lower Rudder Servo Control

Table 5.3A provides all of the part numbers observed on the lower servo control.

Table 5.3A. Lower Rudder Servo Control Observations.

Nomenclature	Part Number	Serial Number	Material Number
Servo Control	31042-130	E9291	
Cylinder Body:	339784	W489	
Valve Block forging:	339416	H0129	Matl AU2GN.B
Body Attachment Fitting	339797-100	W1132	
Valve Block ID Plate	339531	E9348	
Piston Rod	339786	W563	
Piston Rod End	339792	W569	
Hydraulic Block Forging Numbers	5.339794		AU2GN.B 0.31433a
Micro-Switch Support	339657	2190	
Input Lever	339655	422U	AU2GN B

See Table 5.3B for spherical bearing measurements. See Appendix K for attachment hardware dimensional check results.

Table 5.3B. Spherical Bearing Measurements.

Spherical Bearing	Diameter	Nutation Torque
Body end	25.395 mm	0.0 slight play
Piston end	25.396 mm	0.12/0.10/0.11 mdaN

The general condition of the lower servo-control was considered to be visually typical and satisfactory for an in-service unit, with the following observations. The Illustrated Parts List is provided in Appendix C. Images of the servo are provided in Appendix I.

- There was slight surface corrosion on attachment fitting end.
- The Identification plate was missing.
- There was no evidence of impact damage.
- Sealant was observed at both bearings.
- All lockwire was intact.
- Dimensional measurements:
  Cylinder body with attachment end: 541.1 mm
- No apparent damage (scoring, etc.) to inside diameter of spherical bearings.
- The diameter of the input lever clevis with bushings was measured at two orientations:
  - Microswitch side (The sleeve was not present, it was found to be included with the input spring rod bolt):
    7.49 mm
    7.51 mm
  - Opposite clevis of input lever with bushings:
    6.34 mm
    6.34 mm
- The microswitch side clevis of input lever has some slight damage (approximately 2 mm X 0.3 mm).
- There is no obvious damage to the bushings.
- Micro-switch:
  No noted damage or contamination on Pins A, B, and C.
  Wire bundle is flattened.
  Slight debris and corrosion observed on the pins.
- The jamming detection switch was tested under zero pressure:
  - Extension force: 6.4 kgf
  - Retraction force: 5.0 kgf
- Operation of microswitch was confirmed by illumination of the test box light.
- The test finger is extended.

Electrical Measurement:

Pin to pin resistance and mega ohm insulation resistance tests were performed on the microswitch wiring and connector. Results are provided in Appendix E.

Hydraulic Fluid Samples:

Plugs Ca and Cb were removed and collected:
 Cb had corrosion on interior and bottom.
 Ca had no noticeable corrosion.
 Cb contained a white substance.
 Ca had rust-colored chunks of debris on the bottom.

The fluid sample from Cb was contaminated with an unknown substance.

The fluid samples were sent to a lab for further analysis. The results are provided in Appendix J.

Functional Tests:

All tests were performed per the Servo Control Functional Test Procedure, Appendix D. The test results are provided in acceptance test report, Appendix E.

Functional Test Observations:

An additional measurement was made of the gap between the input lever neutral position and the fixed stop on the piston side at 206 bars pressure. The measurement was made with gage blocks: 7.90 mm

The jet pipe consumption test failed (60 cc per minute).

Disassembly:

Disassembly was performed per CMM 27-21-17, Revision 6, with the following observations.

NOTE: White substance refers to what appears to be assembly grease.
Measurements of spring characteristics are provided in Appendix F.

- The input lever and intermediate lever assembly was removed:
  The input lever width was 24.01 mm
  The distance between the valve body manifold stops was 39.61 mm
- The non-return valve was removed:
  The clock valve had rust deposits (IPL 3-100)
- The bypass valve was removed:
  There were corrosion deposits observed between lands, but not on the lands.
  There was light corrosion on the spring to bypass valve pistons.
- The drive shaft bearing assembly was removed:
  The needle bearing cage was darkened.

- The slide and spool valve was removed:
  Moderate corrosion was observed in the cap and between the lands of the spool. The slide appeared undamaged.
  A boroscope was inserted in the spool and a few spots of corrosion were observed.
- The filters were removed and placed in specimen jars.
- The piston was removed:
  Corrosion was observed on the retraction chamber side.
  The machined side only had one small spot of corrosion.
- The cylinder was examined:
  A brown corrosion line was observed on the interior
- The rear bearing was removed (body end piston stop):
  Lots of debris external to the piston cylinder was observed, and a sample was collected

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