

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594



CEN22FA053

HYDRAULIC SERVO EXAMINATION

Specialist's Factual Report

September 22, 2022

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A. ACCIDENT

Location: Perry, OK
Date: October 28, 2021
Time: 1658 CST
2158 UTC
Helicopter: Bell 206B / N59600

B. HYDRAULIC SERVO EXAMINATION

Helicopter Specialist Van S. McKenny IV
NTSB / AS40
Washington, DC

Party Coordinator Aaron Jarvis, Sr Engineer
Woodward Inc
Santa Clarita, CA

C. DETAILS OF THE EXAMINATION

Examination of the servos took place at the Woodward Inc facility in Santa Clarita, California, on Sept 12th & 13th, 2022. Three flight control servos (left, right and middle) were hand carried by the NTSB specialist to the Woodward facility.

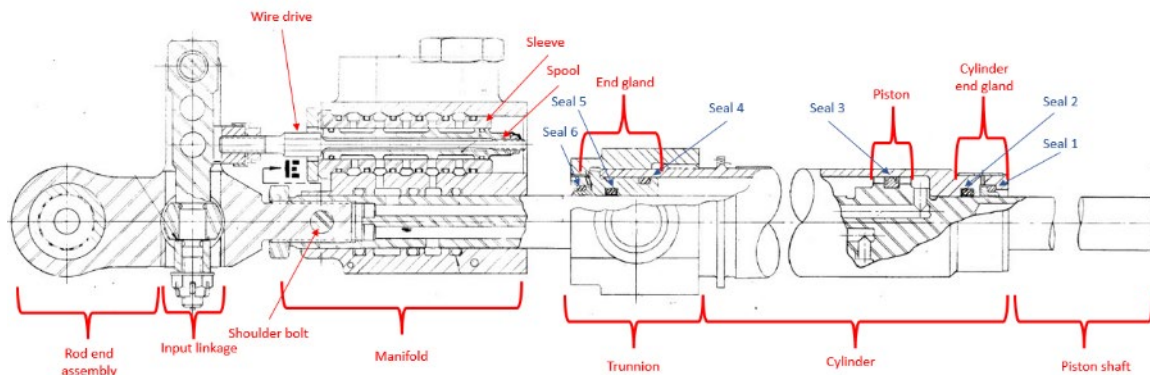


Figure 1. Hydraulic servo actuator diagram. (Source: Figure provided by Woodward and edited by NTSB).

Each of the gland seals (Figure 1) consist of two components. A blue Teflon exterior and a black polymer o-ring behind the Teflon.

Table 1. Hydraulic Servo Seal Identification

No.	Nomenclature	Description
Seal 1	Cylinder end gland scraper seal	Teflon outer sheath and backing o-ring
Seal 2	Cylinder primary seal	Teflon outer sheath and backing o-ring
Seal 3	Piston seal	Elastomeric "T" seal with Teflon disks on either side of the elastomer seal (backup disks).
Seal 4	Static o-ring seal	O-ring
Seal 5	End gland primary seal	Teflon outer sheath and backing o-ring
Seal 6	End gland scraper seal	Teflon outer sheath and backing o-ring

The Computed Tomography Specialist's Factual Report that examined the three hydraulic servos identified specific areas of interest on each servo that warranted further examination.

In the right actuator, there were indications of seal distortions and seal gaps in seals 1 and 2. Seals 3, 4, 5, and 6 appeared to have minimal anomalies.

In the middle actuator, the seals appeared to have minimal anomalies except for seal 6 which had indications of voids throughout the seal.

In the left actuator, there were indications of seal distortions and seal gaps in seals 1, 2, 3, 5, and 6. Seal 4 appeared to have minimal anomalies.

These specific areas of interest were the driving factors for the physical examination of each servo and is the focus of this report.

1.0 Right Servo Actuator

The servo was manufactured by Hydraulic Research & Mfg Co., part number (PN) 4100067015-XX (dash number was illegible), and serial number (SN) 2023 (Figure 2). The servo was covered in dark soot and had a light oil coating over the cylinder. All castellated nuts were cotter keyed. The primary spherical bearing was assessed to be very loose. The control rod that mates with the clevis shank was fractured at the top of the clevis shank. The input linkage moved manually within the normal range of movement (typical), was connected, and moved the spool. The trunnion lugs didn't appear to have heavy wear. The cylinder was measured as extended 4.4 inches from the cylinder face to manifold face. The servo was manually extended to full extension of 5.5 inch. No fluid drained during this action.

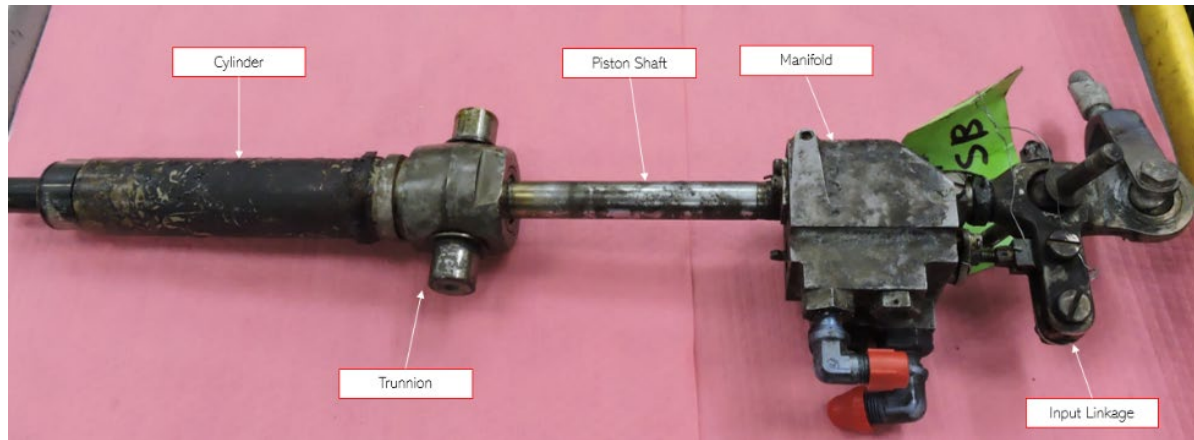


Figure 2. Right servo actuator as received.

1.1 Manifold

The disassembly of the servo started by removing the cotter pins on the manifold bolts and the piston shoulder bolt. No preload torque was observed on the shoulder bolt castellated nut (nylock nut). The wire drive retaining nut was removed; the wire drive o-ring was present with normal wear. The shaft translated freely in and out and rotated freely.

The input linkage and manifold were removed from the piston shaft assembly. The wire drive and spool (SN: 608) was extracted from the manifold input housing. The wire drive was connected and intact at both ends of the spool. The o-ring seals on both ends of the spool were in place and showed normal wear. No damage was observed on the spool metering edges. No visual damage on the wire drive was noted. The wire drive was partially disassembled to confirm drive continuity. The main piston shaft seals were removed from the manifold. All the seals were intact and pliable. The sleeve (SN: 608) was removed; the o-rings were present, intact, and had a permanent set (flat) outer diameter. The shutoff and relief valve assembly were disassembled; all o-rings were present, undamaged, and had a thermal set. The differential relief valve was disassembled; all o-rings and spring were intact. The check valve was disassembled; the o-rings and spring were intact. No damage or blocked hydraulic fluid ports were observed.

1.2 Cylinder

The cylinder end gland scraper and seals were in good condition. The piston rod was in good condition with no scoring. The fluid ports were open and clear. The cylinder end gland (seal 1, Figure 3) exhibited heat damage, and the o-ring behind the Teflon was carbonized. Seal 2's blue Teflon sheathing was removed intact (Figure 4); the o-ring material behind it was carbonized.



Figure 3. Cylinder gland scraper seal (seal 1) stretched out, and carbonized o-ring fragments.



Figure 4. Cylinder gland primary seal (seal 2).

2.0 Middle Servo Actuator

The servo was manufactured by Hydraulic Research & Mfg Co., PN 41000670-003, and SN 4233 (Figure 5). The servo was covered in a light amount of soot and a light layer of oil coating on the manifold. All castellated nuts were cotter keyed and safety wires were intact. The primary spherical bearing was assessed to be very loose. The control rod that mates with the clevis shank was fractured at the top of the clevis shank. The input linkage moved manually within the normal range of movement (typical), was connected, and moved the spool. The trunnion lugs didn't appear to have heavy wear. The cylinder was measured in the as-received extended position of 2.8 inches from the cylinder face to manifold face.

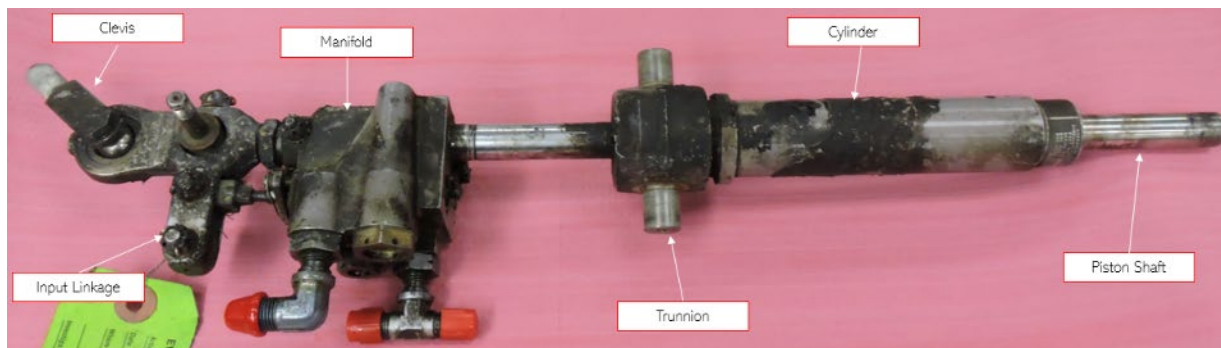


Figure 5. Middle servo as received.

2.1 Manifold

The piston shoulder bolt was removed and no preload torque was observed on the castellated nut (nylock nut). The input linkage and manifold were removed from the piston shaft. The wire drive retaining nut was removed. The wire drive and spool (SN: 341) was extracted. The wire drive was connected and intact at both ends of the spool. The o-ring seals on both ends of the spool were in place and exhibited normal wear. No damage was observed on the spool metering edges. No visual damage on wire drive was noted. The wire drive was fully disassembled to confirm

drive continuity. The sleeve (SN: 341) was removed; o-rings were present, intact, and the o-rings had a permanent set (flat) on the outer diameter. The main piston shaft seals were extracted from the manifold. All seals were intact and pliable. The hydraulic port fittings were unscrewed and removed. The shutoff and relief valve assembly were disassembled; all o-rings were present, undamaged, and had a thermal set. The differential relief valve was disassembled, all o-rings were intact as was the spring. No damaged or blocked hydraulic fluid ports observed. The check valve was disassembled, o-rings and the spring were intact.

2.2 Cylinder

The trunnion was unscrewed from the power cylinder and the cylinder end gland was slid from the piston shaft. The piston shaft had interior oil/fluid present; black flakes/particles were observed in the oil. The black particles were non-substantive (not hard or granular). The end gland static o-ring (seal 4) appeared to have more wear than normally found. A brown surface coating was surrounding the piston head area. The coating was easily removed using a cloth or cotton swab. The primary seal (seal 5, Figures 6 and 7) was removed intact, both the outer Teflon and inner o-ring had pliable characteristics. The scraper seal (seal 6, Figures 6 and 8) was removed. It's o-ring was hard and broke during the removal. The cylinder end gland interior primary seal (seal 2) had visible damage to the blue Teflon. The scraper seal was removed (seal 1). The Teflon portion was removed whole and pliable; the o-ring portion was slightly stiff and broke while being removed. The Teflon portion primary seal (seal 2) was removed whole and was pliable. The backing o-ring was removed whole and was pliable. All seals were slightly damaged during removal.



Figure 6. End gland seals.



Figure 7. Seal 5, primary seal removed from the end gland.



Figure 8. Seal 6, scraper seal removed from the end gland.

3.0 Left Servo Actuator

The servo was manufactured by Hydraulic Research & Mfg Co., PN 41000670-003, and SN 1789 (Figure 9). The servo was covered in a heavy amount of soot on the manifold and rod end linkage, with bluing of the metal on the end of the cylinder side piston shaft. All castellated nuts were cotter keyed and safety wires intact. Teflon o-ring material extruded out of the return port fitting. There was an extruded seal on the cylinder end gland. The primary spherical bearing was assessed to be very loose. The control rod that mates with the clevis shank was fractured at the top of the clevis shank. The input linkage moved manually within the normal range of movement (typical), was connected, and moved the spool. There was a heavy buildup of carbon like material around the cylinder end gland. The trunnion lugs didn't appear to have heavy wear. The cylinder was measured in the as-received extended position of 0.7 inches from the cylinder face to manifold face.

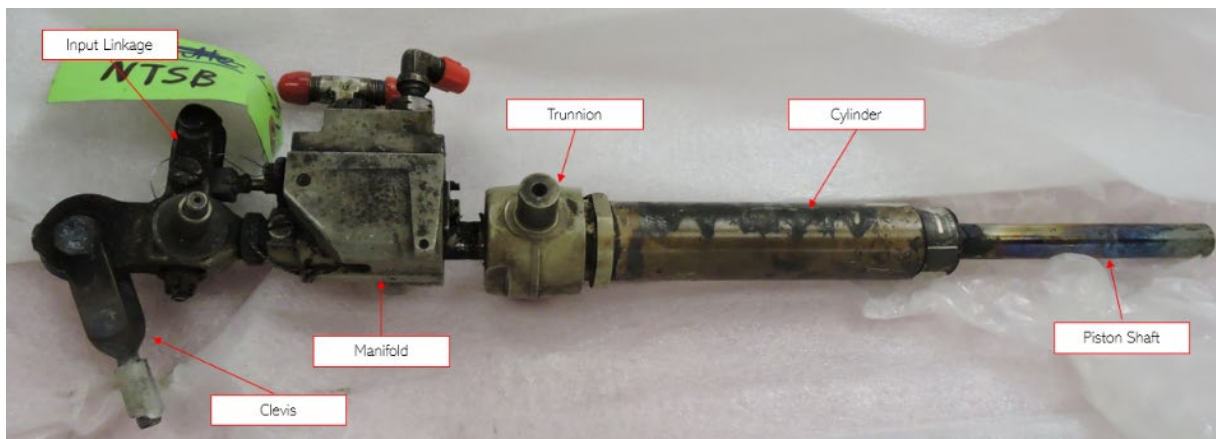


Figure 9. Left servo actuator as received.

3.1 Manifold

The piston shoulder bolt was removed and no preload torque was observed on the castellated nut (nylock nut). The input linkage was removed from the piston shaft. The wire drive retaining nut was removed and the manifold was pulled from the

piston shaft. The main piston seals were removed from the manifold. All three seals were intact, pliable, but had a permanent thermal set. All three seals were damaged during the removal. The wire drive and spool (SN: 166) was removed, the drive was connected and intact at both ends of the spool. The spool o-ring seals on both ends of the spool were in place and showed normal wear. No damage was observed on the spool metering edges. No visual damage on the wire drive was noted. The wire drive was partially disassembled to confirm drive continuity. The sleeve (SN: 166) was removed; all the o-rings were present, intact, and had a permanent set (flat) on the outer diameter. The hydraulic port fittings were unscrewed and removed. The shutoff and thermal relief valve assembly was disassembled. All o-rings were present, undamaged and had a permanent thermal set. The plug threads and cap had particle debris lightly adhered to them. A few specs of dark particle debris were observed in the port cavity. The differential relief valve was disassembled; all the o-rings and the spring were intact. No damage or blocked hydraulic ports observed. The differential relief valve was disassembled; all the o-rings and the spring were intact. The check valve was disassembled; however, the seat cap could not be removed. The o-rings and spring were intact.

3.2 Cylinder

The trunnion was unscrewed from the cylinder, and the cylinder end gland was slid off the piston shaft. The piston shaft was then slid out of the cylinder. Black powder like debris dropped out of the cylinder once the piston was removed. The piston head seal and Teflon backup disks were present; the o-ring elastomer was brittle and broke apart into chunks (Figure 10). Seal 4 was in the same condition as seal 3. Brownish discoloration was observed on the piston rod on either side of the piston head.

The cylinder end gland seals (seals 1 and 2, Figure 11), scraper and primary, were both present. Both seals exhibited a section that had been extruded (pushed out) of position in the same location (Figure 11, 12, 13). Seal 1 was removed; the Teflon scraper was mostly intact with a section of outward deformation and separation. The inner o-ring was brittle and carbonized. The primary seal's (seal 2) Teflon was mostly intact except for a section missing and separation; the primary o-ring was carbonized and brittle. A 5-millimeter bare metal witness mark was created while removing the cylinder from the end gland. The end gland exterior had a similar mark that was created on the interior of the cylinder where the end gland mated with the cylinder. The end gland was pressed from the piston rod. The scraper (seal 6, Figures 14 and 16) and primary (seal 5, Figures 14 and 15) were in place. A Teflon section of both seals had been deformed in the same location. The seal 6 Teflon scraper was removed intact; the o-ring behind it had been carbonized. The primary seal (seal 5, Figure 15) Teflon was removed with damage observed in one area; the backing o-ring had been carbonized.

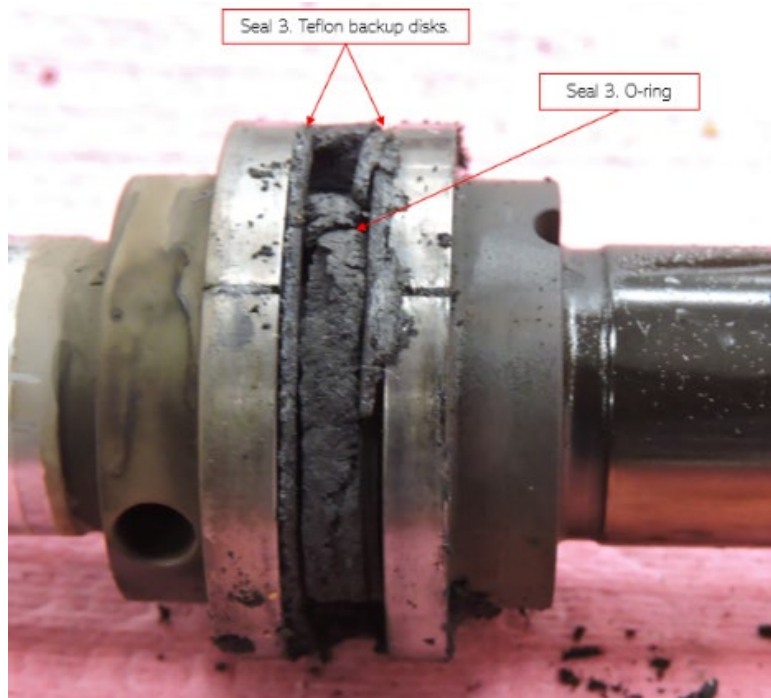


Figure 10. Piston and piston seal (seal 3).



Figure 11. Cylinder end gland



Figure 12. Seal 1, Teflon scraper seal and o-ring fragments.



Figure 13. Seal 2, primary seal, Teflon portion.



Figure 14. End gland seals (seals 5 & 6).



Figure 15. Primary seal, seal 5. Teflon seal and carbonized o-ring fragments.



Figure 16. Scraper seal, seal 6. Teflon scraper and pieces of carbonized o-ring.

Submitted by:

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