SUBSYSTEM: THRUST VECTOR CONTROL

ITEM NAME: Power Spool and Bushing Assembly, Part of Servoactuator

PART NO.: A05331-3 (Bushing, Spool and Sleeve Assembly), A22484-1 (Spool and Drive Rod Assembly), A05317 (Closure/Stop), A05318 (Retainer), A05319 (Drive Rod), 110-78686-26 (Spring Washer)

FM CODE: A01

ITEM CODE: 20-02-09

REVISION: Basic

CRITICALITY CATEGORY: 1

REACTION TIME: Seconds

NO. REQUIRED: 2 (one per actuator)

DATE: March 1, 2002

CRITICAL PHASES: Boost

SUPERCEDES: March 1, 1996

FMEA PAGE NO.: A-215

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SHEET 1 OF 7

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FAILURE MODE AND CAUSES: Erroneous output (high, low, loss of, or erratic) from power spool caused by:

- Friction between spool and bushing due to incorrect tolerances or contamination
- Spool jams due to contaminants
- Loose end plug
- Loose or broken drive rod
- Broken or incorrectly assembled Bellville washers
- Improper assembly

FAILURE EFFECT SUMMARY: Loss of control of power spool leading to actuator going hardover. Loss of Thrust Vector Control will lead to loss of vehicle, mission and crew.

RATIONALE FOR RETENTION:

A. DESIGN

- The Power Spool and Bushing Assembly is designed and qualified in accordance with end item specification 10SPC-0055. (All failure causes)

- Material selection is in compliance with MSFC-SPEC-522A. (Broken Drive Rod, friction between spool and bushing)

- The power spool and bushing assembly is designed to provide chip-shear capability. The shear force capability is 500 pounds. (Spool Jams due to Contaminants)

- The spool-to-bushing spacing is tightly controlled to provide 150 to 170 microinches diametral clearance. This precise spacing is designed to permit laminar (thin-film) leakage only, thereby eliminating the need for o-ring seals between bushing and spool. Oil balancing grooves are incorporated into spool lands to maximize fluid distribution and minimize side loading. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination)

- The power valve bushing, spool and sleeve assembly (BSSA) is a fitted and nulled matched set not to be separated and is traceable by serial number. The BSSA is polished to a surface finish ranging from 5 to 8 rms. The BSSA intermediate sleeve, spool stub, end bushing, drive piston, drive piston stub and intermediate sleeve, end sleeve and drive piston stub are fitted within 180 to 220 microinches. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination)

- The power valve spool and bushing are made of 440C CRES, heat treated and stress relieved. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination)

- The drive rod is pinned to the power spool with a 0.1886 diameter alloy steel dowell pin by an interference fit in rod and spool. The pin has a shear strength of 150,000 psi. The drive rod is made of 17-4PH CRES, heat treated to condition H1025 and passivated. Enlarged shoulders are provided along power rod to prevent spool buckling. (Loose or Broken Drive Rod)

- The drive rod is threaded at both ends. Specially designed locknuts are used to secure the drive pistons to the drive rod. (Loose or Broken Drive Rod, Improper Assembly)

- Contamination is controlled by the system five micron filter provided in each of the hydraulic systems that supply fluid to the actuator. Fluid supplied to the spool drive areas is via the 10 micron (15 micron absolute) servovalve inlet filter and the 20 micron (35 micron absolute) filters in each of the servovalves. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination)

- All power spool and bushing assembly piece-part and subassemblies are cleaned and assembled in a controlled environment conforming to Class 100,000 clean room. Clean room is certified per Moog QAP 803-001-100. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination, Spool Jams due to Contaminants)

- The assembly is designed for a static pressure gain at null, with actuator stalled, of greater than 5000 psig per millampere. (All Failure Causes)

- Threaded end plugs retain the bushings and Bellville washers in the power valve housing and seal both ends to the bushing bore. The end plugs are made of 17-4PH CRES, heat treated to condition H1025 and passivated. To prevent loosening, the end plugs are torqued and safety wired. (All Failure Causes)

- The Bellville washers are made from 302 stainless steel. The springs are compressed/retained by the threaded retainer which is lockwired. The Bellville washers are designed for an operating force of 500 pounds. (Broken or Incorrectly Assembled Bellville Washers)

- The power spool and bushing assembly, as part of the servoactuator, was subjected to qualification testing which verified the design requirements, including a burst pressure conducted at Moog. The test results are reported in Qualification Test Report MSFC-RPT-900. The Moog conducted burst pressure testing results are reported in Moog Report No. MR T-2980. Two units were subjected to qualification testing. After completion of the MSFC/Moog conducted testing, the two units were torn down and inspected. There was no evidence of wear, damage or other anomalies as reported in Moog disassembly and inspection analysis reports MR M-2982 and MR M-2983. (All Failure Causes)

B. TESTING

VENDOR RELATED TESTING

- Prior to installation the power valve is tested in accordance with Moog Procedure MR A-2406 to verify that the pressure gain exceeds 5000 psig/ ma. (All Failure Causes)

- Servoactuator Acceptance Tests are performed per Moog Report MR A-2406. This procedure includes: (All Failure Causes)

  - Proof Pressure
  - System Stability
  - Static Performance
  - Actuator Frequency Response
  - Transient Response
  - Cleanliness

- A two minute flushing procedure is followed when a hydraulic line is removed or reinstalled per MR A-2406. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination, Spool Jams due to Contaminants)

- Refurbished servoactuators are tested as follows: (All Failure Causes)

  - Proof Load Test per Moog EI - 1037

  - End Item Acceptance Test per Moog MR A-2406
    This is the same ATP as new hardware except some component level tests are not required when teardown does not affect the validity of

the previous component test. These component tests are Power Valve Pressure Gain, Transient Load Relief Valve and Servovalve Differential Pressure Transducers.

KSC RELATED TESTING

- Helium is verified for cleanliness and composition (purity and particulate count) prior to introduction to on-board circuits per 10REQ-0021, para. 2.3.2.5. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination, Spool Jams due to Contaminants)

- Hydraulic fluid is verified for cleanliness and composition (purity and particulate count) prior to introduction to on-board Hydraulic circuits per 10REQ-0021, para. 2.3.2.6. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination, Spool Jams due to Contaminants)

- Effluent hydraulic fluid is verified for moisture content and cleanliness (water content and particulate count) from the rock actuator, the tilt reservoir, the rock reservoir and the tilt actuator per 10REQ-0021, para. 2.3.12.3. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination, Spool Jams due to Contaminants)

- Functional operation of the actuators is verified during hotfire per 10REQ-0021, para. 2.3.16.3. (All Failure Causes)

- Actuator null, linearity and polarity and servovalve redundancy verification tests are performed per 10REQ-0021, para. 2.3.14. (All Failure Causes)

- Hydraulic fluid is verified for cleanliness and composition (purity and particulate count) prior to introduction to on-board Hydraulic circuits during prelaunch operations per OMRSD File V, Vol. 1 Requirement Number B42HP0.010. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination, Spool Jams due to Contaminants)

- Ascent Thrust Vector Control/SRB-TVC system response to predefined input commands per OMRSD File II, Vol. 1 Requirement Number S00000.650 (Gain Test). (All Failure Causes)

- Dynamic operation of the Ascent Thrust Vector Control/SRB-TVC System Failure Detection and Isolation Circuitry per OMRSD File II, Vol. 1 Requirement Numbers S00000.670 and .680 respectively (Individual Channel Test). (All Failure Causes)

- Frequency response (gain and phase) and step response of the Ascent Thrust Vector Control/SRB-TVC system per OMRSD File II, Vol. 1 Requirement Numbers S00000.720 and .750 respectively. (All Failure Causes)

o Gimbal test performed after SRB HPU start under control of automated software in GLS and RSLS verifies actuator performance by monitoring actuator position, servovalve differential pressure, isolation valve events and APU turbine speed (related to actuator pressure switch). Pass/fail criteria for automated portions of terminal countdown are controlled by OMRSD File II, Vol. 1, Requirement Number S00FS0.030 and launch commit criteria. This is the last test that verifies actuator performance. (All Failure Causes)

The above referenced OMRSD testing is performed every flight.

C. INSPECTION

VENDOR RELATED INSPECTIONS

o USA SRBE PQAR witnesses final servoactuator ATP per USA SRBE SIP 1127. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination)

o USA SRBE PQAR verifies hydraulic fluid is inspected for contamination before loading per USA SRBE SIP 1127. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination)

o USA SRBE PQAR verifies all material certifications per USA SRBE SIP 1127. (All Failure Causes)

o USA SRBE PQAR verifies traceability records per USA SRBE SIP 1127. (All Failure Causes)

o USA SRBE PQAR verifies bushing, spool, sleeve and drive fits per USA SRBE SIP 1127. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination)

o The following components are magnetic particle inspected per ASTM E1444.

- Power spool drive rod
- Power valve spool
- Power valve bushing
- Power spool intermediate sleeve
- Power spool drive piston
- Power spool end sleeve
- Power valve end bushing
- Threaded retainer

o Power spool closure stop raw material is ultrasonically inspected per MIL-I-8950, Class A. The closure stop is penetrant inspected per EP2067. (Loose End Plugs)

o During refurbishment and prior to reuse, the servoactuator is disassembled, cleaned, inspected and tested to ensure proper performance per 10SPC-0131. Preliminary evaluation includes: (All Failure Causes)

- Clean and inspect external surfaces
- Check main piston runout
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- Disassembly as required to inspect the body/cylinder interface and bushing, spool and sleeve assemblies of the: selector valve, lock valve, servovalves and power valve for evidence of seawater contamination.

o Extent of repair is determined from this evaluation and accomplished per the following general requirements. (All Failure Causes)

- Total disassembly is required if any wetted hydraulic surface discloses seawater contamination.

- All repairs are processed by the cognizant Material Review Board.

- All seals which have been removed from the installed position or exposed to seawater contamination are replaced.

- All hydraulic surfaces that have been exposed to seawater contamination are recleaned per Moog Documents 800-000-100, supplement 32 and MR-Q-6428.

- Reassembly per the same procedures and controls as new hardware.

o Critical Processes/Inspections:

- Heat Treat, Power Valve Bushing per EP 3203, Power Spool, Drive Rod, Threaded Retainer, per EP3233

- Stress Relief, Power Valve Bushing, Power Spool, per EP3211

- Passivation, Drive Rod, Threaded Retainer, per EP3204

- Magnetic Particle Inspection, Drive Rod, Power Spool, Valve Bushing, Intermediate Sleeve, Drive Piston, nd Sleeve, End Bushing, Threaded Retainer, per ASTM E1444.

- Ultrasonic Inspection, Spool Closure/Stop, per MIL-I-8950, Class A

- Penetrant Inspection, Spool Closure/Stop, per EP2067

KSC RELATED INSPECTIONS

o Helium cleanliness and composition (purity and particulate count) are verified prior to introduction to on-board circuits per 10REQ-0021, para. 2.3.2.5. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination, Spool Jams due to Contaminants)

o Hydraulic fluid cleanliness and composition (purity and particulate count) are verified prior to introduction to on-board hydraulic circuits

per 10REQ-0021, para. 2.3.2.6. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination, Spool Jams due to Contaminants)

- The moisture content and cleanliness (water content and particulate count) of the effluent hydraulic fluid from the rock actuator, the tilt reservoir, the rock reservoir and the tilt actuator are verified per 10REQ-0021, para. 2.3.12.3. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination, Spool Jams due to Contaminants)

- Proper function of TVC system is demonstrated during hotfire per 10REQ-0021, para. 2.3.16. (All Failure Causes)

- Hydraulic fluid cleanliness and composition (purity and particulate count) are verified prior to introduction to on-board Hydraulic circuits during prelaunch operations per OMRSD File V, Vol. 1 Requirement Number B42HP0.010. (Friction between Spool and Bushing due to Incorrect Tolerance or Contamination, Spool Jams due to Contaminants)

- SRB TVC actuator positioning test is verified per OMRSD File II, Vol. 1, Requirement Number S00000.650. (All Failure Causes)

- Both SRB individual channel null test and actuator individual channel ramp test are verified per OMRSD File II, Vol. 1 Requirement Numbers S00000.670 and .680 respectively. (All Failure Causes)

- Both SRB Actuator Frequency response and step response tests are verified per OMRSD File II, Vol. 1, Requirement Number S00000.720 and .750 respectively. (All Failure Causes)

D. FAILURE HISTORY

Criticality Category 1:

- Failure Histories may be obtained from the PRACA database.

E. OPERATIONAL USE

- Not applicable to this failure mode.