SUBSYSTEM: THRUST VECTOR CONTROL

ITEM NAME: Servovalve Assembly,
Part of Servoactuator

PART NO.: A07468-3 FM CODE: A02

ITEM CODE: 20-02-04 REVISION: Basic

CRITICALITY CATEGORY: 1R REACTION TIME: Seconds

NO. REQUIRED: 8 (4 per actuator) DATE: March 1, 2002

CRITICAL PHASES: Boost SUPERCEDES: March 1, 1996

FMEA PAGE NO.: A-193 ANALYST: K. Schroeder/S. Finnegan

SHEET 1 OF 8 APPROVED: S. Parvathaneni

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FAILURE MODE AND CAUSES: Incorrect or uncontrolled flow/pressure from three or four servovalves (if isolation occurs) caused by:

- Abnormal coil current/resistance due to shorted turns
- Flapper is bent, broken or motion is restricted
- Armature friction
- Particles collect at torque motor airgap
- Inlet nozzle drain orifice or filter restricted by contamination
- Nozzle backout
- Second stage spool jams off null due to contamination or improper clearance
- Erosion of spool lands or metering edges
- Broken flexure sleeve or attachment
- Bent or broken feedback wire(s)
- Loose feedback wire end ball or fit

FAILURE EFFECT SUMMARY: Loss of three or four servovalves leading to inadequate performance or to actuator going hardover. Loss of Thrust Vector Control will lead to vehicle breakup and loss of mission and crew. Three success paths remain after the first failure.

REDUNDANCY SCREENS AND MEASUREMENTS:

- Pass - ATP is conducted on all units. Redundancy is verified during ATP.

- Pass - Abnormal flow/pressure is detectable from delta pressuremeasurements B58P1311A through B581318A, by actuator positionmeasurements B58H1150C and B58H1151C and isolation valvecommand measurements V79X5100X, V79X5101X, V79X5105X,V79X5106X, V79X5110X, V79X5111X, V79X5115X and V79X5116X.

o Fail - Fluid contamination.

RATIONALE FOR RETENTION:

A. DESIGN

o The Servovalve Assembly is designed and qualified in accordance with the end item specification 10SPC-0055. (All Failure Causes)

o Material selection is in compliance with MSFC-SPEC-522A.

o Servovalve torque motor coils are designed with insulated wiring with mutual insulation resistance of 50 megohms minimum, with 500 vdc test potential applied and a dielectric strength capable of withstanding 500 ± 50 volts rms, 60 hertz between insulated turns without breaking down or a current leakage of not more than 500 microamperes between actuator housing or coil turns. (Abnormal Coil Current/Resistance Due to Shorted Turns)

o The torque motor coils are designed for continuous operation at 100 to 140 milliamperes. The operational (orbiter) command currents are limited to ±55 ma per ICD-2-14001. In addition, software (orbiter) limits on actuator commands are imposed which are equivalent to 20 ma from T - 20 minutes to T + 2.5 seconds, and 44.9 ma from T + 2.5 seconds to separation. (Abnormal Coil Current/Resistance Due to Shorted Turns)

o All servovalve piece-part, subassemblies and assemblies are cleaned and assembled in a controlled environment conforming to Class 100,000 clean room. The Moog clean room is certified per Moog QAP 803-001-100. (Particles Collect at Torque Motor Airgap; Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jam Off Null Due to Contamination or Improper Clearance)

o The servovalve first stage orifices are protected by a 20 micron, 35 micron absolute filter. Further contamination protection is provided by the 5 micron absolute system filter and the servovalve inlet filter (10 micron nominal, 15 micron absolute). (Particles Collect at Torque Motor Airgap; Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jam Off Null Due to Contamination or Improper Clearance)

o Sampling valve ports are provided on the servoactuator for sampling the hydraulic fluid at the primary inlet and at the return. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jam Off Null Due to Contamination or Improper Clearance)

o The servovalve first stage consists of a two inch-pound torque motor and a conventional four leg orifice bridge. The overall torque motor size is selected to overcome a torque value of 0.277 inch-pounds to achieve rated flow. (Armature Friction)

- The armature and flexure sleeve assembly is electron beam welded. (Broken Flexure Sleeve or Attachment)

- The feedback assembly (including flapper) is designed to 0.0012 inches clearance at the first stage orifices. Clearances and flapper motion freedom are verified after torque motor and feedback mechanism assembly. (Armature Friction; Flapper is Bent, Broken or Motion is Restricted; Broken Flexure Sleeve or Attachment)

- Nozzles are secured within the servovalve assembly by press fit and are installed with a specially-designed nozzle-pushing fixture. (Nozzle Backout)

- The second stage spool and bushing are designed to 150 to 200 micro-inches, lap finished clearance. The spool and bushing materials are 440C CRES to prevent thermal expansions from binding the spool. The bushing, spool and sleeve are heat treated. The spool, bushing and servovalve body are stress relieved before finish machining. The servovalve body, bushing, spool and sleeve are fitted and become a matched assembly traceable by body serial number. (All Failure Causes)

- Mechanical position feedback of second stage servovalve and power valve spools is accomplished by wire spring elements. Feedback wires fit into the flapper and the free end terminates in a spherical ball which rides in a groove in the spool. Spherical surfaces are integrally formed on the power valve wire and resistance welded on the servovalve wire. All materials are 440C CRES heat treated for wear resistance. (Loose Feedback Wire End Ball or Fit)

- The servoactuator (including servovalves) is designed, per 10SPC-0055, to a service life of: (All Failure Causes)

  - 200,000 cycles, $\pm$0.01 inch displacement at 10 Hz
  - 200,000 cycles, $\pm$0.25 inch displacement at 10 Hz
  - 4,000 cycles, $\pm$1.0 inch displacement at 0.25 Hz
  - 400 cycles, $\pm$6.0 inch displacement at 0.1 Hz

- The servovalve assemblies, as part of the servoactuator, were 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

o Servoactuator acceptance tests are performed per Moog Report No. MR A-2406. This procedure includes: (All Failure Causes)

- Servovalve Torque Motor Coils
- Command Current Limiting Response
- Servovalve Pressure Gain
- Failure Response
- Dynamic Acceptance Tests
- Cleanliness
- Coil Dielectric Strength
- Coil Insulation Resistance
- Coil Resistance

o A two minute flushing procedure is performed when a hydraulic line is removed or reinstalled per Moog report MR A-2406. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jams Off Null Due to Contamination or Improper Clearance)

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

- 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

o 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. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jams Off Null Due to Contamination or Improper Clearance)

o 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. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jams Off Null Due to Contamination or Improper Clearance)

o 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. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jams Off Null Due to Contamination or Improper Clearance)

- o Actuator response to predefined input commands during hotfire per 10REQ-0021, paras. 2.3.16.3 and 2.3.16.4. (All Failure Causes)

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

- o 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. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jams Off Null Due to Contamination or Improper Clearance)
- o 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)

- o 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. (Individual Channel Null and Ramp Test). (All Failure Causes)

- o Both SRB actuator 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 per OMRSD File II, Vol. 1, requirement number S00FSO.030 and launch commit criteria. This is the last test that verifies actuator performance.

The above referenced OMRSD testing is performed every flight.

C. INSPECTION

VENDOR RELATED INSPECTIONS

- o USA SRBE PQAR witnesses servoactuator ATP according to USA SRBE SIP 1127. (All Failure Causes)

- o USA SRBE PQAR verifies hydraulic fluid is inspected for contamination before loading according to USA SRBE SIP 1127. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jams Off Null Due to Contamination or Improper Clearance)

- o USA SRBE verifies all material certifications in accordance with 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 assembly operations per USA SRBE SIP 1127. (All Failure Causes)

- 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
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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 nonhermetic electrical/electronic parts which have been exposed to seawater are replaced.
  - 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 Servovalve Body per EP3210
  - Heat Treat, Flapper per EP3233
  - Electronic Beam Welding, Feedback Assembly, Flapper per EP 3223
  - Heat Treat, Bushing, Spool, Sleeve per EP 3202
  - Stress Relief, Bushing, Spool, Sleeve per EP 3211
  - Passivation, Flapper per EP 3204
  - Magnetic Particle Inspection, Body, Bushing, Flapper per ASTM E1444
  - Resistance Welding, Feedback Wire per EP 3218

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. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jams Off Null Due to Contamination or Improper Clearance)

- 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. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jams Off Null Due to Contamination or Improper Clearance)

- o 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. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jams Off Null Due to Contamination or Improper Clearance)

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

- o 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. (Inlet Nozzles, Drain Orifices or Filters Restricted by Contamination; Second Stage Spool Jams Off Null Due to Contamination or Improper Clearance)

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

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

- o Both SRB actuator frequency response and step response tests are verified per OMRSD File II, Vol. 1 Requirement Numbers S00000.720 and .750 respectively. (All Failure Causes)

D. FAILURE HISTORY

- o Failure Histories may be obtained from the PRACA database.

E. OPERATIONAL USE

- Not applicable to this failure mode.

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