SUBSYSTEM: THRUST VECTOR CONTROL

ITEM NAME: Servovalve Differential Pressure Sensor, Part of Servoactuator

PART NO.: A24011-2 FM CODE: A02

ITEM CODE: 20-02-06 REVISION: Basic

CRITICALITY CATEGORY: 1R REACTION TIME: Seconds

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

CRITICAL PHASES: Boost SUPERCEDES: March 1, 1993

FMEA PAGE NO.: A-202 ANALYST: K. Schroeder/S. Finnegan

SHEET 1 OF 7 APPROVED: S. Parvathaneni

CN 044

FAILURE MODE AND CAUSES: Erroneous output from three of four sensors per actuator caused by:

- Friction or contamination seizes piston/LVDT core off-null
- Either control port blocked
- LVDT coil windings shorted
- Broken centering spring(s)
- Improper assembly

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

REDUNDANCY SCREENS AND MEASUREMENTS:

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

- Pass - Erroneous pressure sensor outputs are detectable by measure-ments Delta pressure B58P1311A through B58P1318A, by actuatorposition B58H1150C and B58H1151C and isolation valve commandsV79X5100X, V79X5101X, V79X5105X, V79X5106X, V79X5110X,V79X5111X, V79X5115X and V79X5116X.

- Fail - Fluid contamination.

RATIONALE FOR RETENTION:

A. DESIGN

- The Servovalve Differential Pressure Sensor is designed and qualified in accordance with 10SPC-0055. (All Failure Causes)

- Material selection is in compliance with MSFC-SPEC-522A. (All Failure Causes)

- Fluid procurement is controlled by SE-S-0073. (Contamination)

- Servoactuator piece parts, 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. (All Failure Causes)

- The pressure sensor is protected from contamination by the 5 micron absolute system filter, the 10 micron (15 micron absolute) servovalue inlet filter and by the servovalve 20 micron (35 micron absolute) first stage filter. (Friction or Contamination Seizes Piston/LVDT Core Off Null, Either Control Port Blocked)

- Sampling ports are provided on the servoactuator for sampling the hydraulic fluid at the primary inlet and at the return. (Friction or Contamination Seizes Piston/LVDT Coreoff Null, Either Control Port Blocked)

- The servoactuator, including differential pressure sensors, are designed to withstand, without loss of performance, a proof pressure (4875 psig) 1.5 times the operating pressure and a burst pressure, without failure, of 8125 psig which is 2.5 times the operating pressure. The sensor is also designed to operate within performance specification for 700,000 full pressure cycles from -3250 to +3250 psid. (All Failure Causes)

- The differential pressures sensor tube is made from A286 Cres, passivated and surface finished to 32 rms. The piston is made from 316 CRES, passivated and hard chrome plated. The sleeve and flanged sleeve are made aluminum bronze and surface finished to 32 rms. (Friction or Contamination Seizes Piston/LVDT Core Off Null)

- The piston/sleeve is machine-finished to 150 to 170 microinches diametral clearance with a surface finish not to exceed 5 rms. After tube, sleeve and piston are fitted, they become a matched assembly not to be separated. (Friction or Contamination Seizes Piston/LVDT Core Off Null, Improper Assembly)

- The centering springs are heat treated, cleaned and demagnetized. The spring constants are rated at 741 lb/in to prevent piston seizing off null. The centering springs are designed and selected to obtain an LVDT output of 5.0 volts $\pm$1% at the rated delta pressure of 3,000 psi. (Broken Centering Spring(s))

- Four pivots are provided, one at each of two centering spring assembly seats and one at each of two piston to spring assembly interfaces, to decouple piston/spring lateral motions and reduce friction. (Broken Centering Spring(s), Friction or Contamination Seizes Piston/LVDT Core Off Null)

- o Control ports are 0.093 inches in I.D. which is sufficient size to tolerate, without malfunction, the maximum influent contamination. (Either Control Port Blocked)

- o The LVDT coils are wound with insulated wire whose mutual insulation resistance is 100 megohms, minimum with 500 vdc test potential applied and has a dielectric strength capable of withstanding 500 volts without breaking down or a current leakage of not more than 500 microamps between coil turns and housing. (LVDT Coil Windings Shorted)

- o The LVDT coils are prevented from shifting position by a Belleville Washer whose load compliance is certified. (Improper Assembly, Friction or Contamination Seizes Piston/LVDT Core Off Null)

- o The Servovalve Differential Pressure Sensor, as part of the servoactuator, was subjected to qualification testing which verified the design requirements, including a qualification burst pressure test 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 Differential Pressure Transducers
  - Proof Pressure
  - Command Current Limiting Response
  - Isolation Valves
  - Servovalve Pressure Gain
  - Failure Response
  - Cleanliness
  - Dielectric Strength
  - Insulation Resistance

- o A two minute flushing procedure is followed when a hydraulic line is removed or reinstalled Moog ATP MR A-2406. (Friction or Contamination Seizes Piston/LVDT Core Off Null)

- o 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 or Contamination Seizes Piston/LVDT Core Off Null)

- 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 or Contamination Seizes Piston/LVDT Core Off-Null, Either Control Port Blocked)

- Effluent hydraulic fluid is verified for moiture 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 or Contamination Seizes Piston/LVDT Core Off-Null, Either Control Port Blocked)

- Acutator response to predefined input commands during hotfire per 10REQ-0021, paras. 2.3.16.3 and 2.3.16.4. (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 or Contamination Seizes Piston/LVDT Core Off-Null, Either Control Port Blocked)

- 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 (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. (Frt/Step Response Test). (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 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 witnesses final acceptance tests per USA SRBE SIP 1127. (All Failure Causes)

o USA SRBE PQAR verifies hydraulic fluid is inspected for contamination before actuator loading per USA SRBE SIP 1127. (Friction or Contamination Seizes Piston/LVDT Core Off Null)

o USA SRBE verifies material certifications per USA SRBE SIP 1127. (Broken Centering Spring(s), LVDT Coil Windings Shorted)

o USA SRBE PQAR verifies traceability records per USA SRBE SIP 1127. (Broken Centering Spring(s), LVDT Coil Windings Shorted)

o USA SRBE PQAR verifies assembly operations per USA SRBE SIP 1127. (Improper Assembly)

o The diferential pressure transducer tube raw material is ultasonic inspected MIL-I-8950. The tube is penetrant inspected per EP2067. (All Failure Causes)

o The sensor housing assembly and end cap stock are ultrasonic inspected per MIL-I-8950, Class A. The parts are penetrant inspected per EP2017. (All Failure Causes)

o The support tube stock is ultrasonic inspected per MIL-I-8950. The support tube is penetrant inspected per EP2067. (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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CN 044

- 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:

  - Ultrasonic Inspection, Tube, Support Tube, per MIL-I-8950, Class A
  - Penetrant Inspection, Tube, Support Tube, per EP2067
  - Demagnetization, Spring, per 110-98562
  - Passivation, Tube, per EP 3204
  - Passivation, Pivot, Pivot Valve, per EP 1204
  - Passivation, Spring Seat, Threaded Retainer, per EP 3204
  - Hard chrome plating, Piston, per QQ-C-320, Class 2C
  - Heat treat, Pivot, per EP 1202
  - Heat treat, Spring Seat, Threaded Retainer, per EP 3233
  - Heat treat, Spring, per EP 3389

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 or Contamination Seizes Piston/LVDT Core Off-Null, Either Control Port Blocked)

- 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 or Contamination Seizes Piston/LVDT Core Off-Null, Either Control Port Blocked)

- 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. (Friction or Contamination Seizes Piston/LVDT Core Off-Null, Either Control Port Blocked)

- o Proper function of TVC system is demonstrated during hotfire operations 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. (Friction or Contamination Seizes Piston/LVDT Core Off Null)

- 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 channel 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.