SUBSYSTEM: THRUST VECTOR CONTROL

ITEM NAME: Servovalve Differential Pressure Sensor,
Part of Servoactuator

PART NO.: A24011-2 (Pressure Sensor)
A20434-4 (Electrical Connector)
A20434-1 (Electrical Connector)

FM CODE: A04

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, 1995

FMEA PAGE NO.: A-205

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FAILURE MODE AND CAUSES: Loss of output of one or more sensors (including failure of two, three or four associated servovalves) caused by:

- Piston/LVDT core seized due to contamination, core debond, galling or broken spring
- Bearing clearance seizes piston/LVDT core
- Both inlet ports clogged
- Open LVDT coil
- Broken wiring
- Damaged connector

FAILURE EFFECT SUMMARY: Loss of capability to isolate faulty servovalves leading to actuator going hardover. Loss of thrust vector control will lead to loss of the vehicle, mission and crew. One success path remains after the first failure.

REDUNDANCY SCREENS AND MEASUREMENTS:

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

- Pass - Loss of pressure sensor outputs are detectable by measurementsB58P1311A through B58P1318A and by actuator position measure-ments B58H1150C and B58H1151C.

- Fail - Fluid contamination.

RATIONALE FOR RETENTION:

A. DESIGN

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

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

- 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 in accordance with Moog QAP 803-001-100. (Piston/LVDT Core Seized due to contamination, core debond, galling or broken spring; bearing clearance seizes piston/LVDT Core, Both Inlet Ports Clogged)

- The pressure sensor is protected from contamination by the 5 micron absolute system filter, the 10 micron (15 micron absolute) servovalve inlet filter and by the servovalve 20 micron (35 micron absolute) first stage filter. (Piston/LVDT Core Seized due to contamination, core debond, galling or broken spring; bearing clearance seizes Piston/LVDT Core, Both Inlet Ports Clogged)

- Sampling ports are provided on the servoactuator for sampling the hydraulic fluid at the primary inlet and at the hydraulic return. (Friction or Contamination Seizes Piston/LVDT Core)

- 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 pressure 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 heated. The sleeve and flanged sleeve are made aluminum bronze and surface finished to 32 rms. (All Failure Causes)

- The piston/sleeve is machine-finished to 150 to 170 micron diametral clearance with a surface roughness not to exceed 5 rms. After tube, sleeve and piston are fitted, they become a matched assembly not to be separated. (Piston/LVDT Core Seized due to contamination, core debond, galling or broken spring; bearing clearance seizes Piston/LVDT Core)

- The centering springs are heat treated, cleaned and demagnetized. 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. The spring constants are rated at 741 lb/in to prevent piston siezing off null. (All Failure Causes)

- 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. (Bearing Clearance Seized Piston/LVDT Core)

- Control ports are 0.093 inches in I.D. which is sufficient size to tolerate, without malfunction, the maximum influent contamination. (Both Inlet Ports Clogged)

- The LVDT coil insulation and impregnation materials are compatible with the hydraulic fluids. (Open LVDT Coil)

- The LVDT coils are prevented from shifting position by a Belleville washer whose load compliance is certified. (Open LVDT Coil)

- Lead wires are teflon insulated conductors rated for 600 vdc and 200C. Lead wires are covered with heat shrink tubing and are supported by cable clamps between the coil and the connector. (Broken Wiring)

- External connectors are sealed, underwater type that have been qualified for SRB application. Metal protective caps are provided for installation on the connectors at all times except when access is required for test and/or flight cable installation. Lubricants, compatible with connector O-ring seals, are provided to facilitate connector installation and matings. (Damaged Connector)

- The 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 MR T-2980. Two units were subjected to qualification testing. After completion of the MSFC/Moog 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

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

  - Servovalve Differential Pressure Tranducer
  - 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 per Moog ATP MR A-2406. (Piston/LVDT Core Seized due to Contamination,core debond, galling or broken spring; Both Inlet Ports Clogged)

- 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

- 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. (Piston/LVDT Core Seized Due To Contamination, core debond, galling or broken spring; Both Inlet Ports Clogged)

- 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. (Piston/LVDT Core Seized Due To Contamination, core debond, galling or broken spring; Both Inlet Ports Clogged)

- 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. (Piston/LVDT Core Seized At Null Due To Contamination, Both Inlet Ports Clogged)

- 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. These automated tests verify the requirements of SE-019-051-2H. (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. (Piston/LVDT Core Seized due To Contamination, core debond, galling or broken spring; Both Inlet Ports Clogged)

- 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 Test). (All Failure Causes)

o 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)

The above referenced OMRSD testing is performed every flight.

C. INSPECTION

VENDOR RELATED INSPECTIONS

o USA SRBE PQAR witnesses final acceptance tests per USA SRBE SIP 1127. (All Failure Causes)

o USA SRBE PQAR performs final visual inspection, including connector pins, of deliverable unit per USA SRBE SIP 1127. (Damaged Connector)

o USA SRBE PQAR verifies hydraulic fluid is inspected for contamination before actuator loading per USA SRBE SIP 1127. (Piston/LVDT Core Seized due to Contamination, core debond, galling or broken spring; Both Inlet Ports Clogged)

o USA SRBE PQAR verifies 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 assembly operation per USA SRBE SIP 1127. (All Failure Causes)

o The differential pressure transducer tube stock is ultrasonic inspected per MIL-I-8950, Class A. The tube is penetrant inspected per EP2067. (Bearing Clearance Seizes Piston/LVDT Core)

o The support tube is ultrasonic inspected per MIL-I-8950, Class A. The support tube is penetrant inspected per EP2067. (Bearing Clearance Seizes Piston/LVDT Core)

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.

- 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 andMR-Q-6428.
  - Reassembly per the same procedures and controls as new hardware.

- 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, Spring Seat, Threaded Retainer, per EP 3204
  - Passivation, Pivot, Pivot Valve, per EP 1204
  - Heat treat, Spring Seat, Threaded Retainer, Per EP 3233
  - Hard chrome plating, Piston, per QQ-C-320, Class 2C
  - Heat treat, Pivot, Pivot Valve, per EP 1202
  - Heat treat, Spring, per EP 3389

KSC RELATED INSPECTIONS

- 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.(Piston/LVDT Core Seized due To Contamination, core debond, galling or broken spring; Both Inlet Ports Clogged)

- 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. (Piston/LVDT Core Seized due To Contamination, core debond, galling or broken spring; Both Inlet Ports Clogged)

- 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. (Piston/LVDT Core Seized due To Contamination, core debond, galling or broken spring; Both Inlet Ports Clogged)

- 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. (Piston/LVDT Core Seized due To Contamination, core debond, galling or broken spring; Both Inlet Ports Clogged)

- 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 test are verified per OMRSD File II, Vol. 1 Requirement Numbers S00000.720 and .750 respectively. (All Failure Causes)

D. FAILURE HISTORY

- Failure Histories may be obtained from the PRACA database.

E. OPERATIONAL USE

- Not applicable to this failure mode.