SUBSYSTEM: THRUST VECTOR CONTROL

ITEM NAME: Feedback Linkages, Part of Servoactuator

PART NO.: A05642 (Spring Post), A05843-2 (Bellcrank and Roller Assembly), A05373-2 (Feedback Cage Assembly), A05769 (Cage Loading Spring), A05385 (Adjustor)

FM CODE: A02

ITEM CODE: 20-02-08

REVISION: Basic

CRITICALITY CATEGORY: 1

REACTION TIME: Seconds

NO. REQUIRED: 4 (two per actuator)

DATE: March 1, 2002

CRITICAL PHASES: Boost

SUPERCEDES: March 1, 1993

FMEA PAGE NO.: A-211

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FAILURE MODE AND CAUSES: Failure of mechanical feedback to two servovalves caused by:

- Broken spring post
- Damaged bellcrank or roller
- Broken feedback cage assembly
- Broken cage loading spring
- Loss of cage adjustment

FAILURE EFFECT SUMMARY: All four actuator servovalves will be isolated 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 Feedback Linkages are designed and qualified in accordance with end item specifications 10SPC-0055. (All failure causes)

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

- The servoactuator feedback linkages are designed to withstand, without damage or impairment of performance, the transmitted induced environments

including nozzle induced vibration, exposure to the transmitted acoustical noise, aft skirt and nozzle induced shocks (including ordnance, SRB parachute deployment and SRB water landing) and water entry loads. (All Failure Causes)

o The feedback linkages are designed to a service life of (per 10SPC-0055): (All Failure Causes)

- 200,000 cycles, ±0.01 inch displacement at 10 Hz.
- 200,000 cycles, ±0.25 inch displacement at 10 Hz.
- 4,000 cycles, ±1.0 inch displacement at 10 Hz.
- 400 cycles, ±6.0 inch displacement at 0.1 Hz

o The spring post is made of Aluminum Alloy 6061-T6, T651, T6510 or T6511 material andchromic acid anodized. (Broken Spring Post)

o The bellcrank roller is made of 17-4 PH CRES and heat treated to H1025. The roller is lubricated with solid film lubricant. The bellcrank is a one piece construction from 6061-T6, T651 or T6511 aluminum alloy and chromic acid anodized. Traceability by lot number is required of all bellcrank and roller assembly parts. (Damaged Bellcrank or Roller)

o The feedback cage is made of Aluminum Alloy 6061-T6, T651 or T6511 and is chromic acidanodized. The cage support leaf springs are made of beryllium-copperalloy, heat treated. The leaf spring retainer and retainer/adjuster are made of 17-4 PH CRES, heat treated and passivated. The assembly andparts are traceable by lot number. (Broken Feedback Cage Assembly, Broken Cage Loading Spring)

o The cage loading springs are made of 17-7PH CRES, heat treated to condition CH900. The springs are traceable by lot number. (Broken Cage Loading Spring)

o Fracture Mechanics Analysis was conducted per Fracture Mechanics Report for SRB TVC servoactuator, Battelle Laboratories, 4-30-78. (All Failure Causes)

o The feedback linkages, 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

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

  - System Stability
  - Static Performance
  - Failure Response
  - Dynamic Acceptance Tests, Actuator Assembly

- 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

- 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)

- 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. (All Failure Causes)

- 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 no. 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 Acceptance tests are witnessed by USA SRBE PQAR per USA SRBE SIP 1127. (All Failure Causes)
- o USA SRBE PQAR performs final visual inspection of deliverable unit 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 in-process inspections per USA SRBE SIP 1127. (All Failure Causes)
- o USA SRBE PQAR verifies material certification per USA SRBE SIP 1127. (All Failure Causes)
- o The bellcrank is etched and penetrant inspected per EP2067. (Damaged Bellcrank or Roller)
- o The feedback cage raw material is ultrasonically inspected per MIL-I-8950, Class A. The raw material is etched and penetrant inspected per EP2067. The cage is detergent cleaned and penetrant inspected per EP2067 after machining. (Broken Feedback Cage Assembly)
- 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 contamiation.
- 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:

- Anodizing, Bellcrank, Spring Post, Cage, per EP3203.

- Heat Treat, Roller per EP3233 Leaf Springs per EP3264, Cage Loading Springs per EP3389.

- Penetrant Inspection, Bellcrank, Feedback Link, Feedback Cage, per EP2067.

- Ultrasonic Inspection, Feedback Cage, per MIL-I-8950, Class A.

- Passivation, Leaf Spring Retainer, Spring, Adjustor, per EP 3204.

KSC RELATED INSPECTIONS

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

o SRB TVC actuator positioning test is verified per OMRSD File II, Vol. 1, Requirement Numbers 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 tests and step response are verified post-test, by SPC, 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

o Not applicable to this failure mode.