

SRB CRITICAL ITEMS LIST

SUBSYSTEM: THRUST VECTOR CONTROL

ITEM NAME: Piston and Cylinder Assembly,  
Part of Servoactuator

PART NO.: A23917 (Piston), A21160-439 (Packing, Preformed), A07051-3 (Seal, Cap O-Ring), A23914-1 (Cylinder and Bearing Assembly), A22030 (Spring Cap and Bushing Assembly) FM CODE: A01

ITEM CODE: 20-02-12 REVISION: Basic

CRITICALITY CATEGORY: 1 REACTION TIME: Seconds

NO. REQUIRED: 2 (one per actuator) DATE: March 1, 2002

CRITICAL PHASES: Boost SUPERCEDES: March 31, 1999

FMEA PAGE NO.: A-223 ANALYST: K. Schroeder/S. Finnegan

SHEET 1 OF 8 APPROVED: S. Parvathaneni

CN 044

FAILURE MODE AND CAUSES: Loss of output force or motion capability caused by:

- o Structural failure of piston head due to fatigue or defective material
- o Defective or damaged piston head seal
- o Cylinder bore wear due to contamination
- o Failure of transient load relief valve bushing

FAILURE EFFECT SUMMARY: Loss of actuator control capability leading to actuator going hardover resulting in loss of Thrust Vector Control will lead to vehicle breakup and loss of mission and crew.

RATIONALE FOR RETENTION:

A. DESIGN

- o The Piston and Cylinder Assembly is designed and qualified in accordance with end item specification 10SPC-0055. (All failure causes)
- o Material selection is in compliance with MSFC-SPEC-522A. Servoactuator piece part, subassembly and assembly materials have been reviewed and approved in accordance with USA SRBE 10SPC-0055. (All Failure Causes)
- o The piston and cylinder assembly is designed to a service life of: (All Failure Causes)

- 200,000 cycles,  $\pm 0.01$  inch displacement at 10.0 Hz.
  - 200,000 cycles,  $\pm 0.25$  inch displacement at 10.0 Hz
  - 4,000 cycles,  $\pm 1.0$  inch displacement at 0.25 Hz
  - 400 cycles,  $\pm 6.0$  inch displacement at 0.1 Hz
- o The piston and cylinder assembly is designed to withstand, without damage or impairment of performance, the transmitted induced environments including transmitted acoustical noise levels, transmitted shocks, water entry loads and a constant side load of 5,000 pounds applied through the actuator center of gravity with the actuator at midstroke. (All Failure Causes)
  - o The cylinder is made of a blank of 17-4PH CRES, vacuum melt and heat treated to H1025 condition. The actuator cylinder blank is traceable by lot number. The cylinder bore is shot peened and hard chrome plated. (Cylinder Bore Wear Due to Contamination)
  - o The piston blank is made from a 17-4PH CRES forging or hot rolled, solution heat treat bar stock. The piston blank is heat treated to condition H1075. The blank is traceable by lot number, passivated, shot peened and hard chrome plated. The piston is traceable by serial number. (Structural Failure of Piston Head Due to Fatigue or Defective Material)
  - o The piston cap seal is compatible with test and operating hydraulic fluids and is compatible with seawater. The cap seal is traceable by lot number. (Defective or Damaged Piston Head Seal)
  - o The transient load relief valve inner bushing is made of 17-4PH CRES, heat treated and passivated. The inner bushing is traceable by serial number. The inner bushing and spool are fitted to provide 100 to 200 microinches diametral clearance. After fitting the assembly becomes a matched set not to be separated. The assembly bushing and spools are traceable by serial number. (Failure of Transient Load Relief Valve Bushing)
  - o The transient load relief valve outer bushing is made of 17-4PH CRES, heat treated, passivated and chrome plated. After clearance machining of outer bushing, the transient load relief outer bushing and inner bushing assembly become a matched set not to be separated. The bushing assembly is traceable by inner bushing serial number. (Failure of Transient Load Relief Valve Bushing)
  - o 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. (Cylinder Bore Wear Due to Contamination)
  - o The influent hydraulic fluid passes through a hydraulic system filter with the capability to trap and retain nonsoluble contaminants larger than 5 microns. (Defective or Damaged Piston Head Seal, Cylinder Bore Wear Due to Contamination)

- o The servoactuator, including piston and cylinder assembly and transient load relief valve assembly, is designed to withstand without failure a burst pressure of 8125 psig which is 2.5 times the maximum operating pressure, proof tested to 4875 psig and pressure impulse loading applied to primary and secondary inlet ports over a pressure range of 200 to 4,000 psig for a minimum of 100,000 cycles. (Structural Failure of Piston Head Due to Fatigue or Defective Material, Defective or Damaged Piston Head Seal, Failure of Transient Load Relief Valve Bushing)
- o Fracture Mechanics Analysis was conducted per Fracture Mechanics Report for SRB TVC Servoactuator, Battelle Laboratories, 4-30-78. (Structural Failure of Piston Head Due to Fatigue or Defective Material)
- o As part of the servoactuator, the piston and cylinder assembly transient load relief valve assembly was subjected to twenty mission qualification testing. Test results are reported in Qualification Test Report MSFC-RPT-900 and Moog Report MR T-2980, "Qualification Burst Pressure Testing". (All Failure Causes)

## B. TESTING

### VENDOR RELATED TESTING

- o Servoactuator acceptance tests are performed per Moog Report MR A-2406. This procedure includes: (All Failure Causes)
  - Transient Load Relief Valve
  - Proof Pressure
  - Quiescent Leakage
  - Interflow Leakage
  - Dynamic Leakage
  - Loaded Piston Velocity
  - Maximum Piston Rate During Failure
  - Cleanliness
- o A two minute flushing procedure is followed when a hydraulic line is removed or reinstalled per Moog ATP MR A-2406. (Cylinder Bore Wear Due to Contamination)
- 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. (Cylinder Bore Wear Due to Contamination)
- 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. (Cylinder Bore Wear Due to Contamination)
- 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. (Cylinder Bore Wear Due to Contamination)
- o Verify external leakage at actuator rod ends is less than 1 drop per minute per 10REQ-0021, para. 2.3.12.1. (Cylinder Bore Wear Due to Contamination)
- o TVC system internal leakage with one hydraulic system pressurized is verified by test to be less than 6.7 GPM per 10REQ-0021, para. 2.3.12.4. (All Failure Causes)
- o TVC system internal leakage of an isolated tilt or rock system with both systems pressurized is verified by test to be less than 3.7 GPM per 10REQ-0021, para. 2.3.12.4. (All Failure Causes)
- o Functional operation of the actuators is verified per 10REQ-0021, para. 2.3.15.4 and 2.3.16.3. (All Failure Causes)
- o Functional operation of the actuators is verified during hotfire per 10REQ-0021, para. 2.3.16. (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. (Cylinder Bore Wear Due to Contamination)
- o Verify external leakage at actuator rod ends is less than 0.001 cubic inches per second per OMRSD File V, Vol. 1 Requirement Number B42AT0.030. (Cylinder Bore Wear Due to Contamination)
- 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 Verify lock/Bypass function per 10REQ-0021, para 2.3.10.1 and 2.3.16.4. (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. (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. (Structural Failure of Piston Head Due to Fatigue or Defective Material, Defective or Damaged Piston Head Seal, Failure of Transient Load Relief Valve Bushing)

The above referenced OMRSD testing is performed every flight.

#### C. INSPECTION

##### VENDOR RELATED INSPECTIONS

- o Acceptance tests are witnessed by USA SRBE PQAR according to 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. (Cylinder Bore Wear Due to Contamination)
- 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 operations per USA SRBE SIP 1127. (All Failure Causes)
- o The cylinder blank is ultrasonically inspected for defects per MIL-I-8950, Class A. (Cylinder Bore Wear Due to Contamination)
- o Cylinder and piston are magnetic particle inspected per ASTM E1444. (Structural Failure of Piston Head Due to Fatigue or Defective Material)
- o The piston blank is ultrasonically inspected for defects per MIL-I-8950, Class A. (Cylinder Bore Wear Due to Contamination)

- o Transient load relief valve bushing blanks (inner and outer) are inspected per Moog QAP 812-005-100. (Failure of Transient Load Relief Valve Bushing)
- o Transient load relief valve and bushing assembly and parts are magnetic particle inspected per ASTM E 1444. (Failure of Transient Load Relief Valve Bushing)
- 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
  - 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, Cylinder Blank, TLRV Outer Bushing, per AMS 5643, Cond. H1025
  - Heat Treat, TLRV Inner and Outer Bushings, EP 3233
  - Heat Treat, Piston Blank Stock, per AMS 5643, Cond. H1025
  - Heat Treat, Piston Blank, per EP 3367
  - Shot Peening, Cylinder Bore, Piston, per MIL-S-13165
  - Hard Chrome Plating, Cylinder Bore, per QQ-C-320, Class 2E
  - Hard Chrome Plating, Piston per QQ-C-320 type 2, 850 VHN minimum.
  - Passivation, TLRV Inner & Outer Bushings per EP 3204
  - Passivation, Piston per ASTM-A-967.
  - Ultrasonic Inspection, Cylinder Blank, Piston Blank, per MIL-I-8950, Class A
  - Magnetic Particle Inspection, Cylinder, Piston, TLRV Parts, per ASTM E1444.

## 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. (Cylinder Bore Wear Due to Contamination)
- 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. (Cylinder Bore Wear Due to Contamination)
- 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. (Cylinder Bore Wear Due to Contamination)
- o Internal leakage of rock and tilt servo valve is verified per 10REQ-0021, para. 2.3.12.4. (All Failure Causes)
- o Verify external leakage at actuator rod ends is less than 1 drop per minute per 10REQ-0021, para. 2.3.12.1. (Cylinder Bore Wear Due to Contamination)
- o Proper function of TVC system is demonstrated 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. (Cylinder Bore Wear Due to Contamination)
- o SRB TVC actuator positioning test is performed 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 performed per OMRSD File II, Vol. 1 Requirement Numbers S00000.670 and .680 respectively. (All Failure Causes)
- o Frequency response and step response tests are verified per OMRSD File II, Vol. 1 Requirement Numbers S00000.720 and .750 respectively. (All Failure Causes)
- o Verify actuator rod end leakage is less than or equal to 0.001 cubic inches per second per OMRSD File V, Vol. 1 Requirement Number B42AT0.030. (Cylinder Bore Wear Due to Contamination)

## D. FAILURE HISTORY

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

## E. OPERATIONAL USE

- o Not applicable to this failure mode.

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