

**SSME FMEA/CIL
REDUNDANCY SCREEN**

Component Group: Pneumatic Controls
 CIL Item: C200-17
 Component: Pneumatic Control Assembly
 Part Number: R0019450
 Failure Mode: Fails to actuate fully (Emergency shutdown PAV, HPOTP Intermediate seal purge PAV, and Purge sequence PAV).

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 Approved: T. Nguyen
 Approval Date: 6/2/99
 Change #: 1
 Directive #: CGBD ME3-01-5213

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Phase	Failure / Effect Description	Criticality Hazard Reference
P 4.1	<p>Failure of PAV midstroke allows high flowrate out the vent port. If flowrate is sufficiently high to cause HPOTP intermediate seal purge pressure to fall below limit. Controller issues inhibit. Launch delay. Loss of vehicle due to HPOTP fire may result if loss of helium to HPOTP IMSL purge is not detected</p> <p>Redundancy Screens: PNEUMATIC SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY</p> <p>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Pass - Loss of a redundant hardware items is detectable during flight. C: Fail - Loss of redundant hardware items could result from a single credible event.</p>	1R ME-C1S
PM 4.1	<p>Failure of PAV midstroke allows high flowrate out the vent port, depleting engine helium supply during mainstage. HPOTP intermediate seal purge falls below limit. Controller detects out-of-limit condition and initiates engine shutdown. Depletion of helium supply for this engine until vehicle terminates supply. Mission abort.</p> <p>Redundancy Screens: PNEUMATIC SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY</p> <p>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Pass - Loss of a redundant hardware items is detectable during flight. C: Fail - Loss of redundant hardware items could result from a single credible event.</p>	1R ME-G10C

C-53

**SSME A/CIL
DESIGN**

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Design / Document Reference

FAILURE CAUSE: A: Emergency shutdown PAV, HPOTP intermediate seal purge PAV, Purge sequence PAV failure: Poppet jammed mid-stroke.
 C: Emergency shutdown PAV, HPOTP intermediate seal purge PAV, purge sequence PAV failure: Excessive internal leakage due to: Contamination.
 E: Emergency shutdown PAV, HPOTP intermediate seal purge PAV, purge sequence PAV failure: Excessive internal leakage due to: Damaged guide (contamination jammed between guides, piston, and body).

DETAIL PARTS AND TEST FIXTURES ARE CLEANED (1) PRIOR TO ASSEMBLY (2). ASSEMBLY AND TEST ARE PERFORMED IN A CLEAN ROOM (3). LUBRICANTS ARE NOT ALLOWED FOR ASSEMBLY OR TEST (2). COMPONENT LEVEL TEST FLUIDS ARE NITROGEN AND HELIUM WHICH MEET THE HARDWARE CLEANLINESS REQUIREMENTS (1). THE COMPONENT PARTS AND SUBASSEMBLY ARE FREE OF VISIBLE FOREIGN PARTICLES AT THE TIME OF ASSEMBLY (2). AT THE ENGINE LEVEL, A 15-MICRON FILTER IN THE PNEUMATIC CONTROL ASSEMBLY (4) AND 15-MICRON FILTERS AT THE INLET AND OUTLET OF THE SOLENOID VALVE (5) ENSURE THAT CONTAMINANTS LARGER THAN 15-MICRONS WILL BE REMOVED. THE PRESSURE ACTUATED VALVES (6), INCORPORATE TEFLON GUIDES WHICH PREVENT METAL-TO-METAL RUBBING AND METAL PARTICLE GENERATION. THESE DESIGN FEATURES PREVENT GENERATION OF METALLIC PARTICLES WHICH COULD JAM THE PAV PISTON, SHAFT, OR SPACER ASSEMBLIES. THE LD RATIO ON THESE PIECES PREVENTS COOKING. THE PAV PISTON ASSEMBLY AND SHAFT ARE HELD IN ALIGNMENT AT EACH END (6). IN THE EVENT THAT METALLIC PARTICLES FROM ANOTHER SOURCE GET INTO THESE AREAS, THE PARTICLES BECOME IMBEDDED IN THE TEFLON SLEEVE. THIS PREVENTS GALLING BETWEEN THE BODY AND POPPET AND PREVENTS JAMMING.

(1) RL100C1; (2) RL00346, RL00312, RL00347; (3) RQ0711-600; (4) R0019450; (5) RS010341; (6) R0011040, RS000021, R0019401

FAILURE CAUSE: B: Emergency shutdown PAV, HPOTP intermediate seal purge PAV, Purge sequence PAV failure: Broken spring.

THE PRESSURE ACTUATED VALVE SPRINGS (1) ARE MANUFACTURED FROM ELGILOY WIRE. STRENGTH AND ELASTIC LIMIT, TOGETHER WITH ELASTIC MODULUS, ARE THE PRIMARY REASONS FOR USING ELGILOY. THE MATERIAL IS CORROSION RESISTANT AND EXHIBITS RESISTANCE TO STRESS CORROSION CRACKING (2) FOR THIS APPLICATION. THE SPRINGS ARE STRAIN RELIEVED AND INCORPORATE CLOSED AND DEBURRFED ENDS, REDUCING STRESS CONCENTRATIONS THAT MAY CAUSE BREAKAGE (1).

(1) RS008025, R0011028, R0019404; (2) RSS-8582-6

FAILURE CAUSE: D: Emergency shutdown PAV, HPOTP intermediate seal purge PAV, purge sequence PAV failure: Excessive internal leakage due to: Damaged/defective sealing surface.

THE EMERGENCY SHUTDOWN PAV (1) AND HPOTP INTERMEDIATE SEAL PURGE PAV (2) POPPETS ARE MADE FROM 321 CRES. STRENGTH AND DUCTILITY ARE THE PRIMARY REASONS FOR SELECTING 321 CRES. THIS MATERIAL IS CORROSION RESISTANT AND EXHIBITS A RESISTANCE TO STRESS CORROSION CRACKING (3). THE PAV SEATS (4) ARE MADE FROM 7075-T73 ALUMINUM ALLOY (3). LIGHT-WEIGHT, STRENGTH AND RESISTANCE TO STRESS CORROSION CRACKING ARE THE REASONS FOR USING THIS MATERIAL. THE POPPET SEALS ARE MADE FROM KEL-F (3). COLD-FLOW CHARACTERISTICS AND DUCTILITY ARE THE PRIMARY REASONS FOR USING KEL-F. THE PURGE SEQUENCE PAV (5) USES 440C CRES FOR THE SEATS (6). HARDNESS AND WEAR RESISTANCE ARE THE PRIMARY REASONS FOR USING 440C CRES. THE MATERIAL ALSO EXHIBITS SUFFICIENT CORROSION RESISTANCE TO BE SUITABLE FOR THE APPLICATION (3). THE PURGE SEQUENCE PAV POPPET IS MADE FROM TUNGSTEN CARBIDE (7). TUNGSTEN CARBIDE WAS SELECTED FOR ITS RESISTANCE TO WEAR AND ITS VIRTUALLY POROSITY-FREE STRUCTURE. THE MATERIAL IS CORROSION RESISTANT AND, WHERE USED, IS NOT SUBJECT TO STRESS CORROSION CRACKING (3).

(1) RS000021, RS000027; (2) R0011040, R0011031; (3) RSS-8582-6; (4) RS008030, R0011028; (5) R0019401; (6) R0019410; (7) R0019409

FAILURE CAUSE: ALL CAUSES

THE PNEUMATIC CONTROL ASSEMBLY HAS SUCCESSFULLY PASSED DESIGN VERIFICATION TESTING (1), WHICH INCLUDED PRESSURE TESTING (2), PRESSURE CYCLING (3), AND VIBRATION TESTING (4). HIGH CYCLE AND LOW CYCLE FATIGUE LIFE, AS WELL AS THE MINIMUM FACTORS OF SAFETY FOR THE PCA, MEET CEI REQUIREMENTS (5). THE PCA WAS CLEARED FOR FRACTURE MECHANICS/DE FLAW GROWTH, SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (6). THE DESIGN HAS BEEN FURTHER VERIFIED BY REPRESENTATIVE VALVES BEING REMOVED FROM ENGINE 0107 AND DISASSEMBLED. THE VALVES SHOWED NO DEGRADATION OR WEAR OF DETAIL PARTS (7). THESE VALVES HAD ACCUMULATED OVER 19,000 SECONDS AND 58 STARTS. THE HPOTP INTERMEDIATE SEAL PURGE PRESSURE REDLINE WILL LIMIT CRITICALITY OF FAILURE TO ENGINE SHUTDOWN. THE CONTROLLER MONITOR SYSTEM IS COMPRISED OF REDUNDANT SENSOR ELECTRONICS, REDUNDANT HARNESSSES, AND REDUNDANT CONTROLLER CHANNELS (8).

(1) DVS-SSME-610; (2) RSS-510-46; (3) RSS-510-51; (4) RSS-510-50; (5) RL00532, CP320R0003B, RSS-8546; (6) NASA TASK 117; (7) SSME-63-0230; (8) CP409R0002 PT 1 3.2.3.6 4

**SSME FMEA/CIL
INSPECTION AND TEST**

Component Group: Pneumatic Controls
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A, C, E	PNEUMATIC CONTROL ASSEMBLY FILTER PRESSURE ACTUATED VALVE - MS PURGE PRESSURE ACTUATED VALVE - PURGE SEQUENCE PRESSURE ACTUATED VALVE - EMSD		R0019450 RES1107 R0011040 R0019401 RS008021
	CLEANLINESS OF COMPONENTS	THE PNEUMATIC CONTROL ASSEMBLY, THE PRESSURE ACTUATED VALVES, AND THE SOLENOID VALVES ARE CLEANED TO OXYGEN/FUEL SERVICE PER SPECIFICATION AND DRAWING REQUIREMENTS.	RL10001 R0019450 R0011040 R0019401 RS008021
		DURING ASSEMBLY OF THE PRESSURE ACTUATED VALVE, THE ACTUATION AND DEACTUATION OPERATION IS VERIFIED. OPERATION OF THE VALVE VERIFIES NO CONTAMINATION BLOCKAGE IN MOVING PARTS.	RL00346 RL00312 RL00347
	FILTER INTEGRITY	FILTERS ARE INSPECTED TO MEET FLOW AND FILTRATION REQUIREMENTS PER SPECIFICATION.	RC1090 RC1107
B	SPRING SPRING SPRING MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS. AFTER MACHINING, SPRING CHARACTERISTICS ARE INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS. LOAD RANGE OF THE DEPRESSED SPRING IS TESTED PER DRAWING REQUIREMENTS.	RS008025 R0011028 R0019404 RA0102-012 RS008025

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
B	MATERIAL INTEGRITY	SPRING HEAT TREAT VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-021
C	POPPET SEAT POPPET SEAT POPPET SEAT SEAL		RS008027 RS008030 R0011031 R0011026 R0019409 R0019410 RS008028
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS. HEAT TREAT IS VERIFIED PER DRAWING REQUIREMENTS AS APPLICABLE	R0011026 RS008030 R0019409
		SEALING SURFACES ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008027 RS008030 R0011031 R0011026 R0019409 R0019410 RS008028
		PAV SEAL OPERATIONS ARE VERIFIED DURING ASSEMBLY AND FUNCTIONAL TESTING.	RL00346 RL00312 RL00347
ALL CAUSES	PNEUMATIC CONTROL ASSEMBLY		R0019450
	ASSEMBLY TESTING	THE FOLLOWING TESTS ARE PERFORMED DURING ASSEMBLY AND FUNCTIONAL TESTING OF THE PNEUMATIC CONTROL ASSEMBLY: - SEAT LEAKAGE IS VERIFIED TO BE WITHIN SPECIFICATION FOR BOTH ENERGIZED AND DE-ENERGIZED OPERATION. - ASSEMBLY OPERATION IS VERIFIED BY TESTING EACH FUNCTION OF THE PNEUMATIC CONTROL ASSEMBLY. - ASSEMBLY FUNCTION IS VERIFIED BY INSPECTION OF THE RATE AND PRESSURE DURING FLOW CHECK.	RL00344 RL00344 RL00344
	HOT-FIRE ACCEPTANCE TESTING (GREEN RUN)	PNEUMATIC CONTROL ASSEMBLY OPERATION IS VERIFIED THROUGH HOT-FIRE ACCEPTANCE TESTING	RL00461
	PRE-FLIGHT CHECKOUT	INTERNAL PGA LEAKAGE (ALL VALVES DEACTIVATED EXCEPT PURGE SEQUENCE PAV) IS VERIFIED EACH FLIGHT FLOW. PNEUMATIC OPERATION IS VERIFIED DURING SSME ELECTRICAL CHECKOUT PRIOR TO FLIGHT OR AFTER ANY REPLACEMENT OF RELATED COMPONENTS BY PERFORMING THE FOLLOWING OMRSD REQUIREMENTS:	OMRSD V41BQ0.090 OMRSD V41BQ0.091

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
ALL CAUSES	PRE-FLIGHT CHECKOUT	<ul style="list-style-type: none"> - FLIGHT READINESS TEST INCLUDING PNEUMATIC SHUTDOWN. - FLIGHT READINESS TESTS AND VALVE CYCLE VERIFICATION. - PRE-CRYO LOADING. (LAST TEST) 	OMRSD V41AS0 030 OMRSD S00FA0.211 OMRSD S00FA0.213

Failure History: Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PRACN)
 Reference: NASA letter SA21/08/308 and Rocketdyne letter 88RC09761.

Operational Use: Not Applicable.