SSME EA/CIL
REDUNDANCY SCREEN

Component Group:	Pneumatic Controls	**Prepared:**	P. Lowrimore
CIL Item:	C200-18	**Approved:**	T. Nguyen
Component:	Pneumatic Control Assembly	**Approval Date:**	6/2/99
Part Number:	R0019450	**Change #:**	1
Failure Mode:	Fails to actuate fully (Fuel system purge PAV and Oxidizer bleed PAV).	**Directive #:**	CCBD ME3-01-6213
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Phase	Failure / Effect Description	Criticality Hazard Reference
S 4.1	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 detects out-of-limit condition and initiates engine shutdown. Depletion of helium supply for this engine until vehicle terminates supply. Mission scrub. Loss of vehicle due to HPOTP fire may result if loss of helium to HPOTP IMSL purge is not detected. Redundancy Screens: PNEUMATIC SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY 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.	1R ME-C1S, ME-G3A
SM 4.1	Failure of PAV midstroke during start 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. Redundancy Screens: PNEUMATIC SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY 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.	1R ME-C1S, ME-C1M

SSME FMEA/CIL
DESIGN

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Design / Document Reference

FAILURE CAUSE: **A: Fuel system purge PAV, Oxidizer bleed valve PAV failure: Poppet jammed midstroke.**
C: Fuel system purge PAV, oxidizer bleed valve PAV failure: Excessive internal leakage due to: Contamination.
E: Fuel system purge PAV, oxidizer bleed valve 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 L/D RATIO ON THESE PIECES PREVENTS COCKING. 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) RL10001; (2) RL00347 (3) RQ0711-600; (4) R0019450; (5) RSD10341; (6) RS008021

FAILURE CAUSE: **B: Fuel system purge PAV, Oxidizer bleed valve 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 DEBURRED ENDS, REDUCING STRESS CONCENTRATIONS THAT MAY CAUSE BREAKAGE (1).

(1) RS008025. (2) RSS-8582-6

FAILURE CAUSE: **D: Fuel system purge PAV, oxidizer bleed valve PAV failure: Excessive internal leakage due to: Damaged/defective sealing surface.**

THE FUEL SYSTEM PURGE PAV (1) AND THE OXIDIZER BLEED VALVE PAV (1) POPPETS (2) 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.

(1) RS008021; (2) RS008027 (3) RSS-8582-6; (4) RS008030

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/NDE FLAW GROWTH, SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (6). THE DESIGN HAS BEEN FURTHER VERIFIED BY 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 55 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 HARDNESSES, AND REDUNDANT CONTROLLER CHANNELS (8).

(1) DVS-SSME-510; (2) RSS-510-46; (3) RSS-510-51; (4) RSS-510-50; (5) RL00532, CP320R0003B, RSS-8546; (6) NASA TASK 117. (7) SSME-83-0230; (8) CP406R0002 PT 1 3.2.3 5.4

SSME FM CIL
INSPECTION AND TEST

Component Group: Pneumatic Controls
CIL Item: C200-18
Component: Pneumatic Control Assembly
Part Number: R0019450
Failure Mode: Fails to actuate fully (Fuel system purge PAV and Oxidizer bleed PAV).

Prepared: P. Lowrimore
Approved: T. Nguyen
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Change #: 1
Directive #: CCBD ME3-01-5213

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A, C, E	PNEUMATIC CONTROL ASSEMBLY FILTER PRESSURE ACTUATED VALVE - EMSD		R0019450 RES1107 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 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.	RL00347
	FILTER INTEGRITY	FILTERS ARE INSPECTED TO MEET FLOW AND FILTRATION REQUIREMENTS PER SPECIFICATION.	RC1090 RC1107
B	SPRING		RS008025
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		AFTER MACHINING, SPRING CHARACTERISTICS ARE INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS008025 RA0102-012
		LOAD RANGE OF THE DEPRESSED SPRING IS TESTED PER DRAWING REQUIREMENTS.	RS008025
		SPRING HEAT TREAT VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-021
D	POPPET SEAT SEAL		RS008027 RS008030 RS008028
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		HEAT TREAT IS VERIFIED PER DRAWING REQUIREMENTS AS APPLICABLE	RS008018

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
D	SEALING SURFACES	SEALING SURFACES ARE INSPECTED PER DRAWING REQUIREMENTS.	RS008027 RS008030 RS008028
		PAV SEAL OPERATIONS ARE VERIFIED DURING ASSEMBLY AND FUNCTIONAL TESTING.	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.	RL00344
		- ASSEMBLY OPERATION IS VERIFIED BY TESTING EACH FUNCTION OF THE PNEUMATIC CONTROL ASSEMBLY.	RL00344
		- ASSEMBLY FUNCTION IS VERIFIED BY INSPECTION OF THE RATE AND PRESSURE DURING FLOW CHECK.	RL00344
	HOT-FIRE ACCEPTANCE TESTING (GREEN RUN)	PNEUMATIC CONTROL ASSEMBLY OPERATION IS VERIFIED THROUGH HOT-FIRE ACCEPTANCE TESTING.	RL00461
	PRE-FLIGHT CHECKOUT	INTERNAL PCA LEAKAGE (ALL VALVES DEACTIVATED EXCEPT PURGE SEQUENCE PAV) IS VERIFIED EACH FLIGHT FLOW.	OMRSD V41BQ0.090 OMRSD V41BQ0.097
		PNEUMATIC OPERATION IS VERIFIED DURING SSME ELECTRICAL CHECKOUT PRIOR TO FLIGHT OR AFTER ANY REPLACEMENT OF RELATED COMPONENTS BY PERFORMING THE FOLLOWING OMRSD REQUIREMENTS: - FLIGHT READINESS TEST INCLUDING PNEUMATIC SHUTDOWN. - FLIGHT READINESS TESTS AND VALVE CYCLE VERIFICATION. - PRE-CRYO LOADING. (LAST TEST)	OMRSD V41AS0.030 OMRSD S00FA0.21* OMRSD S00FA0.213

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

Operational Use: Not Applicable