SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group:	Actuators	Prepared:	S. Heater
CIL Item:	E140-08	Approved:	T. Nguyen
Part Number:	RES1008-6XXX	Approval Date:	6/9/00
Component:	Oxidizer Preburner Oxidizer Valve Actuator	Change #:	1
FMEA Item:	E140	Directive #:	CCBD ME3-01-5624
Failure Mode:	Inadvertently goes into hydraulic lockup.	Page:	1 of 1

Phase	Failure / Effect Description	Criticality Hazard Reference
M 4.1	Loss of current to both failsafe servoswitch coils, the actuator remains in its last position in hydraulic lockup. The OPOVA/OPOV will not respond to commands. Failure of both channels detected by SEII will result in hydraulic lockup. Mission abort may result when hydraulic lockup occurs during Max Q throttling. Redundancy Screens: ACTUATOR SYSTEM - CONTROLLER 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: Pass - Loss of redundant hardware items could not result from a single credible event.	1R ME-G4M
M 4.2	Failure to respond to commands during throttling may result in engine limit shutdown due to turbine discharge temperature. Mission abort. Redundancy Screens: ACTUATOR 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: Pass - Loss of redundant hardware items could not result from a single credible event.	1R ME-G4M

SSME EA/CIL DESIGN

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FAILURE CAUSE: **A: Failsafe servoswitch: Nozzle or orifice restricted.**

HYDRAULIC LINES AND ACTUATOR DETAILS ARE CLEANED PRIOR TO ACTUATOR ASSEMBLY (1). THE HYDRAULIC FLUID USED FOR ASSEMBLY AND TEST IS EITHER IN ACCORDANCE WITH JSC SPECIFICATION REQUIREMENTS OR PER AN MSFC APPROVED WAIVER (2). THE HYDRAULIC FLUID CLEANLINESS IS CONTROLLED. THE SERVOSWITCH AND ACTUATOR ASSEMBLY ARE PERFORMED IN A CONTAMINATION CONTROLLED AREA (1). HYDRAULIC FLUID CLEANLINESS IS CONTROLLED IN COMPONENT TEST FACILITIES BOTH PRIOR TO INSTALLING ACTUATORS AND PRIOR TO REMOVING THEM AFTER COMPONENT LEVEL TESTS BY MAKING A PARTICLE COUNT (2). A 25-MICRON GLASS BEAD RATED FILTER (3) IS INSTALLED BETWEEN THE HYDRAULIC SUPPLY AND THE ACTUATOR. FILTER RATING IS VERIFIED ON EACH UNIT BY BUBBLE POINT TEST. IN ADDITION, THE SERVOSWITCH (4) INCORPORATES A FILTER (5) TO PROTECT THE ORIFICES AND ALSO INCORPORATES 50-MICRON FILTERS IMMEDIATELY UPSTREAM OF THE NOZZLES FOR FILTERING THE FIRST STAGE FLUID SUPPLY. THE ORIFICE FILTER IS DESIGNED TO CONTAIN ALL PARTICLES WHOSE SMALLEST DIMENSIONS ARE 50-MICRONS OR LARGER. THE FILTER MUST ALSO RETAIN 95% OF ALL PARTICLES WHOSE TWO SMALLEST DIMENSIONS ARE 25-MICRONS (5).

(1) RL10012; (2) RC1008; (3) RES1008-3003; (4) 84000259; (5) 28003065

FAILURE CAUSE: **B: Failsafe servoswitch: Torque motor contamination, open or short circuit.**

THE TORQUE MOTOR PARTS ARE CLEANED PRIOR TO ASSEMBLY. THE TORQUE MOTOR DAMPING FLUID CLEANLINESS IS CONTROLLED (1). THE SERVOSWITCH IS ASSEMBLED IN A LAMINAR FLOW BENCH AREA TO PREVENT CONTAMINATION ENTRY (1). THE ELECTRICAL HARNESS WIRE AND THE SERVOSWITCH COIL WIRE (1) ARE PROCURED TO GOVERNMENT SPECIFICATIONS. THE ELECTRICAL CONNECTORS ARE MADE TO ROCKETDYNE APPROVED SPECIFICATIONS (2). THE COILS ARE WOUND IN LAMINAR FLOW STATIONS TO REDUCE CONTAMINATION POTENTIAL. THE COIL IS WOUND TO ENSURE THAT COIL WIRES CANNOT CROSS THE LEADWIRE FROM THE OTHER END OF THE COIL (1) (3). ALL HARNESS WIRES ARE INSTALLED IN PROTECTIVE WIREWAYS. THE INTERFACE FASTENERS ARE LOCKWIRED AND THE WIREWAYS ARE SUPPORTED WITH CLAMPS. WIREWAYS ARE FILLED WITH PLASTIC POTTING COMPOUND. COIL AND LEADWIRE TERMINATIONS ARE ENCAPSULATED (4). TEFLON WIRE GUIDES, AND COIL AND WIRE POTTING MINIMIZES THE POSSIBILITY OF MECHANICAL DAMAGE TO THE INSULATION AND WIRE, AND VIBRATION INDUCED ELECTRICAL DISCONTINUITIES. ELECTRICAL CONTINUITY AT LEADWIRE-TO-CONNECTOR AND COIL-TO-LEADWIRE CONNECTIONS IS ENSURED BY SOLDERED JOINTS (4).

(1) RC1008; (2) RES1229; (3) 28006768, 28006769; (4) 41003720

FAILURE CAUSE: **C: Failsafe servoswitch: Broken flapper or torque tube.**

THE FLAPPER (1) AND TORQUE TUBE (2) ARE MADE FROM BERYLLIUM COPPER. THIS MATERIAL WAS SELECTED FOR ITS DUCTILITY, MODULUS OF ELASTICITY, AND YIELD STRENGTH (3). THE FLAPPER AND TORQUE TUBE ARE DEFLECTION LIMITED. THIS IN COMBINATION WITH THE MATERIAL PROPERTIES PREVENTS LOW AND HIGH CYCLE FATIGUE FAILURE.

(1) 28003504; (2) 28003056; (3) RSS-8582

FAILURE CAUSE: **D: Failsafe servoswitch: Filter O-ring leakage.**

THE FILTER O-RING IS BUNA-N (1). THE MATERIAL WAS SELECTED FOR ITS ELASTIC CHARACTERISTICS, RESISTANCE TO PERMANENT SET AND ITS COMPATIBILITY WITH HYDRAULIC FLUID, THE CONTACTING METAL COMPONENTS, AND THE OPERATING TEMPERATURES (2). THE ASSEMBLY DESIGN PERMITS VISUAL INSPECTION OF THE O-RING AFTER INSTALLATION (3).

(1) 82005510; (2) RSS-8582; (3) 84000259

FAILURE CAUSE: **E: Failsafe servoswitch: Loss of damping fluid.**

THE DAMPING FLUID IS CONTAINED BETWEEN THE TORQUE MOTOR COVER (1) AND THE SERVO-COMPONENT HOUSING (2). THE COVER-TO-HOUSING JOINT IS SEALED IN WITH AN O-RING SEAL. THE DAMPING FLUID IS SEALED FROM THE HYDRAULIC CIRCUIT BY AN O-RING BETWEEN THE HOUSING AND THE TORQUE MOTOR FRAME (3). THE TORQUE MOTOR CAVITY IS FILLED BY INJECTING A MEASURED AMOUNT OF FLUID. THE O-RING SEALS ARE MADE FROM BUNA-N. BUNA-N WAS SELECTED FOR ITS COMPATIBILITY WITH THE OPERATING ENVIRONMENT AND RESISTANCE TO PERMANENT SET (4). THE O-RINGS ARE LIFE LIMITED BY MAJOR WAIVER (5). THE TORQUE MOTOR WILL OPERATE SATISFACTORILY WITHOUT DAMPING FLUID. HOWEVER, DAMPING FLUID LOSS MAY REDUCE THE HIGH CYCLE FATIGUE LIFE OF THE TORQUE MOTOR ASSEMBLY.

(1) 28003031; (2) 28003079; (3) 28003045; (4) RSS-8582; (5) DAR 2988

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FAILURE CAUSE: ALL CAUSES

THE HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE ACTUATOR MEET CEI REQUIREMENTS (1). THE MINIMUM FACTORS OF SAFETY FOR THE ACTUATOR MEET CEI REQUIREMENTS (2). THE ACTUATOR WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH, SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (3). THE ACTUATOR HAS COMPLETED DESIGN VERIFICATION TESTING (4). DVS TEST RESULTS ARE DOCUMENTED (5). THE OPOVA FROM ENGINE 2010 WAS DISASSEMBLED AND EXAMINED. THE ACTUATOR SHOWED NO DETRIMENTAL DEFECTS OR WEAR. THIS ACTUATOR HAD 28 STARTS AND 10,332 SECONDS HOT FIRE TIME, INCLUDING 6,651 SECONDS AT FPL (6). A FAILURE IN WHICH THE ACTUATOR INADVERTENTLY GOES INTO HYDRAULIC LOCKUP IS DETECTED BY THE CONTROLLER SELF TEST (7). THE RESULT OF THE ERROR DETECTION IS A CONTROLLER INITIATED HYDRAULIC LOCKUP OF ALL ACTUATORS (8).

(1) RL00532, CP320R0003B; (2) RSS-8546, CP320R0003B; (3) NASA TASK 117; (4) DVS-SSME-512; (5) RSS-512; (6) SSME-82-2316; (7) CP406R0002 PT 1 3.2.3:3.2.3; (8) CP406R0002 PT 1 3.2.3:1.7.2

SSME FI CIL
INSPECTION AND TEST

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	NOZZLE ORIFICE/FILTER ASSEMBLY FILTER SERVOSWITCH		28003074 28006493 28003065 84000259
	COMPONENT AND FLUID CLEANLINESS	FACILITY TEST FLUIDS ARE INSPECTED FOR PARTICULATES PRIOR TO AND AFTER ACTUATOR FUNCTIONAL TESTING.	RC1008
		THE ACTUATOR AND SERVOSWITCH COMPONENTS ARE VERIFIED TO BE CLEAN PRIOR TO ASSEMBLY.	RC1008, RL10012
		CONTAMINATION CONTROL OF THE ACTUATOR AND SERVOSWITCH ASSEMBLY AREAS IS VERIFIED.	RC1008, RL10012
	FILTER INTEGRITY	SERVOSWITCH FILTER IS VERIFIED TO MEET THE PARTICULATE FILTRATION REQUIREMENTS PER DRAWING.	28003065 28006493
		SERVOSWITCH NOZZLE IS EXAMINED FOR BURRS, RADIAL SCRATCHES, AND NICKS.	28003074
	FUNCTIONAL INTEGRITY	SERVOSWITCH AND ACTUATOR FUNCTIONAL TESTING VERIFIES NOZZLE AND ORIFICE ARE NOT RESTRICTED.	RC1008 84000259
B	COIL COIL SERVOSWITCH		28006769 28006768 84000259
	ELECTRICAL INTEGRITY	THE COIL WINDING IS INSPECTED TO ASSURE COIL WIRE ENDS DO NOT CROSS EACH OTHER OR THE OPPOSITE END LEADWIRE.	28006769 28006768
		SOLDERING OF ELECTRICAL CONNECTIONS IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RC1008, RL10009
		ELECTRIC COIL INSULATION, WIRE RESISTANCE, AND DIELECTRIC STRENGTH ARE TESTED.	RC1008
		COIL LEADWIRE TERMINATION ENCAPSULATION IS INSPECTED.	RC1008 RL10008
		VIBRATION, THERMAL, AND INDUCTION KICK TESTS ARE PERFORMED TO DETECT INCIPIENT SHORTS.	RC1008
		ELECTRICAL RESPONSE TESTING VERIFIES ELECTRICAL INTEGRITY.	RC1008
		THE TORQUE MOTOR AREA IS VERIFIED TO BE CLEAN PRIOR TO CLOSEOUT OF THE CAVITY.	84000259
C	FLAPPER TORQUE TUBE ARMATURE ASSEMBLY		28003504 28003056 28003508
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	28003504 28003056

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C	MATERIAL INTEGRITY	HEAT TREAT OF THE FLAPPER AND TORQUE TUBE IS VERIFIED PER DRAWING REQUIREMENTS.	28003504 28003056
	BRAZE INTEGRITY	BRAZING OF THE FLAPPER AND TORQUE TUBE IS INSPECTED PER DRAWING REQUIREMENTS.	28003508
		BRAZE INTEGRITY IS VERIFIED BY LEAK TEST PER DRAWING REQUIREMENTS.	28003508
	ASSEMBLY TESTING	FLAPPER AND TORQUE TUBE INTEGRITY IS VERIFIED BY SERVOSWITCH AND ACTUATOR ACCEPTANCE TESTING.	RC1008
D	SERVOSWITCH SEAL		84000259 82005510-005
	SEAL INTEGRITY	THE FILTER O-RINGS ARE LOT SAMPLE INSPECTED PER MIL-STD-105 FOR VISUAL SURFACE QUALITY, PHYSICAL QUALITY, FLUID COMPATIBILITY, STRETCH, AND COMPRESSION.	29000020, HRQP 5.150
	ASSEMBLY INTEGRITY	FILTER O-RING INSTALLATION AND SEALING ARE VERIFIED BY SERVOSWITCH "PULL IN" AND "DROPOUT" TESTS.	RC1008 84000259
E	SERVOSWITCH		84000259
	TORQUE MOTOR DAMPING	PROPER FILLING OF TORQUE MOTOR CAVITY WITH DAMPING FLUID IS VERIFIED.	84000259
		SSME COMPONENTS EXTERNAL INSPECTION VERIFIES THERE IS NO EVIDENCE OF FLUID LEAKAGE PRIOR TO EACH FLIGHT.	OMRSD V41BU0.030
ALL CAUSES	COMPONENT CLEANLINESS	ALL ACTUATOR DETAILS ARE VERIFIED TO BE CLEAN PRIOR TO INSTALLATION.	RC1008, RL10012
	FUNCTIONAL INTEGRITY	HOTFIRE TESTING AND SECOND E & M INSPECTIONS VERIFY SATISFACTORY OPERATION.	RL00050-04 RL00056-06 RL00056-07
		ACTUATOR OPERATION IS VERIFIED PRIOR TO EACH FLIGHT DURING HYDRAULIC SYSTEM CONDITIONING.	OMRSD S00FA0.211
		ACTUATOR OPERATION IS VERIFIED DURING THE ACTUATOR CHECKOUT MODULE PRIOR TO EACH FLIGHT.	OMRSD V41AS0.010
		ACTUATOR OPERATION IS VERIFIED DURING FLIGHT READINESS CHECKOUT PRIOR TO EACH FLIGHT. (LAST TEST)	OMRSD V41AS0.030

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: FAILURE MODE CAN BE DETECTED IN REALTIME BY THE FLIGHT CONTROL TEAM WHO WILL EVALUATE EFFECTS UPON VEHICLE PERFORMANCE AND ABORT CAPABILITY. BASED ON THIS EVALUATION THE APPROPRIATE ABORT MODE OR SYSTEM CONFIGURATION WILL BE SELECTED. FAILURE DETECTION CUES AND ASSOCIATED SSME PERFORMANCE DATA HAVE BEEN COORDINATED BETWEEN THE ENGINEERING AND FLIGHT OPERATIONS ORGANIZATIONS WITH THE RESPONSES DOCUMENTED IN MISSION FLIGHT RULES.