SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group:	Electrical Harnesses	Prepared:	P. Ho
CIL Item:	H109-01, H122-01	Approved:	T. Nguyen
Part Number:	RS008109, RS008122	Approval Date:	5/3/00
Component:	Lightning Braided - Fuel Flowmeter 1W9, 1W22	Change #:	1
FMEA Item:	H109, H122	Directive #:	CCBD ME3-01-5287
Failure Mode:	Open or short circuit in harness. Loss of connector.	Page:	1 of 1

Phase	Failure / Effect Description	Criticality Hazard Reference
S 4.4	Failure of both harnesses causing erroneous signals from one or more sensors within qualification limits but sufficient to cause off-nominal mixture ratio may result in turbine discharge temperature SLE indication and controller initiated shutdown. Mission scrub. Loss of vehicle due to turbine or heat exchanger failure may result if turbine overtemperature condition occurs and is not detected. Redundancy Screens: HARNESS SYSTEM - ENGINE SYSTEM: UNLIKE REDUNDANCY A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Fail - Loss of a redundant hardware items is not detectable during flight. C: Pass - Loss of redundant hardware items could not result from a single credible event.	1R ME-G6S,A
SM 4.1	Failure of one or both harnesses causing erroneous signal from one or more sensor(s) within qualification limits may result in off-nominal mixture ratio. Mission abort may result if off-nominal propellant consumption leads to a SLE engine shutdown or premature propellant depletion. Redundancy Screens: HARNESS SYSTEM - ENGINE SYSTEM: UNLIKE REDUNDANCY A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Fail - Loss of a redundant hardware items is not detectable during flight. C: Pass - Loss of redundant hardware items could not result from a single credible event.	1R ME-G4M
M 4.3	Failure of both harnesses causing erroneous signals from all sensors outside qualification limits results in sensor disqualification(s), a MCF indication, and electrical lockup response. Mission abort may result when electrical lockup occurs during Max Q throttling. Redundancy Screens: HARNESS SYSTEM: LIKE 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 4.4	Failure of both harnesses causing erroneous output signals from one or more sensor(s) sufficient to cause off-nominal mixture ratio operation may result in an SLE indication. Controller initiates shutdown. Mission abort. Redundancy Screens: HARNESS SYSTEM - ENGINE SYSTEM: UNLIKE REDUNDANCY A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Fail - Loss of a redundant hardware items is not detectable during flight. C: Pass - Loss of redundant hardware items could not result from a single credible event.	1R ME-G4M

SSME FEA/CIL
DESIGN

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Design / Document Reference

FAILURE CAUSE: **A: Conductor or insulation damage caused by vibration, flexure, routing, or clamping.**

MATERIAL SELECTION OF THE WIRES, INSULATORS, CONNECTORS, AND ASSEMBLY TECHNIQUES ARE CONTROLLED BY SPECIFICATION (1) TO GUARD AGAINST THE FAILURE OF THE HARNESS IN THE ENVIRONMENTS IT IS EXPOSED TO. THESE CONTROLS ARE ESTABLISHED BY GOVERNMENT SPECIFICATIONS FOR CONNECTORS (2) AND WIRE SELECTION (3), AND ARE KEYED TO THE FUNCTION AND USAGE OF THE HARDWARE. TO PRECLUDE SINGLE POINT ELECTRICAL FAILURES, REDUNDANT FUNCTIONS ARE IMPLEMENTED IN SEPARATE HARNESSES, ROUTED THROUGH DIFFERENT PATHWAYS. TO PREVENT DETERIORATION OF THE CONDUCTOR OR INSULATOR, WIRES ARE OF SUCH CROSS SECTION AS TO PROVIDE AMPLE AND SAFE CURRENT CARRYING CAPACITY. THE MAXIMUM DESIGN CURRENT IN ANY WIRE IS LIMITED SO THAT "WIRE TOTAL TEMPERATURE" WILL NEVER EXCEED THE RATED WIRE TEMPERATURE (1). HARNESS ASSEMBLIES INCORPORATE A FLEXIBLE GLASS FILLER CORD TO ENHANCE CABLE ROUNDING (1). THE CORD HELPS IN ELIMINATING EXCESSIVE BEND RADII THAT MAY CAUSE WIRE DAMAGE. TEFLON FILM WRAP AND TEFLON TAPE COVER THE WIRE BUNDLES TO PROTECT THE INSULATION FROM ADRASIVE DAMAGE. A WIRE MESH SHEATH PROTECTS THE ENTIRE WRAP FROM SHARP IMPACTS, HANDLING DAMAGE, AND PROVIDES EMI PROTECTION (4). BRAID WIRE TYPE, SIZE, AND COVERAGE ARE CONTROLLED BY SPECIFICATION (5). CABLE ROUTING IS CONTROLLED BY THE ASSEMBLY DRAWINGS (6) THAT ESTABLISH THE RETAINING CLAMPS AND RESTRAINING TIES. THE SECURING CLAMPS (7) INCORPORATE RUBBER GROMMETS THAT PREVENT PINCHING OR CUTTING OF THE INSTALLED HARNESS.

(1) RL10014; (2) 40M39569; (3) 40M50577, 40M50578; (4) RL00249; (5) RA1613-004; (6) RS007007; (7) RE127-2018

FAILURE CAUSE: **B: Loose, worn, or damaged pin or pins.**
C: Damaged contact or crimp.
E: Connector shell failure.
F: Torque lock damage (non-extended life).

CONNECTOR SELECTION OF THE ASSEMBLIES IS CONTROLLED BY SPECIFICATION REQUIREMENTS (1). THE REQUIREMENTS INCORPORATE CONTROLS (2) THAT ARE KEYED TO GUARD AGAINST THE ENVIRONMENTS THEY ARE EXPOSED TO. THE CONNECTORS MEET CEI REQUIREMENTS FOR HIGH CYCLE FATIGUE, LOW CYCLE FATIGUE, AND MINIMUM FACTORS OF SAFETY (3). THE CONNECTORS ARE SELECTED IN ACCORDANCE WITH MSFC STANDARDS FOR USE ON ROCKET PROPELLED VEHICLES (4). BENT OR WORN PINS ARE REMOVABLE AND REPLACEABLE. BAYONET LOCKING RINGS ARE PROVIDED TO PREVENT CONNECTORS FROM BACKING OFF (2).

(1) RL10014; (2) RES1230, RES1235; (3) RL00532, RSS-8546, CP320R0003B; (4) 40M39569

FAILURE CAUSE: **D: Corrosion or moisture.**

THE ELECTRICAL COMPONENTS OF THE WIRE HARNESS ARE PROTECTED FROM CORROSION BY INHERENT MATERIAL DESIGN AND PROTECTIVE EXTERNAL COVERING OF THE CABLE. THE WIRE INSULATION IS COMPOSED OF TEFLON (1). TEFLON HAS RESISTANCE TO FLUIDS AND ATMOSPHERIC VAPORS. THE CONNECTOR CONTACTS ARE PLATED WITH GOLD OVER NICKEL UNDERPLATE (2). GOLD IS RESISTANT TO WATER CORROSION AND HUMIDITY. EXCEPT FOR POTTED CONNECTORS, THE CONNECTOR BACKSHELL IS PROTECTED BY SILICON RUBBER (3) TO PROTECT THE CONNECTOR FROM THE MAXIMUM SPECIFIED OPERATIONAL ENVIRONMENTS. PIN INSERT INTERFACIAL SEALS (4) ARE PROVIDED TO REDUCE CORROSION. CONNECTORS ARE MAINTAINED IN THEIR SEALED BAGS UNTIL READY FOR ASSEMBLY. CONNECTORS ARE PROTECTED TO PREVENT DAMAGE OR CONTAMINATION RESULTING FROM CONTACT WITH EACH OTHER OR ADJACENT OBJECTS (5).

(1) 40M50577; (2) MSFC-SPEC-250; (3) RL10014; (4) RC1230, RC1235; (5) RL00249

FAILURE CAUSE: **ALL CAUSES**

THE CONTROLLER SOFTWARE IS CONFIGURED TO DETECT AND RESPOND PROPERLY TO THE FAILURES IDENTIFIED, IMPLEMENT THE NECESSARY REDUNDANT CONTROLLER CHANNEL SWITCHING AND COMMAND A SAFE ENGINE STATE WHEN REDUNDANCY IS LOST (1). FUNCTIONS ARE CONTROLLED ON REDUNDANT HARNESSES. THE HARNESS DESIGN IS TESTED PER HARNESS DESIGN VERIFICATION TESTING (2), INCLUDING VIBRATION TESTING (3), SAFETY FACTOR CRITERIA TESTING (4), DURING SENSOR VIBRATION TESTING (5) WHERE THE FLIGHT DESIGNED HARNESS IS CONNECTED TO THE SENSOR UNDER TEST, AND DURING ENGINE DVS TESTING (6).

(1) CP406R0008; (2) DVS-SSME-202; (3) RSS-202-6; (4) RSS-202-20; (5) DVS-SSME-203; (6) DVS-SSME-101

SSME FMEA/CIL
INSPECTION AND TEST

Component Group: Electrical Harnesses
CIL Item: H109-01, H122-01
Part Number: RS008109, RS008122
Component: Lightning Braided - Fuel Flowmeter 1W9, 1W22
FMEA Item: H109, H122
Failure Mode: Open or short circuit in harness. Loss of connector.

Prepared: P. Ho
Approved: T. Nguyen
Approval Date: 5/3/00
Change #: 1
Directive #: CCBD ME3-01-5287

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	1W9 HARNESS 1W22 HARNESS		RS008109 RS008122
	ASSEMBLY INTEGRITY	THE FOLLOWING TESTS AND INSPECTIONS ARE PERFORMED DURING MANUFACTURING AND ASSEMBLY ACCEPTANCE: - LIGHTNING BRAID IS INSPECTED FOR ACCEPTABILITY. - ALL WIRES ARE SUBJECTED TO SPARK AND DIELECTRIC TESTING. - ALL CONTACTS IN THE CONNECTORS ARE SUBJECTED TO A RETENTION TEST. - A RESISTANCE TEST BETWEEN THE BRAID AND MATING CONNECTOR FLANGE IS PERFORMED ON THE LIGHTNING BRAID/CONNECTOR AND VERIFIED TO BE WITHIN SPECIFICATION. - EACH WIRE RUN IS VERIFIED FOR END-TO-END CONTINUITY. - INSULATION RESISTANCE BETWEEN EACH CONDUCTOR AND EVERY OTHER CONDUCTOR IS VERIFIED TO BE WITHIN SPECIFICATION. - A DIELECTRIC WITHSTANDING VOLTAGE TEST BETWEEN EACH CONDUCTOR AND EVERY OTHER CONDUCTOR, SHELL OR SHIELD VERIFIES THE LEAKAGE CURRENT TO BE WITHIN SPECIFICATION.	RL00249 RB0150-044, 40M50577 RL00249 RL00249 RL00128 RL00128 RL00128
	INSTALLATION INTEGRITY	INSTALLATION OF THE HARNESSES IS VERIFIED PER SPECIFICATIONS DEFINING THE: - INSPECTION OF HARNESSES PRE- AND POST-INSTALLATION. - ROUTING REQUIREMENTS WHICH INCLUDE: INSTALLATION PATH, CLAMP LOCATIONS, AND SIZES. SEPARATION DISTANCE REQUIREMENTS FROM OBJECTS WHICH COULD CAUSE CABLE OR CONNECTOR DAMAGE. MINIMUM BEND RADII . - INSPECTION OF CONNECTORS PRIOR TO MATING. THIS INCLUDES BACKSHELL, PINS, AND GROMMET INSPECTIONS.	RL00039 RS007007 RS007007 RL00039 RL00039
B, C, E, F	CONNECTOR CONNECTOR		RES1230 RES1235
	HARNESS/CONNECTOR ASSEMBLY INTEGRITY	HARNESS/CONNECTOR ASSEMBLY PROCESSES ARE VERIFIED PER SPECIFICATIONS WHICH INCLUDE: - CRIMPING OF ELECTRICAL CONNECTOR CONTACTS. - USE OF FLEXIBLE INSULATION SLEEVING. - INSTALLATION OF HEAT SHRINKABLE, SILICON RUBBER, STRAIGHT TUBING, AND MOLDED PARTS. - SELECTION AND USAGE OF PROTECTIVE CLOSURES.	RA1613-005 RB0150-009 RA0605-018 RA0116-054
		COMPLETED ASSEMBLY IS INSPECTED FOR PROTECTIVE BRAID FRAYING AT THE CONNECTOR JUNCTION, CONTACT PIN RETENTION, MISSING PARTS, AND DAMAGE OR DEFECTS TO SHELL OR PINS PER SPECIFICATION REQUIREMENTS.	RL00249
		FOLLOWING INSTALLATION, THE CONNECTOR TORQUE STRIP IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RS007007 RA1606-018
D	CONNECTOR CONNECTOR		RES1230 RES1235

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Approved: **T. Nguy**
Approval Date: **5/3/00**
Change #: **1**
Directive #: **CCBD ME3-01-5287**

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
D	CLEANLINESS OF COMPONENTS	CLEANLINESS REQUIREMENTS ARE VERIFIED PER SPECIFICATION DURING MANUFACTURING OF THE HARNESS ASSEMBLY.	RL00249
		METAL TYPE DUST AND MOISTURE PROOF CAPS ARE VERIFIED INSTALLED ON THE CONNECTOR WHEN NOT IN USE.	RL00249
	SURFACE FINISH	THE PLATING ON THE CONNECTOR PINS IS INSPECTED PER SPECIFICATION REQUIREMENTS.	RC1230 RC1235
	ASSEMBLY INTEGRITY	PRIOR TO CONNECTOR MATING, THE CONNECTOR IS INSPECTED FOR ANY CORROSION OR DAMAGE WHICH WOULD ALLOW MOISTURE TO ENTER THE CONNECTOR.	RL00039
ALL CAUSES	1W9 HARNESS 1W22 HARNESS		RS008109 RS008122
	ASSEMBLY INTEGRITY	ALL CONTROLLER DATA FROM THE PREVIOUS FLIGHT IS REVIEWED. ANY ANOMALOUS CONDITION NOTED REQUIRES FURTHER TESTING OR HARDWARE REPLACEMENT PRIOR TO THE NEXT FLIGHT.	MSFC PLN 1228
		RE-TEST REQUIREMENTS AFTER HARNESS REPLACEMENT OR CONNECTOR DEMATE VERIFY THAT THE PROPER CONTROLLER ELECTRICAL CHECKOUTS ARE PERFORMED TO RE-VALIDATE THE HARNESS ASSEMBLY.	OMRSD V41ZA0.010
		HARNESSES ARE INSPECTED FOR DAMAGE, PROPER ROUTING, AND PROPER TORQUE LOCK APPLICATION DURING POST FLIGHT EXTERNAL INSPECTION.	OMRSD V41BU0.030
		HARNESS OPERATION IS VERIFIED EVERY MISSION FLOW AND AFTER ANY REPAIR OR REPLACEMENT BY THE FOLLOWING CONTROLLER ELECTRICAL CHECKOUTS: (LAST TEST) - SENSOR CHECKOUT. - FLIGHT READINESS TEST. - PNEUMATIC CHECKOUT.	 OMRSD V41AQ0.010 OMRSD V41AS0.030 OMRSD V41AS0.020

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.