SSME EA/CIL
REDUNDANCY SCREEN

Component Group: Igniters and Sensors
CIL Item: J601-01, J602-01
Component: Fuel Flow Transducers (KF1bF, KF1cF)
Part Number: RES7005, RES7005
Failure Mode: No or intermittent electrical output signal.

Prepared: M. Oliver
Approved: T. Nguyen
Approval Date: 3/30/99
Change #: 1
Directive #: CCBD ME3-01-4994

Phase	Failure / Effect Description	Criticality Hazard Reference
S 4.4	Intermittent output signals from one or more sensors sufficient to cause off-nominal mixture ratio operation may result in a turbine discharge temperature limit exceeded, SLE indication and controller initiated engine 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: SENSOR 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	Erroneous output signal(s) from one or both sensor(s) such that the averaged value is within the qualification limits results in off-nominal mixture ratio. Mission abort may occur if off-nominal propellant consumption leads to an SLE engine shutdown or premature propellant depletion. Redundancy Screens: SENSOR SYSTEM: LIKE 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	Output signal from all sensors outside qualification limits results in sensor disqualification, a MCF indication, and electrical lockup response. Mission abort may result if lockup occurs during Max Q throttling. Redundancy Screens: SENSOR 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	Intermittent output signals from one or more sensors sufficient to cause off-nominal mixture ratio operation may result in SLE indication and controller initiated shutdown. Mission abort. Redundancy Screens: SENSOR SYSTEM: LIKE 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 FMEA/CIL
DESIGN

Component Group:	Igniters and Sensors	Prepared:	M. Oliver
CIL Item:	J601-01, J602-01	Approved:	T. Nguyen
Component:	Fuel Flow Transducers (KF1bF, KF1cF)	Approval Date:	3/30/99
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Design / Document Reference

FAILURE CAUSE: A: Coil winding open, broken leadwire or leadwire connections. Coil winding short, leadwire short.

ELECTRONIC, ELECTRICAL, AND ELECTROMECHANICAL PARTS FOR THE CIRCUITS INVOLVED IN THIS FUNCTION HAVE BEEN SELECTED FROM THE CLASS S OR EQUIVALENT APPROVED PARTS SELECTION (1). THE TRANSDUCER CONSISTS OF DUAL SENSING COILS WOUND ON MAGNETIC MATERIAL. A PARALLEL WIRE WINDING TECHNIQUE IS UTILIZED TO ENSURE MAXIMUM COIL-TO-COIL COUPLING AND EQUIVALENT OUTPUTS. PROCESSES USED FOR BRAZING AND LEADWIRE CONNECTIONS ARE CONTROLLED BY SPECIFICATION (2). LEADWIRE CONNECTIONS ARE BRAZED IN A STRAIN FREE CONFIGURATION AND COVERED WITH AN INSULATING HEAT SHRINK TUBING. UPPER WIRING POTTING PREVENTS WIRE MOVEMENT AND SUBSEQUENT WIRE FAILURE (3).

(1) 85M03928; (2) RC7005; (3) RL10008

FAILURE CAUSE: B: Shorting pin-to-pin or pin-to-shell.

CONNECTOR SELECTION OF THE ASSEMBLIES IS CONTROLLED BY ROCKETDYNE SPECIFICATION REQUIREMENTS (1). THE CONNECTOR DESIGN INCORPORATES FEATURES SUCH AS RUBBER SEALS, CORROSION RESISTANT PINS, LOCKING CONNECTORS, AND CONTROLLED ELECTRICAL CONNECTIONS TO PREVENT MALFUNCTION. THE CONNECTORS ARE IN ACCORDANCE WITH STANDARDS FOR USE ON ROCKET PROPELLED VEHICLES (2). THE PINS ARE NICKEL UNDERPLATED AND GOLD OVERPLATED TO PREVENT CORROSION AND MINIMIZE CONTACT RESISTANCE. THE PLATING IS CONTROLLED PER SPECIFICATION (2). THE CONNECTORS HAVE COMPLETED HARNESS DVS TESTING AND SENSOR DVS TESTING (3).

(1) RC7005; (2) RC1232; (3) DVS-SSME-202, DVS-SSME-203

FAILURE CAUSE: C: Change of internal resistance caused by moisture, corrosion, or contamination.

SENSORS ARE HERMETICALLY SEALED TO PROTECT FROM CONTAMINATION. A BACK FILL OF THE SENSOR CAVITY IS DONE TO INCORPORATE AN INERT PURGE, PREVENTING CORROSION OR CONDENSATION IN THE SENSOR (1). LEAK RATE REQUIREMENTS ARE CONTROLLED PER SPECIFICATION TO PREVENT INDUCTANCE OF FOREIGN SUBSTANCES AND PREVENT LOSS OF THE INERT GAS BACKFILL. INTERNAL POTTING PROTECTS FROM CORROSION (1).

(1) RC7005

FAILURE CAUSE: ALL CAUSES

SENSOR SYSTEM DESIGN PROVIDES REDUNDANCY TO THE ELECTRICAL COMPONENTS TO PRECLUDE ALL SINGLE POINT FAILURES OF THE CONTROL FUNCTIONS. THE SENSORS ARE A VENDOR ITEM, DRAWING SPECIFICATION AND MANUFACTURING PROCESSES ARE CONTROLLED BY ROCKETDYNE (1). ALL SENSOR DESIGNS ARE SUBJECTED TO A CRITICAL DESIGN REVIEW. ANY DESIGN CHANGES ARE RE-REVIEWED (1). THE RES7005-51 SENSORS HAVE COMPLETED DESIGN VERIFICATION TESTING (2), INCLUDING VIBRATION TESTING (3). THE -61 CONFIGURATION IS IDENTICAL TO THE -51 DESIGN WITH THE ADDITION OF A WORKMANSHIP SCREENING REQUIREMENT. THE RES7005-61 DESIGN HAS BEEN QUALIFIED BY SIMILARITY (4). THE MINIMUM FACTORS OF SAFETY MEET CEI REQUIREMENTS (5). THE SENSORS WERE ANALYZED FOR HIGH CYCLE FATIGUE AND LOW CYCLE FATIGUE LIFE AND MEET CEI REQUIREMENTS (6) THE CONTROLLER MONITOR SYSTEM IS COMPRISED OF REDUNDANT SENSOR ELECTRONICS, REDUNDANT HARNESSES, AND REDUNDANT CONTROLLER CHANNELS (7).

(1) RC7005; (2) DVS-SSME-203, RSS-8660, (3) RSS-203-11; (4) RSS-8660; (5) RSS-8546, CP320R0003B; (6) RL00532, CP320R0003B; (7) CP405R0008 3.2.3.5

SSME FMEA/CIL
INSPECTION AND TEST

Component Group: Igniters and Sensors
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	FLOW TRANSDUCER		RES7005
	INTEGRITY OF INTERNAL COMPONENTS	PROCESSES USED IN THE TRANSDUCER MANUFACTURE AND ASSEMBLY ARE VERIFIED PER SPECIFICATION AND INCLUDE: - ELECTRICAL CONNECTIONS MADE BY BRAZING. - ENCAPSULATION OF COMPONENTS.	RC7005 RL10008
B	FLOW TRANSDUCER CONNECTOR RECEPTACLE		RES7005 RES1232
	CONNECTOR INTEGRITY	PLATING ON THE CONNECTOR PINS IS INSPECTED PER SPECIFICATION REQUIREMENTS.	RC1232
		THE FOLLOWING TESTS ARE PERFORMED DURING MANUFACTURING AND SENSOR ACCEPTANCE: - INSULATION RESISTANCE BETWEEN PINS AND THE CASE IS VERIFIED TO BE WITHIN SPECIFICATION. - DIELECTRIC VOLTAGE TESTS MEASURE THE CURRENT LEAKAGE BETWEEN PINS AND CASE AND VERIFY THEM TO BE WITHIN SPECIFICATION. - TRANSDUCER COIL IMPEDANCE IS VERIFIED TO BE WITHIN SPECIFICATION.	RC7005 RC7005 RC7005
C	FLOW TRANSDUCER		RES7005
	HERMETIC SEAL INTEGRITY	CLEANLINESS REQUIREMENTS ARE VERIFIED PER SPECIFICATION DURING MANUFACTURING OF THE TRANSDUCERS.	RC7005
	WELD INTEGRITY	ALL WELDS ARE INSPECTED TO DRAWING AND SPECIFICATION REQUIREMENTS PER WELD CLASS. INSPECTIONS INCLUDE: VISUAL, DIMENSIONAL, PENETRANT, RADIOGRAPHIC, ULTRASONIC, AND FILLER MATERIAL, AS APPLICABLE	
	ASSEMBLY INTEGRITY	AFTER THE CASE IS WELDED, HELIUM LEAK TESTS ARE PERFORMED TO VERIFY HERMETIC SEAL	
ALL CAUSES	FLOW TRANSDUCER		RES7005
	ASSEMBLY INTEGRITY	ALL VENDOR INSPECTIONS AND TEST CRITERIA IS UNDER ROCKETDYNE APPROVAL AND CONTROL.	RC7005
		TRANSDUCERS ARE SUBJECTED TO A WORKMANSHIP SCREENING ACCEPTANCE TEST INCLUDING VIBRATION AND THERMAL CYCLING	
	HOT FIRE ACCEPTANCE TESTING (GREEN RUN)	SENSOR OPERATION IS VERIFIED THROUGH HOT FIRE ACCEPTANCE TESTING.	RL00461
	DATA REVIEW	ALL CONTROLLER DATA FROM THE PREVIOUS FLIGHT OR HOT FIRE IS REVIEWED. ANY ANOMALOUS CONDITION NOTED REQUIRES FURTHER TESTING OR HARDWARE REPLACEMENT PRIOR TO THE NEXT FLIGHT.	MSFC PLN 1228
	PRE-FLIGHT CHECKOUT	SENSOR OPERATION IS VERIFIED EVERY MISSION FLOW BY SUCCESSFUL COMPLETION OF THE CONTROLLER SENSOR ELECTRICAL CHECKOUT. (LAST TEST)	OMRSD V41AQ0.010 OMRSD S00FA0.213

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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference

Failure History: Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PRACA)
Reference: NASA letter SA21/88/306 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.