

**SSME FMEA/CIL
REDUNDANCY SCREEN**

Component Group: Igniters and Sensors
 CIL Item: J228-01
 Component: HPOTP Secondary Seal Cavity Pressure Transducer (D35.2)
 Part Number: RE2233/RES7001
 Failure Mode: No output or erroneous output signal.

Prepared: M. Oliver
 Approved: T. Nguyen
 Approval Date: 3/30/99
 Change #: 1
 Directive #: CC80 ME3-01-1094
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| Phase | Failure / Effect Description | Critically Hazard Reference |
|----------|---|-----------------------------|
| P 4.2 | <p>Erroneous output signal from both sensors within qualification limits from both sensors results in loss of engine start inhibit protection. Loss of vehicle during start due to HPOTP failure may result if HPOTP turbine seal failure occurs and is not detected.</p> <p>Redundancy Screens: SENSOR SYSTEM: LIKE REDUNDANCY</p> <p>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: Fail - Loss of redundant hardware items could result from a single credible event.</p> | 1R ME-C1S,M |
| S 4.4 | <p>Loss of output or erroneous output signals from both qualified sensors or remaining qualified sensor within the redline limits results in loss of redline protection. Loss of vehicle due to HPOTP failure may result if HPOTP turbine seal failure occurs and is not detected.</p> <p>Redundancy Screens: SENSOR SYSTEM: LIKE REDUNDANCY</p> <p>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: Fail - Loss of redundant hardware items could result from a single credible event.</p> | 1R ME-C1S,M |
| M 4.1 | <p>Outputs signal from both sensors that is outside the qualification limit will result in disqualification of the sensor and a MCF indication; resulting in loss of redline monitoring. Loss of vehicle due to HPOTP failure may result if HPOTP turbine seal failure occurs and is not detected.</p> <p>Redundancy Screens: SENSOR SYSTEM: LIKE REDUNDANCY</p> <p>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: Fail - Loss of redundant hardware items could result from a single credible event.</p> | 1R ME-C1S,M |
| M 4.2 | <p>Output signals from both qualified sensors or the remaining qualified sensor that exceeds the redline limit will result in a SLE indication and controller initiated shutdown. Mission abort.</p> <p>Redundancy Screens: SENSOR SYSTEM: LIKE 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-G4M |

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Component: up: Igniters and Sensors
 CIL Item: J228-01
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Prepared: M. Olive
 Approved: T. Nguyen
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| Phase | Failure / Effect Description | Criticality Hazard Reference |
|----------|--|---------------------------------|
| M 4.3 | <p>Loss of output or erroneous output signal(s) from one or both qualified sensors within the redline limits results in loss of redline protection. Loss of vehicle due to HPOTP failure may result if HPOTP turbine seal failure occurs and is not detected.</p> <p>Redundancy Screens: SENSOR SYSTEM LIKE REDUNDANCY</p> <p>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: Fail - Loss of redundant hardware items could result from a single credible event.</p> | 1R ME-C1S,M |

SSME FMEA/CIL
DESIGN

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Design / Document Reference

FAILURE CAUSE: A: Broken or shorted conductors.

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). STRAIN GAUGE OPERATION IS WITHIN ITS ELASTIC RANGE, BELOW THE MATERIAL YIELD POINT. SUPPORT FOR THE STRAIN GAUGES IS PROVIDED BY ADHESIVE AND FILM USED IN CONSTRUCTION AND ATTACHMENT OF THE STRAIN GAUGES (2). INTERCONNECTING WIRES FROM DIAPHRAGM TO TERMINAL HEADER ARE SECURED BY POTTING STRIPS TO PREVENT MOVEMENT AND WIRE FATIGUE. THE ADHESIVE AND FILM PROVIDE INSULATION FOR STRAIN GAUGES. LEADWIRES ARE INSULATED TO PREVENT SHORTING. PROCESSES USED FOR SOLDERING OF ELECTRICAL CONNECTIONS AND TERMINAL CONNECTIONS ARE CONTROLLED BY SPECIFICATION (3). UPPER WIRING POTTING PREVENTS WIRE MOVEMENT AND SUBSEQUENT WIRE FAILURE (4).

(1) 85M03926; (2) RC7001; (3) RL1000B, RL10007, MSFC-SPEC-278; (4) RL1000B

FAILURE CAUSE: B: Shorts caused by metallic contamination.

DESIGN PRACTICES SPACE HEADER TERMINALS AT MAXIMUM INTERVALS TO REDUCE SHORTING BY CONDUCTIVE CONTAMINATION. THE ASSEMBLY IS HERMETICALLY SEALED. CLEANLINESS IS CONTROLLED DURING MANUFACTURE BY SPECIFICATION (1), (2). PASSIVATION, ADHESIVE, AND VARNISH PROVIDE INSULATION FROM SHORTING (1). THE WELDING IS CONTROLLED PER SPECIFICATION (1) TO PREVENT METALLIC DROP THROUGH.

(1) RC7001; (2) RL10001

FAILURE CAUSE: C: Sensor inlet plugged.

ORBITER SYSTEM DESIGN INCORPORATES A FILTER IN THE OXYGEN AND FUEL FEED SYSTEM ELIMINATING PROPELLANT CONTAMINATION SOURCES (1). THE HELIUM SUBSYSTEM HAS A FILTER IN THE PCA PREVENTING CONTAMINATION ENTERING THE SYSTEM DURING PURGES (2). INLET PORT PASSAGE SIZE PROVIDES CONTAMINATION PROTECTION (3). MINOR FLOW IN THE SENSOR INLET DUE TO CLOSED CAVITY DESIGN REDUCES POTENTIAL FOR PARTICLE CONTAMINATION. PARTIAL BLOCKAGE OF THE INLET WILL NOT DEGRADE SENSOR FUNCTION. COMPLETE BLOCKAGE FORMING A PRESSURE VESSEL IS REQUIRED TO ALTER SENSOR FUNCTION.

(1) ICD 13M15000; (2) RCD19450; (3) RC7001

FAILURE CAUSE: E: Fractured sensor diaphragm.

THE DIAPHRAGM IS MANUFACTURED FROM A-286. A-286 EXHIBITS RESISTANCE TO CORROSION, HYDROGEN ENVIRONMENT EMBRITTLEMENT, AND ADEQUATE STRENGTH (1). DESIGN CRITERIA FOR BURST AND PROOF PRESSURE REQUIREMENTS ARE IDENTICAL IN BOTH DESIGNS (2). THE MINIMUM FACTORS OF SAFETY MEET CEI REQUIREMENTS (3). THE DIAPHRAGM MEETS HIGH CYCLE AND LOW CYCLE FATIGUE LIFE CEI REQUIREMENTS (4).

(1) RSS-8582; (2) RC7001; (3) RSS-8546, CP320RC003B; (4) RL00532, CP320R0003B

FAILURE CAUSE: F: Vacuum reference cavity damaged causing loss of vacuum.

THE OUTER CASE IS MANUFACTURED FROM CORROSION RESISTANT 304L CRES. THE OUTER CASE, CONNECTOR ASSEMBLY, AND BASE ASSEMBLY ARE WELDED TOGETHER TO FORM THE VACUUM REFERENCE CAVITY. THE CAVITY IS HERMETICALLY SEALED PER DESIGN REQUIREMENT (1). SHOULD VACUUM BE LOST, THE CHANGE OF THE SENSOR ACCURACY COMPARED TO THE OPERATING PRESSURE RANGE IS MINIMAL.

(1) RC7001

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Design / Document Reference

FAILURE CAUSE: G: Broken pins.

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 (3). THE CONNECTORS HAVE COMPLETED HARNESS DVS TESTING AND SENSOR DVS TESTING (3).

(1) RC7001; (2) RC1231; (3) DVS-SSME-202, DVS-SSME-203

FAILURE CAUSE: H: 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. LEAK RATE REQUIREMENTS ARE CONTROLLED PER SPECIFICATION TO PREVENT INDUCTANCE OF FOREIGN SUBSTANCES AND PREVENT LOSS OF THE INERT GAS BACKFILL. INTERNAL POTTING, PASSIVATION, VARNISHING, AND COATING WITH ADHESIVE PROTECTS FROM INTERNAL CORROSION (1).

(1) RC7001

FAILURE CAUSE: ALL CAUSES

SENSOR SYSTEM DESIGN PROVIDES REDUNDANCY TO THE ELECTRICAL COMPONENTS TO PRECLUDE ALL SINGLE POINT FAILURES OF THE CONTROL FUNCTIONS. AN IDENTICAL DESIGN SENSOR IS USED AT THE FUEL PREBURNER P_c PORT WHERE THE ENVIRONMENT IS MORE EXTREME. THE SENSORS ARE A VENDOR ITEM. DRAWING SPECIFICATIONS 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 SENSORS HAVE COMPLETED DESIGN VERIFICATION TESTING (2), INCLUDING VIBRATION TESTING (3). THE MINIMUM FACTORS OF SAFETY MEET CEI REQUIREMENTS (4). THE SENSORS WERE ANALYZED FOR HIGH CYCLE FATIGUE AND LOW CYCLE FATIGUE LIFE AND MEET CEI REQUIREMENTS (5). TABLE J228 LISTS ALL THE FMEA/CIL WELDS AND IDENTIFIES THOSE WELDS IN WHICH THE CRITICAL INITIAL FLAW SIZE IS NOT DETECTABLE, AND THOSE WELDS IN WHICH THE ROOT SIDE IS NOT ACCESSIBLE FOR INSPECTION. THESE WELDS HAVE BEEN ASSESSED AS ACCEPTABLE FOR FLIGHT BY RISK ASSESSMENT (6). SENSORS FROM ENGINE 2010 WERE RE-SUBJECTED TO ACCEPTANCE TESTING. ALL SENSORS MET ACCEPTANCE CRITERIA WITH THE EXCEPTION OF ONE WHICH EXHIBITED A MINOR ZERO SHIFT. THE CONTROLLER MONITOR SYSTEM IS COMPRISED OF REDUNDANT SENSOR ELECTRONICS, REDUNDANT HARNESSSES, AND REDUNDANT CONTROLLER CHANNELS (7).

(1) RC7001; (2) DVS-SSME-200, RSS-8660; (3) RSS-203-13, RSS-203-14; (4) RSS-8546, CP320R0003B; (5) RL00532, CP320R0003B; (6) RSS-8756; (7) CP406R0008 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 | SINGLE PICKUP, DUAL OUTPUT, PRESSURE TRANSDUCER | | RE2233 / RES7001 |
| | INTEGRITY OF INTERNAL ELECTRONICS COMPONENTS | PROCESSES USED IN THE TRANSDUCER MANUFACTURE AND ASSEMBLY ARE VERIFIED PER SPECIFICATION AND INCLUDE: - SOLDERING OF ELECTRICAL CONNECTIONS. - ATTACHMENT TO TERMINALS. - ENCAPSULATION OF COMPONENTS. | RL10009 RL10007 RL10008 |
| B | PRESSURE TRANSDUCER INTERNAL CLEANLINESS | CLEANLINESS REQUIREMENTS ARE VERIFIED PER SPECIFICATION DURING MANUFACTURING OF THE TRANSDUCERS. | RE2233 / RES7001 RC7001 |
| C | PRESSURE TRANSDUCER EXTERNAL CLEANLINESS | TRANSDUCERS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS. | RE2233 / RES7001 RC7001 |
| E | PRESSURE TRANSDUCER DIAPHRAGM INTEGRITY | TRANSDUCER DIAPHRAGM IS PROOF PRESSURE TESTED PER SPECIFICATION REQUIREMENTS. | RE2233 / RES7001 RC7001 |
| F | PRESSURE TRANSDUCER REFERENCE CAVITY INTEGRITY | TRANSDUCERS ARE PROOF PRESSURE TESTED PER SPECIFICATION REQUIREMENTS. REFERENCE CAVITY IS LEAK CHECKED TO VERIFY SEAL PER SPECIFICATION REQUIREMENTS | RE2233 / RES7001 RC7001 |
| G | PRESSURE TRANSDUCER CONNECTOR RECEPTACLE CONNECTOR INTEGRITY | THE PLATING ON THE CONNECTOR PINS IS INSPECTED PER SPECIFICATION REQUIREMENTS. 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 BRIDGE RESISTANCE IS VERIFIED TO BE WITHIN SPECIFICATION. | RE2233 / RES7001 RES1231 RC1231 RC7001 RC7001 RC7001 |
| H | PRESSURE TRANSDUCER HERMETIC SEAL INTEGRITY | CLEANLINESS REQUIREMENTS ARE VERIFIED PER SPECIFICATION DURING MANUFACTURING OF THE TRANSDUCERS. AFTER THE CASE IS WELDED, HELIUM LEAK TESTS ARE PERFORMED TO VERIFY HERMETIC SEAL. | RE2233 / RES7001 RC7001 |

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Component: Igniters and Sensors
 CIL Item: J228-01
 Component: HPOTP Secondary Seal Cavity Pressure Transducer (D35.2)
 Part Number: RE2233/RES7001
 Failure Mode: No output or erroneous output signal.

Prepared: M. Oily
 Approved: T. Nguyen
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 Change #: 1
 Directive #: CCBD ME3-01-4954
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| Failure Causes | Significant Characteristics | Inspection(s) / Test(s) | Document Reference |
|----------------|---|--|--|
| ALL CAUSES | PRESSURE TRANSDUCER | | RE2233 / RES7001 |
| | ASSEMBLY INTEGRITY | ALL VENDOR INSPECTION AND TEST CRITERIA IS UNDER ROCKETDYNE APPROVAL AND CONTROL. TRANSDUCERS ARE SUBJECTED TO A WORKMANSHIP SCREENING ACCEPTANCE TEST INCLUDING VIBRATION, THERMAL CYCLING, AND FUNCTIONAL TESTS. | RC7001 |
| | 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 | SENSORS ARE VISUALLY INSPECTED. SENSOR OPERATION IS VERIFIED EVERY MISSION FLOW BY SUCCESSFUL COMPLETION OF THE CONTROLLER SENSOR ELECTRICAL CHECKOUT. (LAST TEST) | OMRSD V41BU0.030 OMRSD V41AQ0.010 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 BRCD9761.
 Operational Use: Not Applicable.

J-112

SSME FMEA/CIL
FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

Component Group: Igniters and Sensors
 Item Name: HPOTP Secondary Seal Cavity Pressure Transducer (D35.2)
 Item Number: J228
 Part Number: RE2233/RES7001

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| Base Line Rationale | Variance | Change Rationale | Variant Dash Number |
|--|--|---|--------------------------------|
| J228 - New design improves producibility, inspectability and reliability of the transducer. New design reduces the risk of the introduction of conductive contamination. | An internal vacuum case is used for zero pressure reference point. | New design eliminates internal vacuum case and reduces potential for conductive contamination. USE AS IS rationale: Functionality of zero pressure reference is maintained. | RES7001-202, 222 RE2233-001 |

**SSME EA/CIL
WELD JOINTS**

Component Group: Igniters and Sensors
 GIL Item: J228
 Component: HPOTP Secondary Seal Cavity Pressure Transducer (D35.2)
 Part Number: RE2233/RES7001

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| Component | Basic Part Number | Weld Number | Weld Type | Class | Root Side Not Access | Critical Initial Flaw Size Not Detectable | | Comments |
|---------------------|-------------------|-------------|-----------|-------|----------------------------|---|-----|----------|
| | | | | | | HCF | LCF | |
| PRESSURE TRANSDUCER | RE2233/RES7001 | | | | | | | |
| PRESSURE TRANSDUCER | JKR1900 | CCC-1 | EBW | II | X | | | |
| PRESSURE TRANSDUCER | JLD1900 | CCC-2 | EBW | II | X | X | X | |
| PRESSURE TRANSDUCER | JVA1900 | CCC-5 | FRW | II | X | | | |

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