# SSME FMEA/CIL
# REDUNDANCY SCREEN

| | | | |
|---|---|---|---|
| Component Group: | Fuel Turbopumps | Prepared: | F. Cromwell |
| CIL Item: | B600-04 | Approved: | T. Nguyen |
| Part Number: | RS007601 | Approval Date: | 11/1/99 |
| Component: | Low Pressure Fuel Turbopump | Change #: | 1 |
| FMEA Item: | B600 | Directive #: | CCBD ME3-01-5249 |
| Failure Mode: | Loss of head rise. | Page: | 1 of 1 |

| Phase | Failure / Effect Description | Criticality Hazard Reference |
|---|---|---|
| S<br>4.1 | Reduced LPFTP pump output results in reduced pressure and flow delivered to the HPFTP. The controller senses the increased HPFTP demand and increases the fuel preburner oxidizer flow. In the event of HPFTP cavitation, excessive turbine discharge temperatures may result in a premature engine shutdown. Mission scrub if detected by redline. Loss of vehicle due to HPFTP turbine failure may result if not detected.<br><br>Redundancy Screens: TURBOPUMP SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY<br><br>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround.<br>B: Pass - Loss of a redundant hardware items is detectable during flight.<br>C: Pass - Loss of redundant hardware items could not result from a single credible event. | 1R<br>ME-01S,M |
| M<br>4.1 | Reduced LPFTP pump output results in reduced pressure and flow delivered to the HPFTP. The controller senses the increased HPFTP demand and increases the fuel preburner oxidizer flow. In the event of HPFTP cavitation, excessive turbine discharge temperatures may result in a premature engine shutdown. Mission abort if detected by redline. Loss of vehicle due to HPFTP turbine failure may result if not detected.<br><br>Redundancy Screens: TURBOPUMP SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY<br><br>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround.<br>B: Pass - Loss of a redundant hardware items is detectable during flight.<br>C: Pass - Loss of redundant hardware items could not result from a single credible event. | 1R<br>ME-01S,M |

# SSME FMEA/CIL
# DESIGN

| | | | |
|---|---|---|---|
| Component Group: | Fuel Turbopumps | Prepared: | F. Cromwell |
| CIL Item: | B600-04 | Approved: | T. Nguyen |
| Part Number: | RS007601 | Approval Date: | 11/1/99 |
| Component: | Low Pressure Fuel Turbopump | Change #: | 1 |
| FMEA Item: | B600 | Directive #: | CCBD ME3-01-5248 |
| Failure Mode: | Loss of head rise. | Page: | 1 of 1 |

Design / Document Reference

FAILURE CAUSE: A: Fracture, distortion of inducer vane.

THE PUMP INDUCER (1) INCORPORATES FOUR FULL VANES AND FOUR LONG PARTIAL VANES WHICH ARE HYDRODYNAMICALLY SHAPED TO PROVIDE THE REQUIRED HEAD RISE TO THE HPFTP PUMP INLET AND MEET THE ICD MINIMUM NET POSITIVE SUCTION PRESSURE (NPSP) REQUIREMENTS. THE INDUCER WAS DESIGNED TO MAINTAIN A CONTROLLED OPERATING CLEARANCE WITH THE PUMP HOUSING (2) TO MAXIMIZE PUMP EFFICIENCY. THE INDUCER IS MATED TO THE SHAFT (3) BY INVOLUTE SPLINES. A RETAINING NUT (4) IS INSTALLED AND LOCKED (5) TO SECURE THE INDUCER. THE INDUCER HUB PROVIDES JOURNALS FOR THE TURBINE-END (6) AND PUMP-END BEARINGS (7). FOUR HOLES LOCATED IN THE INDUCER HUB NEAR THE VANE LEADING EDGES ALLOW THE BEARING COOLANT TO RETURN TO THE MAIN FLOW STREAM. THE INDUCER VANE FILLETS ARE RADIUSED TO REDUCE STRESS RISERS. THE INDUCER IS MANUFACTURED UTILIZING FORGED 5AL-2 5SN (ELI) TITANIUM ALLOY (8). THIS MATERIAL WAS SELECTED FOR ITS TOUGHNESS AND MECHANICAL AND FATIGUE PROPERTIES AT CRYOGENIC TEMPERATURES. THIS ALLOY IS NOT SUSCEPTIBLE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AT OPERATING TEMPERATURES. THE MATERIAL IS ANNEALED TO IMPROVE PROPERTIES. THE ROTATING ASSEMBLY HAS BEEN DESIGN VERIFICATION TESTED FOR VIBRATION CHARACTERISTICS (9). THE INDUCER HAS BEEN DESIGN VERIFICATION TESTED FOR VIBRATION CHARACTERISTICS (10).

(1) RS007604; (2) RS007632 R0019864; (3) RS007628; (4) RS007619; (5) RS007620; (6) RS007606; (7) RS007605; (8) RSS-8577; (9) RSS-402; (10) RSS-402

FAILURE CAUSE: B: Fracture, distortion of diffuser vane.

THE HOUSING VOLUTE (1) HAS 13 DIFFUSER VANES TO GUIDE THE FLOW FROM THE INDUCER TUNNEL INTO THE VOLUTE. THE DIFFUSER VANE FILLETS ARE RADIUSED TO REDUCE STRESS RISERS. THE PUMP VOLUTE IS MANUFACTURED UTILIZING CAST TENS-50 ALUMINUM (2), WHICH WAS SELECTED FOR ITS MECHANICAL PROPERTIES AT CRYOGENIC TEMPERATURES, AND RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT. THE CASTING IS HOT ISOSTATICALLY PRESSED TO IMPROVE MECHANICAL PROPERTIES. THE MATERIAL IS ALSO SOLUTION TREATED AND AGE HARDENED. THE VOLUTE IS ANODIZED FOR CORROSION PROTECTION. THE VOLUTE IS PROOF PRESSURE TESTED TO VERIFY ITS STRUCTURAL INTEGRITY (3). THE FACTOR OF SAFETY ON BURST AND LOW CYCLE FATIGUE LIFE HAS BEEN DEMONSTRATED BY DESIGN VERIFICATION TESTING (4).

(1) R0019854; (2) RSS-8577, (3) RL00408; (4) RSS-402

FAILURE CAUSE: ALL CAUSES

THE HIGH AND LOW CYCLE FATIGUE LIFE FOR THE INDUCER AND VOLUTE HOUSING MEET CEI REQUIREMENTS (1). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (2). THE LPFTP INDUCER AND VOLUTE HOUSING PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY CRITICAL INITIAL FLAW SIZE DETECTABILITY (3). THE CONTROLLER SOFTWARE IS CONFIGURED TO DETECT AND RESPOND PROPERLY TO THE FAILURES IDENTIFIED AND COMMAND A SAFE ENGINE STATE (4). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (5).

(1) RL00532 CP320R0003B; (2) RSS-8546, CP320R0003B; (3) NASA TASK 117; (4) CP406R0002 PT 1 3.2.3.5.3; (5) RL00531

# SSME FMEA/CIL
# INSPECTION AND TEST

Component Group: Fuel Turbopumps
CIL Item: B600 04
Part Number: RS007601
Component: Low Pressure Fuel Turbopump
FMEA Item: B600
Failure Mode: Loss of head rise.

Prepared: F. Cromwell
Approved: T. Nguyen
Approval Date: 11/1/99
Change #: 1
Directive #: CCBD ME3-01-5248



| Failure Causes | Significant Characteristics | Inspection(s) / Test(s) | Document Reference |
|---|---|---|---|
| A | INDUCER | | RS007604 |
| | MATERIAL INTEGRITY | MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS. | RB0170-152 |
| | | INDUCER FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS. | RA0115-116<br>RA0115-012 |
| | | INDUCER IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS. | RA0115-116 |
| | ASSEMBLY INTEGRITY | BLADE FILLET RADII, EDGES, AND DEBURRING ARE INSPECTED PER DRAWING REQUIREMENTS. | RS007604 |
| | | BLADE COORDINATES ARE VERIFIED PER DRAWING REQUIREMENTS. | |
| | | THE BLADE EDGES ARE VISUALLY INSPECTED AT TURBOPUMP ASSEMBLY PER SPECIFICATION REQUIREMENTS | RL00353 |
| | | INDUCER BLADE TIP-TO-HOUSING CLEARANCE IS INSPECTED PER DRAWING REQUIREMENTS. | RS007604<br>R0019864<br>RS007532 |
| | LPFTP | | RS007501 |
| | ASSEMBLY INTEGRITY | TORQUE CHECKS ARE PERFORMED EACH FLIGHT FLOW TO VERIFY ASSEMBLY INTEGRITY. | CMRSD V41BS0.010 |
| B | VOLUTE HOUSING ASSEMBLY | | R0019864<br>RS007532 |
| | MATERIAL INTEGRITY | MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS. | RB0170-009 |
| | | CASTING HOT ISOSTATIC PRESS IS VERIFIED PER SPECIFICATION REQUIREMENTS. | RL00372 |
| | | HOUSING IS PROOF PRESSURE TESTED PER SPECIFICATION REQUIREMENTS. | RL00408 |
| | | CASTING IS RADIOGRAPHIC INSPECTED PER SPECIFICATION REQUIREMENTS | RL10003 |
| | | THE PENETRANT AND HIDDEN SURFACE INSPECTIONS ARE PERFORMED ON THE VOLUTE PRIOR TO AND AFTER PROOF PRESSURE TESTING PER DRAWING AND SPECIFICATION REQUIREMENTS | R0019864<br>RA0115-116<br>RL00374 |
| | HEAT TREAT | HEAT TREAT IS VERIFIED PER DRAWING REQUIREMENTS. | R0019864 |
| | SURFACE FINISH | THE CAST SURFACE FINISH IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS. | R0019864<br>RA0115-007 |
| | | VOLUTE ANODIZATION IS VERIFIED PER SPECIFICATION REQUIREMENTS. | RA1609-003 |
| ALL CAUSES | LPFTP | | RS007501 |
| | ASSEMBLY INTEGRITY | THE PUMP SUBASSEMBLIES ARE INSPECTED DURING OVERHAUL PER SPECIFICATION REQUIREMENTS. INSPECTIONS INCLUDE: VISUAL, DIMENSIONAL, PENETRANT, AND REPLACEMENT OF USAGE ITEMS AS APPLICABLE, PER OVERHAUL CLASSIFICATION. | RL00531<br>RA0115-116 |

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|---|---|---|---|
| Component Group: | Fuel Turbopumps | Prepared: | R. Cranwell |
| CIL Item: | B600-04 | Approved: | T. Nguyen |
| Part Number: | RS007601 | Approval Date: | 11/1/99 |
| Component: | Low Pressure Fuel Turbopump | Change #: | 1 |
| FMEA Item: | B600 | Directive #: | CCBD ME3-01-5248 |
| Failure Mode: | Loss of head rise. | Page: | 2 of 2 |

| Failure Causes | Significant Characteristics | Inspection(s) / Test(s) | Document Reference |
|---|---|---|---|
| ALL CAUSES | ASSEMBLY INTEGRITY | OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS | RL00050-04<br>RL00050-06<br>RL00050-07<br>RL00461 |
| | | DATA FROM PREVIOUS FLIGHT OR HOT-FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE. (LAST TEST) | MSFC PLN 1228 |

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.

Component Group: Fuel Turbopumps
CIL Item: B600
Part Number: RS007601
Component: Low Pressure Fuel Turbopump
FMEA Item: B600

Prepared: P. Cromwell
Approved: T. Nguyen
Approval Date: 11/1/99
Change #: 2
Directive #: CCBD ME3-01-5248
Page: 1 of 1

| Component | Basic Part Number | Weld Number | Weld Type | Class | Root Side Not Access | Critical Initial Flaw Size Not Detectable HCF | Critical Initial Flaw Size Not Detectable LCF | Comments |
|---|---|---|---|---|---|---|---|---|
| MANIFOLD | RS007603 | 1 | EBW | Ia | X | | | |
| MANIFOLD | RS007603 | 2 | GTAW | I | | | | |
| MANIFOLD | RS007603 | 5,8,10 | GTAW | II | X | X | | |
| MANIFOLD | RS007603 | 9,10 | GTAW | II | X | | | |
| MANIFOLD | RS007603 | 13 | GTAW | I | | | | |
| MANIFOLD | RS007603 | 17 | EBW | II | X | X | X | |
| MANIFOLD | RS007603 | 18 | GTAW | I | X | X | X | |

# SSME FMEA/CIL

## FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

Component Group: Fuel Turbopumps
Item Name: Low Pressure Fuel Turbopump
Item Number: B600
Part Number: RS007601

Prepared: F. Cromwell
Approved: T. Nguyen
Approval Date: 11/1/99
Change #: 3
Directive #: CCBD ME3-01-5248



| Base Line Rationale | Variance | Change Rationale | Variant Dash Number |
|---|---|---|---|
| 1. B600-05: RS007605, RS007606; CAUSE A. THE INNER AND OUTER BEARING RINGS ARE EDDY CURRENT INSPECTED PER RA1615-034. | BEARING RINGS RECEIVED FROM SUPPLIER SPLIT BALL BEARING INCORPORATED RECEIVED NO GENERAL EDDY CURRENT INSPECTION. | GENERAL EDDY CURRENT INSPECTION OF RINGS REPLACES TYPE IVC IN PENETRANT INSPECTION IN DETECTING SURFACE FLAWS. USE AS IS RATIONALE: 1 RINGS ARE SUPPLIED BY SPLIT BALL BEARING INCORPORATED RECEIVED 10X VISUAL AND TYPE IVC PENETRANT INSPECTION INSTEAD OF GENERAL EDDY CURRENT INSPECTION. FLAW DETECTABILITY RELIABILITY LEVELS BETWEEN PENETRANT AND GENERAL EDDY CURRENT INSPECTIONS ARE 0.060 AND 0.057 RESPECTIVELY | SEE DAR 2745 FOR VARIANT PART SERIAL NUMBERS |
| 2 B600-10. THE HOUSING INSULATION IS PROTECTED BY A KEVLAR COMPOSITE SURFACE WITH L-T-90 FIRE RETARDANT ALUMINUM TAPE APPLIED TO THE KEVLAR SURFACE | CERTAIN FLIGHT HOUSINGS HAVE NICKEL PLATED INSULATION WITH COPPER PLATED TIE-IN AREAS. | THE BLOCK I AND PHASE II HAVE NICKEL PLATING TO PROTECT THE INSULATION FROM MECHANICAL DAMAGE AND PROVIDE A MOISTURE BARRIER. THE HOUSING IS COPPER PLATED AT THE INSULATION CLOSE-OUT AREAS TO IMPROVE THE NICKEL BOND. THE MINIMUM FACTORS OF SAFETY FOR THE INSULATED HOUSING MEET C.E.I. REQUIREMENTS. DAR 2068 ADDRESSES THE TIME CONSTRAINTS FOR NICKEL PLATED INSULATION WITH COPPER PLATED TIE-IN CONFIGURATIONS. | RS007632 121, -131, -231, -21* |
| 3. B600-05 THE BALLS ARE POSITIONED BY AN FEP COATED ARMALON CAGE. FEP COATING ON CAGES USED TO REDUCE POCKET AND BALL WEAR THUS INCREASING BEARING LIFE. | BLOCK I AND PHASE II PUMPS DO NOT HAVE FEP COATED CAGES. | BLOCK I AND PHASE II CAGES HAVE TEFLON CONTAINED IN THE FIBERGLASS CAGE THAT PROVIDES BEARING LUBRICATION. | RS007605-027 RS007606-007, -025 |
| 4. B600-01. BLOCK II NOZZLE ASSEMBLY ALLOWS A MINIMUM OF 12 OF THE 43 NOZZLE PASSAGES TO BE BLOCKED. | BLOCK I PHASE II NOZZLE ASSEMBLY ALLOWS A MINIMUM OF 16 OF THE 43 NOZZLE PASSAGES TO BE BLOCKED | THE BLOCK I PHASE II NOZZLE ASSEMBLY DOES NOT VIOLATE THE REQUIREMENTS OF THE BLOCK II NOZZLE ASSEMBLY. BLOCK I PHASE II NOZZLE MEETS CEI NOZZLE VANE REQUIREMENTS. | R0019780-091 |
| 5 B600-02. CAUSE B,C THE SECOND STAGE ROTOR BRAZE JOINT INTEGRITY IS ULTRASONIC INSPECTED PER DRAWING REQUIREMENTS. | CERTAIN SECOND STAGE ROTORS RECEIVED NO ULTRASONIC INSPECTION OF THE BRAZE JOINT. | THE BRAZE JOINTS OF ALL SECOND STAGE ROTORS HAVE RECEIVED A VISUAL AND PENETRANT INSPECTION. ALL PARTS SUSPECTED TO HAVE BRAZE JOINT ANOMALIES HAVE BEEN ADDRESSED. | RS007625-031 |
| 6. B600-02. CAUSE D NOZZLE COPPER PLATING ADHESION IS VERIFIED PER DRAWING REQUIREMENTS. | CERTAIN NOZZLES DID NOT RECEIVE A BAKE TEST. | ADHESION BAKE TEST IS NOT REQUIRED FOR NOZZLES WHICH HAVE BEEN PREVIOUSLY HOT FIRE TESTED. THE HOT FIRE ENVIRONMENT ADEQUATELY VERIFIES THE COPPER PLATING ADHESION INTEGRITY. | RS007622-025 R0019783-023 |
| 7. B600-02. CAUSE E. THE STATOR COPPER PLATING ADHESION IS VERIFIED PER DRAWING REQUIREMENTS | CERTAIN STATORS DID NOT RECEIVE A BAKE TEST. | ADHESION BAKE TEST IS NOT REQUIRED FOR STATORS WHICH HAVE BEEN PREVIOUSLY HOT FIRE TESTED. THE HOT FIRE ENVIRONMENT ADEQUATELY VERIFIES THE COPPER PLATING ADHESION INTEGRITY | RS007623-031 |