

**SSME FTA/CIL  
REDUNDANCY / SCREEN**

Component Group: Fuel Turbopumps  
 CIL Item: B600-08  
 Part Number: RS007601  
 Component: Low Pressure Fuel Turbopump  
 FMEA Item: B600  
 Failure Mode: Turbine seal leakage.

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

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| Phase    | Failure / Effect Description   | Criticality<br>Hazard Reference |
|----------|--|---------------------------------|
| S<br>4.1 | Excessive leakage of warm hydrogen gas into LPFTP discharge decreases the density of the fluid at the HPFTP inlet. In event of HPFTP cavitation, excessive turbine discharge temperature results in a redline 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. | IR<br>ME-DIS,M                  |
| M<br>4.1 | Excessive leakage of warm hydrogen gas into LPFTP discharge decreases the density of the fluid at the HPFTP inlet. In event of HPFTP cavitation, excessive turbine discharge temperature results in a redline 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.  | IR<br>ME-DIS,M                  |

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**SSME FMEA/CIL  
DESIGN**

Component Group: Fuel Turbopumps  
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Design / Document Reference

FAILURE CAUSE: A: Excessive wear or failure of carbon insert.

THE TURBINE SEAL ASSEMBLY (1) UTILIZES A CARBON RING (2), ASSEMBLED IN AN ADAPTER, WHICH IS AXIALLY PRELOADED IN THE HOUSING BY A WAVE SPRING AND PLATE. THE PLATE IS SECURED TO THE HOUSING UTILIZING 8 SCREWS, WHICH ARE STAKED TO PREVENT ROTATION. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (3). THE TURBINE SEAL IS DESIGNED TO MINIMIZE THE LEAKAGE OF TURBINE GAS INTO THE PUMP DISCHARGE. THE CARBON RING IS ALLOWED TO FLOAT RADIALLY IN THE HOUSING TO ACCOMMODATE SHAFT (4) RADIAL MOVEMENT DURING OPERATION. THE CARBON RING INSIDE DIAMETER IS TAPERED TO ALLOW HYDRODYNAMIC CENTERING DURING OPERATION. THE HOUSING AXIAL SURFACE WHICH CONTACTS THE CARBON RING IS DRY-FILM LUBRICATED TO REDUCE WEAR. THE SEAL RING IS MANUFACTURED UTILIZING PRESSURE MOLDED CARBON GRADE P-5N (5) WHICH WAS SELECTED FOR ITS RESISTANCE TO WEAR IN LIQUID HYDROGEN SERVICE. THE SEAL RING ADAPTER, HOUSING AND PLATE ARE MANUFACTURED UTILIZING FORGED A-286 CRES (6), WHICH WAS SELECTED FOR ITS MECHANICAL PROPERTIES AND ITS RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE WAVE SPRING IS MANUFACTURED UTILIZING 301 CRES (5) WHICH WAS SELECTED FOR ITS STRENGTH, DUCTILITY AT CRYOGENIC TEMPERATURES, AND ITS INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT. THE HIGH AND LOW CYCLE FATIGUE LIFE OF THESE PARTS MEET CEI REQUIREMENTS (6). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (7). THE TURBINE SEAL ASSEMBLY PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NOE FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS (8). THE CONTROLLER SOFTWARE IS CONFIGURED TO DETECT AND RESPOND PROPERLY TO THE FAILURES IDENTIFIED AND COMMAND A SAFE ENGINE STATE (9). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (10).

(1) R0019504; (2) R0019278; (3) RL00353; (4) RS007628; (5) RSS-8577; (6) RL00532, CP320R0003B; (7) RSS 8546, CP320R0003B; (8) NASA TASK 117; (9) CP406R0002 PFT 1 3 2 3 5 3; (10) RL00531

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**SSME FMECA OIL  
INSPECTION AND TEST**

Component Group: Fuel Turbopumps  
 CIL Item: B600-08  
 Part Number: RS007601  
 Component: Low Pressure Fuel Turbopump  
 FMEA Item: B600  
 Failure Mode: Turbine seal leakage.

Prepared: F. Cromwell  
 Approved: T. Nguyen  
 Approval Date: 11/1/99  
 Change #: 1  
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| Failure Causes | Signifcant Characteristics | Inspection(s) / Test(s)  | Document Reference   |
|----------------|----------------------------|--|--|
| A              | SHAFT<br>SEAL ASSEMBLY     |  | RS007620<br>RC019804                                       |
|                | MATERIAL INTEGRITY         | MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.   | RS007620<br>RB0130-115<br>R0019278<br>R0019804<br>AMS 5737 |
|                |                            | SEAL HOUSING AND ADAPTER ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS  | RA0116-116   |
|                |                            | THE SHAFT IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENT.  |  |
|                | HEAT TREAT                 | THE SHAFT, SEAL HOUSING, AND SEAL ADAPTER HEAT TREAT ARE VERIFIED PER DRAWING REQUIREMENTS.  | RS007620<br>RC019804<br>R0019278                           |
|                | CLEANLINESS OF COMPONENTS  | THE SEAL ASSEMBLY IS VERIFIED CLEANED (TO FUEL SERVICE) PER SPECIFICATION REQUIREMENTS.  | RL10001  |
|                | SURFACE FINISH             | THE SEAL HOUSING CARBON MATING SURFACE DRY FILM LUBRICATION IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.  | RC019304<br>RA0112-000                                     |
|                |                            | CARBON INSERT FLATNESS IS VERIFIED PER DRAWING REQUIREMENTS.   | R0019278   |
|                |                            | CARBON INSERT FIT IS VERIFIED PER DRAWING REQUIREMENTS.  |  |
|                | ASSEMBLY INTEGRITY         | THE CARBON SEAL RING-TO-SHAFT CLEARANCE IS INSPECTED PER DRAWING REQUIREMENTS.   | R0019278<br>RS007628                                       |
|                |                            | THE ROTATING DETAIL BALANCE IS VERIFIED PER SPECIFICATION REQUIREMENTS.  | RL00946  |
|                | LPFTP                      |  | RS007601   |
|                | 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>RA0115-115                                      |
|                |                            | OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS.   | RL00050-04<br>RL00055-06<br>RI 00056-07<br>RL00481         |
|                |                            | DATA FROM PREVIOUS FLIGHT OR HOT-FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE. (LAST TEST)  | MSFC PLN 1225  |

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Component Group: Fuel Turbopumps  
CIL Item: B600-08  
Part Number: RS007601  
Component: Low Pressure Fuel Turbopump  
FMEA Item: B600  
Failure Mode: Turbine seal leakage

Prepared: F. Croftwell  
Approved: T. Nguyen  
Approval Date: 11/1/99  
Change #: 1  
Directive #: CCBD ME3-01-5249

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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)<br>Reference: NASA letter SA21/38/308 and Rocketdyne letter 95RC09761. |                         |                    |
| Operational Use: | Not Applicable  |                         |                    |

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**WELDED JOINTS**

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

Prepared: F. Cromwell  
 Approved: T. Nguyen  
 Approval Date: 11/1/99  
 Change #: 2  
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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 |          |
| 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   |          |

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**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

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| Base Line Rationale  | Variance  | Change Rationale  | Variant Dash Number                          |
|--|---|---|--|
| 1. B600-06. RS007606, RS007605; 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:<br>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-80 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.       | RS007632-171, -181, -201, -211               |
| 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<br>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.   | R0019793-091                                 |
| 6. 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<br>R0019793-023                 |
| 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                                 |

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