# SSME FMEA/CIL
# REDUNDANCY SCREEN

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|---|---|---|---|
| Component Group: | Fuel Turbopumps | Prepared: | D. Early |
| CIL Item: | B200-17 | Approved: | T. Nguyen |
| Component: | High Pressure Fuel Turbopump | Approval Date: | 4/21/99 |
| Part Number: | RS007501 | Change #: | 1 |
| Failure Mode: | Loss of coolant flow to turbine discs. | Directive #: | CCBD ME3-01-5206 |
| | | Page: | 1 of 1 |

| Phase | Failure / Effect Description | Criticality Hazard Reference |
|---|---|---|
| SMC 4.1 | Loss of coolant to one side of disc can allow disc deflection and platform seal rubbing. Excessive coolant loss can allow turbine first-stage or second-stage disc to overheat and burst. Loss of vehicle.<br><br>Redundancy Screens: SINGLE POINT FAILURE: N/A | 1 ME-D1S,M. ME-D1A,C |

# SSME FMEA/CIL
# DESIGN

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|---|---|
| Component Group: | Fuel Turbopumps |
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| Page: | 1 of 3 |

Design / Document Reference

FAILURE CAUSE: A: Lift-off seal binding/ closure.

THE LIFT-OFF SEAL (1) IS A SPRING LOADED, PRESSURE ACTIVATED FACE RIDING, CARBON NOSED SEAL. THE SEAL HOUSING AND PISTON RING ARE MANUFACTURED UTILIZING A-286 CRES BAR (2). A-286 CRES WAS SELECTED FOR ITS COMPRESSIVE STRENGTH, RESISTANCE TO HIGH PRESSURE HYDROGEN DEGRADATION, AND CRYOGENIC MECHANICAL PROPERTIES. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE SEAL PREVENTS HYDROGEN LEAKAGE INTO THE TURBINE DURING PRESTART AND PROPELLANT DUMP. THE TURBOPUMP IS ASSEMBLED WITH A PRELOAD ON THE SEAL NOSE WHICH MATES WITH THE OUTSIDE DIAMETER LIP OF THE THIRD-STAGE SLEEVE (3). THE SEAL NOSE IS MANUFACTURED UTILIZING P5N CARBON, WHICH WAS SELECTED FOR ITS SURFACE VELOCITY WEAR CHARACTERISTICS (2). THE PISTON RING IS DESIGNED TO PROVIDE AN INTERFERENCE FIT WITH THE OUTSIDE DIAMETER OF THE CARBON RING. HT424 EPOXY RESIN IS UTILIZED TO BOND THE CARBON RING IN THE PISTON. THE MATING LIP OF THE THIRD-STAGE SLEEVE IS HARD CHROME PLATED AND POLISHED TO PROVIDE A SMOOTH AND WEAR RESISTANT SEALING SURFACE. BOTH THE SLEEVE MATING SURFACE AND THE LIFT-OFF SEAL NOSE ARE REQUIRED TO BE FLAT WITHIN 3 HELIUM LIGHTBANDS. THE SEAL PRELOAD IS SUPPLIED BY 55 MAIN SPRINGS MANUFACTURED UTILIZING 302 CRES WIRE (2). THIS MATERIAL WAS SELECTED FOR ITS MODULUS OF ELASTICITY AND DUCTILITY AT CRYOGENIC TEMPERATURES, AND ITS PROPERTIES ARE NOT DEGRADED IN A HYDROGEN ENVIRONMENT (2).

DURING START, A PRESSURE UNBALANCE DEVELOPS ACROSS THE SEAL TO OFFSET THE SPRING LOAD AND RETRACT THE SEAL ALLOWING HYDROGEN COOLANT TO ENTER THE TURBINE. THE SEAL REMAINS OPEN UNTIL THE PRESSURE DECAYS DURING ENGINE SHUTDOWN. THE SEAL RETRACTION IS ACCOMMODATED BY AN INTERNAL CAVITY, WHICH IS VENTED TO AMBIENT PRESSURE THROUGH AN EXTERNAL DRAIN LINE. THE CAVITY DRAIN LINE IS ELECRO-DISCHARGE MACHINED THROUGH THE SEAL HOUSING, ELIMINATING THE NEED FOR PLUG WELDS, AND MATES WITH A PASSAGE AT THE MAIN HOUSING (4) INTERFACE. THE SEAL AT THIS LOCATION IS PROVIDED BY A PRESSURE-ASSISTED "DOUGHNUT" STATIC SEAL (5), WHICH SEATS IN A GROOVE ON THE SEAL HOUSING FLANGE. THE SEAL IS MANUFACTURED UTILIZING SILVER-PLATED A-286 CRES BAR (2). A-286 CRES WAS SELECTED FOR ITS COMPRESSIVE STRENGTH, RESISTANCE TO HIGH-PRESSURE HYDROGEN DEGRADATION, AND ITS MECHANICAL PROPERTIES AT CRYOGENIC TEMPERATURES. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE SILVER PLATING PERMITS CONFORMANCE OF THE SEAL TO MINOR IRREGULARITIES IN THE MATING SURFACES. A WIRE RETAINER (6) MANUFACTURED UTILIZING 302 CRES, HOLDS THE "DOUGHNUT" SEAL IN THE RECESS OF THE LIFT-OFF SEAL, TO PREVENT DISLODGEMENT DURING HANDLING AND INSTALLATION. THE BOLT PATTERN OF THE LIFT-OFF SEAL AND MAIN HOUSING ARE NON-SYMMETRICAL TO ASSURE PROPER ALIGNMENT OF THE DRAIN LINE PASSAGES. DESIGN ANALYSIS SHOWS THAT WITH THE WORST COMBINATION OF TOLERANCES, ADEQUATE SEAL COMPRESSION WOULD BE MAINTAINED OVER THE FULL RANGE OF POSSIBLE DEFLECTIONS. DRAIN LINE PRESSURE AND TEMPERATURE ARE MONITORED ON ALL GREEN RUNS WHICH WOULD INDICATE ANY HOT-GAS LEAKAGE PAST THIS SEAL. THE STATIC SEAL IS A NON-SERIALIZED PART WHICH IS NOT TIME HISTORY TRACKED, BUT HAS INFINITE ALLOWABLE LIFE (7)

THE INTERNAL CAVITY IS FORMED BY STEPPED DIAMETERS ON THE SEAL PISTON AND MATING DIAMETERS ON THE SEAL HOUSING. THE TWO SPRING-LOADED INTERNAL SEALS PROVIDE SEALING BETWEEN THE HIGH-PRESSURE HYDROGEN AND THE CAVITY DURING OPERATION. THE SEALS ARE MANUFACTURED UTILIZING VESPEL SP-211, WHICH WAS SELECTED FOR ITS SEALING AND LUBRICATING CHARACTERISTICS (2). THE SEALS ARE BOTTOMED AGAINST THE HOUSING UTILIZING WEDGE RINGS MANUFACTURED UTILIZING 303 CRES BAR. THE WEDGE RING PRELOAD IS SUPPLIED BY 36 SPRINGS MANUFACTURED UTILIZING 302 CRES WIRE. THE PUMP-END SPRINGS ARE BOTTOMED AGAINST A 302 CRES PLATE, WHICH IS SECURED BY A MATING GROOVE IN THE HOUSING. THE TURBINE-END SEAL SPRINGS ARE BOTTOMED AGAINST A-286 CRES PLATE, WHICH IS SECURED TO THE HOUSING UTILIZING TWELVE 300 SERIES CRES SCREWS. A-286 AND THE 300 SERIES CRES ALLOYS WERE SELECTED FOR THE SAME CHARACTERISTICS DISCUSSED ABOVE. THE SCREWS ARE STAKED AT THE SEAL ASSEMBLY TO PREVENT ROTATION. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (8). MOVEMENT OF THE SEAL PISTON IS GUIDED BY A BUSHING WHICH PILOTS IN A GROOVE IN THE SEAL HOUSING. THE BUSHING IS MANUFACTURED UTILIZING VESPEL SP-211 WHICH WAS SELECTED FOR ITS LUBRICATING CHARACTERISTICS (2). THE PISTON DIAMETERS WHICH MATE WITH THE VESPEL SEALS AND THE BUSHING ARE CHROME PLATED TO PROVIDE A SMOOTH SLIDING SURFACE. THE CAVITY DRAIN LINE IS SIZED TO ACCOMMODATE THE PREDICTED LEAKAGE WHICH WOULD RESULT FROM ONE SECONDARY SEAL MISSING.

THE LIFT-OFF SEAL HOUSING IS SECURED TO THE MAIN HOUSING BY 12 BOLTS (9) AND CUPWASHERS (10), WHICH ALSO ATTACH THE TURBINE HUB LABYRINTH SEAL (11) AND THE SECOND-STAGE AFT PLATFORM SEAL (12). THE LIFT-OFF SEAL HOUSING OUTSIDE DIAMETER AND MAIN HOUSING INSIDE DIAMETER ARE CLOSELY TOLERANCED TO ASSURE ACCURATE PILOTING OF THE SEAL STACK AND MINIMIZE THE EFFECT OF HOUSING DEFLECTIONS ON THE SEAL INTERNAL CLEARANCES. GROOVES IN THE MAIN HOUSING AND TURBINE HUB LABYRINTH SEAL PILOT THE STATIC SEALS (13) AT THESE LOCATIONS. ANALYSIS REVEALS THAT THE LIFT-OFF SEAL DESIGN ALONG WITH OPERATING CLEARANCES PRECLUDES A COMPLETE LIFT-OFF SEAL CLOSURE (14).

THE LIFT-OFF SEAL FUNCTIONAL OPERATION WAS DEMONSTRATED BY DESIGN VERIFICATION TESTS (15).

Design / Document Reference

(1) R0019230; (2) RSS-8580-10; (3) RS007501, RS007584; (4) RS007577, RS007568; (5) RES1116; (6) R0019234 (7) RL00532, CP320R0003B; (8) RL00351; (9) RS007595; (10) RS007523; (11) RS007553; (12) RS007593; (13) RD261-3015, RE1621; (14) IL SSME-0806; (15) RSS-404-11

FAILURE CAUSE: B: Coolant flow passage blockage.

HYDROGEN COOLANT IS SUPPLIED TO THE TURBINE BY FLOW PAST THE LOW-PRESSURE ORIFICE RING (1) OF THE BALANCE PISTON CAVITY AND PAST THE LIFT-OFF SEAL (2). A PORTION OF THE COOLANT ENTERS 8 HOLES ON THE HUB OF THE SECOND-STAGE TURBINE DISK (3) JUST UPSTREAM OF THE HUB LABYRINTH SEAL (4). THE FLOW CONTINUES DOWN THE CENTRAL CAVITY OF THE SECOND-STAGE DISK. A PORTION OF THIS COOLANT FLOWS THROUGH THE 16 HOLES IN THE ORIFICE RING (5) BETWEEN THE TURBINE DISKS. THIS FLOW IS SPLIT AND GUIDED BY THE TURBINE INTERSTAGE SEAL (6) TO COOL THE DOWNSTREAM SIDE OF THE FIRST-STAGE DISK (7) AND THE UPSTREAM SIDE OF THE SECOND-STAGE DISK. THE REMAINDER OF THE FLOW CONTINUES THROUGH THE FIRST-STAGE DISK AND COOLS THE TURBINE END BEARINGS (8). THIS FLOW IS THEN SPLIT AND GUIDED BY THE TURBINE BEARING SEAL (9), TO COOL THE UPSTREAM SIDE OF THE FIRST-STAGE DISK AND THE TURBINE BEARING SUPPORT (10). THE FLOW ENTERS THE BEARING SUPPORT BODY THROUGH 4 HOLES AND THEN ENTERS AN INTERNAL SHEET METAL MANIFOLD THROUGH 13 HOLES. THE COOLANT THEN IS DISTRIBUTED TO 3 HOLES IN EACH OF THE INLET STRUTS AND IS COLLECTED IN A MANIFOLD AND DISCHARGED THROUGH 13 ORIFICES TO COOL THE BELLOWS (11).

THE REMAINDER OF THE FLOW FROM THE LIFT-OFF SEAL FLOWS THROUGH THE LABYRINTH STEPS OF THE TURBINE HUB LABYRINTH SEAL. PART OF THIS FLOW IS DIVERTED THROUGH 4 HOLES IN THE SEAL DOWNSTREAM OF THE FIRST STEP. THE FLOW IS COLLECTED IN A MANIFOLD AT THE LIFT-OFF SEAL HUB LABYRINTH SEAL INTERFACE BEFORE CONTINUING THROUGH 12 HOLES IN THE LIFT-OFF SEAL AND MAIN HOUSING (12) TO ENTER THE COOLANT LINER. THE COOLANT CONTINUES THROUGH 3 HOLES IN EACH OF THE MAIN HOUSING STRUTS AND ENTERS A MANIFOLD AT THE DOWNSTREAM END OF THE TURBINE INNER RING. NINETY-SIX COOLANT PASSAGES IN THE INNER RING CARRY THE FLOW TO A MANIFOLD AT THE TURBINE MOUNT RING (13) INTERFACE. NINETY-SIX COOLANT PASSAGES IN THE MOUNT RING AND THE TURBINE BEARING SUPPORT GUIDE THE FLOW TO A MANIFOLD, WHERE IT DISCHARGES OUT 12 ORIFICES AND JOINS THE TURBINE BEARING SUPPORT COOLANT FLOW TO COOL THE BELLOWS. THE COMBINED COOLANT FLOW THEN CONTINUES OUT A GAP AT THE PREBURNER AND TURBINE BELLOWS SHIELD (14) INTERFACE WHERE IT ENTERS THE TURBINE EXHAUST.

THE REMAINDER OF THE COOLANT FLOW THROUGH THE TURBINE HUB LABYRINTH SEAL IS UTILIZED TO COOL THE DOWNSTREAM SIDE OF THE SECOND-STAGE DISK.

THE NUMBER OF PARALLEL PASSAGES FOR THE COOLANT FLOW, THE SIZE OF THE PASSAGES, AND THE QUANTITY OF THE FLOW MAKES THE TURBINE COOLANT CIRCUIT INSENSITIVE TO MINOR FLOW BLOCKAGE. THE PROPELLANT FILTER AT THE EXTERNAL TANK PRECLUDES CONTAMINANTS LARGE ENOUGH TO BLOCK THE PASSAGES (15). POST FLIGHT/TEST DRYING PURGES PREVENTS BLOCKAGE FROM ICE FORMATION RESULTING FROM THE ACCUMULATION OF MOISTURE BETWEEN HOT-FIRES (16).

(1) RS007559; (2) R0019230; (3) RS007510; (4) RS007553; (5) RS007589; (6) RS007592; (7) RS007517, (8) RS007502; (9) RS007547; (10) RS007524; (11) RS007505; (12) RS007577, RS007568; (13) RS007596; (14) RS007599; (15) ICD 13M15000; (16) RL00050-04, OMRSD V41CB0.050, OMRSD V41CB0.080 (PHASE II), OMRSD V41CB0.081 (PHASE II), OMRSD 41CB0.082 (BLOCK I/IIA), OMRSD V41CB0.083 (BLOCK I/IIA)

FAILURE CAUSE: C: Failure of turbine hub labyrinth seal.

THE TURBINE HUB LABYRINTH SEAL (1) IS MANUFACTURED UTILIZING AN INCONEL 718 FORGING (2). THIS MATERIAL WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING, CRYOGENIC DUCTILITY, AND INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT IN ITS OPERATING ENVIRONMENT. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE SEAL HAS THREE STEPS, WITH EACH HAVING A SERIES OF TEETH. THE STEPS ALIGN WITH A SIMILAR SET OF STEPS ON THE HUB OF THE SECOND-STAGE DISK (3). THE SEAL IS CONFIGURED AT THE INNER DIAMETER TO DISTRIBUTE COOLANT FLOW TO THE TURBINE BEARINGS (4) AND TURBINE DISK/COOLANT LINER CIRCUITS. THE SEAL RESISTANCE DRIVES PART OF THE COOLANT FLOW FROM THE LIFT-OFF SEAL THROUGH 8 HOLES IN THE SECOND-STAGE DISK. THIS FLOW IS USED TO COOL THE TURBINE END BEARINGS AND THE TURBINE DISKS. PART OF THE FLOW PASSING THROUGH THE LABYRINTH STEPS IS DIVERTED THROUGH 4 HOLES IN THE HUB SEAL BETWEEN THE FIRST AND SECOND LABYRINTH STEPS. THE FLOW IS ROUTED INTO THE HOUSING COOLANT LINER CIRCUITS THROUGH CHANNELS IN THE HUB LABYRINTH SEAL AND HOLES IN THE LIFT-OFF SEAL (6) FLANGE AND TURBOPUMP HOUSING (7). THE REMAINDER OF THE FLOW ENTERS THE CAVITY BETWEEN THE SEAL AND DISK. A LIP ON THE END OF THE HUB LABYRINTHS DIRECTS THE COOLANT AT THE HEADS OF THE DISC BOLTS (8) AND ACROSS THE FACE OF THE DISK. THE OUTSIDE DIAMETER OF THE HUB LABYRINTH SEAL PILOTS THE SECOND-STAGE AFT PLATFORM SEAL (9). A GROOVE IN THE HUB LABYRINTH SEAL FLANGE SERVES TO PILOT A STATIC SEAL (10) BETWEEN THE HUB LABYRINTH AND LIFT-OFF SEALS. THE HUB LABYRINTH SEAL IS SECURED TO THE TURBOPUMP THROUGH THE LIFT-OFF SEAL HOUSING BY 12 BOLTS (11) AND CUPWASHERS (12). STRETCH BOLTS ARE UTILIZED TO ASSURE THE REQUIRED CLAMPING LOAD AT ASSEMBLY IS APPLIED.

(1) RS007553; (2) RSS-8580-10; (3) RS007510; (4) RS007502; (5) RS007510, RS007517; (6) R0019230; (7) RS007577, RS007568; (8) RS007580; (9) RS007593; (10) RE1621, (11) RS007595; (12) RS007523

Design / Document Reference

**FAILURE CAUSE: D: Failure of vortex control paddle or its torque pin on end of shaft.**

THE STUD (1) IS MANUFACTURED UTILIZING INCONEL 718 BAR. AN INCONEL 718 BAFFLE (1) IS THREADED TO THE TURBINE END AND LOCKED WITH AN INCONEL 718 PIN (1). INCONEL 718 WAS SELECTED FOR ITS STRENGTH AND DUCTILITY AT CRYOGENIC TEMPERATURES AND ITS RESISTANT TO CORROSION AND STRESS CORROSION CRACKING IN THE CRYOGENIC ENVIRONMENT IT IS INSENSITIVE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT (2). THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE ANTI-VORTEX BAFFLE ASSURES ORDERLY FLOW OF THE COOLANT TO THE TURBINE END BEARINGS AND DISKS.

(1) RS007514, R0019256; (2) RSS-8590-10

**FAILURE CAUSE: E: Failure of interstage seal.**

THE SECOND-STAGE FORWARD PLATFORM SEAL - TURBINE INTERSTAGE SEAL ASSEMBLY (1) IS MANUFACTURED UTILIZING HAYNES 188 FORGINGS (2). THE SEAL MINIMIZES PARASITIC HOT-GAS LEAKAGE THAT COULD DILUTE COOLANT EFFECTIVENESS OR REDUCE TURBINE EFFICIENCY. HAYNES 188 WAS SELECTED FOR ITS TEMPERATURE STRENGTH PROPERTIES, AND RESISTANCE TO DEGRADATION AND OXIDATION IN A HIGH-PRESSURE HYDROGEN RICH STEAM ATMOSPHERE. THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. THE INTERSTAGE SEAL DIRECTS THE COOLANT FROM THE CURVICS CAVITY ACROSS THE DISC FACES. THE SECOND-STAGE COOLANT CIRCUIT HAS A SERIES OF LABYRINTH TEETH TO INCREASE THE RESISTANCE RELATIVE TO THE FIRST-STAGE SIDE. THE INTERSTAGE SEAL IS CONNECTED TO THE SECOND-STAGE FORWARD PLATFORM SEAL THROUGH A-286 CRES RADIAL PINS, WHICH ALLOW FREEDOM OF RELATIVE MOTION DUE TO THE THERMAL ENVIRONMENT. A-286 CRES WAS SELECTED FOR ITS RESISTANCE TO HYDROGEN DEGRADATION AND ITS MECHANICAL PROPERTIES. THE MATERIAL IS SOLUTION-TREATED AND AGE-HARDENED. THE PRESSURE LOAD ACROSS THE INTERSTAGE SEAL IS MINIMIZED BY VENT PASSAGES CONNECTING THE UPSTREAM AND DOWNSTREAM SIDES.

(1) RS007592; (2) RSS 8580-10

**FAILURE CAUSE: ALL CAUSES**

THE HIGH AND LOW CYCLE FATIGUE LIFE FOR THE LIFT-OFF SEAL, TURBINE HUB LABYRINTH SEAL, VORTEX CONTROL PADDLE AND PIN, AND THE TURBINE INTERSTAGE SEAL MEET CEI REQUIREMENTS (1). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (2). THE HARDWARE PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS, EXCEPT FOR THE SECOND-STAGE DISK WHICH WAS CLEARED BY CRITICAL INITIAL FLAW SIZE DETECTABILITY (3). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (4). TABLE B200 LISTS ALL 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. THOSE WELDS IN WHICH THE CRITICAL INITIAL FLAW SIZE IS NOT DETECTABLE ARE ACCEPTABLE FOR FLIGHT BY RISK ASSESSMENT (4). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (5).

(1) RL00532 CP320R0003B; (2) RSS-8546-16, CP320R0003B; (3) NASA TASK 117; (4) RSS-8756; (5) RL00528

# SSME FMEA/CIL
# INSPECTION AND TEST

Component Group: Fuel Turbopumps
CIL Item: B200-17
Component: High Pressure Fuel Turbopump
Part Number: RS007501
Failure Mode: Loss of coolant flow to turbine discs.

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 4/21/99
Change #: 1
Directive #: CCBD ME3-01-5206



| Failure Causes | Significant Characteristics | Inspection(s) / Test(s) | Document Reference |
|---|---|---|---|
| A | LIFT-OFF SEAL ASSEMBLY | | R0019230 |
| | MATERIAL INTEGRITY | MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS. | R0019230<br>RB0130-115<br>RB0130-090 |
| | | EDM RECAST REMOVED PER DRAWING AND SPECIFICATION REQUIREMENTS. | R0019230<br>RA1103-001 |
| | | EPOXY INTEGRITY, CURE, AND BOND THICKNESS ARE VERIFIED PER DRAWING REQUIREMENTS. | R0019230<br>RA1106-005 |
| | SPRING INTEGRITY | SPRING CHARACTERISTICS ARE VERIFIED PER DRAWING REQUIREMENTS | R0019230 |
| | | THE TENSILE STRENGTH IS VERIFIED PER DRAWING REQUIREMENTS. | |
| | | SPRING CLOSED ENDS ARE GROUND SQUARE AND DEBURRED PER DRAWING REQUIREMENTS. | |
| | 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. | RL10011<br>RA0607-054<br>RA0115-116<br>RA0115-006<br>RA1115-001<br>RA0115-127 |
| | SURFACE FINISH | THE SEAL CHROME PLATING IS VERIFIED PER SPECIFICATION REQUIREMENTS. | RA1609-002<br>RL00528 |
| | | SEAL NOSE FLATNESS IS VERIFIED PER DRAWING REQUIREMENTS | R0019230 |
| | CLEANLINESS OF COMPONENTS | COMPONENTS ARE VERIFIED CLEANED TO FUEL SERVICE PER SPECIFICATION REQUIREMENTS. | RL10001 |
| | ASSEMBLY INTEGRITY | THE FOLLOWING ACCEPTANCE TESTS ARE PERFORMED PER DRAWING AND SPECIFICATION REQUIREMENTS<br>- AMBIENT AND CRYOGENIC LOAD DEFLECTION.<br>- NOSE LEAK CHECK.<br>- SECONDARY SEAL LEAK CHECK<br>- SEAL ACTUATION AND RESEAT CHECK. | R0019230<br>RL00505<br>RL00505<br>RL00505 |
| | | ASSEMBLY OF THE LIFT OFF SEAL IS VERIFIED PER SPECIFICATION REQUIREMENTS. | RL00807 |
| | | SCREW STAKING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS. | R0019230<br>RA1618-005 |
| | | LIFT-OFF SEAL ACTUATION IS VERIFIED DURING IN-HOUSING BALANCE PER SPECIFICATION REQUIREMENTS. | RL00352 |
| | HPFTP | | RS007501 |
| | ASSEMBLY INTEGRITY | SEAL IS LEAK CHECKED AT TURBOPUMP ASSEMBLY. | RL00351 |

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| Failure Causes | Significant Characteristics | Inspection(s) / Test(s) | Document Reference |
|---|---|---|---|
| A | ASSEMBLY INTEGRITY | SEAL LEAK CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT. | OMRSD V41BQ0.010<br>OMRSD V41BQ0.020<br>OMRSD V41BQ0.050 |
| | | TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT. | OMRSD V41BS0.020 |
| B | HPFTP | | RS007501 |
| | CLEANLINESS OF COMPONENTS | COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS. | RL10001 |
| | | POST FLIGHT DRYING PURGES ARE PERFORMED PER SPECIFICATION REQUIREMENTS. | OMRSD V41CB0.050<br>OMRSD V41CB0.080 (PHASE II)<br>OMRSD V41CB0.081 (PHASE II)<br>OMRSD V41CB0.082 (BLOCK IIIA)<br>OMRSD V41CB0.083 (BLOCK IIIA) |
| C | SEAL<br>DISK | | RS007553<br>RS007510 |
| | MATERIAL INTEGRITY | MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS | RS007510<br>RB0170-153 |
| | | THE SEAL AND DISK ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS. | RA0115-116 |
| | HEAT TREAT | HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS | RA0611-020<br>RB0170-152 |
| | SURFACE FINISH | THE SEALING SURFACE IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS. | RS007510<br>RF0004-027 |
| | ASSEMBLY INTEGRITY | THE SEAL AND DISK DIAMETERS ARE VERIFIED PER DRAWING REQUIREMENTS. | RS007553<br>RS007510 |
| | | THE ROTATING ASSEMBLY BALANCE IS VERIFIED PER SPECIFICATION REQUIREMENTS. | RL00352 |
| | HPFTP | | RS007501 |
| | ASSEMBLY INTEGRITY | TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT. | OMRSD V41BS0.020 |
| | | TRAVEL CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT. | |
| D | BAFFLE, HP FUEL TURBOPUMP<br>PIN | | R0019256<br>RS007514 |
| | MATERIAL INTEGRITY | MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS. | RS007514<br>RB0170-153 |
| | | THE BAFFLE IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS. | RA0115-116 |

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|---|---|---|---|
| D | HEAT TREAT | HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS. | RA0611-020 |
| | ASSEMBLY INTEGRITY | BAFFLE TORQUE IS VERIFIED PER DRAWING REQUIREMENTS. | RS007514 |
| | | PIN STAKING IS VERIFIED PER DRAWING REQUIREMENTS. | |
| E | SEAL, INTERSTAGE HPFTP DISK | | RS007592<br>RS007510 |
| | MATERIAL INTEGRITY | MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS. | |
| | | FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS. | RA0115-116<br>RA0115-012 |
| | 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 | RL10011<br>RA0807-094<br>RA0115-116<br>RA0115-006<br>RA1115-001<br>RA0115-127 |
| | ASSEMBLY INTEGRITY | THE SEAL CLEARANCE WITH THE DISK AND BLADES IS VERIFIED AT ASSEMBLY PER SPECIFICATION REQUIREMENTS. | RL00351 |
| | | SEAL DIAMETERS ARE VERIFIED PER DRAWING REQUIREMENTS. | RS007592 |
| | | THE ROTATING ASSEMBLY BALANCE IS VERIFIED PER SPECIFICATION REQUIREMENTS. | RL00352 |
| | HPFTP | | RS007501 |
| | ASSEMBLY INTEGRITY | TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT. | OMRSD V41BS0.020 |
| | | TRAVEL CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT. | |
| ALL CAUSES | HPFTP | | RS007501 |
| | CLEANLINESS OF COMPONENTS | COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS. | RL10001 |
| | ASSEMBLY INTEGRITY | OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS. | RL00050-04<br>RL00056-06<br>RL00056-07<br>RL00461 |
| | | 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. | RL00528<br>RA0115-116 |
| | | DATA FROM PREVIOUS FLIGHT OR HOT FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE. (LAST TEST) | MSFC PLN 1228 |

| 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 SA21/88/308 and Rocketdyne letter 88RC09761.

Operational Use Not Applicable.

# SSME FMEA/CIL
# FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

Component Group: Fuel Turbopumps
Item Name: High Pressure Fuel Turbopump
Item Number: B200
Part Number: RS007501

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 4/21/99
Change #: 2
Directive #: CCBD ME3-01-5208



| Base Line Rationale | Variance | Change Rationale | Variant Dash Number |
|---|---|---|---|
| 1. B200-15 RS007502; CAUSE A. B200-24; RS007605; CAUSE A THE INNER AND OUTER BEARING RACES ARE EDDY CURRENT INSPECTED PER RL00743. | BEARING RACES RECEIVED FROM SUPPLIER SPLIT BALL BEARING INCORPORATED RECEIVED NO GENERAL EDDY CURRENT INSPECTION | GENERAL EDDY CURRENT INSPECTION OF RACES REPLACES TYPE IVC IN PENETRANT INSPECTION IN DETECTING SURFACE FLAWS<br>USE AS IS RATIONALE:<br>1. RACES 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. B200-13 RS007527, RS007532, CAUSE A & B. B200-26: RS007532; CAUSE B. DIFFUSER HIDDEN SURFACES ARE PENETRANT INSPECTED PER RL00343. | SOME DIFFUSERS MAY NOT RECEIVE THE POST PROOF TEST HIDDEN SURFACE IIa PENETRANT INSPECTION | USE AS IS RATIONALE<br>1 IMPLEMENTATION OF HIDDEN SURFACE INSPECTION REQUIREMENT IS NOT A RESULT OF AN OBSERVED HARDWARE ANAOMALY BUT AS A RESULT OF ROCKETDYNE'S STAND DOWN. | SEE DAR 2751 FOR VARIANT PART SERIAL NUMBERS |
| 3 B200-14 CAUSE A, RS007568 B200-21 CAUSE B, RS007568 B200-26 CAUSE A, RS007568 WELD JOINTS RS007568 TABLE B200 HPFTP FMEA/CIL WELD JOINTS RS007568 HOUSING CURRENT CONFIGURATION IS THE ONE(1) PIECE "-113" CAP, USING FOUR (4) WELDS AND FOUR (4) WELD NUMBERS | SOME HOUSINGS (POSSIBLY TWO) MAY HAVE BEEN FABRICATED WITH THE TWO (2) PIECE "-113" CAPS (THIS HAS AN EXTRA WELD: #13 AND THREE EXTRA WELD NUMBERS 13, 68 & 69) | TO REDUCE CONFUSION ON THE DRAWING AND ON THE MANUFACTURING FLOOR | SEE MCR 2524. SAME -113 DASH NUMBER. |
| 4 B200-02; CAUSE A, RS007524 CAUSE B, RS007524; CAUSE C, RS007524 | SOME TURBINE BEARING SUPPORTS (RS007524) ARE FABRICATED USING A WELDMENT OF HAYFS 188 SHEET METAL INSTEAD OF THE EDM FORGING. | HIGH CYCLE FATIGUE INDUCED INLET SHEET METAL CRACKS DO OCCUR FROM THE OPERATIONAL ENVIRONMENT EXPERIENCED DURING ENGINE OPERATION. THE CRACKING IS CONTROLLED PER THE REQUIREMENTS OF THE SHEET METAL INSPECTION SPECIFICATION (RL00655) WHICH LIMITS THE CRACKING LENGTH, SPACING, AND SHAPE, TO PRECLUDE SHEET METAL PIECES FROM DISLODGING. THE CRITERIA IS BASED ON CRACK GROWTH RATES AND ENGINE TEST EXPERIENCE. ANY CRACKS, WHICH EXCEED THE SPECIFICATION LIMITS, ARE WELD REPAIRED (RF0001-007). THE TURBINE BEARING SUPPORT WITH WELDED SHEET METAL IS LIFE LIMITED BY MAJOR WAIVER DAR 2709. | RS007524-201 AND SUBS. |

Component Group: Fuel Turbopumps
Item Name: High Pressure Fuel Turbopump
Item Number: B200
Part Number: RS007501

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 4/21/99
Change #: 2
Directive #: CCBD ME3-01-5206



| Base Line Rationale | Variance | Change Rationale | Variant Dash Number |
|---|---|---|---|
| 5 B200-16 CAUSE A, B200-17 CAUSE A, B200-18 CAUSE A, B200-19 CAUSE A, B200-22; CAUSE A,B,C,E | SOME LIFT-OFF SEAL HOUSING DRAIN LINES ARE FABRICATED USING INTERSECTING LINE DRILLED HOLES THE HOLE THAT INTERSECTS THE OUTSIDE DIAMETER OF THE HOUSING FLANGE HAS A PLUG INSTALLED. THE PLUG IS THEN WELDED AT THE HOUSING OUTSIDE DIAMETER TO FORM A TIGHT GAS SEAL | LOW CYCLE FATIGUE CRACKING HAS BEEN OBSERVED IN THE PLUG WELD. CRACK INITIATION AND PROPAGATION OCCURS AT SHUTDOWN/COOLDOWN ALL UNITS RECEIVE A STANDARD POST FLIGHT INSPECTIONS BY LEAK CHECK. LEAK CHECK POST FLIGHT WILL DETECT A CRACK PRIOR TO REFLIGHT. POST LEAKAGE AT THE DRAIN LINE IS LIMITED TO 10 SCIM. ALL FLIGHT UNITS WILL CONTINUE TO RECEIVE A LEAK CHECK POST FLIGHT FOR THE DRAIN LINE PLUG WELD UNITL THE ENTIRE FLEET IS RETROFIT WITH THE EDM DRAIN LINE CONFIGURATION | R0019230-071 AND SUBS. |

# SSME FMEA/CIL
# WELD JOINTS

Component Group: Fuel Turbopumps
CIL Item: B200
Component: High Pressure Fuel Turbopump
Part Number: RS007501

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 4/21/99
Change #: 2
Directive #: CCBD ME3-01-5206


| Component | Basic Part Number | Weld Number | Weld Type | Class | Root Side Not Access | Critical Initial Flaw Size Not Detectable HCF | LCF | Comments |
|---|---|---|---|---|---|---|---|---|
| SHIELD | R0012171 | 1-24, 28-62 | GTAW | II | X | | | |
| SHIELD | R0012171 | 26 | GTAW | II | | | | |
| LIFT-OFF SEAL | R0019230 | 1, 2 | GTAW | II | X | | | |
| SHIELD | R0019788 | 26, 28 | GTAW | II | | | | |
| SHIELD | R0019788 | 27 50 | GTAW | II | X | | | |
| SHIELD | R0019788 | 51, 52 | GTAW | I | | | | |
| SHIELD | R0019788 | 53, 55 | GTAW | II | | | | |
| BELLOWS | RS007505 | 1-4 | GTAW | I | | X | | |
| BELLOWS | RS007505 | 5, 6 | EBW | I | | X | | |
| INLET | RS007512 | 4 | GTAW | I | | X | | |
| INLET | RS007512 | 5-6 | GTAW | I | | | | |
| INLET | RS007512 | 7-10, 12, 13 | GTAW | I | | | | |
| INLET | RS007512 | 11 | EBW | II | | | | |
| INLET | RS007512 | 14 15 | GTAW | I | | | | |
| INLET | RS007512 | 16 | GTAW | I | | X | | |
| BEARING SUPPORT | RS007524 | 14 | EBW | I | | | | |
| BEARING SUPPORT | RS007524 | 18 | EBW | I | X | | | |
| BEARING SUPPORT | RS007524 | 29, 30 | GTAW | I | X | X | | |
| BEARING SUPPORT | RS007524 | 1*8 | GTAW | I | X | | | |
| BEARING SUPPORT | RS007524 | 119, 121 | EBW | I | | | | |
| BEARING SUPPORT | RS007524 | 120 | GTAW | II | X | | | |
| BEARING SUPPORT | RS007524 | 229-241 | GTAW | II | X | | | |
| HOUSING | RS007568 | 75 223, 228 230 298 | GTAW | I | X | X | X | |
| HOUSING | RS007568 | 74 | GTAW | I | | | | |
| HOUSING | RS007568 | 48 | EBW | I | X | X | X | |
| HOUSING | RS007568 | 49 | GTAW | I | X | | | |
| HOUSING | RS007568 | 51 | GTAW | II | X | X | | |
| HOUSING | RS007568 | 52 | GTAW | II | X | | | |
| HOUSING | RS007568 | 53 | EBW | I | | | | |

| Component | Basic Part Number | Weld Number | Weld Type | Class | Root Side Not Access | Critical Initial Flaw Size Not Detectable HCF | LCF | Comments |
|---|---|---|---|---|---|---|---|---|
| HOUSING | RS007568 | 55 | EBW | II | X | | | |
| HOUSING | RS007568 | 56 | GTAW | II | X | | | |
| HOUSING | RS007568 | 57, 324 325 | GTAW | II | | | | |
| HOUSING | RS007568 | 58 | GTAW | II | X | X | X | |
| HOUSING | RS007568 | 59 | EBW | I | | | | |
| HOUSING | RS007568 | 74, 229, 297 | GTAW | I | X | X | X | |
| HOUSING | RS007568 | 76, 77 | GTAW | I | | X | | |
| HOUSING | RS007568 | 78-89 | GTAW | II | X | | | |
| HOUSING | RS007568 | 90-101 | GTAW | II | X | | | |
| HOUSING | RS007568 | 102 | GTAW | I | X | | | |
| HOUSING | RS007568 | 139 | GTAW | II | X | | | |
| HOUSING | RS007568 | 140 | GTAW | II | X | | | |
| HOUSING | RS007568 | 153, 154 | GTAW | II | X | | | |
| HOUSING | RS007568 | 174-185 | GTAW | II | X | | | |
| HOUSING | RS007568 | 191 192, 195, 196 245, 455 456 | GTAW | II | X | X | | |
| HOUSING | RS007568 | 193, 194, 197-202 204-207 | GTAW | II | | X | | |
| HOUSING | RS007568 | 203, 217, 218, 234, 236 | GTAW | II | X | X | | |
| HOUSING | RS007568 | 212, 213 | GTAW | II | | | | |
| HOUSING | RS007568 | 214 215 | GTAW | II | X | | | |
| HOUSING | RS007568 | 222, 239 | GTAW | I | | X | | |
| HOUSING | RS007568 | 224, 225 | GTAW | I | | X | X | |
| HOUSING | RS007568 | 226, 227 | GTAW | I | | X | | |
| HOUSING | RS007568 | 231, 232 | GTAW | II | X | X | | |
| HOUSING | RS007568 | 233 | GTAW | II | X | | | |
| HOUSING | RS007568 | 237 238 | GTAW | II | | | | |
| HOUSING | RS007568 | 246-248 | GTAW | II | | | | |
| HOUSING | RS007568 | 326-349 | GTAW | II | X | | | |
| HOUSING | RS007568 | 374-397 | GTAW | II | X | | | |
| HOUSING | RS007568 | 399 | GTAW | I | X | X | X | |

| 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 |
|---|---|---|---|---|---|---|---|---|
| HOUSING | RS007568 | 401-424 | GTAW | II | X | | | |
| HOUSING | RS007568 | 425-448 | GTAW | II | X | | | |
| HOUSING | RS007568 | 450 (OPT) | GTAW | II | | | | |
| HOUSING | RS007568 | 450 (OPT) | EBW | II | X | | | |
| HOUSING | RS007568 | 454 | GTAW | II | X | | | |
| HOUSING | RS007568 | 537 (OPT) | GTAW | II | | | | |
| ROTOR SEAL | RS007588 | 1 | EBW | I | | | | |
| SEAL | RS007592 | 25 | EBW | II | X | | | |