

**SSME FMEA/CIL**  
**REDUNDANCY SCREEN**

Component Group: Fuel Turbopumps  
 CIL Item: B200-18  
 Component: High Pressure Fuel Turbopump  
 Part Number: RS007501  
 Failure Mode: Loss of coolant flow to turbine inlet support struts and turbine bearing support bellows.

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

Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4 I	Possible failure of turbine bearing support bellows resulting in leakage from turbine inlet to discharge. Possible structural buckling of inlet support struts resulting in loss of concentricity with rotating parts and resultant turbine blade failure. Loss of vehicle.  Redundancy Screens: SINGLE POINT FAILURE. N/A	1 ME-D1S,M ME-D1A,C

## SSME FMEA/CIL DESIGN

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Page: 1 of 3

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**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 ELECTRO-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. 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 110LDS THE "DOUGHNUT" SEAL IN THE RECESS OF THE LIFT-OFF SEAL TO PREVENT DISLODGE MENT 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 LEAKAGES 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 STATIC SEALS (13) AT THESE LOCATIONS. ANALYSIS REVEALS 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).

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Page: 2 of 3

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) RD261-3016 RE1621; (14) IL \$SME-0806; (15) RSS-404-111

**FAILURE CAUSE: B: Coolant flow passage blockage.**

HYDROGEN COOLANT IS SUPPLIED TO THE TURBINE BY FLOW PAST THE LOW-PRESSURE ORIFICE (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 BELLOW (11). THE REMAINDER OF THE FLOW FROM THE LIFT-OFF SEAL FLOWS THROUGH THE LABYRINTH STEPS OF THE TURBINE HUB LABYRINTH SEAL INTERFACE BEFORE CONTINUING THROUGH 12 HOLES IN THE LIFT-OFF SEAL OF THE FIRST STEP. THE FLOW IS COLLECTED IN A MANIFOLD AT THE LIFT-OFF SEAL HUB LABYRINTH SEAL INTERFACE. THE COOLANT CONTINUES 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 BELLOW. THE COMBINED COOLANT FLOW THEN CONTINUES OUT A GAP AT THE PREBURNER AND TURBINE BELLOW 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 TEST/FLIGHT DRYING PURGES PREVENTS BLOCKAGE FROM ICE FORMATION RESULTING FROM ACCUMULATION OF MOISTURE BETWEEN HOT FIRES (15).

(1) RS007559; (2) R0019230; (3) RS007510; (4) RS007553; (5) RS007569; (6) RS007592; (7) RS007517; (8) RS007502; (9) RS007547; (10) RS007524; (11) RS007505; (12) RS007577, RS007568; (13) RS007598; (14) RS007599; (15) ICD 13M15000 (16) RL00050-04, OMRSD V41CB0 050, OMRSD V41CB0.080 (PHASE II), OMRSD V41CB0 081 (PHASE II), OMRSD V41CB0.082 (BLOCK IIIA), OMRSD V41CB0.083 (BLOCK IIIA)

**FAILURE CAUSE: C: Failure of turbine bearing labyrinth seal.**

THE TURBINE BEARING LABYRINTH SEAL (1) IS MANUFACTURED UTILIZING A HAYNES 188 FORGING, WHICH WAS SELECTED FOR ITS OXIDATION RESISTANCE, TENSILE STRENGTH AT ELEVATED TEMPERATURES AND LOW CYCLE FATIGUE LIFE IN A HIGH-PRESSURE HYDROGEN RICH STEAM ENVIRONMENT (2). THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. THE SEAL IS ATTACHED TO THE TURBINE SUPPORT (3) BY 8 BOLTS (4) LOCKED BY CUPWASHERS (5). TWO LABYRINTH STEPS CAUSE THE COOLANT FLOW TO DIVIDE AS IT EXITS THE BEARINGS. PART OF THE FLOW IS ROUTED THROUGH THE TURBINE SUPPORT COOLANT CIRCUIT. THE REMAINDER PASSES THROUGH THE LABYRINTHS AND ALONG THE UPSTREAM FACE OF THE FIRST-STAGE DISK (6). THE SHAPE OF THE SEAL IS DESIGNED TO ROUTE THE COOLANT MORE EFFECTIVELY OVER THE DISKS, BOLTS (7), AND THE NUTS (8).

(1) RS007547; (2) RSS-8580-10; (3) RS007524; (4) RS007668; (5) RS007523; (6) RS007517; (7) RS007580; (8) RS007582

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CIL Item: B200-18  
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Failure Mode: Loss of coolant flow to turbine inlet support struts and turbine bearing support bellows.

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Page: 3 of 3

Design / Document Reference

**FAILURE CAUSE: D: 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 ITS 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 18 HOLES IN THE SECOND-STAGE DISK. THIS FLOW IS USED TO COOL THE TURBINE-END BEARINGS AND THE TURBINE DISKS (5). 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 LABYRINTH DIRECTS THE COOLANT AT THE HEADS OF THE DISK 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 CUP WASHERS (12). STRETCH BOLTS ARE UTILIZED TO ASSURE THE REQUIRED CLAMPING LOAD AT ASSEMBLY IS APPLIED.

(1) RS007553; (2) RSS-8580-10; (3) RSC07510; (4) RS007502; (5) RS007510, RS007517; (6) R0019230; (7) RS007577, RS007668; (8) RS007580; (9) RS007593; (10) RE1621; (11) RS007595; (12) RS007523

**FAILURE CAUSE: E: 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 RESISTANCE 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-8580-10

**FAILURE CAUSE: F: Extensive failure of turbine bellows shield.**

THE SHIELD (1) PROTECTS THE TURBINE BELLOWS (2) FROM HIGH TEMPERATURE TURBINE EXHAUST GAS. IT FORMS A CAVITY BETWEEN ITSELF AND THE TURBINE BELLOWS PERMITTING COOLANT FLOW ALONG THE OUTSIDE DIAMETER OF THE BELLOWS. THE BELLOWS SHIELD IS MANUFACTURED UTILIZING A HAYNES 188 FORGING. HAYNES 188 WAS SELECTED FOR ITS STRENGTH AT ELEVATED TEMPERATURES AND LOW CYCLE FATIGUE LIFE IN HIGH PRESSURE HYDROGEN (3). THE MATERIAL IS SHOT PEENED AND ANNEALED. THE SHIELD IS PILOTTED BY ENGAGEMENT OF ITS UPSTREAM LIP BENEATH THE MAIN HOUSING HATBAND. SIX PEDESTALS AXIALLY BOTTOM THE SHIELD AGAINST THE TURBINE BEARING SUPPORT. FOUR STANDOFFS ON THE DOWNSTREAM LIP OF THE SHIELD PERMITS THE COOLANT TO DISCHARGE INTO THE TURBINE EXHAUST.

(1) RS007599; (2) RS007505, RS007524; (3) RSS-8580-10

**FAILURE CAUSE: ALL CAUSES**

THE HIGH AND LOW CYCLE FATIGUE LIFE FOR THE LIFT-OFF SEAL, TURBINE BEARING SEAL, TURBINE HUB LABYRINTH SEAL, VORTEX CONTROL PADDLE AND PIN, AND TURBINE BELLOWS SHIELD 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 FIRST AND SECOND-STAGE DISKS WHICH WERE 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 B20D 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) RL00632, CP320R0003B; (2) RSS-8546-16 CP320R0003B (3) NASA TASK 117; (4) RSS-B756; (5) RL00528

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**INSPECTION AND TEST**

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 Page: 1 of 4

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 RB0130-115 RB0130-090
		EDM RECAST REMOVED PER DRAWING AND SPECIFICATION REQUIREMENTS	R0019230 RA1103-001
		EPOXY INTEGRITY CURE AND BOND THICKNESS ARE VERIFIED PER DRAWING REQUIREMENTS.	R0019230 RA1108-005
	SPRING INTEGRITY	SPRING CHARACTERISTICS ARE VERIFIED PER DRAWING REQUIREMENTS. THE TENSILE STRENGTH IS VERIFIED PER DRAWING REQUIREMENTS. SPRING CLOSED ENDS ARE GROUND SQUARE AND DEBURRED PER DRAWING REQUIREMENTS.	R0019230
	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 RA0607-094 RA0115-116 RA0115-008 RA1115-001 RA0115-127
	SURFACE FINISH	THE SEAL CHROME PLATING IS VERIFIED PER SPECIFICATION REQUIREMENTS. SEAL NOSE FLATNESS IS VERIFIED PER DRAWING REQUIREMENTS.	RA1609-002 RL00528 R0019230
	CLEANLINESS OF COMPONENTS	COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS.	RL10001
	ASSEMBLY INTEGRITY	THE FOLLOWING ACCEPTANCE TESTS ARE PERFORMED PER DRAWING AND SPECIFICATION REQUIREMENTS: - AMBIENT AND CRYOGENIC LOAD DEFLECTION. - NOSE LEAK CHECK. - SECONDARY SEAL LEAK CHECK. - SEAL ACTUATION AND RESEAT CHECK. ASSEMBLY OF THE LIFT-OFF SEAL IS VERIFIED PER SPECIFICATION REQUIREMENTS SCREW STAKING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS SEAL ACTUATION IS VERIFIED DURING IN-HOUSING BALANCE PER SPECIFICATION REQUIREMENTS.	R0019230 RL00505 RL00505 RL00505 RL00807 R0019230 RA1618-005 RL00362
	HPFTP		RS007501
	ASSEMBLY INTEGRITY	SEAL IS LEAK CHECKED AT TURBOPUMP ASSEMBLY.	RL00361

B - 125

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 Page: 2 of 4

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A	ASSEMBLY INTEGRITY	SEAL LEAK CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41BQ0.010 OMRSD V41BQ0.020 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 OMRSD V41CB0.080 (PHASE II) OMRSD V41CB0.081 (PHASE II) OMRSD V41CB0.082 (BLOCK I/IIA) OMRSD V41CB0.083 (BLOCK I/IIA)
C	SEAL, TURBINE BEARING DISK		RS007547 RS007517
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS	AMS 5772 RB0170-182
		FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-118 RA0115-012
	ASSEMBLY INTEGRITY	SEAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS. SEAL LABYRINTH AND DISK SEALING DIAMETERS ARE INSPECTED PER DRAWING REQUIREMENTS.	RA0115-116 RS007547 RS007517
		THE ROTATING ASSEMBLY BALANCE IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RL00352
	ASSEMBLY INTEGRITY	TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT. TRAVEL CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT.	RS007501 OMRSD V41BS0.020
D	SEAL DISK		RS007563 RS007510
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007510 RB0170-153
	HEAT TREAT	THE SEAL AND DISK ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS. HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS	RA0115-116 RA0611-020 RB0170-182

B - 126

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D	SURFACE FINISH	THE SEALING SURFACE IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007510 RF0004-027
	ASSEMBLY INTEGRITY	THE SEAL AND DISK DIAMETERS ARE VERIFIED PER DRAWING REQUIREMENTS	RS007553 RS007510
	HPFTP	THE ROTATING ASSEMBLY BALANCE IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RL00352
	ASSEMBLY INTEGRITY	TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT. TRAVEL CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT.	RS007501 OMRSD V41B50.020
E	BAFFLE, HPFTP PIN		R0018256 RS007514
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007514 RB0170-153
	HEAT TREAT	THE BAFFLE IS PENETRANT INSPECTED FOR SURFACE FLAWS BY PENETRANT INSPECTION PER SPECIFICATION REQUIREMENTS.	RA0115-116
	ASSEMBLY INTEGRITY	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS. BAFFLE TORQUE IS VERIFIED PER DRAWING REQUIREMENTS. PIN STAKING IS VERIFIED PER DRAWING REQUIREMENTS.	RA0611-020 RS007514
F	SHIELD		RS007599
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116 RA0115-012
	ASSEMBLY INTEGRITY	SHIELD IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS SHOT PEENING IS VERIFIED PER DRAWING REQUIREMENTS PASSIVATION IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0115-116 RS007599 RA0110-018
	HPFTP ASSEMBLY INTEGRITY	AN INTERNAL BORESCOPE INSPECTION IS PERFORMED PRIOR TO EACH FLIGHT. SHIELD IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS	RS007501 OMRSD V41BU0.075 OMRSD V41BU0.080
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 RL00056-08 RL00058-08

B-127

Component: Fuel Turbopumps  
 CIL Item: B200-18  
 Component: High Pressure Fuel Turbopump  
 Part Number: RS007501  
 Failure Mode: Loss of coolant flow to turbine inlet support struts and turbine bearing support bellows.

Prepared: D. Early  
 Approved: T. Nguyen  
 Approval Date: 4/21/98  
 Change #: 1  
 Directive #: CCBD ME3-01-5206

Page: 4 of 4

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
ALL CAUSES	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.  DATA FROM PREVIOUS FLIGHT OR HOT-FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE. (LAST TEST)	RL0052B RA0115-115  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 Rockwell 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

Page: 1 of 2

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 USE AS IS RATIONALE: 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 IIP PENETRANT INSPECTION	USE AS IS RATIONALE 1. IMPLEMENTATION OF HIDDEN SURFACE INSPECTION REQUIREMENT IS NOT A RESULT OF AN OBSERVED HARDWARE ANOMALY 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 HPFT 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 HAYES 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.

B-181

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

Page: 2 of 2

Base Line Rationale	Variance	Change Rationale	Variant Dash Number
5 B200-18 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 UNTIL 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  
 Page: 1 of 3

B - 183

Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable		Comments
						HCF	LCF	
SHIELD	R0012171	1,24, 29-52	GTAW	II	X			
SHIELD	R0012171	26	GTAW	II				
LIFT-OFF SEAL	R0019230	1, 2	GTAW	II	X			
SHIELD	R0019788	25, 26	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	118	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	14	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 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  
 Page: 2 of 3

B - 184

Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable		Comments
						HCF	LCF	
HOUSING	RS007568	56	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	150, 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 Group: Fuel Turbopumps  
 CIL Item: B200  
 Component: High Pressure Fuel Turbopump  
 Part Number: RS007501

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 Approved: T. Nguyen  
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 Change #: 2  
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 Page: 3 of 3

Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable		Comments
						HCF	LCF	
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				
SEA.	RS007592	25	EBW	II	X			