SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group:	Fuel Turbopumps
CIL Item:	B200-15
Component:	High Pressure Fuel Turbopump
Part Number:	RS007501
Failure Mode:	Loss of support or position control at pump end.

Prepared:	D. Early
Approved:	T. Nguyen
Approval Date:	4/21/99
Change #:	1
Directive #:	CCBD ME3-01-5206
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Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4 1	Results in reduced speed, flow, pump output pressure and increased vibration levels. Possible turbine blade failure or disintegration of rotating assembly. Loss of vehicle. Redundancy Screens: SINGLE POINT FAILURE. N/A	1 ME-D1S,M, ME-D1A,C

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Design / Document Reference

FAILURE CAUSE: A: Bearing failure: Ball failure. Cage failure. Loss of coolant. Corrosion. Contamination. Race failure.

THE ROTOR IS SUPPORTED RADIALLY ON 4 ANGULAR CONTACT BALL BEARINGS (1). THE BEARINGS ARE INSTALLED IN PAIRS THAT ARE SPRING PRELOADED TO TAKE UP THE BEARING INTERNAL CLEARANCE AND OBTAIN THE REQUIRED RADIAL STIFFNESS FOR ROTORDYNAMIC PERFORMANCE. EACH SPRING (2) IS INDIVIDUALLY CALIBRATED TO ASSURE THE REQUIRED PRELOAD IS ACCURATELY ACHIEVED. A BEARING SPACER (3) INSTALLED BETWEEN THE BEARING PAIRS IS SIZED UTILIZING THE SPRING CALIBRATION DATA TO SET THE PRELOAD. THE BEARING INNER RACE IS INSTALLED WITH AN INTERFERENCE FIT ON THE BEARING JOURNALS OF THE FIRST-STAGE IMPELLER (4) AND FIRST-STAGE DISK (5). A NUT (6) IS UTILIZED TO BOTTOM THE INNER RACES AGAINST THE SLINGERS (7). THE NUT IS LOCKED (8) TO PREVENT ROTATION. THE PUMP INTERSTAGE SEALS (9) PROVIDE ADDITIONAL RADIAL SUPPORT AND DAMPING. THE BEARINGS ARE NOT EXPOSED TO ANY SIGNIFICANT AXIAL LOAD DURING OPERATION. THE OUTER RACES ARE FREE TO SLIDE AXIALLY IN THE BEARING CARRIER (10) BORES ENABLING THE BALANCE PISTON TO SET AND MAINTAIN THE ROTOR AXIAL POSITION. THE BORE OF THE BEARING CARRIERS IS CHROME PLATED FOR WEAR RESISTANCE AND LUBRICATED TO REDUCE FRICTION. THE THRUST BEARING (11) ENGAGES AND REACTS THE AXIAL LOAD DURING START AND SHUTDOWN WHEN THERE IS INSUFFICIENT FLUID PRESSURE TO OPERATE THE BALANCE PISTON.

THE BEARINGS ARE COOLED BY THROUGH FLOW OF LIQUID HYDROGEN. COOLANT IS SUPPLIED TO THE PUMP-END BEARINGS BY RECIRCULATION FLOW AROUND THE FIRST-STAGE IMPELLER (12) BACK SHROUD. THE FLOW CONTINUES THROUGH 14 HOLES IN THE IMPELLER HUB AND 14 HOLES IN THE PUMP-END SLINGER (13) WHERE IT ENTERS THE BEARINGS. THE FLOW RETURNS TO THE FIRST-STAGE IMPELLER EYE THROUGH 12 HOLES IN THE PUMP BEARING CARRIER FLANGE, BEARING CARRIER SHIM, AND PUMP INLET (14) MATING FLANGE, AND TWENTY SLOTS ON THE INLET INSIDE DIAMETER. HYDROGEN COOLANT IS SUPPLIED TO THE TURBINE-END BEARINGS BY FLOW PAST THE LOW-PRESSURE ORIFICE (15) AND LIFT-OFF SEAL (16) AT SPEEDS ABOVE 7,000 RPM. PART OF THIS FLOW ENTERS 8 HOLES IN THE HUB OF THE SECOND-STAGE DISK (17), JUST UPSTREAM OF THE TURBINE HUB LABYRINTH SEAL (18). THE FLOW CONTINUES THROUGH THE CENTRAL CAVITY OF THE FIRST- AND SECOND-STAGE DISKS AND ENTERS THE TURBINE-END BEARINGS. THE TURBINE BEARING SEAL SPLITS THE BEARING DISCHARGE FLOW TO COOL THE TURBINE BEARING SUPPORT (19) AND THE FIRST-STAGE DISK. THE NUMBER OF PARALLEL PASSAGES FOR THE COOLANT FLOW, THE SIZE OF THE PASSAGES, AND THE QUANTITY OF THE FLOW MAKE THE BEARING COOLANT CIRCUIT INSENSITIVE TO MINOR FLOW BLOCKAGE. THE PROPELLANT FILTER AT THE EXTERNAL TANK PRECLUDES CONTAMINANTS LARGE ENOUGH TO CAUSE COOLANT BLOCKAGE OR BEARING DAMAGE. THE BEARINGS ARE CLEANED, PACKAGED, AND STORED TO PRECLUDE INTRODUCTION OF CONTAMINANTS PRIOR TO SERVICE (20).

THE BEARING RACES AND BALLS ARE MANUFACTURED UTILIZING 440C CRES BAR (21). THIS MATERIAL WAS SELECTED FOR ITS SURFACE HARDNESS, WEAR RESISTANCE, CORROSION RESISTANCE, AND ITS INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AT TEMPERATURES BELOW -200 DEGREES F. THE MATERIAL IS HARDENED, COLD STABILIZED, TEMPERED, AND STRESS RELIEVED TO ACQUIRE THE DESIRED PROPERTIES. THE BALLS ARE POSITIONED BY A FEP (FLUORINATED ETHYLENE POLYMER) COATED (22) ARMALON CAGE. THE FEP COATING WHICH SURROUNDS THE MANDREL WRAPPED FIBERGLASS CAGE PROVIDES BEARING LUBRICATION. FEP WAS SELECTED FOR ITS LUBRICITY, IMPERMEABILITY, RESISTANCE TO CHEMICAL ATTACK, ADEQUATE WEAR CHARACTERISTICS AND SATISFACTORY MECHANICAL PROPERTIES AT CRYOGENIC TEMPERATURES (23).

POST TEST/FLIGHT BEARING PURGES PRECLUDE ACCUMULATION OF MOISTURE ON THE BEARINGS BETWEEN HOT FIRES (24). THE TURBOPUMP ROTOR SUBASSEMBLY IS ASSEMBLED USING THE AXIAM STRAIGHT STACK PROCESS AND IS IN-HOUSING BALANCED TO MINIMIZE THE RADIAL LOADS EXPERIENCED DURING OPERATION (25). HOUSING MOUNTED ACCELEROMETERS ARE UTILIZED TO MONITOR ROTOR VIBRATION CHARACTERISTICS. THE BEARINGS ARE REPLACED AT TURBOPUMP OVERHAUL (26) DUE TO DAMAGE OF THE INNER RACES CAUSED BY THE REMOVAL FROM THE INTERFERENCE FIT ON THE JOURNALS. THE ROTATING ASSEMBLY INCLUDING THE BEARINGS HAVE BEEN DESIGN VERIFICATION TESTED FOR SPRING RATE (LOAD DEFLECTION) AND NATURAL FREQUENCY (VIBRATION) DETERMINATION (27).

(1) RS007502; (2) R0012170; (3) RS007519; (4) R0019226; (5) RS007517; (6) RS007506; (7) R0019985, R0019219 (8) RS007551; (9) RS007531; (10) RS007544; (11) RS007605; (12) R0019226; (13) R0019985; (14) RS007535, RS007512; (15) RS007558; (16) R0019230; (17) RS007510; (18) RS007553; (19) RS007524; (20) RL00916; (21) RSS-8580-10; (22) RA1608-011; (23) MPR-91-0911; (24) RL00050-04 OMRSD V41CB0.050; (25) RL00429 (26) RL00528; (27) RSS-404-37

Design / Document Reference

FAILURE CAUSE: B: Fracture, distortion of bearing carrier or excessive loss of bolt preload.

THE BEARING CARRIER (1) TRANSMITS THE RADIAL BEARING LOADS TO THE PUMP INLET (2) AND TURBINE BEARING SUPPORT (3) AND PERMITS FREE AXIAL MOTION OF THE ROTOR DURING OPERATION. THE BEARINGS ARE NOT EXPOSED TO ANY SIGNIFICANT AXIAL LOADS. THE RELATIVE AXIAL MOTION OCCURS BETWEEN THE BEARING CARRIER AND THE BEARING OUTER RACE. THE BEARING CARRIER WAS DESIGNED WITH A CROSS-SECTION THAT ACCOMMODATES INLET AND TURBINE BEARING SUPPORT DEFLECTIONS WHILE STILL MAINTAINING STIFFNESS. THE BEARING CARRIERS ARE SHIMMED AT ASSEMBLY TO ASSURE PROPER ALIGNMENT WITH THE OUTER RACES. THE CARRIER IS MANUFACTURED UTILIZING AN INCONEL 718 FORGING. INCONEL 718 WAS SELECTED FOR ITS TENSILE STRENGTH AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (4). THIS ALLOY IS NOT SUSCEPTIBLE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AT OPERATING TEMPERATURES. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE CARRIER INSIDE DIAMETER IS CHROME-PLATED FOR WEAR RESISTANCE AND LUBRICATED WITH DRY-FILM LUBRICANT TO REDUCE FRICTION. THE TURBINE END BEARING CARRIER IS ATTACHED TO THE TURBINE BEARING SUPPORT UTILIZING 12 A-286 CRES BOLTS (5) AND 321 CRES CUPWASHERS (6), WHICH ALSO RETAINS THE KAISER CAP (7). THE PUMP-END BEARING CARRIER IS ATTACHED TO THE INLET UTILIZING 12 A-286 CRES BOLTS (8) AND 6 302 CRES DOG-BONE LOCKS (9). A-286 CRES WAS SELECTED FOR ITS RESISTANCE TO HIGH-PRESSURE HYDROGEN DEGRADATION, MECHANICAL PROPERTIES, RETENTION OF TOUGHNESS AT CRYOGENIC TEMPERATURES, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (4). THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. 321 CRES AND 302 CRES WERE SELECTED FOR THEIR DUCTILITY AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING, AND INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT (4). THESE MATERIALS ARE ANNEALED TO IMPROVE MECHANICAL PROPERTIES. DRY-FILM LUBRICATION IS APPLIED TO THE BOLT THREADS AT ASSEMBLY, WHICH REDUCES THE FRICTIONAL FORCES PROVIDING A MORE CONSISTENT CLAMPING LOAD. THE CUPWASHERS AND "DOG-BONE" LOCKS ARE DEFORMED TO PREVENT BOLT ROTATION. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (10).

(1) RS007544; (2) RS007535, RS007512; (3) RS007524; (4) RSS-8580-10 (5) RS007668; (6) MS9880-10; (7) RS007539; (8) RD111-1016-5402; (9) RS007581; (10) RL00351

FAILURE CAUSE: C: Excessive loss of bearing retaining nut preload.

THE BEARING RETAINING NUT (1) PROVIDES THE CLAMPING LOAD TO THE BEARING (2) INNER RACES. THE NUT WORKS IN CONJUNCTION WITH THE INNER RACE SPACERS (3) AND THE OUTER RACE PRELOAD SPRINGS (4) TO SET BEARING PRELOAD. THE BEARINGS ARE SPRING PRELOADED TO TAKE UP THE BEARING INTERNAL CLEARANCE AND TO OBTAIN THE REQUIRED RADIAL STIFFNESS FOR ROTORDYNAMIC PERFORMANCE. THE NUT IS RETAINED BY THE NUT LOCK (5). ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (6). THE NUT IS MANUFACTURED UTILIZING A-286 CRES BAR (7). A-286 CRES HAS THE REQUIRED RESISTANCE TO HIGH-PRESSURE HYDROGEN DEGRADATION, MECHANICAL PROPERTIES AT CRYOGENIC TEMPERATURES, AND RETENTION OF TOUGHNESS AND DUCTILITY. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE LOCK IS MANUFACTURED UTILIZING 302 CRES (7) WHICH WAS SELECTED FOR ITS DUCTILITY, INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING. THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. THE NUT ASSEMBLY TORQUE IS INCREASED IN INCREMENTS UNTIL BOTTOMING OF THE BEARING STACK CAN BE VERIFIED. THE FINAL ASSEMBLY TORQUE DOES NOT EXCEED A SPECIFIED VALUE TO PRECLUDE OVERLOADING THE NUT (6). THESE PARTS ARE NON-SERIALIZED AND ARE NOT TIME HISTORY TRACKED BUT HAVE INFINITE ALLOWABLE LIFE (8).

(1) RS007506; (2) RS007502, (3) RS007519; (4) R0012170; (5) RS007551; (6) RL00351; (7) RSS-8580-10, (8) RL00532, CP320R0003B

FAILURE CAUSE: D: Excessive clearance at pump interstage seals.

THERE ARE TWO PUMP INTERSTAGE SEALS (1) POSITIONED BETWEEN THE IMPELLERS TO CONTROL LEAKAGE BETWEEN STAGES AND TO PROVIDE ROTOR DAMPING. THEY ARE MANUFACTURED UTILIZING ALUMINUM ALLOY 6061-T651 BAR. THIS ALLOY WAS SELECTED FOR ITS RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT, CORROSION, AND STRESS CORROSION CRACKING (2). THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. A HARD ANODIZE COATING IS APPLIED TO THE SEAL INSIDE DIAMETER AND COVERED WITH DRY-FILM LUBRICATION TO ENHANCE ITS RUBBING CHARACTERISTICS. THE REMAINDER OF THE SURFACES ARE CHROMIC OR SULFURIC ACID ANODIZED TO FURTHER INCREASE ITS CORROSION RESISTANCE. THE FUNCTIONAL LENGTH OF THE SEAL INSIDE DIAMETER IS KNURLED FOR ROTORDYNAMIC STABILITY AND TAPERED TO COMPENSATE FOR DEFLECTIONS AND PROVIDE A CONSTANT RADIAL CLEARANCE WITH THE IMPELLER SLEEVES (3) IN OPERATION. THE SEALS ARE ATTACHED TO FLANGES ON THE DIFFUSERS (4) (5) BY 13 A-286 CRES BOLTS (6) THREADED INTO THE SEAL AND LOCKED WITH A-286 CRES CUPWASHERS (7). A-286 CRES WAS SELECTED FOR ITS RESISTANCE TO HIGH-PRESSURE HYDROGEN DEGRADATION, MECHANICAL PROPERITIES, RETENTION OF TOUGHNESS AND DUCTILITY AT CRYOGENIC TEMPERATURES, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (2). THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE CUPWASHERS ARE STAKED AT ASSEMBLY TO PREVENT BOLT ROTATION. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (8). THE BOLTS ARE SILVER PLATED AND DRY FILM LUBRICATION IS APPLIED TO THE THREADS AT ASSEMBLY TO REDUCE THE FRICTION, RESULTING IN A MORE CONSISTENT CLAMPING LOAD. THE CLEARANCE BETWEEN THE SEAL AND THE SLEEVE IS CONTROLLED TO MINIMIZE RUBBING WHILE REDUCING BYPASS LEAKAGE.

(1) RS007531; (2) RSS-8580-10; (3) RS007563, RS007531; (4) RS007527, (5) RS007532; (6) RS007792; (7) RS007794; (8) RL00351

Design / Document Reference

FAILURE CAUSE: E: Failure or excessive wear of bearing preload spring.

THE PRELOAD SPRING (1) PROVIDES THE PRELOAD FORCE APPLIED TO THE BEARING OUTER RACES. EACH SPRING IS INSTALLED BETWEEN THE TWO OUTER RACES AND WORKS IN CONJUNCTION WITH THE INNER RACE SPACER (2) AND THE RETAINING NUT (3) TO SET THE PRELOAD. THE SPRING IS A DEFLECTED BEAM CONFIGURATION. EACH SPRING IS INDIVIDUALLY CALIBRATED TO ASSURE THE REQUIRED PRELOAD IS ACHIEVED. THE SPRING IS MANUFACTURED UTILIZING INCOLOY 903 SHEET (4). INCOLOY 903 IS AN IRON-BASED ALLOY WHICH HAS THE REQUIRED STRENGTH AND RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT. THIS ALLOY IS RESISTANT TO CORROSION AND STRESS CORROSION CRACKING. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED.

(1) R0012170, (2) RS007519; (3) RS007506; (4) RSS-8580-10

FAILURE CAUSE: F: Pump slinger pin failure.

THE PUMP END BEARING SLINGER ANTI-ROTATION PIN (1) IS MANUFACTURED UTILIZING A-286 CRES BAR (2). A-286 CRES WAS SELECTED FOR ITS RESISTANCE TO HIGH-PRESSURE HYDROGEN DEGRADATION AND MECHANICAL PROPERTIES AT CRYOGENIC TEMPERATURES. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE ANTI-ROTATION PIN PREVENTS ROTATION OF THE SLINGER (3) RELATIVE TO THE TURBOPUMP ROTOR DURING OPERATION. MATERIAL IS REMOVED FROM THE SLINGER BY GRINDING AS PART OF THE IN-HOUSING BALANCE OPERATION. IN THE EVENT OF A SHEARED PIN, THE PIECES WOULD BE TRAPPED AND COULD NOT CAUSE DOWNSTREAM CONTAMINATION DAMAGE. AN AXIAL LINE IS ETCHED AT ASSEMBLY ACROSS THE SLINGER OUTSIDE DIAMETER AND IMPELLER HUB TO SERVE AS AN ALIGNMENT INDICATOR.

(1) R0019999, (2) RSS-8580-10, (3) R0019985

FAILURE CAUSE: G: Stud failure or loss of preload.

THE STUD (1) IS MANUFACTURED UTILIZING INCONEL 718 BAR (2). AN INCONEL 718 BAFFLE (3) 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. IT IS RESISTANT TO CORROSION AND STRESS CORROSION CRACKING, AND IN A CRYOGENIC ENVIRONMENT DOES NOT REQUIRE HYDROGEN ENVIRONMENT EMBRITTLEMENT PROTECTION (2). THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE ANTI-VORTEX BAFFLE ASSURES ORDERLY FLOW OF THE COOLANT TO THE TURBINE. THREE SETS OF RAISED LANDS SPACED ALONG THE LENGTH OF THE STUD (TIE BOLT) PROVIDE CLOSE RADIAL CLEARANCE WITH THE FIRST AND SECOND STAGE IMPELLER BORES (4) TO LIMIT DEFLECTION OF THE STUD. FIRST AND SECOND STAGE IMPELLER BORE WEAR IS CONTROLLED BY UTILIZING REPLACEABLE SACRIFICAL INSERTS (5) FIRST AND SECOND STAGE IMPELLER INSETS ARE MANUFACTURED FROM COBALT BASE L-605 (STELITE 25) FORGING (6). THIS ALLOY WAS SELECTED FOR ITS TOUGHNESS, RESISTANCE TO GALLING WITH THE INCONEL 718 STUD, RESISTANCE TO HYDROGEN EMBRITTLEMENT AND RESISTANCE TO THERMAL SHOCK (7). THE MATERIAL IS COLD WORKED TO DEVELOP THE REQUIRED HARDNESS (8). IMPELLER BORE INSERTS ARE PERIODICALLY INSPECTED FOR WEAR (9). IMPELLER BORE INSERTS WITH WEAR IN EXCESS OF SPECIFICATION LIMITS ARE REPLACED (10). EACH LAND IS INTERRUPTED AROUND ITS CIRCUMFERENCE IN THREE PLACES TO PERMIT FLOW OF HYDROGEN AXIALLY ALONG THE STUD. THE STUD IS THREADED INTO THE SECOND-STAGE DISK (11) AND CAPTURES A STATIC SEAL (12) TO PREVENT HYDROGEN LEAKAGE. AFTER ASSEMBLY WITH THE IMPELLERS AND SLEEVES, THE STUD IS STRETCHED TO BOTTOM THE ROTOR STACK. A SHAFT NUT (13) IS INSTALLED AND LOCKED (14) IN PLACE ON THE END OF THE SHAFT ONCE THE REQUIRED STUD STRETCH IS ACHIEVED. THE NUT IS MANUFACTURED UTILIZING INCONEL 718, WHICH WAS SELECTED FOR ITS STRENGTH AND DUCTILTY AT CRYOGENIC TEMPERATURES, AND ITS RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING, AND INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AT OPERATING TEMPERATURES (2). THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE LOCK IS MANUFACTURED UTILIZING 302 CRES, WHICH WAS SELECTED FOR ITS DUCTILITY, RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING, AND INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT (2). THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (15). THE STUD DOES NOT TRANSMIT TORQUE DURING OPERATION. TORQUE TRANSMISSION OCCURS ONLY AT THE IMPELLER SLEEVES. THE ROTATING ASSEMBLY HAS BEEN DESIGN VERIFICATION TESTED FOR SPRINGRATE (LOAD DEFLECTION) AND NATURAL FREQUENCY (VIBRATION) DETERMINATION (16).

(1) RS007514; (2) RSS-8580-10; (3) R0019258; (4) R0019226, RS007555; (5) R0019226-023, RS007555-025. (6) AMS 5759; (7) MPR-91-1426; (8) R0019226, RS007555; (9) RL00050-04, RL00528, RL0004-302; (10) RL00528, RL0004-302; (11) RS007510; (12) RES1190; (13) RS007508; (14) RS007579; (15) RL00351; (16) RSS-404-37

Component Group:	Fuel Turbopumps	Prepared:	D. Early
CIL Item:	B200-15	Approved:	T. Nguyen
Component:	High Pressure Fuel Turbopump	Approval Date:	4/21/99
Part Number:	R5007501	Change #:	1
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FAILURE CAUSE: ALL CAUSES

THE HIGH AND LOW CYCLE FATIGUE LIFE FOR THE BEARING CARRIER, BEARING RETAINER NUT, PUMP INTERSTAGE SEALS, PUMP SLINGER PIN AND THE STUD MEET CEI REQUIREMENTS (1). TURBINE AND PUMP END BEARINGS ARE LIFE LIMITED BY MAJOR WAIVER (5) BEARING PRELOAD SPRINGS ARE LIFE LIMITED BY MAJOR WAIVER (6) 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 HOUSING WHICH WAS CLEARED BY CRITICAL INITIAL FLAW SIZE DETECTABILITY (3). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (4)

(1) RL00532, CP320R0003D; (2) RSS-8646-16, CP320R0003B (3) NASA TASK 117; (4) RL00528; (5) DAR 2162; (6) DAR 2726

SSME FMEA/CIL
INSPECTION AND TEST

Component Group: Fuel Turbopumps
CIL Item: B200-16
Component: High Pressure Fuel Turbopump
Part Number: RS007501
Failure Mode: Loss of support or position control at pump end.

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 4/21/88
Change #: 1
Directive #: CCBD ME3-01-5206

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	FORWARD BEARING		RS007502
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RB0130-013 RB0160-054 RS007502
		THE BEARING BALLS AND INNER AND OUTER RACES ARE EDDY CURRENT INSPECTED PRIOR TO INSTALLATION.	RS007502 RL00564 RL00743
		THE INNER AND OUTER RACES ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	THE BEARING BALLS AND INNER AND OUTER RACES ARE HEAT TREATED PER SPECIFICATION REQUIREMENTS.	RA1611-005
	ASSEMBLY INTEGRITY	THE BEARING BALLS AND INNER AND OUTER RACES ARE INSPECTED VISUALLY PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007502 RL00916
		THE BEARING BALLS ARE INSPECTED PER DRAWING REQUIREMENTS TO AFBMA STANDARDS FOR SIZE AND GRADE.	RS007502
		BEARINGS ARE ASSEMBLED AND DISASSEMBLED PER SPECIFICATION REQUIREMENTS.	RL00916
		THE INNER AND OUTER RACES AND CAGE ARE VERIFIED TO BE COPLANAR PER DRAWING REQUIREMENTS.	RS007502
		THE BEARING CAGE FABRIC LAYERS ARE INSPECTED PER DRAWING REQUIREMENTS.	
		FEP COATING IS APPLIED TO BEARING CAGE PER SPECIFICATION REQUIREMENTS.	RA1608-011
		THE ROTATING ASSEMBLY BALANCE IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RL00352
	CLEANLINESS OF COMPONENTS	THE BEARING RACES AND BALLS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS.	RA1610-051 RL10001
		THE CAGE IS INSPECTED FOR ORGANIC FLUIDS PER DRAWING REQUIREMENTS.	RS007502
		THE BEARINGS ARE INSPECTED FOR CORROSION PRIOR TO PACKAGING, BEFORE ASSEMBLY, AND BEFORE INSTALLATION IN THE PUMP.	RL00916 RS007502 RS007501 RL00006
		THE UPSTREAM COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RL10001 RS007501 RS007502
		POST FLIGHT DRYING PURGES ARE PERFORMED PER SPECIFICATION REQUIREMENT	OMRSD V41CB0.050
B	BEARING CARRIER HOUSING BOLT WASHER-CUPLOCK		RS007544 RS007568 RS007558 MS9880

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B	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007568 RS007668 MS9860 RB0170-153
		THE CARRIER IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HOUSING AND CARRIER HEAT TREAT ARE VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	THE CARRIER CHROMIUM PLATE IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RA1609-002 RS007544
		DRY FILM LUBE IS VERIFIED PER DRAWING REQUIREMENTS.	RS007544
	ASSEMBLY INTEGRITY	THE BOLT TORQUE IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS	RS007501 RL00351
		CUPWASHER DEFORMATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS007501
	CLEANLINESS OF COMPONENTS	COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS.	RL10001
C	NUT LOCK		RS007506 RS007551
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		NUT IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	NUT HARDNESS IS VERIFIED PER DRAWING REQUIREMENTS.	RS007506
	ASSEMBLY INTEGRITY	THE BOLT TORQUE IS VERIFIED PER ASSEMBLY DRAWING REQUIREMENTS.	RS007501
		THE NUT LOCK DEFORMATION IS INSPECTED AFTER INSTALLATION AND PRIOR TO DISASSEMBLY.	RS007501 RL00528
	CLEANLINESS OF COMPONENTS	COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS	RL10001
D	SEAL INTERSTAGE HP FUEL TURBOPUMP		RS007531
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		THE SEAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER DRAWING REQUIREMENTS	RS007531
	SURFACE FINISH	KNURLING IS VERIFIED PER DRAWING REQUIREMENTS.	
		THE CHROMIC OR SULFURIC ACID ANODIZE OR HARD ANODIZE SURFACE FINISH IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1609-003
		THE DRY FILM LUBE IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0140-020
	ASSEMBLY INTEGRITY	THE DIAMETERS OF THE SEAL AND SLEEVE ARE VERIFIED PER DRAWING REQUIREMENTS	RS007531

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
E	SPRING		R0012170
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-186
		THE SPRING IS PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	R0012170
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	ASSEMBLY INTEGRITY	THE SPRING LOAD TEST IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	R0012170 RL00388
		THE SHIM SIZING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS	RS007501 RL00351
		THE NUT TORQUE IS VERIFIED PER ASSEMBLY DRAWING REQUIREMENTS.	RS007501
F	SLINGER PIN		R0019999
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS	
	HEAT TREAT	THE PIN HARDNESS IS VERIFIED PER DRAWING REQUIREMENTS	
G	STUD ASSEMBLY		RS007514
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-153
		STUD IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RA0611-020 RS007514
	CLEANLINESS OF COMPONENTS	COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS	RL10001
	ASSEMBLY INTEGRITY	TORQUE AND STRETCH ARE VERIFIED PER DRAWING REQUIREMENTS	RS007501
		STUD LUBE IS VERIFIED PER DRAWING REQUIREMENTS	
		NUT TORQUE IS VERIFIED PER DRAWING REQUIREMENTS.	
		THE NUT LOCK DEFORMATION IS INSPECTED AFTER INSTALLATION AND PRIOR TO DISASSEMBLY	RS007501 RL00528
	OVERHAUL	IMPELLER HUB AND BORE ARE VISUALLY INSPECTED PER SPECIFICATION REQUIREMENTS AT INTERVALS DEFINED BY MAJOR WAIVER.	RF0004-302 DAR 2061
	IMPELLER INSERT IMPELLER INSERT		R0019226-023 RS007555-025
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	AMS 5759
		MATERIAL HARDNESS IS VERIFIED PER DRAWING REQUIREMENTS.	R0019226 RS007555
		INSERTS ARE PENETRANT INSPECTED PER DRAWING REQUIREMENTS.	RA0115-116
	OVERHAUL	IMPELLER INSERTS ARE INSPECTED FOR BORE WEAR PER SPECIFICATION REQUIREMENTS.	RF0004-302

Component Group: Fuel Turbopumps
CIL Item: B200-15
Component: High Pressure Fuel Turbopump
Part Number: RS007501
Failure Mode: Loss of support or position control at pump end.

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
ALL CAUSES	HPFTP		
	ASSEMBLY INTEGRITY		RS007501
		OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS.	RL00050-04 RL00050-06 RL00050-07 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 RA0115-116
		TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41BS0.020
		SHAFT TRAVEL IS PERFORMED PRIOR TO EACH FLIGHT.	
		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.

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 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 IIa PENETRANT INSPECTION	USE AS IS RATIONALE 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			