SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group:	Fuel Turbopumps
CIL Item:	B200-06
Component:	High Pressure Fuel Turbopump
Part Number:	RS007501
Failure Mode:	Platform seal leakage.

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
S 4.1	Leakage causes loss in turbine power which reduces turbopump speed, flow and discharge pressure. Decreased flow is sensed by controller which increases fuel preburner oxidizer flow. Excess turbine discharge temperature will cause redline shutdown. Mission scrub if detected by redline. Loss of vehicle due to HPFTP turbine failure may result if not detected. Redundancy Screens: TURBOPUMP SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Pass - Loss of a redundant hardware items is detectable during flight. C: Pass - Loss of redundant hardware items could not result from a single credible event.	1R ME-D1S,M
M 4.1	Leakage causes loss in turbine power which reduces turbopump speed, flow and discharge pressure. Decreased flow is sensed by controller which increases fuel preburner oxidizer flow. Excess turbine discharge temperature will cause redline shutdown. Mission abort if detected by redline. Loss of vehicle due to HPFTP turbine failure may result if not detected. Redundancy Screens: TURBOPUMP SYSTEM - SENSOR SYSTEM: UNLIKE REDUNDANCY A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround. B: Pass - Loss of a redundant hardware items is detectable during flight. C: Pass - Loss of redundant hardware items could not result from a single credible event.	1R ME-D1S,M

SSME FMEA/CIL
DESIGN

Component Group:	Fuel Turbopumps	Prepared:	D. Early
CIL Item:	B200-06	Approved:	T. Nguyen
Component:	High Pressure Fuel Turbopump	Approval Date:	4/21/99
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Design / Document Reference

FAILURE CAUSE: A: Excessive loss of bolt preload.
B: Seal fracture.
C: Seal erosion.

THE FIRST-STAGE FORWARD PLATFORM SEAL (1) IS BI-METALLIC. THE INNER STRUCTURE IS MANUFACTURED UTILIZING RENE 41 FORGING (2), BECAUSE OF THE MATERIALS RUPTURE STRENGTH. HYDROGEN ENVIRONMENT EMBRITTLEMENT IS NOT A PROBLEM AS THE SEAL OPERATES IN THE ELASTIC RANGE. THE ACTIVE PLATFORM SEAL PORTION IS MANUFACTURED UTILIZING AN INCONEL 625 RING (2), WHICH IS ELECTRON BEAM WELDED TO THE RENE 41. ELECTRON BEAM WELDS PRODUCE A CLEAN WELD WITH A SMALL HEAT AFFECTED ZONE AND MINIMAL DISTORTION. THE INCONEL 625 HAS THE REQUIRED THERMAL PROPERTIES, HIGH CYCLE FATIGUE LIFE, AND IS INSENSITIVE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AT OPERATING TEMPERATURES (2). THE MATERIAL IS SOLUTION-TREATED AND AGE-HARDENED. THE SEAL MINIMIZES PARASITIC HOT-GAS LEAKAGE THAT COULD DILUTE COOLANT EFFECTIVENESS OR REDUCE TURBINE EFFICIENCY. THE SEAL IS SECURED TO THE TURBINE SUPPORT (3) BY 24 A-286 CRES BOLTS (4) AND 321 CRES CUPWASHERS (5). A-286 CRES WAS SELECTED FOR ITS RESISTANCE TO HIGH PRESSURE HYDROGEN DEGRADATION, MECHANICAL PROPERTIES, 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. 321 CRES WAS SELECTED FOR ITS DUCTILITY, ITS RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING, AND ITS INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT (2). THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. THE CUPWASHERS ARE STAKED TO PREVENT ROTATION OF THE BOLTS. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (6). DRY-FILM LUBRICANT IS APPLIED TO THE BOLT THREADS AT ASSEMBLY AND THE BOLTS ARE SILVER-PLATED WHICH REDUCES THE FRICTIONAL FORCES, PROVIDING A MORE CONSISTENT CLAMPING LOAD. A STATIC SEAL (7) BETWEEN THE PLATFORM SEAL AND THE TURBINE SUPPORT PREVENTS DIRECT EXPOSURE OF THE BOLTS TO THE HIGH TEMPERATURE TURBINE GASES. THE PLATFORM SEAL IS RADIALLY PILOTED BY 4 PINS IN THE TURBINE BEARING SUPPORT WHICH ENGAGE SLOTS IN THE SEAL FLANGE. CLEARANCE BETWEEN THE BLADES AND SEAL IS CONTROLLED TO MINIMIZE RUBBING WHILE REDUCING BYPASS LEAKAGE.

THE FIRST-STAGE AFT PLATFORM SEAL (8) IS MANUFACTURED UTILIZING A HAYNES 188 FORGING (2). THIS ALLOY WAS SELECTED FOR ITS TENSILE STRENGTH AT ELEVATED TEMPERATURES, LOW CYCLE FATIGUE LIFE, AND RESISTANCE TO DEGRADATION AND OXIDATION IN A HIGH PRESSURE HYDROGEN RICH STEAM ATMOSPHERE. THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. THE SEAL MINIMIZES PARASITIC HOT-GAS LEAKAGE THAT COULD DILUTE COOLANT EFFECTIVENESS OR REDUCE TURBINE EFFICIENCY. THE SEAL IS ATTACHED TO THE SECOND-STAGE FORWARD PLATFORM SEAL (9) BY 12 A-286 CRES BOLTS (10) AND 321 CRES CUPWASHERS (11). A-286 CRES WAS SELECTED FOR ITS RESISTANCE TO HIGH PRESSURE HYDROGEN DEGRADATION, MECHANICAL PROPERTIES, RETENTION OF TOUGHNESS AND DUCTILITY AT CRYOGENIC TEMPERATURES, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING. THE MATERIAL IS SOLUTION-TREATED AND AGE-HARDENED. 321 CRES WAS SELECTED FOR ITS DUCTILITY, RESISTANCE TO CORROSION, STRESS CORROSION CRACKING, AND INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT (2). THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. THE CUPWASHERS ARE STAKED TO PREVENT ROTATION OF THE BOLTS. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (6). DRY-FILM LUBRICANT IS APPLIED TO THE BOLT THREADS AT ASSEMBLY, WHICH REDUCES THE FRICTIONAL FORCES, PROVIDING A MORE CONSISTENT CLAMPING LOAD. SIX LUGS EXTEND RADIALLY INWARD FROM THE NOZZLE INNER SHROUD AND ENGAGE 6 SLOTS IN THE SEAL TO PROVIDE RADIAL PILOTING FOR THE PLATFORM AND INTERSTAGE SEAL ASSEMBLY. THE SECOND-STAGE FORWARD PLATFORM SEAL PILOTS ON THE INSIDE DIAMETER OF THE FIRST-STAGE AFT PLATFORM SEAL. THIS PILOTING ARRANGEMENT ACCOMMODATES THE THERMAL GROWTHS OF THE SEALS. THE SLOTS ARE DIMENSIONED TO PROVIDE A SMALL DEGREE OF AXIAL MOTION RELATIVE TO THE LUGS AND ASSURES EVEN, UNIDIRECTIONAL LOADING OF THE LUGS. THE CLEARANCE BETWEEN THE BLADES AND THE SEAL IS CONTROLLED TO MINIMIZE RUBBING WHILE REDUCING BYPASS LEAKAGE.

THE SECOND-STAGE FORWARD PLATFORM SEAL TURBINE INTERSTAGE SEAL ASSEMBLY (9) 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 ELEVATED 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 FLOWING FROM THE CURVICS CAVITY PAST 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 MECHANICAL PROPERTIES AT CRYOGENIC TEMPERATURES. 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. THE CLEARANCE BETWEEN THE BLADES IS CONTROLLED TO MINIMIZE RUBBING WHILE REDUCING BYPASS LEAKAGE.

THE SECOND-STAGE AFT PLATFORM SEAL (12) IS MANUFACTURED UTILIZING A RENE 41 FORGING, WHICH WAS SELECTED FOR ITS ELEVATED TEMPERATURE AND STRENGTH

Design / Document Reference

PROPERTIES, AND CORROSION RESISTANCE (2). THE MATERIAL IS SOLUTION-TREATED AND AGE-HARDENED. THE SEAL IS COPPER-PLATED TO PROTECT THE BASE MATERIAL FROM HYDROGEN ENVIRONMENT EMBRITTLEMENT (2) THE SEAL CONTROLS THE ENVIRONMENT ON THE DOWNSTREAM SIDE OF THE SECOND-STAGE DISK. IT IS PILOTED AT ASSEMBLY ON THE OUTSIDE DIAMETER OF THE HUB LABYRINTH SEAL (13). PILOTING IN OPERATION IS PROVIDED BY 6 RADIAL TANGS WHICH ENGAGE SLOTS IN A RETAINER (14). A THIN CIRCULAR LIP ON THE PLATFORM SEAL ENGAGES A SLIGHTLY WIDER GROOVE IN THE RETAINER. THIS POSITIONS THE SEAL AXIALLY WHILE PERMITTING THE SEAL TO EXPAND AND CONTRACT FREELY UNDER ITS OWN THERMAL ENVIRONMENT TO REDUCE ITS OPERATING STRESSES THE RETAINER IS SECURED TO THE LIFT-OFF SEAL STACK BY 12 A-286 CRES BOLTS (15) AND 321 CRES CUPWASHERS (11). A-286 CRES WAS SELECTED FOR ITS RESISTANCE TO HIGH PRESSURE HYDROGEN DEGRADATION, MECHANICAL PROPERTIES, 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. 321 CRES 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 AND THE CUPWASHERS ARE YIELDED PRIOR TO ASSEMBLY TO INCREASE THEIR COMPRESSIVE STRENGTH. THE CUPWASHERS ARE STAKED AT ASSEMBLY TO PREVENT ROTATION OF THE BOLTS. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (6). STRETCH BOLTS ARE UTILIZED TO ASSURE THE REQUIRED PRELOAD ON THE STACK IS ACHIEVED THE CLEARANCE BETWEEN THE BLADES AND THE SEALS IS CONTROLLED TO MINIMIZE RUBBING WHILE REDUCING BYPASS LEAKAGE.

THE HIGH AND LOW CYCLE FATIGUE LIFE FOR THE FOUR PLATFORM SEALS, BOLTS, AND CUPWASHERS MEET CEI REQUIREMENTS (16) THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (17). THE FIRST AND SECOND-STAGE FORWARD AND AFT PLATFORM SEALS PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS (18) THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (19). 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 (19). THE CONTROLLER SOFTWARE IS CONFIGURED TO DETECT AND RESPOND PROPERLY TO THE FAILURES IDENTIFIED AND COMMAND A SAFE ENGINE STATE (20). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (21).

(1) RS007588. (2) RSS-8580-10; (3) RS007524; (4) R0019815; (5) RS007667; (6) RL00351. (7) RES1192; (8) RS007591; (9) RS007592; (10) RS007868; (11) RS007523. (12) RS007593. (13) RS007553; (14) RS007596 (15) RS007595; (16) RL00532 CP320R0003B; (17) RSS-8546-16, CP320R0003B; (18) NASA TASK 117; (19) RSS-8755; (20) CP406R0002 PT 1 3.2.3:5.3; (21) RL00528

FAILURE CAUSE: D: Platform erosion.

THE FIRST AND SECOND-STAGE BLADES (1) ARE MANUFACTURED UTILIZING INVESTMENT CASTINGS. THE MATERIAL IS MAR-M-246 (HF MOD) (2) AND IS DIRECTIONALLY SOLIDIFIED. MAR-M-246 (HF MOD) HAS THE HIGHEST STATIC MECHANICAL PROPERTIES OF THE NICKEL BASE ALLOYS FROM ROOM TEMPERATURE TO 2800 R. THIS ALLOY WAS SELECTED FOR ITS RUPTURE STRENGTH AND RESISTANCE TO CREEP. THE HAFNIUM ADDITION TO THE BASIC ALLOY IMPROVES THE DUCTILITY AND THE CASTABILITY OF THIN WALLED SECTIONS. THESE PROPERTIES OPTIMIZE THIS ALLOY'S RESISTANCE TO EROSION. FIRST-STAGE BLADE PLATFORM EROSION DOES OCCUR DUE TO THE HIGH THERMAL SPIKE EXPERIENCED DURING THE ENGINE START TRANSIENT. SINCE THE INCORPORATION OF THE FUEL PREBURNER AND ENGINE START SEQUENCE MODIFICATIONS (3) THIS EROSION HAS BEEN MINOR. THE AMOUNT OF ACCEPTABLE EROSION IS CONTROLLED PER FIELD SPECIFICATION (4). THE CONTROLLER SOFTWARE IS CONFIGURED TO DETECT AND RESPOND PROPERLY TO THE FAILURE IDENTIFIED AND COMMAND A SAFE ENGINE STATE (5).

(1) R0019821 RS007520; (2) RSS-8580-10; (3) ECP 654, 669; (4) RF0001-053 OMRSD V41BU0.075; (5) CP406R0002 PT 1 3.2.3 5.3

SSME FMEA/CIL
INSPECTION AND TEST

Component Group: Fuel Turbopumps
CIL Item: B200-06
Component: High Pressure Fuel Turbopump
Part Number: RS007501
Failure Mode: Platform seal leakage.

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	BOLT FIRST-STAGE FORWARD PLATFORM SEAL SUPPORT		R0019815 RS007524
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		THE BOLT IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RB0160-014 RS007524
	SURFACE FINISH	THE BOLT DRY-FILM LUBRICATION IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0112-003
	ASSEMBLY INTEGRITY	BOLT TORQUE IS VERIFIED PER ASSEMBLY DRAWING REQUIREMENTS.	RS007501
		SUBASSEMBLY IS VERIFIED BOTTOMED PER SPECIFICATION REQUIREMENTS.	RL00351
	CUPWASHER		RS007667
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS	
	ASSEMBLY INTEGRITY	THE CUPWASHER DEFORMATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS007501
	BOLT, FIRST-STAGE AFT AND SECOND- STAGE PLATFORM SEAL SEAL ASSEMBLY		RS007668 RS007592
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS	
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS	RS007668 AMS-5731
	SURFACE FINISH	THE DRY-FILM LUBRICATION IS VERIFIED PER SPECIFICATION REQUIREMENTS	RA0112-003
	ASSEMBLY INTEGRITY	THE BOLT TORQUE IS VERIFIED PER ASSEMBLY DRAWING REQUIREMENTS	RS007501
	CUPWASHER		RS007523
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		CUPWASHER IS LOAD TESTED PER DRAWING REQUIREMENTS.	
		A PENETRANT INSPECTION IS PERFORMED AFTER LOAD TESTING PER SPECIFICATION REQUIREMENTS.	RA0115-116
	ASSEMBLY INTEGRITY	THE CUPWASHER DEFORMATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS007501
	BOLT, SECOND-STAGE AFT PLATFORM SEAL HOUSING		RS007595 RS007568
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		THE BOLT IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116

Component Group: Fuel Turbopumps
CIL Item: B200-06
Component: High Pressure Fuel Turbopump
Part Number: RS007501
Failure Mode: Platform seal leakage.

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 4/25/99
Change #: 1
Directive #: CCBD ME3-01-5206
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0160-014 RA0611-020
	SURFACE FINISH	THE DRY-FILM LUBRICANT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0112-003
	ASSEMBLY INTEGRITY	BOLT TORQUE IS VERIFIED PER ASSEMBLY DRAWING REQUIREMENTS.	RS007501
		SUBASSEMBLY IS VERIFIED BOTTOMED PER SPECIFICATION REQUIREMENTS.	RL00351
	CUPWASHER, SECOND-STAGE PLATFORM SEAL		RS007523
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		THE CUPWASHER IS LOAD TESTED PER DRAWING REQUIREMENTS	
		A PENETRANT INSPECTION IS PERFORMED AFTER LOAD TESTING PER SPECIFICATION REQUIREMENTS	RA0115-116
	ASSEMBLY INTEGRITY	THE CUPWASHER DEFORMATION IS VERIFIED PER DRAWING REQUIREMENTS.	RS007501
B, C	FORWARD ROTOR SEAL FIRST-STAGE ROTOR		RS007588
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-049
		THE FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS	RA0115-116 RA0115-012
		THE SEAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	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 RA0115-006 RA1115-001 RA0115-127
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	ASSEMBLY INTEGRITY	THE DIAMETRICAL CLEARANCE IS INSPECTED PER DRAWING REQUIREMENTS	RS007588 RS007501
	TURBINE BLADE PLATFORM HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS		

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
B, C	ASSEMBLY INTEGRITY HPFTP	TURBINE BLADE PLATFORM HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS	R0019821 RS007501
	ASSEMBLY INTEGRITY	THE SEAL IS BORESCOPE INSPECTED PRIOR TO EACH FLIGHT	OMRSD V41BU0.075
	AFT ROTOR SEAL FIRST-STAGE ROTOR		RS007591
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS	
		THE FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116 RA0115-012
		THE SEAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	ASSEMBLY INTEGRITY	THE DIAMETRICAL CLEARANCE IS INSPECTED PER DRAWING REQUIREMENTS.	RS007591 RS007501
		TURBINE BLADE PLATFORM HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS.	R0019821
	FORWARD ROTOR SEAL SECOND-STAGE ROTOR		RS007592
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS	
		DETAIL FORGINGS ARE PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116 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 RA0607-094 RA0115-116 RA0115-006 RA1115-001 RA0115-127

Component Group:	Fuel Turbopumps	Prepared:	D. Early
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
B C	ASSEMBLY INTEGRITY	THE DIAMETRICAL CLEARANCE IS INSPECTED PER DRAWING REQUIREMENTS.	RS007592 RS007501
		TURBINE BLADE PLATFORM HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS.	RS007520
	AFT ROTOR SEAL SECOND-STAGE ROTOR		RS007593
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-049
		FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116 RA0115-012
		THE SEAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	THE HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	COPPER PLATING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RA1109-002
	ASSEMBLY INTEGRITY	THE DIAMETRICAL CLEARANCE IS INSPECTED PER DRAWING REQUIREMENTS.	RS007593 RS007501
		TURBINE BLADE PLATFORM HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS.	RS007520
D	FIRST-STAGE BLADE SECOND-STAGE BLADE		R0019821 RS007520
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-236
		BLADES CAST SURFACES ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		BLADES MACHINED SURFACES ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA1615-022
	HPFTP		RS007501
	ASSEMBLY INTEGRITY	THE FIRST-STAGE BLADE PLATFORMS ARE BORESCOPE INSPECTED PRIOR TO EACH FLIGHT.	OMRSD V41BU0.075
ALL CAUSES	HPFTP		

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
ALL CAUSES	CLEANLINESS OF COMPONENTS	COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS.	RL10001
	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.	RL00528 RA0115-115
		OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E&M TESTS ON INSPECTIONS.	RL00050-04 RL00056-06 RL00056-07 RL00461
	DATA REVIEW	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 SA21/88/309 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			