SSME FMEA/CIL
REDUNDANCY SCREEN

Component Group: Fuel Turbopumps
CIL Item: B200-04
Component: High Pressure Fuel Turbopump
Part Number: RS007501
Failure Mode: Structural failure of turbine blades.

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

Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4.1	Leads to multiple blade failures resulting in immediate loss of turbine power and rotor unbalance. Rotor unbalance results in excessive vibration which would cause more rubbing and additional component failures. Extensive turbine damage from impact and over-temperature. Possible burst of pump inlet due to pressure surge. Loss of vehicle. Redundancy Screens: SINGLE POINT FAILURE: N/A.	1 ME-D1S,M ME-D1A,C

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Page:	1 of 6

Design / Document Reference

FAILURE CAUSE: A: Rotor blade cracks.

THERE ARE 83 FIRST-STAGE AND 59 SECOND-STAGE BLADES (1) WHICH CONVERT THE HOT-GAS FLOW ENERGY INTO SHAFT POWER THROUGH EXPANSION. THE BLADES ARE RADIALLY RETAINED IN THE DISKS (2) BY A 4 LOBE FIR-TREE. ACCEPTABLE BLADE FITUP AND EVEN LOAD SHARING IS ACHIEVED BY STRINGENTLY CONTROLLED BLADE AND DISK FIR-TREE TOLERANCES. FIRST STAGE BLADE FIT UP AND EVEN LOAD SHARING IS VERIFIED BY ASSEMBLY LEVEL TANGENTIAL BLADE TRAVEL CHECK (8). AXIAL RETENTION DURING OPERATION IS PROVIDED BY A LUG AT THE ROOT OF THE FIR-TREE ON THE UPSTREAM SIDE, WHICH IS BOTTOMED AGAINST THE DISK BY PRESSURE FORCES. AN EYELET AND BOWTIE ARE UTILIZED ON THE DOWNSTREAM SIDE AT THE ROOT OF THE FIR-TREE TO PROVIDE AXIAL RESTRAINT WHEN THE TURBOPUMP IS NOT OPERATING. THE BLADES INCORPORATE DAMPERS (2), WHICH FIT BETWEEN THE BLADES IN POCKETS MACHINED UNDER THE PLATFORMS. THE DAMPERS REDUCE THE ALTERNATING STRESSES EXPERIENCED BY THE BLADES DURING OPERATION. THE BLADES (1) ARE MANUFACTURED UTILIZING INVESTMENT CASTINGS. THE MATERIAL IS MAR-M-246 (HAFNIUM MOD) (4) AND IS DIRECTIONALLY SOLIDIFIED. MAR-M-246 (HI MOD) HAS EXCELLENT MECHANICAL PROPERTIES OVER THE OPERATING RANGE OF 110R TO 2070R. THIS ALLOY WAS ALSO 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. THE MATERIAL IS SOLUTION TREATED, AGE-HARDENED, AND STRESS RELIEVED. THE BLADES SHANKS ARE RECONTOURED TO REDUCE STRESS CONCENTRATIONS. THE SECOND-STAGE BLADE SHANK AND FIRST AND SECOND-STAGE FIR-TREES ARE SHOT-PEENED TO IMPROVE SURFACE PROPERTIES. THE BLADES AIRFOILS ARE COATED WITH NICRALY TO PROTECT THE BASE MATERIAL FROM THE THERMAL SHOCK EXPERIENCED DURING THE ENGINE START TRANSIENT. THE ENTIRE FIRST-STAGE BLADE SHANK AND THE DOWNSTREAM SIDE OF THE SECOND-STAGE BLADE SHANK HAVE A PROTECTIVE COATING APPLIED TO REDUCE THERMALLY INDUCED STRESSES. THE SURFACE FINISH ON THE SECOND-STAGE BLADE DOWNSTREAM FACE IS TIGHTLY CONTROLLED AND THE FIR-TREE CORNERS ARE RADIUSED TO REDUCE STRESS CONCENTRATIONS. ACCEPTABLE BLADE POROSITY IS TIGHTLY CONTROLLED TO PRECLUDE LOCAL STRESS RISERS. THE FIRST AND SECOND-STAGE TURBINE BLADE PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY RISK ASSESSMENT (5). THE BLADES HAVE BEEN DESIGN VERIFICATION TESTED FOR STRESS RUPTURE (6). THE BLADE DESIGN IS TOLERANT TO CRACKS IN CERTAIN LOCATIONS. CONTINUED USE WITH ALLOWABLE DISCREPANCIES RESULTING FROM OPERATION IS EVALUATED AND CONTROLLED PER THE REQUIREMENTS OF THE MAINTENANCE CONTROL DOCUMENT (7).

(1) R0019821, RS007520 (2) RS007517, RS007510; (3) R0019273 R0019203; (4) RSS-8580-10. (5) NASA TASK 117; (6) RSS-404-27; (7) RSS-8793; (8) RL00352

FAILURE CAUSE: B: Loss of blade damper(s).

THE DAMPERS (1) (2) ARE WIRE ELECTRO-DISCHARGE MACHINED FROM A BLOCK OF HAYNES 188 AND TUMBLE DE-BURRED. THE DAMPERS ARE RETAINED BY POCKETS MACHINED UNDER EACH OF THE BLADE PLATFORMS. THE DAMPER POCKET DIMENSIONS ARE CLOSELY TOLERANCED TO ASSURE DAMPER RETENTION. DESIGN ANALYSIS SHOWS STACK-UP TOLERANCES PRECLUDE THE DAMPERS FROM DISLODGING DURING OPERATION. A FINAL CHECK AT ASSEMBLY IS PERFORMED TO VERIFY DAMPER MOTION AND THAT THE DAMPER CANNOT BECOME DISLODGED (3). HAYNES 188 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 (4). THE MATERIAL IS ANNEALED TO IMPROVE PROPERTIES. THE LOSS OF ONE DAMPER ON ANY GIVEN PAIR OF BLADES DOES NOT HAVE SIGNIFICANT EFFECT ON BLADE HIGH CYCLE FATIGUE LIFE. THE FIRST AND SECOND-STAGE BLADE DAMPER PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS (5).

(1) R0019273; (2) R0019203; (3) RL00352. (4) RSS-8580-10; (5) NASA TASK 117

Design / Document Reference

FAILURE CAUSE: C: Excessive tip rubbing.
D: Tip seal failure.

THE FIRST-STAGE TIP SEALS (1) ARE MANUFACTURED UTILIZING A RENE 41 FORGING (2), WHICH WAS SELECTED FOR ITS TEMPERATURE AND STRENGTH PROPERTIES AND CORROSION RESISTANCE. HYDROGEN ENVIRONMENT EMBRITTLEMENT IS NOT A PROBLEM AS THE SEALS OPERATE WITHIN THE ELASTIC RANGE. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE SEAL RING CONSISTS OF 6 SEGMENTS. THE SEGMENTS ARE RETAINED ON THE UPSTREAM SIDE BY ENGAGEMENT WITH A GROOVE IN THE TURBINE MOUNT RING (3). EACH SEGMENT MATES WITH AN ANTI-ROTATION PIN IN THE GROOVE. THIRTEEN RETAINING LUGS ON THE MAIN HOUSING (4) RETAIN THE DOWNSTREAM LIP OF EACH SEGMENT. THE DOWNSTREAM LIP IS SLOTTED AND THE OUTSIDE DIAMETER OF THE TIP SEAL IS CHANNELED TO REDUCE THE OPERATIONAL LOADS AT THE RETAINING JOINTS. THE SEGMENTS ARE INSTALLED WITH A TANGENTIAL GAP WHICH PRECLUDES INTERFERENCE BETWEEN THE SEGMENTS DURING OPERATION. THE SEGMENTS ARE ECCENTRICALLY MACHINED TO ALLOW FOR ROTOR DEFLECTION FROM THE TURBINE TRANSVERSE DELTA PRESSURE GENERATED BY THE HOT-GAS MANIFOLD. THE SEALS ARE GROUND AT ASSEMBLY TO PROVIDE THE REQUIRED CLEARANCE WITH THE BLADE TIPS FOR EACH BUILD (5). LIGHT RUBBING OCCURS ONLY AT THE 12 O'CLOCK POSITION DURING THE START TRANSIENT. THE CONTACT DOES NOT AFFECT THE STRUCTURAL INTEGRITY OF THE BLADES OR TIP SEALS. THE FIRST AND SECOND-STAGE TIP SEALS PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS (6). THE SECOND-STAGE TIP SEALS (7) MANUFACTURING IS THE SAME AS THE FIRST-STAGE TIP SEALS EXCEPT A NICKEL RING IS BRAZED TO THE RENE 41 TO PROVIDE A SOFTER MATERIAL IN THE EVENT OF BLADE CONTACT. A FLOW DAM ON THE UPSTREAM SIDE SHIELDS THE BRAZE JOINT FROM DIRECT HOT-GAS IMPINGEMENT. THE SEAL RING CONSISTS OF 6 SEGMENTS. THE SEGMENTS ARE RETAINED ON THE UPSTREAM AND DOWNSTREAM SIDES BY ENGAGEMENT WITH GROOVES IN THE MAIN HOUSING (4). THE SECOND-STAGE NOZZLE PISTON RING (8) RESTRICTS AXIAL MOTION IN THESE GROOVES. EACH SEGMENT INCORPORATES AN ANTI-ROTATION PIN ON THE OUTSIDE DIAMETER WHICH ENGAGES WITH A SLOT IN THE MAIN HOUSING. THE SEGMENTS ARE INSTALLED WITH A TANGENTIAL GAP WHICH PRECLUDES INTERFERENCE BETWEEN THE SEGMENTS DURING OPERATION. EACH SEGMENT IS GROUND AT ASSEMBLY TO PROVIDE THE REQUIRED CLEARANCE WITH THE BLADE TIPS FOR EACH BUILD (5). LIGHT RUBBING OCCURS ONLY AT THE 12 O'CLOCK POSITION DURING THE START TRANSIENT. THE CONTACT DOES NOT AFFECT THE STRUCTURAL INTEGRITY OF THE BLADES OR TIP SEALS.

(1) RS007691, RS007501; (2) RSS-8560-10; (3) RS007598; (4) RS007577, RS007568; (5) RL000351; (6) NASA TASK 117, (7) RS007692, RS007501; (8) RS007672

FAILURE CAUSE: E: Housing pilot lip failure.

THE TURBINE MOUNT RING (1) AND TURBINE BEARING SUPPORT (2) ARE BOLTED TO THE MAIN HOUSING (3). THE HOUSING PILOT WITH THE TURBINE MOUNT RING CONTROLS THE CONCENTRICITY OF THE FIRST-STAGE TIP SEALS AND NOZZLE. THE HOUSING UTILIZES A DUAL PILOT CONFIGURATION, WHICH WAS DESIGNED TO REDUCE THE OPERATIONAL STRESSES. PILOTING OCCURS ON THE INNER PILOT AT ASSEMBLY AND ON THE OUTER PILOT AT ENGINE INSTALLATION AND DURING OPERATION. THE MAIN HOUSING IS MANUFACTURED UTILIZING INCONEL 718 (4). THIS MATERIAL HAS THE REQUIRED STRENGTH, CRYROGENIC DUCTILITY, RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING AND IS PROTECTED IN SELECTED LOCATIONS FROM HYDROGEN ENVIRONMENT EMBRITTLEMENT BY COPPER PLATING. THE TURBINE MOUNT RING AND TURBINE BEARING SUPPORT PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS (5).

(1) RS007598; (2) RS007524; (3) RS007577, RS007568; (4) RSS-8560-10; (5) NASA TASK 117

FAILURE CAUSE: F: Housing retaining lug failure.

THE HOUSING (1) LUGS RETAIN THE DOWNSTREAM LIP OF THE FIRST-STAGE TIP SEALS (2). THE LUGS ARE AN INTEGRAL PART OF AND MACHINED FROM THE SAME INCONEL 718 (3) FORGING AS THE MAIN HOUSING, TAKING ADVANTAGE OF THE SAME MATERIAL PROPERTIES LISTED IN FAILURE CAUSE "E". IN ADDITION, THE LUGS ARE COATED WITH NICRALY-OXIDE FOR THERMAL PROTECTION. THERE ARE 6 TIP SEAL SEGMENTS. THIRTEEN HOUSING LUGS HOLD EACH SEGMENT. THE DOWNSTREAM LIP OF THE TIP SEAL IS SLOTTED, AND THE OUTSIDE DIAMETER IS CHANNELED TO REDUCE THE STRESS ON THESE LUGS. THE HPFTP HOUSING PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY RISK ASSESSMENT (4).

(1) RS007577, RS007568; (2) RS007691, RS007501; (3) RSS-8560-10; (4) NASA TASK 117

Design / Document Reference

FAILURE CAUSE: G: Nozzle failure.

THE FIRST-STAGE TURBINE NOZZLE (1) IS MANUFACTURED UTILIZING AN INVESTMENT CASTING. THE MATERIAL IS MAR-M-246 (HF MOD) (2) WHICH HAS THE HIGHEST STATIC MECHANICAL PROPERTIES OF THE NICKEL BASE ALLOYS FROM ROOM TEMPERATURE TO 2800 R. THE ALLOY WAS ALSO 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. THE CASTING IS HOT ISOSTATIC PRESSED TO FURTHER IMPROVE MECHANICAL PROPERTIES. THE NOZZLE IS CAST WITH HOLLOW VANE CORES TO REDUCE THE THERMAL STRESSES DURING OPERATION. THE NOZZLE INCORPORATES 41 VANES WHICH PROVIDE THE AERODYNAMIC PASSAGE TO GUIDE AND ACCELERATE THE HOT-GAS FLOW TO THE FIRST-STAGE BLADES. THE OPERATIONAL TORQUE IS REACTED BY 41 LUGS ON THE NOZZLE OUTSIDE DIAMETER, WHICH ENGAGE WITH LUGS IN THE TURBINE MOUNT RING (3). FORTY-ONE LUGS ON THE INSIDE DIAMETER SERVE AS AN AXIAL STOP AT ASSEMBLY. THIRTEEN SCALLOPS IN THE OUTER SHROUD ALIGN WITH THE 13 STRUTS IN THE TURBINE BEARING SUPPORT TO REDUCE THE INDUCED OPERATIONAL LOADS AT THIS LOCATION. THE NOZZLE INNER SHROUD IS MACHINED TO ELIMINATE INTERFERENCE WITH THE INLET SHEET METAL, WHICH REDUCES THE OPERATIONAL LOADS AT THIS LOCATION. THE SECOND-STAGE TURBINE NOZZLE (4) MANUFACTURING IS THE SAME AS THE FIRST-STAGE EXCEPT THE NOZZLE INCORPORATES 39 VANES AND THE OPERATIONAL TORQUE IS REACTED BY 39 LUGS ON THE NOZZLE OUTSIDE DIAMETER WHICH ENGAGE WITH LUGS IN THE MAIN HOUSING (5). SIX LUGS ON THE INSIDE DIAMETER SERVE AS A RADIAL PILOT FOR THE TURBINE INTERSTAGE SEAL (6). LOW CYCLE FATIGUE CRACKING OF THE FIRST-STAGE AND SECOND-STAGE NOZZLE SHROUDS AND VANES DOES OCCUR DUE TO THE LARGE THERMAL SHOCK EXPERIENCED BY THE NOZZLE DURING ENGINE START AND SHUTDOWN. THE CRACKING IS CONTROLLED PER THE NOZZLE DAR (7) AND INSPECTION SPECIFICATION (8). REMOVAL OF THE NOZZLE FOR PERIODIC INSPECTION IS REQUIRED BY DAR (7). THE SPECIFICATION CRITERIA CONTROLS THE LENGTH, SPACING, AND LOCATION OF TIE CRACKS. THE SPECIFICATION CRITERIA IS BASED ON CRACK GROWTH RATE AND ENGINE TEST EXPERIENCE. CONTINUED USE WITH ALLOWABLE DISCREPANCIES RESULTING FROM OPERATION IS EVALUATED AND CONTROLLED PER THE REQUIREMENTS OF THE MAINTENANCE CONTROL DOCUMENT (9). THE HIGH CYCLE FATIGUE LIFE (10) AND MINIMUM FACTORS OF SAFETY MEET CEI REQUIREMENTS (11). THE FIRST AND SECOND-STAGE TURBINE NOZZLE PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY RISK ASSESSMENT (12).

(1) RS007503; (2) RSS-8580-10; (3) RS007598; (4) RS007552; (5) RS007577, RS007568; (6) RS007592; (7) DAR 1288; (8) RL00718; (9) RSS-8793. (10) RLC0532, CP320R0003B; (11) RSS-8546-16, CP320R0003B; (12) NASA TASK 117

FAILURE CAUSE: H: Impact from macroscopic contaminant.

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 IMPACT DAMAGE. EXPERIENCE WITH INGESTING FUEL PREBURNER LOX POST ALIGNMENT PINS AND THERMAL SHIELD NUTS DID NOT RESULT IN BLADE FAILURE. THE BLADES HAVE BEEN DESIGN VERIFICATION TESTED FOR STRESS RUPTURE (3).

(1) R0019821; (2) RSS-8580-10; (3) RSS-404-27

FAILURE CAUSE: I: Disk fir-tree yielding or fracture.

THE DISKS (1) ARE MANUFACTURED UTILIZING WASPALOY FORGINGS (2), AND CRITICAL AREAS ARE GOLD PLATED FOR HYDROGEN ENVIRONMENT EMBRITTLEMENT PROTECTION. THIS ALLOY WAS SELECTED FOR ITS STRENGTH AND DUCTILITY AT CRYOGENIC AND ELEVATED TEMPERATURES AND STRENGTH TO WEIGHT RATIO. THE MATERIAL IS THERMO-MECHANICALLY PROCESSED WHICH CONSISTS OF HOT-COLD WORK FOLLOWED BY A SOLUTION TREATMENT AND AGING TO IMPROVE HIGH TEMPERATURE MATERIAL PROPERTIES. THE GRAIN DIRECTION IS SPECIFIED BY DRAWING REQUIREMENTS TO ACHIEVE MAXIMUM MATERIAL PROPERTIES IN THE DIRECTION OF THE HIGHEST LOADS. EACH DISK IS INDIVIDUALLY SPUN AS PART OF THE MANUFACTURING PROCESS TO PRE-YIELD THE DISK AND VERIFY THE STRUCTURAL INTEGRITY. THE DISK FIR-TREES ARE BROACHED BEFORE AND AFTER GOLD PLATING TO ASSURE PROPER BLADE FIT-UP. THE TURBINE DISKS HAVE BEEN DESIGN VERIFICATION TESTED FOR PRIMARY STRESS, LOW CYCLE FATIGUE LIFE, AND VIBRATION CHARACTERISTICS (3). THE FIRST AND SECOND-STAGE DISKS PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY CRITICAL INITIAL FLAW SIZE DETECTABILITY (4)

(1) RS007517, RS007510; (2) RSS-8580-10; (3) RSS-404-34 RSS-404-9; (4) NASA TASK 117

Design / Document Reference

FAILURE CAUSE: J: Excessive rubbing of platform seals.

THE FIRST-STAGE FORWARD PLATFORM SEAL (1) IS BI METALLIC. THE INNER STRUCTURE IS MANUFACTURED UTILIZING A 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 THERMAL CHARACTERISTICS THAT PROVIDE THE REQUIRED 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, RESISTANCE TO CORROSION AND 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 LUBRICATION 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 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. THE CLEARANCE BETWEEN THE BLADES AND THE SEAL IS CONTROLLED TO MINIMIZE RUBBING WHILE REDUCING BYPASS LEAKAGE. LIGHT BLADE PLATFORM RUBBING ON THE UPPER AND LOWER LIP OF THE "FISHMOUTH" SEAL DOES OCCUR DUE TO THE CONTROLLED CLEARANCES REQUIRED TO MAINTAIN TURBINE EFFICIENCY. THE RUBBING IS MONITORED BY POST-TEST/FLIGHT BORESCOPE INSPECTIONS (8) AND CONTROLLED PER FIELD SPECIFICATION (9).

THE FIRST-STAGE AFT PLATFORM SEAL (10) 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 STREAM 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 (11) BY 12 A-286 CRES BOLTS (12) AND 321 CRES CUPWASHERS (13). 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 AND STRESS CORROSION CRACKING, AND INSENSITIVITY TO HYDROGEN ENVIRONMENT EMBRITTLEMENT (2). THE MATERIAL IS ANNEALED TO IMPROVE MECHANICAL PROPERTIES. THE CUPWASHERS ARE STAKED TO PREVENT BOLT ROTATION. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (6). DRY FILM LUBE 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 (11) IS MANUFACTURED UTILIZING A HAYNES 188 FORGING (2). 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 SEAL MINIMIZES PARASITIC HOT-GAS LEAKAGE THAT COULD DILUTE COOLANT EFFECTIVENESS OR REDUCE TURBINE EFFICIENCY. THE CLEARANCE BETWEEN THE BLADES AND THE SEAL IS CONTROLLED TO MINIMIZE RUBBING WHILE REDUCING BYPASS LEAKAGE.

THE SECOND-STAGE AFT PLATFORM SEAL (14) IS MANUFACTURED UTILIZING A RENE 41 FORGING, WHICH WAS SELECTED FOR ITS ELEVATED TEMPERATURE AND STRENGTH PROPERTIES, AND CORROSION RESISTANCE (2). THE MATERIAL IS SOLUTION TREATED AND AGE- HARDENED. IT 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. THE SEAL IS PILOTED AT ASSEMBLY ON THE OUTSIDE DIAMETER OF THE HUB LABYRINTH SEAL (15). PILOTING IN OPERATION IS PROVIDED BY 6 RADIAL TANGS WHICH ENGAGE SLOTS IN A RETAINER (16). A THIN CIRCULAR LIP ON THE PLATFORM SEAL ENGAGES A SLIGHTLY WIDER GROOVE IN THE RETAINER. THIS POSITIONING THE SEAL AXIALLY WHILE PERMITTING IT TO EXPAND AND CONTRACT FREELY UNDER ITS OWN ENVIRONMENT TO REDUCE ITS OPERATING STRESSES. THE RETAINER IS SECURED TO THE LIFT-OFF SEAL STACK BY 12 A-286 CRES BOLTS (17) AND 321 CRES CUPWASHERS (13). 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

Design / Document Reference

PRIOR TO ASSEMBLY TO INCREASE THEIR COMPRESSIVE STRENGTH. THE CUPWASHERS ARE STAKED 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 SEAL STACK IS ACHIEVED. THE CLEARANCE BETWEEN THE BLADES AND THE SEAL IS CONTROLLED TO MINIMIZE RUBBING WHILE REDUCING BYPASS LEAKAGE. 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).

(1) RS007588; (2) RSS-8580-10; (3) RS007524; (4) R0019815; (5) RS007667; (6) RL00351; (7) RES1192; (8) RL00050-04; (9) RF0001-053, OMRSD V41BU0.075; (10) RS007591; (11) RS007592; (12) RS007668; (13) RS007523; (14) RS007593; (15) RS007553, (16) RS007596; (17) RS007595; (18) NASA TASK 117

FAILURE CAUSE: ALL CAUSES

THE HIGH AND LOW CYCLE FATIGUE LIFE FOR THE DAMPERS, FIRST AND SECOND-STAGE TIP SEALS, HOUSING PILOT LIP, HOUSING RETAINING LUGS, AND THE FOUR PLATFORM SEALS MEET CEI REQUIREMENTS (1). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (2). THE FIRST AND SECOND STAGE BLADES ARE LIFE LIMITED BY MAJOR WAIVER (5). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH BY THE WELD ASSESSMENT (3). TABLE B200 I 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 (3). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (4).

(1) RL00532, CP320R0003B (2) RSS-8546-16, CP320R0003B; (3) RSS-8756; (4) RL00528; (5) DAR 2552

SSME FMEA/CIL
INSPECTION AND TEST

Component Group: Fuel Turbopumps
CIL Item: B200-04
Component: High Pressure Fuel Turbopump
Part Number: RS007501
Failure Mode: Structural failure of turbine blades.

Prepared: D. Early
Approved: T. Nguyen
Approval Date: 4/21/99
Change #: 4
Directive #: CCBD ME3-01-6206

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	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
		10 K CONFIGURATION BLADES ARE COMPUTED TOMOGRAPHY INSPECTED PER SPECIFICATION REQUIREMENTS.	RF0001-113
	HEAT TREAT	BLADE STRESS RELIEF IS VERIFIED PER SPECIFICATION REQUIREMENTS.	R0019821 RS007520 RA1611-008
	SURFACE FINISH	SURFACE BLEND OF THE BLADE IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RF0004-056
		PLASMA SPRAY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-244 RA1609-038
		GRIND RADII ARE INSPECTED PER DRAWING REQUIREMENTS.	R0019821 RS007520
		SHOT PEENING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1618-003
		AIRFOIL AND SHANKS ARE DEFRACTO INSPECTED PER DRAWING REQUIREMENTS	R0019821 RS007520
	ASSEMBLY INTEGRITY	FIR-TREE DIMENSIONS ARE INSPECTED PER DRAWING REQUIREMENTS.	R0019821 RS007520 RS007510 RS007517
	HPFTP		RS007501
	ASSEMBLY INTEGRITY	FIRST STAGE BLADE FITUP AND LOAD SHARING IS VERIFIED BY TANGENTIAL BLADE TRAVEL CHECK.	RL00352
		FIRST-STAGE TURBINE BLADES ARE BORESCOPE INSPECTED PRIOR TO EACH FLIGHT.	OMRSD V41BU0.075
		FIRST-STAGE TURBINE BLADE AIRFOIL LEADING EDGES ARE 22X INSPECTED AFTER ACCEPTANCE TESTING AND AFTER 10 STARTS WITH SUBSEQUENT INSPECTION AT 3 START INTERVALS THEREAFTER.	OMRSD V41BU0.079
		SECOND-STAGE TURBINE BLADES ARE BORESCOPE INSPECTED AT EACH TURBOPUMP REMOVAL.	OMRSD V41BU0.080
B	BLADE DAMPER FIRST-STAGE		R0019273
	BLADE DAMPER SECOND-STAGE		R0019203

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
B	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	R0019273 R0019203
	ASSEMBLY INTEGRITY	BLADE DAMPER POCKET DIMENSIONS ARE INSPECTED PER DRAWING REQUIREMENTS.	R0019821 RS007520
		DAMPER DIMENSIONS ARE INSPECTED PER DRAWING REQUIREMENTS.	R0019273 R0019203
		DAMPER RETENTION CHECK IS PERFORMED AT TURBOPUMP ASSEMBLY.	RL00352
	HPFTP		RS007501
	ASSEMBLY INTEGRITY	DAMPERS ARE BORESCOPE INSPECTED AT EACH TURBOPUMP REMOVAL	OMRSD V41BU0.080
C, D	TIP SEAL FIRST-STAGE TIP SEAL SECOND-STAGE		RS007691 RS007692
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		FIRST-STAGE SEALS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT-TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	BRAZE INTEGRITY	SECOND-STAGE TIP SEAL BRAZING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0107-010
		THE BRAZE FILLET ON SECOND STAGE TIP SEALS IS VERIFIED PER DRAWING REQUIREMENTS.	RS007692
		THE SECOND-STAGE TIP SEAL BRAZE JOINT ULTRASONIC INSPECTION IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0115-125
	ASSEMBLY INTEGRITY	FIRST-STAGE TIP SEAL ECCENTRICITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007501 RL00351
		TIP SEAL GRINDING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RL00351
		TIP SEAL CLEARANCE IS VERIFIED AT ASSEMBLY PER SPECIFICATION REQUIREMENTS	

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
C, D	ASSEMBLY INTEGRITY	TURBINE BLADE HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS.	R0019821 RS007520
	HPFTP		RS007501
	ASSEMBLY INTEGRITY	THE FIRST-STAGE TIP SEALS ARE BORESCOPE INSPECTED PRIOR TO EACH FLIGHT	OMRSD V41BU0.075
		THE SECOND-STAGE TIP SEALS ARE BORESCOPE INSPECTED AT EACH TURBOPUMP REMOVAL.	OMRSD V41BU0.080
		THE ROTATING ASSEMBLY BALANCE IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RL00352
E, F	HOUSING		RS007568
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS	
		FORGING IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS	RA0115-116 RA0115-012
		HOUSING IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS	RA0115-116
		MAGNETIC PARTICLE INSPECTION IS PERFORMED PER SPECIFICATION REQUIREMENTS.	RA0115-115
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	NICRALY OXIDE COATING IS VERIFIED PER DRAWING REQUIREMENTS.	RS007568
	ASSEMBLY INTEGRITY	PILOT LIP DIAMETERS ARE INSPECTED PER DRAWING REQUIREMENTS.	
G	NOZZLE 1ST-STAGE NOZZLE 2ND-STAGE		RS007503 RS007552
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-166

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
G	MATERIAL INTEGRITY	CASTING IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		CASTING IS HOT ISOSTATIC PRESSED PER SPECIFICATION REQUIREMENTS.	RL00314 RL00368
		HIDDEN SURFACES ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116 RL00314
		MACHINED SURFACES ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	ASSEMBLY INTEGRITY	SHROUD AND VANE SURFACES ARE INSPECTED PER SPECIFICATION REQUIREMENTS	RA0115-007
	HPFTP		RS007501
	ASSEMBLY INTEGRITY	THE FIRST-STAGE NOZZLE IS BORESCOPE INSPECTED PRIOR TO EACH FLIGHT.	OMRSD V41BU0.075
		THE SECOND-STAGE NOZZLE IS BORESCOPE INSPECTED AT EACH TURBOPUMP REMOVAL	OMRSD V41BU0.080
H	HPFTP		RS007501
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS	RB0170-236
	CLEANLINESS OF COMPONENTS	UPSTREAM COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS.	RL10001 RA0110-018
	HPFTP		RS007501
	ASSEMBLY INTEGRITY	FIRST-STAGE BLADES ARE BORESCOPE INSPECTED PRIOR TO EACH FLIGHT.	OMRSD V41BU0.075
		SECOND-STAGE TURBINE BLADES ARE BORESCOPE INSPECTED AT EACH TURBOPUMP REMOVAL.	OMRSD V41BU0.080
I	DISK ROTOR FIRST-STAGE DISK ROTOR SECOND-STAGE		RS007517 RS007510
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS	RB0170-182
		THE GRAIN DIRECTION IS VERIFIED PER DRAWING REQUIREMENTS.	RS007516
		TENSILE SPECIMEN TEST IS PERFORMED PER DRAWING REQUIREMENTS	RS007516
		THE SPIN TEST IS PERFORMED PER DRAWING REQUIREMENTS.	RS007517 RS007510
		THE DISK IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS BEFORE AND AFTER SPIN TEST	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-182
	SURFACE FINISH	THE GOLD PLATING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1109-009
		TURBINE END COMPONENTS ARE BORESCOPE INSPECTED FOR EVIDENCE OF LOSS OF GOLD PLATING PRIOR TO EACH FLIGHT	OMRSD V41BU0.075
	ASSEMBLY INTEGRITY	FIR-TREE BROACHING IS VERIFIED BEFORE AND AFTER GOLD PLATING PER DRAWING REQUIREMENTS.	RS007517 RS007510

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
J	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 RA0115-008 RA1115-001 RA0115-127
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS	RA0611-020
	ASSEMBLY INTEGRITY	FORWARD ROTOR SEAL/TURBINE BLADE INTERFACE DIAMETER IS VERIFIED PER DRAWING REQUIREMENTS.	RS007588 RS007501
		TURBINE BLADE PLATFORM HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS	R0019821
		BOLT TORQUE IS VERIFIED PER DRAWING REQUIREMENTS.	RS007501
		CUPWASHER DEFORMATION IS VERIFIED PER DRAWING REQUIREMENTS.	
	HPFTP		
	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	AFT ROTOR SEAL/TURBINE BLADE INTERFACE DIAMETER IS VERIFIED PER DRAWING REQUIREMENTS.	RS007591 RS007501
		TURBINE BLADE PLATFORM HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS.	R0019821
		BOLT TORQUE IS VERIFIED PER DRAWING REQUIREMENTS.	RS007501
		CUPWASHER DEFORMATION IS VERIFIED PER DRAWING REQUIREMENTS.	
	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

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
J	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
	ASSEMBLY INTEGRITY	FORWARD ROTOR SEAL/TURBINE BLADE INTERFACE DIAMETER IS VERIFIED PER DRAWING REQUIREMENTS.	RS007592 RS007501
		TURBINE BLADE PLATFORM HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS.	RS007520
		BOLT TORQUE IS VERIFIED PER DRAWING REQUIREMENTS.	RS007501
		CUPWASHER DEFORMATION IS VERIFIED PER DRAWING REQUIREMENTS	
	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 SPECIFICATION REQUIREMENTS.	RA1109-002
	ASSEMBLY INTEGRITY	AFT ROTOR SEAL/ROTOR INTERFACE DIAMETER IS VERIFIED PER DRAWING REQUIREMENTS.	RS007593 RS007501
		TURBINE BLADE PLATFORM HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS.	RS007520
		BOLT TORQUE IS VERIFIED PER DRAWING REQUIREMENTS.	RS007501
		CUPWASHER DEFORMATION IS VERIFIED PER DRAWING REQUIREMENTS.	
ALL CAUSES	HPFTP		RS007501
	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 RA0115-116
		OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS	RL00056-04 RL00056-06 RL00056-07 RL00461
		TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT FLOW.	OMRSD V41BS0.020
		DATA FROM THE PREVIOUS FLIGHT OR HOT FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE. (LAST TEST)	MSFC PLN 1228

Component Group:	Fuel Turbopumps
CIL Item:	B200-04
Component:	High Pressure Fuel Turbopump
Part Number:	RS007501
Failure Mode:	Structural failure of turbine blades.

Prepared:	D. Early
Approved:	T. Nguyen
Approval Date:	4/21/99
Change #:	4
Directive #:	CCBD ME3-01-5206
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Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference

Failure History: Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PRACA)
Reference NASA letter SA21/88/308 and Rocketdyne letter 88RC09781.

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			