

**SSME FMEA/CIL  
REDUNDANCY SCREEN**

Component Group: Fuel Turbopumps  
 CIL Item: B200-05  
 Component: High Pressure Fuel Turbopump  
 Part Number: RS007501  
 Failure Mode: Rotor lip seal leakage.

Prepared: D. Early  
 Approved: T. Nguyen  
 Approval Date: 4/21/99  
 Change #: 2  
 Directive #: CCBD ME3-01-5206  
 Page: 1 of 1

Phase	Failure / Effect Description	Critically Hazard Reference
S 4 1	<p>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.</p> <p>Redundancy Screens: TURBOPUMP SYSTEM - SENSOR SYSTEM; UNLIKE REDUNDANCY</p> <p>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.</p>	1R ME-D1S,M
M 4 1	<p>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.</p> <p>Redundancy Screens: TURBOPUMP SYSTEM - SENSOR SYSTEM; UNLIKE REDUNDANCY</p> <p>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.</p>	1R ME-D1S,M

SSME FMEA/CIL  
DESIGN

Component Group: Fuel Turbopumps  
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Page: 1 of 1

Design / Document Reference

**FAILURE CAUSE:** A: Seal fracture, distortion or rubbing.

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 8 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 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 P 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. THIS CONTACT DOES NOT AFFECT THE STRUCTURAL INTEGRITY OF THE BLADES OR TIP SEALS.

THE SECOND-STAGE TIP SEALS (6) 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 8 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 (7) 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. THIS CONTACT DOES NOT AFFECT THE STRUCTURAL INTEGRITY OF THE BLADES OR TIP SEALS.

THE HIGH AND LOW CYCLE FATIGUE LIFE FOR THE FIRST AND SECOND-STAGE TIP SEALS MEET CEI REQUIREMENTS (8). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (9). THE FIRST AND SECOND-STAGE TIP SEALS PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS AND FLAW GROWTH SINCE THEY CONTAIN NO FRACTURE CRITICAL PARTS (10). THE CONTROLLER SOFTWARE IS CONFIGURED TO DETECT AND RESPOND PROPERLY TO THE FAILURES IDENTIFIED AND COMMAND SAFE ENGINE STATE (11). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (12).

(1) RS007691, RS007501; (2) RSS-8580-10; (3) RS007598; (4) RS007577, RS007559; (5) RL00351; (6) RS007692, RS007501-065; (7) RS007672; (8) RL00632, CP320R0303B; (9) RSS-8546-16, CP320R003B; (10) NASA TASK 117; (11) CP406R0002 PT 1.3.2.3.5.3; (12) RL00528

**SSME FMEA/CIL  
INSPECTION AND TEST**

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 Page: 1 of 2

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
A	TIP SEAL FIRST-STAGE		RS007691
	TIP SEAL SECOND-STAGE		RS007692
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	
		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 IS VERIFIED PER DRAWING REQUIREMENTS	RS007692
		THE 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
		TURBINE BLADE HEIGHT IS INSPECTED PER DRAWING REQUIREMENTS.	R0019821 RS007520
		TIP SEAL CLEARANCE IS VERIFIED AT ASSEMBLY PER SPECIFICATION REQUIREMENTS.	RL00351
	CLEANLINESS OF COMPONENTS	COMPONENTS ARE VERIFIED CLEANED TO FUEL SERVICE PER SPECIFICATION REQUIREMENTS.	RL10001
	HPFTP		RS007501
	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 RAC115 116
	OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS.	RL00050-04 RL00056-06 RL00056-07 RL00461	
	TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT.	CMRSD V41BS0.020	
	THE FIRST-STAGE TIP SEALS ARE BORESCOPE INSPECTED PRIOR TO EACH FLIGHT.	CMRSD V41BU0.075	
	THE SECOND-STAGE TIP SEALS ARE BORESCOPE INSPECTED AT EACH TURBOPUMP REMOVAL.	RL00050-04 CMRSD V41BU0.080	
	DATA FROM THE PREVIOUS FLIGHT OR HOT FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE. (LAST TEST)	MSFC PLN 1228	

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Page: 2 of 2

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 Rocketdync letter 89RC09761		
Operational Use:	Not Applicable.		

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

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Page: 1 of 2

Base Line Rationale	Variance	Change Rationale	Variant Dash Number
1. B200-15 RS007502; CAUSE A, B200-24; RS007605; CAUSE A THE INNER AND OUTER BEARING RACES ARE EDDY CURRENT INSPECTED PER RL00743.	BEARING RACES RECEIVED FROM SUPPLIER SPLIT BALL BEARING INCORPORATED RECEIVED NO GENERAL EDDY CURRENT INSPECTION	GENERAL EDDY CURRENT INSPECTION OF RACES REPLACES TYPE IVC IN PENETRANT INSPECTION IN DETECTING SURFACE FLAWS USE AS IS RATIONALE: 1. RACES SUPPLIED BY SPLIT BALL BEARING INCORPORATED RECEIVED 10X VISUAL AND TYPE IVC PENETRANT INSPECTION INSTEAD OF GENERAL EDDY CURRENT INSPECTION. FLAW DETECTABILITY RELIABILITY LEVELS BETWEEN PENETRANT AND GENERAL EDDY CURRENT INSPECTIONS ARE 0.060 AND 0.057 RESPECTIVELY.	SEE DAR 2745 FOR VARIANT PART SERIAL NUMBERS.
2. B200-13 RS007527, RS007532, CAUSE A & B. B200-26; RS007532; CAUSE B. DIFFUSER HIDDEN SURFACES ARE PENETRANT INSPECTED PER RL00343.	SOME DIFFUSERS MAY NOT RECEIVE THE POST PROOF TEST HIDDEN SURFACE IIP PENETRANT INSPECTION	USE AS IS RATIONALE 1. IMPLEMENTATION OF HIDDEN SURFACE INSPECTION REQUIREMENT IS NOT A RESULT OF AN OBSERVED HARDWARE ANOMALY BUT AS A RESULT OF ROCKETDYNE'S STAND DOWN.	SEE DAR 2751 FOR VARIANT PART SERIAL NUMBERS
3 B200-14 CAUSE A, RS007568 B200-21 CAUSE B, RS007568 B200-26 CAUSE A, RS007568 WELD JOINTS RS007568 TABLE B200 HPFT FMEA/CIL WELD JOINTS RS007568 HOUSING CURRENT CONFIGURATION IS THE ONE (1) PIECE "113" CAP, USING FOUR (4) WELDS AND FOUR (4) WELD NUMBERS	SOME HOUSINGS (POSSIBLY TWO) MAY HAVE BEEN FABRICATED WITH THE TWO (2) PIECE "113" CAPS (THIS HAS AN EXTRA WELD: #13 AND THREE EXTRA WELD NUMBERS 13, 68 & 69)	TO REDUCE CONFUSION ON THE DRAWING AND ON THE MANUFACTURING FLOOR	SEE MCR 2524. SAME -113 DASH NUMBER.
4 B200-02; CAUSE A, RS007524 CAUSE B, RS007524; CAUSE C, RS007524	SOME TURBINE BEARING SUPPORTS (RS007524) ARE FABRICATED USING A WELDMENT OF HAYES 188 SHEET METAL INSTEAD OF THE EDM FORGING.	HIGH CYCLE FATIGUE INDUCED INLET SHEET METAL CRACKS DO OCCUR FROM THE OPERATIONAL ENVIRONMENT EXPERIENCED DURING ENGINE OPERATION. THE CRACKING IS CONTROLLED PER THE REQUIREMENTS OF THE SHEET METAL INSPECTION SPECIFICATION (RL00655) WHICH LIMITS THE CRACKING LENGTH, SPACING, AND SHAPE, TO PRECLUDE SHEET METAL PIECES FROM DISLODGING. THE CRITERIA IS BASED ON CRACK GROWTH RATES AND ENGINE TEST EXPERIENCE. ANY CRACKS, WHICH EXCEED THE SPECIFICATION LIMITS, ARE WELD REPAIRED (RF0001-007). THE TURBINE BEARING SUPPORT WITH WELDED SHEET METAL IS LIFE LIMITED BY MAJOR WAIVER DAR 2709.	RS007524-201 AND SUBS.

B-181

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Page: 2 of 2

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

**SSME FMEA/CIL  
WELD JOINTS**

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 Page: 1 of 3

B - 183

Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable		Comments
						HCF	LCF	
SHIELD	R0012171	1,24, 28-52	GTAW	II	X			
SHIELD	R0012171	26	GTAW	II				
LIFT-OFF SEAL	R0019230	1, 2	GTAW	II	X			
SHIELD	R0019788	25, 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	118	GTAW	I	X			
BEARING SUPPORT	RS007524	119, 121	EBW	I				
BEARING SUPPORT	RS007524	120	GTAW	II	X			
BEARING SUPPORT	RS007524	229-241	GTAW	II	X			
HOUSING	RS007568	75, 223, 228, 230, 298	GTAW	I	X	X	X	
HOUSING	RS007568	74	GTAW	I				
HOUSING	RS007568	48	EBW	I	X	X	X	
HOUSING	RS007568	43	GTAW	I	X			
HOUSING	RS007568	51	GTAW	II	X	X		
HOUSING	RS007568	52	GTAW	II	X			
HOUSING	RS007568	53	EBW	I				

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 Page: 2 of 3

B - 184

Component	Basic Part Number	Weld Number	Weld Type	Class	Root Side Not Access	Critical Initial Flaw Size Not Detectable		Comments
						HCF	LCF	
HOUSING	RS007568	56	EBW	II	X			
HOUSING	RS007568	56	GTAW	II	X			
HOUSING	RS007568	57, 324, 325	GTAW	II				
HOUSING	RS007568	58	GTAW	II	X	X	X	
HOUSING	RS007568	59	EBW	I				
HOUSING	RS007568	74, 229, 297	GTAW	I	X	X	X	
HOUSING	RS007568	76, 77	GTAW	I		X		
HOUSING	RS007568	78-89	GTAW	II	X			
HOUSING	RS007568	90-101	GTAW	II	X			
HOUSING	RS007568	102	GTAW	I	X			
HOUSING	RS007568	139	GTAW	II	X			
HOUSING	RS007568	140	GTAW	II	X			
HOUSING	RS007568	150, 154	GTAW	II	X			
HOUSING	RS007568	174-185	GTAW	II	X			
HOUSING	RS007568	191, 192, 195, 196, 245, 455, 456	GTAW	II	X	X		
HOUSING	RS007568	193, 194, 197-202, 204-207	GTAW	II		X		
HOUSING	RS007568	203, 217, 218, 234, 236	GTAW	II	X	X		
HOUSING	RS007568	212, 213	GTAW	II				
HOUSING	RS007568	214, 215	GTAW	II	X			
HOUSING	RS007568	222, 239	GTAW	I		X		
HOUSING	RS007568	224, 225	GTAW	I		X	X	
HOUSING	RS007568	226, 227	GTAW	I		X		
HOUSING	RS007568	231, 232	GTAW	II	X	X		
HOUSING	RS007568	233	GTAW	II	X			
HOUSING	RS007568	237, 238	GTAW	II				
HOUSING	RS007568	246-248	GTAW	II				
HOUSING	RS007568	326-349	GTAW	II	X			
HOUSING	RS007568	374-397	GTAW	II	X			
HOUSING	RS007568	399	GTAW	I	X	X	X	