

**SSME FMEA/CIL  
REDUNDANCY SCREEN**

Component Group: Fuel Turbopumps  
 CIL Item: B100-03  
 Component: High Pressure Fuel Turbopump  
 Part Number: RS007501  
 Failure Mode: Turbine bearing support bellows failure.

Prepared: D. Early  
 Approved: T. Nguyen  
 Approval Date: 4/21/99  
 Change #: 1  
 Directive #: CCBO ME3-01-5208  
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Phase	Failure / Effect Description	Criticality Hazard Reference
SMC 4.1	Bellows failure would allow rapid hot-gas leakage from the turbine inlet to the discharge. The resulting power loss would result in extensive turbine damage from over-temperature and impact. Possible burst of pump inlet due to pressure surge. Loss of vehicle.  Redundancy Screens: SINGLE POINT FAILURE: N/A	1 ME-01S,M, ME-01A,C

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DESIGN

Component Group: Fuel Turbopumps  
CIL Item: B200-03  
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Design / Document Reference

**FAILURE CAUSE:** A: Parent metal or weld failure.

THE TURBINE BEARING SUPPORT BELLOW (1) SEPARATES THE FUEL PREBURNER COMBUSTION GASES FROM THE TURBINE EXHAUST GASES. THE TURBOPUMP IS INSTALLED IN THE ENGINE WITH A PRELOAD ON THE BELLOW TO SEAT THE STATIC SEAL AT THE PREBURNER/BELLOW INTERFACE. THE AMOUNT OF PRELOAD IS CONTROLLED BY DRAWING REQUIREMENTS. THE BELLOW IS A MULTI-COINVOLUTED TYPE BELLOW, ROLL FORGED FROM 4 PLIES OF INCOLOY 903 SHEET METAL (2). INCOLOY 903 IS AN IRON BASE ALLOY WHICH WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT, CORROSION RESISTANCE AND RESISTANCE TO STRESS CORROSION CRACKING. GRAIN DIRECTION OF THE MATERIAL IS REQUIRED TO BE IN THE DIRECTION CIRCUMFERENTIAL TO THE BELLOW AXIS TO ACHIEVE MAXIMUM MATERIAL PROPERTIES IN THE DIRECTION OF THE HIGHEST LOADS. THE MATERIAL IS SOLUTION TREATED AND AGE-HARDENED. THE BELLOW IS COOLED DURING OPERATION ON BOTH SIDES BY HYDROGEN GAS, TO MAINTAIN MATERIAL PROPERTIES. THE TURBINE BELLOW MEETS THE HIGH AND LOW CYCLE FATIGUE LIFE CEI REQUIREMENTS (3). THE MINIMUM FACTORS OF SAFETY FOR THE BELLOW/BEARING SUPPORT MEET CEI REQUIREMENTS (4). THE TURBINE BELLOW PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/IDE FLAW GROWTH SINCE IT CONTAINS NO FRACTURE CRITICAL PARTS (5). THE FMEA/CIL WELDS ARE CLEARED FOR FRACTURE MECHANICS/IDE FLAW GROWTH BY THE WELD ASSESSMENT (6). 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 (6). THE TURBINE BEARING SUPPORT HAS BEEN DESIGN VERIFICATION TESTED FOR LOW CYCLE FATIGUE AND FACTOR OF SAFETY ON BURST (7). REUSE OF PARTS DURING OVERHAUL IS CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (8).

(1) RS007524, RS007505; (2) RSS-8560-10; (3) RL00532, CP320R0003B; (4) RSS-8546-16 CP320R0003B; (5) NASA TASK 117; (6) RSS-8766; (7) RSS-404-45; (8) RL00528

**SSME FMEA/CIL  
INSPECTION AND TEST**

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Failure Causes	Significant Characteristics	Inspection(s) / Tests	Document Reference
A	BELLOWS		RS007505
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-186 RB0170-196
		BELLOWS IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA1610-044
		THE BELLOWS IS INSPECTED TO VERIFIED PLY GRAIN DIRECTION PER DRAWING REQUIREMENTS	RS007505
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1611-002
	ASSEMBLY INTEGRITY	THE BELLOWS IS INSPECTED TO VERIFY ANGULARITY, SPRING RATE, AND SURFACE IRREGULARITY PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007505 RL00078
	CLEANLINESS OF COMPONENTS	THE INTERPLY CLEAN INESS IS INSPECTED TO SPECIFICATION REQUIREMENTS	RA1610-044
	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 RA1607-079 RA0115-116 RA0115-006 RA1115-001 RA0115-127
	ACCEPTANCE TEST	THE BELLOWS QUALIFICATION AND ACCEPTANCE TESTING IS PERFORMED PER SPECIFICATION REQUIREMENTS. ACCEPTANCE TESTS ON EACH UNIT INCLUDE: - DIMENSIONAL INSPECTION. - SPRING RATE TEST - PROOF TEST - LEAK TEST.	RL00190 RL00190 RL00190 RL00190
	HPF IP		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.  OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT-FIRE TESTING AND 2ND E & M TESTS ON INSPECTIONS.  A BELLOWS HEIGHT VERIFICATION IS PERFORMED DURING PUMP INSTALLATION.  DATA FROM PREVIOUS FLIGHT OR HOT-FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE (LAST TEST)	RL00528 RA0115-116  RLD0050-04 RLD0056-06 RLD0056-07 RLD0461  OMRSD V41BU0.067 MSFC PLN 1228

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Component: Fuel Turbopumps  
CIL Item: B200-03  
Component: High Pressure Fuel Turbopump  
Part Number: R5007501  
Failure Mode: Turbine bearing support bellows failure.

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Approved: T. Nguyen  
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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 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  
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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.

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Component Group: Fuel Turbopumps  
 Item Name: High Pressure Fuel Turbopump  
 Item Number: B200  
 Part Number: RS007501

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

**SSME FMEA/CIL  
WELD JOINTS**

Component Group: Fuel Turbopumps  
 CIL Item: B200  
 Component: High Pressure Fuel Turbopump  
 Part Number: RS007501

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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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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	