

1) CIL ITEM : B400-05
 2) FMEA CODE : B400
 3) COMPONENT : HPOTP
 4) PART NUMBER : RS007701
 5) SYSTEM/SUBSYSTEM : PUMPS/BXMX
 6) FAILURE MODE : TURBINE INTERSTAGE SEAL LEAKAGE

7) PREPARED : SSME RELIABILITY
 8) APPROVED :
 9) DATE : 06-01-95
 10) REVISION/CHANGE : -002/0
 11) EFFECTIVITY : -761
 12) HAZARD REFERENCE : SEE LISTINGS BELOW
 13) CCB # : MK-37-3275

PHASE	FAILURE DESCRIPTION/EFFECT	CRITICALITY
S	<p>INTERSTAGE SEAL LEAKAGE REDUCES TURBINE POWER OUTPUT, RESULTING IN REDUCED PUMP SPEED, FLOW, AND DISCHARGE PRESSURE. REDUCED TURBOPUMP OUTPUT RESULTS IN REDUCED ENGINE THRUST. THIS IS SENSED BY THE CONTROLLER, WHICH INCREASES OXIDIZER PREBURNER FLOW. EXCESS TURBINE DISCHARGE TEMPERATURE WILL CAUSE REDLINE SHUTDOWN. MISSION SCRUB IF DETECTED BY REDLINE. LOSS OF VEHICLE DUE TO HPOTP TURBINE OR HEAT EXCHANGER 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 ITEM IS DETECTABLE DURING FLIGHT. C: PASS. LOSS OF REDUNDANT HARDWARE ITEMS COULD NOT RESULT FROM A SINGLE CREDIBLE EVENT.</p>	<p>1R HAZARD REF: HE-C15,N.</p>
M	<p>INTERSTAGE SEAL LEAKAGE REDUCES TURBINE POWER OUTPUT, RESULTING IN REDUCED PUMP SPEED, FLOW, AND DISCHARGE PRESSURE. REDUCED TURBOPUMP OUTPUT RESULTS IN REDUCED ENGINE THRUST. THIS IS SENSED BY THE CONTROLLER, WHICH INCREASES OXIDIZER PREBURNER FLOW. EXCESS TURBINE DISCHARGE TEMPERATURE WILL CAUSE REDLINE SHUTDOWN. MISSION ABORT IF DETECTED BY REDLINE. LOSS OF VEHICLE DUE TO HPOTP TURBINE OR HEAT EXCHANGER 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 ITEM IS DETECTABLE DURING FLIGHT. C: PASS. LOSS OF REDUNDANT HARDWARE ITEMS COULD NOT RESULT FROM A SINGLE CREDIBLE EVENT.</p>	<p>1R HAZARD REF: HE-C15,N.</p>

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CIL ITEM: 8400-05	DESIGN	DOCUMENT REF.
	<p>FAILURE CAUSE A: INTERSTAGE SEAL DAMAGE DUE TO RUBBING OR CONTAMINATION.</p> <p>THE INTERSTAGE SEAL MINIMIZES BYPASS LEAKAGE BETWEEN THE FIRST-STAGE AND SECOND-STAGE TURBINE. THE SEAL DESIGN IS COMPRISED OF TWO ELEMENTS; A ROTATING INTERSTAGE SEAL RING (1) AND A STATIONARY SEAL SUBASSEMBLY WHICH IS PART OF THE SECOND-STAGE NOZZLE ASSEMBLY (2). THE INTERSTAGE SEAL RING IS MANUFACTURED UTILIZING AN INCOLOY 903 FORGING. INCOLOY 903 IS AN IRON BASE ALLOY WHICH WAS SELECTED FOR ITS TENSILE STRENGTH AND RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AND STRESS CORROSION CRACKING (3). THE ALLOY IS THERMO-MECHANICALLY PROCESSED FOR IMPROVED HIGH TEMPERATURE STRESS RUPTURE DUCTILITY (3), SOLUTION HEAT TREATED, AND AGE-HARDENED (1). THE INTERSTAGE SEAL RING IS PILOTTED BY THE FIRST-STAGE DISC (4) AND SHAFT ASSEMBLY (5). TANGENTIAL RETENTION IS PROVIDED BY FOUR TANGS ON THE INNER DIAMETER OF THE RING (1), WHICH ENGAGES WITH SLOTS ON THE SHAFT CURVIC. THE RING INCORPORATES FOUR VENT HOLES AT THE UPSTREAM LOCATION, WHICH PRESSURIZES THE INTERNAL CAVITY ESTABLISHED BETWEEN THE DISC, SHAFT, AND INTERSTAGE SEAL RING. THIS FEATURE REDUCES THE PRESSURE DIFFERENTIAL ACROSS THE SEAL RING WHILE ENHANCING THE RADIAL PILOT FIT AT THE DOWNSTREAM SHAFT INTERFACE. THE STATIONARY SEAL SUBASSEMBLY CONTAINS A SEAL AND RETAINER ELEMENT. THE SEAL IS MANUFACTURED UTILIZING INCONEL 625, WHICH WAS SELECTED FOR ITS STRENGTH AT ELEVATED TEMPERATURES, FABRICABILITY, AND BRAZEABILITY (3). THE ALLOY IS ANNEALED, FORMED INTO HONEYCOMB CELLS, AND BRAZED (2) ONTO THE RETAINER. ALTHOUGH INCONEL 625 IS AFFECTED BY HIGH PRESSURE HYDROGEN, PROTECTION IS NOT REQUIRED DUE TO THE LOW OPERATIONAL STRAINS (3). THE RETAINER IS MANUFACTURED UTILIZING ANNEALED HAYNES 188, WHICH WAS SELECTED FOR ITS STRENGTH AT ELEVATED TEMPERATURES, CORROSION RESISTANCE, AND RESISTANCE TO DEGRADATION IN A HIGH PRESSURE GASEOUS HYDROGEN ENVIRONMENT (3). THE RETAINER, WITH THE ATTACHED SEAL, IS SECURED TO THE SECOND-STAGE NOZZLE ASSEMBLY BY 8 RIVETS (2). THE HONEYCOMB CELLS ARE DESIGNED TO ACCEPT CONTACT FROM THE INTERSTAGE SEAL RING. DRAWING DIMENSIONAL REQUIREMENTS ENSURE SEALING CONTROL BETWEEN THE TWO TURBINE STAGES. ENGINE DRYING AND PURGING REQUIREMENTS PRECLUDES THE FORMATION OF ICE CONTAMINATION. THE INTERSTAGE SEAL RING MEETS CE1 REQUIREMENTS FOR HIGH CYCLE AND LOW CYCLE FATIGUE LIFE (6). THE SECOND-STAGE NOZZLE MEETS CE1 REQUIREMENTS FOR HIGH CYCLE FATIGUE LIFE (6), BUT IS LOW CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (7). THE MINIMUM FACTORS OF SAFETY FOR THE INTERSTAGE SEAL RING AND THE SECOND-STAGE NOZZLE MEET CE1 REQUIREMENTS (8). THE HARDWARE PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NOE FLAW GROWTH SINCE IT IS NOT A FRACTURE CRITICAL PART, EXCEPT FOR THE SECOND-STAGE NOZZLE WHICH WAS CLEARED BY RISK ASSESSMENT (9). THE CONTROLLER SOFTWARE IS CONFIGURED TO DETECT AND RESPOND TO THE FAILURES IDENTIFIED AND COMMAND A SAFE ENGINE STATE (10). REUSE OF PARTS DURING OVERHAUL ARE CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (11).</p>	<p>(1) RS007957 (2) R0016027, RS007752 (3) RSS-8578-11 (4) RS007705 (5) RS007703 (6) AL00532, CP320RD003B (7) DAR 2947 (8) RSS-8546-16, CP320RD003B (9) NASA TASK 117 (10) CP406RD008 3.2.3:5.2 (11) RL00874</p>

CIL ITEM: B400-05		INSPECTION AND TEST	
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
FAILURE CAUSE A:	RS007957 - INTERSTAGE SEAL RING		RS007957
	RS007752 - SECOND-STAGE NOZZLE		RS007752
	RO016027 - NOZZLE ASSEMBLY		RO016027
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007752 RO016027 RO0170-197
		SEAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		NOZZLE IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		NOZZLE IS ULTRASONICALLY INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-012
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	MA0611-020
	BRAZE INTEGRITY	HONEYCOMB BRAZING IS INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0107-010
	ASSEMBLY INTEGRITY	SEAL DIMENSIONS ARE INSPECTED AT ASSEMBLY PER SPECIFICATION REQUIREMENTS.	RL000814
	ROTATING DETAILS ARE BALANCED AS A UNIT PER SPECIFICATION REQUIREMENTS.	RL000816	
	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.	RL000874 MA0115-116	
	OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT FIRE TESTING AND 2ND E & W INSPECTIONS.	RL00050-04 RL00056-06 RL00056-07 RL00461	
	TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41090.040	

CIL ITEM: B400-05		INSPECTION AND TEST	
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
		DATA FROM PREVIOUS FLIGHT OR HOT FIRE IS REVIEWED FOR PROPER TURBOPUMP OPERATION/PERFORMANCE. (LAST TEST)	MSFC PLM 1228
<p>FAILURE HISTORY: COMPREHENSIVE FAILURE HISTORY DATA IS MAINTAINED IN THE PROBLEM REPORTING DATABASE (PRANS/PRACA). REFERENCE: NASA LETTER 5A21/88/30B AND ROCKETDYNE LETTER 88RC09761.</p>			

OPERATIONAL USE: NOT APPLICABLE.

TABLE 8400. HIGH PRESSURE OXIDIZER TURBOPUMP
FREA/CIL WELD JOINTS

COMPONENT	BASIC PART NO.	WELD NO.	WELD TYPE	CLASS	ROOT SIDE NOT ACCESS	CRITICAL INITIAL		COMMENTS
						FLAW SIZE NOT HCF	DETECTABLE LCF	
MAIN HOUSING	RS007729	1,2	EBW	I	X	X		
MAIN HOUSING	RS007729	3	EBW	I		X		
MAIN HOUSING	RS007729	9,10	GTAW	II	X	X	X	
MAIN HOUSING	RS007729	11,12	GTAW	I		X		
MAIN HOUSING	RS007729	13	EBW	I	X	X		
MAIN HOUSING	RS007729	14-17,16	GTAW	II	X			
MAIN HOUSING	RS007729	18,19	GTAW	II	X	I	X	
MAIN HOUSING	RS007729	21,23	GTAW	II	X			
MAIN HOUSING	RS007729	22,24	GTAW	II	X			
MAIN HOUSING	RS007729	44,53-59	GTAW	I	X			
MAIN HOUSING	RS007729	45	GTAW	I	X			
MAIN HOUSING	RS007729	48	GTAW	I	X	X		X
MAIN HOUSING	RS007729	49	GTAW	I	X			
MAIN HOUSING	RS007729	50	GTAW	I				
MAIN HOUSING	RS007729	51,52	GTAW	I	X			
MAIN HOUSING	RS007729	54	GTAW	I	X			
MAIN HOUSING	RS007729	55,56	GTAW	I	X			
MAIN HOUSING	RS007729	61	GTAW	I				
MAIN HOUSING	RS007729	62	GTAW	I	X			
MAIN HOUSING	RS007729	63	GTAW	I				
MAIN HOUSING	RS007729	64	GTAW	I	X	X		
MAIN HOUSING	RS007729	65	GTAW	I	X			
MAIN HOUSING	RS007729	66-70	GTAW	II	X			
INLET HOUSING	RS007732	4	GTAW	I			I	
INLET HOUSING	RS007732	8,9	GTAW	I			I	
VOLUTE	RS007732	10,15	GTAW	I	X	I		
VOLUTE	RS007732	20,21	GTAW	I				
VOLUTE	RS007732	22,23	GTAW	I				
VOLUTE	RS007732	24,27	GTAW	I		X		X
VOLUTE	RS007732	25,26	GTAW	I				
FLANGE	RS007736	1,2	GTAW	II	X			
FLANGE	RS007736	3,26	GTAW	II	X			

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TABLE 1400. HIGH PRESSURE OXIDIZER TURBOPUMP
FREA/CIL WELD JOINTS

COMPONENT	BASIC PART NO.	WELD NO.	WELD TYPE	CLASS	ROOT	CRITICAL INITIAL		COMMENTS
					SIDE NOT ACCESS	FLAW SIZE NOT HCF	DETECTABLE LCF	
FLANGE	RS007736	6,7	GTAW	II	X			
FLANGE	RS007736	9-12,17	GTAW	II	X			
FLANGE	RS007736	13-16	GTAW	II	X			
FLANGE	RS007736	18,20	GTAW	I	X			
FLANGE	RS007736	19,21	GTAW	II	X			
FLANGE	RS007736	22	EBW	I	X			
FLANGE	RS007736	23	GTAW	II				
FLANGE	RS007736	24	GTAW	II	X			
FLANGE	RS007736	26	GTAW	II	X			
BELLOWS	RS007740	1,2,5,9	GTAW	I		X		
BELLOWS	RS007740	3,4	EBW	I				
HOUSING	RS007746	1,2	GTAW	I	X		X	
HOUSING	RS007746	3	GTAW	I	X			
HOUSING	RS007746	4	GTAW	II	X			
HOUSING	RS007746	5	GTAW	II	X		X	
HOUSING	RS007746	6-17	GTAW	II	X		X	
HOUSING	RS007746	18-29	GTAW	II	X		X	
HOUSING	RS007746	30-41	GTAW	II		X		X
BELLOWS	RS007748	1	EBW	I				
BELLOWS	RS007748	2	GTAW	I	X			
BELLOWS	RS007749	1-4	GTAW	I				
BELLOWS	RS007749	5,6	EBW	I				
BELLOWS	RS007749	11	EBW	I				
BELLOWS	RS007749	12	EBW	I				
BELLOWS	RS007751	3	EBW	I	X			
BELLOWS	RS007751	4	EBW	I	X	X		X
BELLOWS	RS007751	8	GTAW	I	X	X		
SECOND STAGE NOZZLE	RS007752	1,2	EBW	I	X			
SECOND STAGE NOZZLE	RS007752	1	GTAW	I	X	X		X
JET RING	RS007757	1	GTAW	I	X	X		X
FAIRING	RS007774	1-12	GTAW	I		X		
FAIRING	RS007774	13-24	GTAW	I		X		

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TABLE B100. HIGH PRESSURE OXIDIZER TURBOPUMP
FMEAS/CIL WELD JOINTS

COMPONENT	BASIC PART NO.	WELD NO.	WELD TYPE	CLASS	ROOT	CRITICAL INITIAL		COMMENTS
					SIDE NOT ACCESS	FLAW SIZE NOT DEFECTABLE	NOT DEFECTABLE	
						KEF	LCF	
FAIRING	RS007774	25-36	BTAW	I				X
FAIRING	RS007774	74	BTAW	I				
FAIRING	RS007774	75,76	BTAW	II	X			
STRUT	RS007779	23-44, 143-164	BTAW	II	X			
STRUT	RS007779	45-66, 165-186	BTAW	II	X			
STRUT	RS007779	67	BTAW	II	X			
STRUT	RS007779	69,70	EDW	II	X			
STRUT	RS007779	71	EDW	II				
STRUT	RS007779	72	EDW	II				
STRUT	RS007779	73-94	EDW	II				
STRUT	RS007779	95,96	EDW	II	X			
SHIELD	RS007781	1,11	BTAW	II				
SHIELD	RS007781	2,3,4	BTAW	II				
SEAL	RS006848	1 PLC	BTAW	I				
SEAL	RS006857	1 PLC	BTAW	I		X	X	

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FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

CIL ITEMS: B400-XN	HPOIP		P/N RS007791
BASE LINE RATIONALE	VARIANCE	CHANGE RATIONALE	VARIANT DASH NUMBER
<p>1. B400-02, B400-03 SECOND STAGE NOZZLE CASTING IS NOT ISOSTATIC PRESSED PER DRAWING REQUIREMENTS. (ECP 1A-2949)</p>	<p>SECOND STAGE NOZZLE CASTINGS HAVE NOT BEEN HOT ISOSTATIC PRESSED</p>	<p>NOT ISOSTATIC PRESS INCREASES STRUCTURAL INTEGRITY BY REDUCING CASTING MICROPOROSITY.</p> <p>USE AS IS RATIONALE:</p> <ol style="list-style-type: none"> 1. LIFE LIMIT ON NON HOT ISOSTATIC PRESSED 2ND STAGE NOZZLES REDUCES PROBABILITY OF LOW CYCLE FATIGUE CRACKING RESULTING FROM EXCESSIVE MICROPOROSITY. (DAR 2147) 2. A PENETRANT INSPECTION INTERVAL HAS BEEN IMPOSED ON NON HOT ISOSTATIC PRESSED 2ND STAGE NOZZLES TO VERIFY NO CRACKING IN EXCESS OF ALLOWABLE LIMITS. (DAR 2147) 	<p>-121, -131, -141, -151, -161, -171, -181, -191, -201, -211, -221, -231, -241, -251, -261, -271, -291, -301, -311, -351, -351, -371, -401</p>
<p>2. B400-13, B400-22 PROCESSED AND INSPECTED PER SPECIFICATION REQUIREMENTS (RL00916). (ECP 909)</p>	<p>BEARINGS ARE PROCESSED AND INSPECTED PER SPECIFICATION REQUIREMENTS (RL00558).</p>	<p>LONG TERM FATIGUE LIFE OF BEARING IS EXTENDED BY REDUCING THE ALLOWABLE SIZE AND QUANTITY OF ALLOWABLE DEFECTS.</p> <p>USE AS IS RATIONALE:</p> <ol style="list-style-type: none"> 1. WEAR LIFE LIMIT ON BEARINGS PREVENTS WEAR FROM EXCEEDING ALLOWABLE LIMITS. (DAR 2054, DAR 2082) 2. CONTINUED USE WITH ALLOWABLE DISCREPANCIES IS CONTROLLED PER THE MAINTENANCE CONTROL DOCUMENT REQUIREMENTS (RSS-8793). 	<p>-121, -131, -141, -151, -161, -171, -181, -191, -201, -211, -221, -231, -241, -251, -261, -271, -291, -301, -311, -331, -351, -371, -401, -411, -421, -431, -441, -451, -461</p>

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