1) CIL ITEM : 6400-01
2) FMEA CODE : 6400
3) COMPONENT : HPOTP
4) PART NUMBER : RS007701
5) SYSTEM/SUBSYSTEM : PUMPS/BXXX
6) FAILURE MODE : LEAKAGE PAST THE OUTBOARD OPB/HPOTP PRESSURE-ASSISTED SEAL

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) CCBD #: : M63-01-3275

PHASE	FAILURE DESCRIPTION/EFFECT	CRITICALITY
S	TURBINE INLET FLOW LOSS REDUCES TURBINE POWER OUTPUT, RESULTING IN LOSS OF ENGINE THRUST. THIS IS SENSED BY THE CONTROLLER WHICH INCREASES OPOV FLOW. CONTINUED LOSS OF THRUST WILL CAUSE A OPOV COMMAND LIMIT VIOLATION OR AN EXCESSIVE HPOTP TURBINE DISCHARGE TEMPERATURE CAUSING AN ENGINE REDLINE SHUTDOWN. MISSION SCRUB IF DETECTED BY REDLINE, LOSS OF VEHICLE DUE TO HPOTP TURBINE OR HEAT EXCHANGER 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 ITEM IS DETECTABLE DURING FLIGHT. C: PASS. LOSS OF REDUNDANT HARDWARE ITEMS COULD NOT RESULT FROM A SINGLE CREDIBLE EVENT.	1R HAZARD REF: ME-C1S,M.
SM	COOLANT LEAKAGE IMPINGING ON ONE OR BOTH TURBINE DISCHARGE SENSORS WILL RESULT IN ERRONEOUSLY LOW INDICATED TEMPERATURE(S) AND LOSS OF REDLINE PROTECTION. TURBINE INLET FLOW LOSSES RESULT IN REDUCED TURBOPUMP OUTPUT. THIS IS SENSED BY THE CONTROLLER, INCREASING PREBURNER OXIDIZER FLOW AND TURBINE TEMPERATURES. EXCESSIVE TURBINE TEMPERATURES RESULT IN HEAT EXCHANGER OR TURBINE BLADE FAILURE. LOSS OF VEHICLE. REDUNDANCY SCREENS: SINGLE POINT FAILURE: N/A ---	1 HAZARD REF: ME-C1S,M.
N	TURBINE INLET FLOW LOSS REDUCES TURBINE POWER OUTPUT, RESULTING IN LOSS OF ENGINE THRUST. THIS IS SENSED BY THE CONTROLLER, WHICH INCREASES OXIDIZER PREBURNER FLOW. FAILURE CONFINUATION CAUSES EXCESS HPOTP TURBINE DISCHARGE TEMPERATURE OR OPOV OPENS TO COMMAND LIMIT AND MCC Pc DECREASES VIOLATING MCC Pc LOW REDLINE. ENGINE SHUTDOWN. MISSION ABORT IF DETECTED BY REDLINE. LOSS OF VEHICLE DUE TO HPOTP TURBINE OR HEAT EXCHANGER FAILURE MAY RESULT IF NOT DETECTED. REDUNDANCY SCREENS: TURBOPMP 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 ITEM IS DETECTABLE DURING FLIGHT. C: PASS. LOSS OF REDUNDANT HARDWARE ITEMS COULD NOT RESULT FROM A SINGLE CREDIBLE EVENT.	1R HAZARD REF: ME-C1S,M.

CIL ITEM: 8400-01	DESIGN	DOCUMENT REF.
	FAILURE CAUSE A: SEALING SURFACE DAMAGE FAILURE CAUSE B: SEAL FAILURE OR DAMAGE CRYOGENIC HYDROGEN, USED AS COOLANT FOR THE TURBINE COMPONENTS, IS SUPPLIED FROM THE OXIDIZER PREBURNER TO THE HPOTP TURBINE HOUSING (1) AT THE INTERFACE. SEALING IS ACCOMPLISHED BY THE USE OF TWO PRESSURE-ASSISTED SEALS. AN INBOARD SEAL (2) IS UTILIZED TO PREVENT HYDROGEN LEAKAGE INTO THE PREBURNER CHAMBER WHILE AN OUTBOARD SEAL (3) PREVENTS HYDROGEN LEAKAGE TO THE TURBINE EXHAUST MANIFOLD. WHILE PREVENTING LEAKAGE, THE TWO SEALS MAINTAIN THE COOLANT PRESSURE ABOVE THE OPB COMBUSTION PRESSURE, THEREBY PREVENTING HOT-GAS LEAKAGE ACROSS THE INTERFACE. ANALYSIS SHOWS IF THE INBOARD SEAL FAILS, THE LEAKAGE OF COOLANT IS NOT SUFFICIENT TO ALLOW HOT-GAS LEAKAGE FROM THE OPB INTO THE COOLANT CAVITY BETWEEN THE TWO SEALS. IF THE OUTBOARD SEAL FAILS, WITH THE INBOARD SEAL INTACT, THE RESULTANT LEAKAGE WOULD BE SUFFICIENT TO DEGRADE THE COOLANT PRESSURE BELOW THE OPB COMBUSTION PRESSURE AND ALLOW LEAKAGE ACROSS THE INTERFACE. THE SEALS ARE COMPRESSED DURING PUMP INSTALLATION INTO THE ENGINE AND ASSISTED DURING OPERATION BY THE COOLANT PRESSURE. THE TWO SEALS ARE RETAINED IN CONCENTRIC CHANNELS IN THE TURBINE HOUSING FLANGE (1) BY A SET OF CLIPS AND SET SCREWS WHICH MINIMIZE SEAL MOVEMENT AND ASSURE PROPER POSITIONING DURING NON-OPERATIONAL PHASES. THE TURBINE HOUSING FLANGE IS MANUFACTURED UTILIZING AN INCOLOY 903 FORGING. INCOLOY 903 IS AN IRON BASED ALLOY WHICH WAS SELECTED FOR ITS STRENGTH, RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT, CORROSION RESISTANCE AND RESISTANCE TO STRESS CORROSION CRACKING (4). THE ALLOY IS SOLUTION TREATED AND AGE HARDENED (1). SEALING SURFACE FINISH, FLATNESS AND WAVINESS REQUIREMENTS ARE SPECIFIED TO MAINTAIN SEALING FUNCTION (1). THE SEALS ARE MANUFACTURED UTILIZING INCONEL 718, WHICH WAS SELECTED FOR ITS REQUIRED STRENGTH AND EASE OF FABRICATION (4). THE ALLOY IS SOLUTION TREATED AND AGE HARDENED (2) (3). ALTHOUGH INCONEL 718 IS SUSCEPTIBLE TO EMBRITTLEMENT IN HIGH PRESSURE HYDROGEN, THE STRESS LEVELS ARE WITHIN THE ELASTIC RANGE AND DOES NOT REQUIRE PROTECTION (4). THE SEALS ARE SILVER PLATED FOR LUBRICITY AND TO CONFORM TO SEALING SURFACE IRREGULARITIES (2) (3). SURFACE DAMAGE FROM PARTICULATE CONTAMINATION IN THE HYDROGEN SYSTEM IS CONTROLLED BY THE SYSTEM CLEANLINESS REQUIREMENTS (5), DURING HANDLING AND ASSEMBLY, AND BY THE VEHICLE PROPELLANT CLEANLINESS REQUIREMENTS (6) DURING OPERATION. THE SEALS ARE CONFINED IN THE CHANNEL AND CANNOT MIGRATE INTO THE HOT-GAS FLOW STREAM. THE COMPRESSIVE FIT BETWEEN THE TURBINE HOUSING AND THE OPB BECOMES THE CONTROLLING FLOW ORIFICE IN THE EVENT OF SEAL LEAKAGE. THE HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE PRESSURE-ASSISTED SEALS MEET CEI REQUIREMENTS (7). THE TURBINE HOUSING HIGH CYCLE FATIGUE LIFE MEETS CEI REQUIREMENTS (7), BUT IS LOW CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (11). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS MEET CEI REQUIREMENTS (8). THE PRESSURE-ASSISTED SEALS PARENT MATERIAL WAS CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY ARE NOT FRACTURE CRITICAL PARTS, EXCEPT FOR THE TURBINE HOUSING WHICH WAS CLEARED BY RISK ASSESSMENT (9). REUSE OF PARTS DURING OVERHAUL ARE CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (10).	(1) RS007746 (2) RS008848 (3) RS008857 (4) RSS-8578-11 (5) RLT0001 (6) ICD 13N15000 (7) RL00532, CP320R0003B (8) RSS-8546-16, CP320R0003B (9) NASA TASK 117 (10) RL00874 (11) DAR 2141

Crit. ITEM: B400-01		INSPECTION AND TEST	
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
FAILURE CAUSE A,B:	RS008848 - SILVER SEAL RS008857 - SILVER SEAL RS007010 - HOT-GAS MANIFOLD RS007746 - SUPPORT		RS008848 RS008857 RS007010 RS007746
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RBD170-153 RS007746
		THE SEALS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RAD115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	SILVER PLATING AND RHODIUM OVERPLATE ARE INSPECTED PER SPECIFICATION REQUIREMENTS.	RA1609-001
	CLEANLINESS OF COMPONENTS	COMPONENTS ARE VERIFIED CLEANED TO OXYGEN/PROPELLANT/FUEL SERVICE PER SPECIFICATION REQUIREMENTS.	RL10001
	ASSEMBLY INTEGRITY	SEALING SURFACES ARE INSPECTED PER DRAWING REQUIREMENTS.	RS007010 RS007746 RS008848 RS008857
		THE SEALS SEALING SURFACES ARE INSPECTED AT ASSEMBLY OF HPOTP AND INSTALLATION INTO THE POWERHEAD PER SPECIFICATION REQUIREMENTS.	RL00814
		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.	RL00874 RA0115-116
		THE SEALS HEIGHT AND DIAMETERS ARE INSPECTED DURING OVERHAUL PER SPECIFICATION REQUIREMENTS.	RL00323
		OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT FIRE TESTING AND 2ND E & M INSPECTIONS.	RL00050-04 RL00056-06 RL00056-07 RL00461

CIL ITEM: 8400-01		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 PLN 1228

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.

TABLE B400. HIGH PRESSURE OXIDIZER TURBOPUMP
FMEA/CIL WELD JOINTS

COMPONENT	BASIC PART NO.	WELD NO.	WELD TYPE	CLASS	ROOT SIDE NOT ACCESS	CRITICAL INITIAL FLAW SIZE NOT DETECTABLE HCF	LCF	COMMENTS
MAIN HOUSING	RS007729	1,2	EBW	1	X	X		
MAIN HOUSING	RS007729	3	EBW	1		X		
MAIN HOUSING	RS007729	9,10	GTAW	II	X	X	X	
MAIN HOUSING	RS007729	11,12	GTAW	I		X		
MAIN HOUSING	RS007729	13	EBW	1	X	X		
MAIN HOUSING	RS007729	14-17,46	GTAW	II	X			
MAIN HOUSING	RS007729	18,19	GTAW	II	X	X	X	
MAIN HOUSING	RS007729	21,23	GTAW	II	X			
MAIN HOUSING	RS007729	22,24	GTAW	II	X			
MAIN HOUSING	RS007729	44,55-59	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	1	X			
MAIN HOUSING	RS007729	66-70	GTAW	II	X			
INLET HOUSING	RS007732	4	GTAW	I		X		
INLET HOUSING	RS007732	8,9	GTAW	I		X		
VOLUTE	RS007732	10,15	GTAW	I	X	X		
VOLUTE	RS007732	20,21	GTAW	I				
VOLUTE	RS007732	22,23	GTAW	1				
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			

TABLE B400. HIGH PRESSURE OXIDIZER TURBOPUMP
FMEA/CIL WELD JOINTS

COMPONENT	BASIC PART NO.	WELD NO.	WELD TYPE	CLASS	ROOT SIDE NOT ACCESS	CRITICAL INITIAL FLAW SIZE NOT DETECTABLE HCF	LCF	COMMENTS
FLANGE	R0007736	6,7	GTAW	II	X			
FLANGE	R0007736	9-12,17	GTAW	II	X			
FLANGE	R0007736	13-16	GTAW	II	X			
FLANGE	R0007736	18,20	GTAW	I	X			
FLANGE	R0007736	19,21	GTAW	II	X			
FLANGE	R0007736	22	EBW	I	X			
FLANGE	R0007736	23	GTAW	II				
FLANGE	R0007736	24	GTAW	II	X			
FLANGE	R0007736	26	GTAW	II	X			
BELLOWS	R0007740	1,2,5,9	GTAW	I		X		
BELLOWS	R0007740	3,4	EBW	I				
HOUSING	R0007746	1,2	GTAW	I	X	X	X	
HOUSING	R0007746	3	GTAW	I	X			
HOUSING	R0007746	4	GTAW	II	X			
HOUSING	R0007746	5	GTAW	II	X	X		
HOUSING	R0007746	6-17	GTAW	II	X	X		
HOUSING	R0007746	18-29	GTAW	II	X	X	X	
HOUSING	R0007746	30-41	GTAW	II		X	X	
BELLOWS	R0007748	1	EBW	I				
BELLOWS	R0007749	2	GTAW	I	X			
BELLOWS	R0007749	1-4	GTAW	I				
BELLOWS	R0007749	5,6	EBW	I				
BELLOWS	R0007749	11	EBW	I				
BELLOWS	R0007749	12	EBW	I				
BELLOWS	R0007751	3	EBW	I	X			
BELLOWS	R0007751	4	EBW	I	X	X	X	
BELLOWS	R0007751	8	GTAW	I	X	X		
SECOND STAGE NOZZLE	R0007752	1,2	EBW	I	X			
SECOND STAGE NOZZLE	R0007752	1	GTAW	I	X	X	X	
JET RING	R0007757	1	GTAW	I	X	X	X	
FAIRING	R0007774	1-12	GTAW	I		X		
FAIRING	R0007774	13-24	GTAW	I		X		

TABLE B400. HIGH PRESSURE OXIDIZER TURBOPUMP
PREA/CIL WELD JOINTS

COMPONENT	BASIC PART NO.	WELD NO.	WELD TYPE	CLASS	ROOT SIDE NOT ACCESS	CRITICAL INITIAL FLAW SIZE NOT DETECTABLE REF	LCF	COMMENTS
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	EBW	II	X			
STRUT	RS007779	71	EBW	II				
STRUT	RS007779	72	EBW	II				
STRUT	RS007779	73-94	EBW	II				
STRUT	RS007779	95,96	EBW	II	X			
SHIELD	RS007781	1,11	BTAW	II				
SHIELD	RS007781	2,3,4	BTAW	II				
SEAL	RS008848	1 PLC	BTAW	I				
SEAL	RS008857	1 PLC	BTAW	I		X	X	

FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

CIL ITEMS: B400-XX		HPOTP	P/N RS007791
BASE LINE RATIONALE	VARIANCE	CHANGE RATIONALE	VARIANT DASH NUMBER
1. B400-02, B400-03 SECOND STAGE NOZZLE CASTING IS HOT ISOSTATIC PRESSED PER DRAWING REQUIREMENTS. (ECP 1A-2949)	SECOND STAGE NOZZLE CASTINGS HAVE NOT BEEN HOT ISOSTATIC PRESSED	HOT ISOSTATIC PRESS INCREASES STRUCTURAL INTEGRITY BY REDUCING CASTING MICROPOROSITY. USE AS IS RATIONALE: 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)	-121, -131, -141, -151, -161, -171, -181, -191, -201, -211, -221, -231, -241, -251, -261, -271, -291, -301, -311, -331, -351, -371, -401
2. B400-13, B400-22 PROCESSED AND INSPECTED PER SPECIFICATION REQUIREMENTS (RL00916). (ECP 909)	BEARINGS ARE PROCESSED AND INSPECTED PER SPECIFICATION REQUIREMENTS (RL00558).	LONG TERM FATIGUE LIFE OF BEARING IS ENHANCED BY REDUCING THE ALLOWABLE SIZE AND QUANTITY OF ALLOWABLE DEFECTS. USE AS IS RATIONALE: 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-8795).	-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