1) CIL ITEM : B400-20
2) FMEA CODE : B400
3) COMPONENT : HPOTP
4) PART NUMBER : RS007701
5) SYSTEM/SUBSYSTEM : PUMPS/BNKX
6) FAILURE MODE : LOSS OF COOLANT TO FIRST AND SECOND-STAGE TURBINE COMPONENTS

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 # : ME3-01-3275

PHASE	FAILURE DESCRIPTION/EFFECT	CRITICALITY
SMC	OVERHEATING OF INLET STRUT, DISKS AND BLADES, NOZZLE BOX STRUCTURES, AND TURBINE INTERSTAGE SEAL LEADING TO FLOW DISTORTION AND/OR RUBBING. STRUCTURAL COMPONENT FAILURE RESULTS IN DISINTEGRATION OF ROTATING COMPONENTS. LOSS OF VEHICLE. REDUNDANCY SCREENS: SINGLE POINT FAILURE: N/A	1 HAZARD REF: ME-C1S,M, ME-C1A,C

CIL ITEM: B400-20	DESIGN	DOCUMENT REF.
	FAILURE CAUSE A: FRACTURE OR BLOCKAGE OF COOLANT CIRCUITS	
	THE FIRST- AND SECOND-STAGE TURBINE COMPONENTS ARE COOLED BY A HYDROGEN-STEAM MIXTURE. HYDROGEN GAS IS SUPPLIED FROM THE PREBURNER COOLANT SUPPLY AT THE TURBINE HOUSING (1) INTERFACE AND UTILIZES AN INBOARD (2) AND OUTBOARD PRESSURE-ASSISTED SEAL (3) TO PREVENT BYPASS LEAKAGE. EIGHT ORIFICE PLUGS (4) METER HYDROGEN GAS INTO THE INTERNAL BELLOWS CAVITY OF THE TURBINE HOUSING WHERE IT MIXES WITH HOT-GAS ACQUIRED THROUGH EIGHT ORIFICE HOLES IN THE HOUSING. PART OF THIS RESULTANT MIXTURE IS FED INTERNALLY ACROSS THE TWELVE STRUTS, EACH OF WHICH CONTAINS THREE PARALLEL PASSAGES, TO A MANIFOLD THAT SUPPLIES THE JET RING (5). THE JET RING UTILIZES SIX FEED TUBES TO TRANSFER COOLANT FROM THE STRUT MANIFOLD TO THE RING MANIFOLD, WHERE IT IS DISCHARGED TO THE FIRST-STAGE UPSTREAM COMPONENTS VIA 19 JETS. THE TURBINE HOUSING STRUT IS MANUFACTURED UTILIZING INCOLOY 903. INCOLOY 903 IS AN IRON BASE ALLOY WHICH WAS SELECTED FOR ITS TENSILE STRENGTH AND RESISTANCE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT AND STRESS CORROSION CRACKING (6). THE ALLOY IS THERMO-MECHANICALLY PROCESSED TO IMPROVE HIGH TEMPERATURE STRESS REPTURE DUCTILITY (6), SOLUTION HEAT TREATED AND AGE-HARDENED (1). THE ORIFICE PLUGS ARE MANUFACTURED UTILIZING A-286 CRES, WHILE THE JET RING IS MANUFACTURED UTILIZING A COMBINATION OF A-286 CRES AND 347 CRES. THESE ALLOYS WERE SELECTED FOR THEIR TENSILE STRENGTH, DUCTILITY, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (6). BOTH ALLOYS ARE SOLUTION HEAT TREATED (4) (5) AND ARE NOT SIGNIFICANTLY AFFECTED IN AN HYDROGEN ENVIRONMENT (6). THE SHROUDED ATTACHMENT DESIGN OF THE DISTRIBUTION MANIFOLD AND THE "S" TUBE CONFIGURATION ALLOW RELATIVE MOTION OF THE JET RING, WHICH REDUCES THERMAL STRESSES (5). THE JET BUSHINGS ARE TIG BRAZED TO THE MANIFOLD FOR ADDITIONAL STRUCTURAL MARGIN. THE FIRST-STAGE DOWNSTREAM AND SECOND-STAGE UPSTREAM COMPONENTS ARE COOLED BY THE SECOND-STAGE NOZZLE (7). FORTY-ONE TUBES TRANSFER MIXED COOLANT FROM THE TURBINE HOUSING TO THE BOX STRUCTURE MANIFOLD OF THE NOZZLE, WHERE IT IS DISCHARGED AT EACH SIDE OF THE BOX STRUCTURE VIA 19 ORIFICES. THE PASSAGES WHICH CONTAIN THE TUBES ARE PRESSURE LOADED AGAINST THE TURBINE HOUSING DURING OPERATION, PROVIDING A METAL-TO-METAL SEAL. THE TUBES INCORPORATE A PISTON SEAL (8) ON ITS BORE JOURNAL TO GUARD AGAINST EXTERNAL LEAKAGE FROM THE NOZZLE ASSEMBLY. THE NOZZLE IS CAST FROM MAR-M-246, WITH HAFNIUM ADDITION TO THE BASIC ALLOY. THE HAFNIUM ADDITION IMPROVES DUCTILITY, AND CASTABILITY IN THIN WALLED HOLLOW SECTIONS (6). THE ALLOY WAS SELECTED FOR ITS OPTIMUM COMBINATION OF RUPTURE STRENGTH, RESISTANCE TO CREEP, AND REQUIRED STATIC MECHANICAL PROPERTIES FROM ROOM-TO-ELEVATED TEMPERATURES (6). THE STRUCTURAL ANALYSIS FOR DESIGN OF THE TURBINE NOZZLES USED MATERIAL PROPERTIES APPROPRIATE FOR THE OPERATING ENVIRONMENT (HYDROGEN RICH STEAM) AND TEMPERATURE. THE RESULTS OF THE ANALYSIS SHOWED ADEQUATE MARGIN ON STRUCTURAL INTEGRITY BUT LESS THAN CEI LIFE FOR LOW CYCLE FATIGUE. THE AIRFOIL VANES ARE HOLLOW CAST TO REDUCE THERMAL STRESSES DURING OPERATION. THE BOX STRUCTURE IS MANUFACTURED UTILIZING FORGED WASPALOY. THE ALLOY IS SOLUTION HEAT TREATED, STABILIZED AND AGE-HARDENED (7), AND WAS SELECTED FOR ITS REQUIRED TENSILE STRENGTH (6). HYDROGEN PROTECTION IS NOT REQUIRED DUE TO THE LOW OPERATIONAL STRAINS. THE COOLANT TUBES AND PISTON SEALS ARE MANUFACTURED UTILIZING SOLUTION HEAT TREATED AND AGE-HARDENED A-286 CRES. THE REMAINING SECOND-STAGE DOWNSTREAM COMPONENTS RECEIVE COOLANT FROM FOUR PARALLEL CIRCUITS ACROSS THE SECOND-STAGE NOZZLE FLANGE (9), TURBINE DISCHARGE STRUT (10), AND THE MAIN HOUSING (11). THE COOLANT IS INTRODUCED INTERNALLY ACROSS FOUR OF THE STRUTS THAT CONTAIN COOLANT TRANSFER TUBES (12). THE TUBE HEIGHT EXTENDS BEYOND THE STRUT HEIGHT TO PROVIDE POSITIVE ORIENTATION OF THE	(1) RS007746 (2) RS008848 (3) RS008857 (4) RS007799 (5) RS007757 (6) RSS-857B-11 (7) RO016027, RS007752 (8) RES1264 (9) RS007910 (10) RS007779 (11) RS007729 (12) RS007876 (13) RL10001 (14) ICD 13M15000

CIL ITEM: B400-20	DESIGN	DOCUMENT REF.
	COOLANT PASSAGES FROM THE TURBINE HOUSING TO THE MAIN HOUSING. THE TUBES ARE MANUFACTURED UTILIZING A-286 CRES AND ARE SOLUTION HEAT TREATED AND AGE-HARDENED (12). FOUR CORRESPONDING PASSAGES IN THE MAIN HOUSING DELIVER THE COOLANT FROM THE STRUT TO A MANIFOLD, WHERE IT IS SUBSEQUENTLY DISCHARGED VIA 19 ORIFICE JETS. THE SECOND-STAGE NOZZLE FLANGE IS MANUFACTURED UTILIZING RENE 41, WHICH WAS SELECTED FOR ITS HIGH TEMPERATURE STRENGTH PROPERTIES AND CORROSION RESISTANCE (6). THE ALLOY IS SOLUTION HEAT TREATED AND AGE- HARDENED (9). HYDROGEN PROTECTION IS PROVIDED BY COPPER PLATING (9). THE TURBINE DISCHARGE STRUT IS MANUFACTURED UTILIZING THERMO-MECHANICALLY PROCESSED INCOLOY 903. THE MAIN HOUSING IS A WELDED ASSEMBLY MANUFACTURED UTILIZING INCONEL 718, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, AND, RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (6). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (11). CLEANLINESS REQUIREMENTS DURING HANDLING AND ASSEMBLY (13) AND AT THE VEHICLE PROPELLANT CLEANLINESS (14) LEVEL MINIMIZES THE POTENTIAL OF BLOCKAGE FROM FOREIGN CONTAMINATION. ENGINE DRYING AND PURGING WILL PRECLUDE THE FORMATION OF ICE CONTAMINATION.	
	FAILURE CAUSE B: COOLANT PASSAGE CRACKS IN MAIN HOUSING	
	THE MAIN HOUSING (1) CONTAINS TWO COOLANT CIRCUITS, ONE TO COOL THE TURBINE SEALS AND THE OTHER TO COOL THE SECOND-STAGE DOWNSTREAM COMPONENTS. THE MAIN HOUSING FLANGE CONTAINING THE COOLANT PASSAGES IS MANUFACTURED UTILIZING FORGED INCONEL 718, WHICH WAS SELECTED FOR ITS DUCTILITY AND TENSILE STRENGTH OVER A WIDE TEMPERATURE RANGE (2), AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING. THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (1). A SINGLE PASSAGE IS USED FOR THE TURBINE SEAL COOLANT, WHILE FOUR PARALLEL PASSAGES PROVIDE COOLANT TO THE SECOND-STAGE. THE FOUR PASSAGES INTERSECT A COMMON MANIFOLD FROM WHICH 19 ORIFICE JETS DISTRIBUTE THE COOLANT TO THE SECOND-STAGE COMPONENTS. THE PASSAGES ARE DRILLED ACROSS THE FLANGE AND CLOSED OFF AT THE SURFACE BY PLUG WELDS, TO FORM THE INTERNAL CAVITIES. ALTHOUGH INCONEL 718 IS SUSCEPTIBLE TO HYDROGEN ENVIRONMENT EMBRITTLEMENT, PROTECTION IN THE INTERNAL PASSAGEWAYS IS NOT POSSIBLE DUE TO THE GEOMETRY CONSTRAINTS. THE STRUCTURAL ANALYSIS FOR THE DESIGN OF THE MAIN HOUSING FLANGE USED MATERIAL PROPERTIES APPROPRIATE FOR THE OPERATING ENVIRONMENT (HYDROGEN RICH STEAM) AND TEMPERATURE. THE RESULTS OF THE ANALYSIS SHOWED ADEQUATE MARGIN ON STRUCTURAL INTEGRITY. LOSS OF COOLANT DUE TO PASSAGE CRACKS IS MINIMIZED BECAUSE CRACKS ARE AT A REGION OF NEAR COMPRESSIVE LOADING DURING OPERATION.	(1) RS007729 (2) RSS-8578-11

CIL ITEM: B400-20	DESIGN	DOCUMENT REF.
	FAILURE CAUSE C: JET RING FAILURE THE JET RING (1) RECEIVES COOLANT, A MIXTURE OF HYDROGEN-RICH STEAM AND GASEOUS HYDROGEN, FROM THE TURBINE HOUSING (2) AND DISTRIBUTES IT TO THE UPSTREAM DAMPER POCKETS AND FIR TREE AREAS OF THE FIRST-STAGE TURBINE BLADES AND DISC. THE TUBE STIFFENING DOUBLERS, THE DISTRIBUTION MANIFOLD, AND THE 19 EQUALLY SPACED COOLANT JETS ARE MANUFACTURED UTILIZING 347 CRES, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, DUCTILITY, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (3). THE COOLANT INLET "S" TUBES, THE DOUBLERS, JET BUSHINGS, AND MANIFOLD ARE ANNEALED (1). THE COOLANT INLET "S" TUBES, THE MANIFOLD SHROUD, SHROUD STIFFENING COLLAR, AND THE BASE RING ARE MANUFACTURED UTILIZING A-286 CRES, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, DUCTILITY, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (3). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (1). BOTH MATERIALS ARE RESISTANT TO HYDROGEN ENVIRONMENT EFFECTS AND DO NOT REQUIRE EMBRITTLEMENT PROTECTION (3). THE JET RING CONSISTS ENTIRELY OF A FURNACE BRAZED ASSEMBLY, WITH NICKEL PLATING ON THE A-286 COMPONENTS TO IMPROVE BRAZEABILITY (1). THE JET RING EXPERIENCES A THERMAL GRADIENT DUE TO THE LOWER COOLANT TEMPERATURES WITHIN THE JET RING PASSAGES. THE SHROUDED ATTACHMENT DESIGN FOR THE DISTRIBUTION MANIFOLD AND THE "S" SHAPE OF THE COOLANT INLET TUBES ALLOW FOR RELATIVE MOTION BETWEEN THE "S" TUBES AND DISTRIBUTION MANIFOLD, RELATIVE TO THE BASE RING WITHOUT DEVELOPING THERMAL STRESSES. BRAZE FOIL IS INSERTED IN THE JET BUSHING-TO-MANIFOLD JOINTS PRIOR TO FURNACE BRAZING TO ENSURE ADEQUATE BRAZE PENETRATION. SIX COOLANT INLET TUBES PROVIDE REDUNDANT, PARALLEL COOLANT SUPPLY PATHS TO THE DISTRIBUTION MANIFOLD.	(1) RS007757 (2) RS007746 (3) RSS-8578-11
	FAILURE CAUSE D: FAILURE OF SECOND-STAGE NOZZLE/INTERSTAGE SEAL THE SECOND-STAGE NOZZLE ASSEMBLY (1) PROVIDES AERODYNAMIC CONTROL AND GUIDANCE TO THE HOT-GAS FLOWSTREAM; CONTROLS INTERSTAGE LEAKAGE BETWEEN THE FIRST- AND SECOND-STAGE WHILE PROVIDING STIFFNESS AND DAMPING TO THE ROTOR; AND DISTRIBUTES COOLANT TO THE FIRST- AND SECOND-STAGE TURBINE COMPONENTS. THE NOZZLE AIRFOIL STRUCTURE IS CAST FROM MAR-M-246 WITH HAFNIUM ADDITION TO THE BASIC ALLOY. THE HAFNIUM ADDITION IMPROVES DUCTILITY AND CASTABILITY IN THIN WALLED HOLLOW SECTIONS (2). THE ALLOY WAS SELECTED FOR ITS OPTIMUM COMBINATION OF RUPTURE STRENGTH, RESISTANCE TO CREEP, AND REQUIRED STATIC MECHANICAL PROPERTIES FROM ROOM-TO-ELEVATED TEMPERATURES (2). THE BOX STRUCTURE, WHICH MANIFOLDS AND DISTRIBUTES COOLANT VIA 19 EQUALLT SPACED JETS ON BOTH THE UPSTREAM AND DOWNSTREAM FACE, IS MANUFACTURED UTILIZING FORGED WASPALOY. THE ALLOY IS SOLUTION HEAT TREATED, STABILIZED AND AGE-HARDENED (1) AND WAS SELECTED FOR ITS REQUIRED TENSILE STRENGTH (2). HYDROGEN ENVIRONMENT PROTECTION FOR THE BOX STRUCTURE IS NOT REQUIRED DUE TO THE LOW OPERATIONAL STRAINS. THE AIRFOIL AND BOX STRUCTURE ARE AXIALLY PRELOADED AGAINST EACH OTHER AND ARE RETAINED BY 41 TUBES WHICH ACT AS RADIAL FLOW PASSAGES FOR MIXED COOLANT FROM THE TURBINE HOUSING TO THE INTERNAL MANIFOLD OF THE BOX STRUCTURE (1). THE TUBES ARE MANUFACTURED UTILIZING A-286 CRES, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (2). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (1) AND DOES NOT REQUIRE HYDROGEN PROTECTION OVER THE OPERATING RANGE (2). THE INTERSTAGE SEAL SUBASSEMBLY CONTAINS THE SEAL AND RETAINER ELEMENT. THE SEAL IS MANUFACTURED UTILIZING INCONEL 625, WHICH WAS SELECTED FOR ITS STRENGTH AT ELEVATED TEMPERATURES, FABRICABILITY, AND	(1) R0016027, RS007752 (2) RSS-8578-11 (3) RS007746 (4) RS007910 (5) RL00532, CP320R0003B (6) DAR 2147

CIL ITEM: B400-20	DESIGN	DOCUMENT REF.
	BRAZEABILITY (2). THE ALLOY IS ANNEALED, FORMED INTO HONEYCOMB CELLS, AND BRAZED (1) ONTO THE RETAINER. ALTHOUGH INCONEL 625 IS AFFECTED BY HIGH PRESSURE HYDROGEN, PROTECTION IS NOT REQUIRED DUE TO THE LOW OPERATIONAL STRAINS (2). THE RETAINER IS MANUFACTURED UTILIZING ANNEALED HAYNES 188, WHICH WAS SELECTED FOR ITS STRENGTH AT ELEVATED TEMPERATURES, CORROSION RESISTANCE, AND RESISTANCE TO DEGRADATION IN HIGH PRESSURE GASEOUS HYDROGEN (2). THE RETAINER, WITH THE ATTACHED SEAL, IS SECURED TO THE BOX STRUCTURE BY 8 RIVETS (1). THE NOZZLE IS PILOTED TO THE TURBINE HOUSING (3) AND THE SECOND-STAGE NOZZLE FLANGE (4). TANGENTIAL ROTATION IS PREVENTED BY SCALLOPS IN THE NOZZLE FLANGE WHICH ENGAGES WITH THE RADIAL COOLANT TUBE PASSAGES AT THE OUTER DIAMETER (1). THE BOX STRUCTURE, TUBES AND OUTER SHROUD OF THE AIRFOIL STRUCTURE ARE COOLED BY MIXED COOLANT, WHILE THE AIRFOIL VANES ARE CAST WITH HOLLOW CORES TO REDUCE THERMAL STRESSES DURING OPERATION. THE STRUCTURAL ANALYSIS FOR DESIGN OF THE TURBINE NOZZLES USED MATERIAL PROPERTIES APPROPRIATE FOR THE OPERATING ENVIRONMENT (HYDROGEN RICH STEAM) AND TEMPERATURE. THE RESULTS OF THE ANALYSIS SHOWED ADEQUATE MARGIN ON STRUCTURAL INTEGRITY BUT LESS THAN CEI LIFE FOR LOW CYCLE FATIGUE. THE PART MEETS CEI REQUIREMENTS FOR HIGH CYCLE FATIGUE LIFE (5), BUT IS LOW CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (6).	
	FAILURE CAUSE E: OPB/HPOTP PRESSURE-ASSISTED SEAL LEAKAGE	
	CRYOGENIC HYDROGEN, USED AS COOLANT FOR THE TURBINE COMPONENTS, IS SUPPLIED FROM THE OXIDIZER PREBURNER TO THE HPOTP TURBINE HOUSING AT THE INTERFACE. AN INBOARD PRESSURE-ASSISTED SEAL (1) IS UTILIZED TO PREVENT HYDROGEN LEAKAGE INTO THE PREBURNER CHAMBER, WHILE AN OUTBOARD PRESSURE-ASSISTED SEAL (2) PREVENTS HYDROGEN LEAKAGE INTO THE TURBINE EXHAUST MANIFOLD. THE SEALS ARE COMPRESSED DURING INSTALLATION INTO THE ENGINE AND ASSISTED DURING OPERATION BY THE HYDROGEN COOLANT PRESSURE. WHILE PREVENTING LEAKAGE, THE TWO SEALS MAINTAIN THE COOLANT PRESSURE ABOVE THE OPB COMBUSTION PRESSURE, THEREBY PREVENTING HOT-GAS LEAKAGE INTO THE COOLING CIRCUIT. ANALYSIS SHOWS IF THE INBOARD SEAL FAILS, THE LEAKAGE OF COOLANT IS NOT SUFFICIENT TO DEGRADE THE COOLANT SUPPLY OR ALLOW HOT-GAS LEAKAGE 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 HOT-GAS INTO THE COOLING CIRCUIT. THE TWO SEALS ARE RETAINED IN CONCENTRIC CHANNELS IN THE TURBINE HOUSING FLANGE BY A SET OF CLIPS AND SCREWS, WHICH MINIMIZES SEAL MOVEMENT AND ASSURES PROPER POSITIONING DURING NON-OPERATIONAL PHASES (3). 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 (3). THE PRESSURE-ASSISTED SEALS ARE MANUFACTURED UTILIZING INCONEL 718 AND WAS SELECTED FOR ITS REQUIRED STRENGTH AND EASE OF FABRICATION (4). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (1) (2). THE SEALS ARE SILVER PLATED TO PROVIDE LUBRICITY AND CONFORM TO SURFACE IRREGULARITIES (1) (2). ALTHOUGH INCONEL 718 IS SUSCEPTIBLE TO EMBRITTLEMENT IN HIGH PRESSURE HYDROGEN, THE STRESS LEVELS ARE WITHIN THE ELASTIC RANGE AND THEREFORE DOES NOT REQUIRE PROTECTION (4). THE SEALING SURFACE FINISH, FLATNESS, AND WAVINESS REQUIREMENTS FOR THE SEALS AND THE TURBINE FLANGE ARE SPECIFIED TO MAINTAIN SEALING FUNCTION (1) (2) (3). CONTAMINATION FROM PARTICULATES IN THE HYDROGEN SYSTEM IS MINIMIZED BY THE SYSTEM CLEANLINESS REQUIREMENTS (5). THE SEAL IS CONFINED TO THE CHANNEL AND CANNOT MIGRATE INTO THE HOT-GAS FLOW STREAM. THE COMPRESSIVE FIT BETWEEN THE TURBINE HOUSING FLANGE AND THE OPB BECOMES THE CONTROLLING FLOW ORIFICE IF SEAL LEAKAGE OCCURS.	(1) RS008848 (2) RS008857 (3) RS007746 (4) RSS-8578-11 (5) RL10001

CIL ITEM: B400-20	DESIGN	DOCUMENT REF.
	ALL CAUSES: THE HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE DISCHARGE STRUT, SECOND-STAGE NOZZLE FLANGE, MAIN HOUSING, INTERSTAGE SEAL RING, AND PRESSURE-ASSISTED SEALS MEET CEI REQUIREMENTS (1). THE TURBINE HOUSING HIGH CYCLE FATIGUE LIFE MEETS CEI REQUIREMENTS (1), BUT IS LOW CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (5). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS, ALONG WITH THE SECOND-STAGE NOZZLE AND JET RING, MEET CEI REQUIREMENTS (2). THE HARDWARE PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY ARE NOT FRACTURE CRITICAL PARTS, EXCEPT FOR THE TURBINE DISCHARGE STRUT WHICH WAS CLEARED BY CRITICAL INITIAL FLAW SIZE DETECTABILITY, THE TURBINE INLET HOUSING, SECOND-STAGE NOZZLE AND MAIN HOUSING WERE CLEARED BY RISK ASSESSMENT (3). REUSE OF PARTS DURING OVERHAUL ARE CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (4).	(1) RL00532, CP320R0003B (2) RSS-8546-16, CP320R0003B (3) NASA TASK 117 (4) RL00874 (5) DAR 2141

CIL ITEM: B400-20	INSPECTION AND TEST		
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
FAILURE CAUSE A, B:	R0016027 - NOZZLE ASSEMBLY RS007752 - NOZZLE RS007746 - TURBINE HOUSING RS007779 - STRUT RS007729 - MAIN HOUSING RS007736 - FLANGE		R0016027 RS007752 RS007746 RS007779 RS007729 RS007736
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RA0170-153 RA0170-186 RS007752 RS007746
	HEAT TREAT	MAIN HOUSING HEAT TREAT IS VERIFIED BY SPECIFICATION REQUIREMENTS.	RA0611-020
	ASSEMBLY INTEGRITY	SUBASSEMBLIES ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENT.	RA0115-116

CIL ITEM: B400-20	INSPECTION AND TEST		
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
		HOUSING IS PROOF PRESSURE TESTED PER SPECIFICATION REQUIREMENT.	RL00387
		MAIN HOUSING WELDS 22 & 24 ARE MASS SPECTROMETER LEAK CHECKED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	CLEANLINESS OF COMPONENTS	THE HOUSING SEAL DRAIN SYSTEM, COOLANT JETS, INSTRUMENTATION, BLEED AND FLOW PASSAGES AND NOZZLE FLOW PASSAGES ARE VERIFIED FREE OF CONTAMINATION PER SPECIFICATION REQUIREMENTS	RL00814
		SSME SYSTEM CLEANLINESS IS VERIFIED THROUGHOUT ASSEMBLY PER SPECIFICATION REQUIREMENTS.	RL10001
FAILURE CAUSE C:	RS007757 - JET RING		RS007757
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	RS007757
		JET RING ASSEMBLY IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	SURFACE FINISH	NICKEL PLATING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1109-005
	BRAZE INTEGRITY	BRAZING IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007757 RA0107-010 RL10011
	ASSEMBLY INTEGRITY	JET RING IS FLOW TESTED PRIOR TO INSTALLATION INTO TURBOPUMP PER SPECIFICATION REQUIREMENTS.	RL00814
FAILURE CAUSE D:	RS007957 - INTERSTAGE SEAL RING RS007752 - SECOND-STAGE NOZZLE		RS007957 RS007752
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007752 RB0170-197
		SEAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		NOZZLE IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116

CIL ITEM: B400-20	INSPECTION AND TEST		
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
		NOZZLE IS ULTRASONICALLY INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-012
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020
	BRAZE INTEGRITY	HONEYCOMB BRAZING IS INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0107-010
	ASSEMBLY INTEGRITY	SEAL DIMENSIONS ARE INSPECTED AT ASSEMBLY PER SPECIFICATION REQUIREMENTS.	RL00814
		ROTATING DETAILS ARE BALANCED AS A UNIT PER SPECIFICATION REQUIREMENTS.	RL00816
		VANE CONTOURS ARE INSPECTED PER DRAWING REQUIREMENTS.	RS007752
FAILURE CAUSE E:	RS008848 - SILVER SEAL RS008857 - SILVER SEAL RS007010 - HOT-GAS MANIFOLD RS007746 - SUPPORT		RS008848 RS008857 RS007010 RS007746
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007746 RB0170-153
		SEALS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	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 PER SPECIFICATION REQUIREMENTS.	RL10001
	ASSEMBLY INTEGRITY	SEALING SURFACES ARE INSPECTED PER DRAWING REQUIREMENTS.	RS007010 RS007746 RS008848 RS008857
		SEALS SEALING SURFACES ARE INSPECTED AT ASSEMBLY OF HPOTP AND INSTALLATION INTO THE POWERHEAD PER SPECIFICATION REQUIREMENTS.	RL00814

CIL ITEM: B400-20	INSPECTION AND TEST		
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
		SEALS HEIGHT AND DIAMETERS ARE INSPECTED DURING SEAL OVERHAUL PER SPECIFICATION REQUIREMENTS.	RL00323
ALL CAUSES:	RS007701 - HPOTP		RS007701
	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.	RL00876 RA0115-116
		OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT FIRE TESTING AND 2ND E & M INSPECTIONS.	RL00050-04 RL00056-06 RL00056-07 RL00461
		TORQUE CHECKS ARE PERFORMED PRIOR TO EACH FLIGHT.	OMRSD V41BS0.040
		HPOTP MICROSHAFT TRAVEL MEASUREMENTS ARE PERFORMED PRIOR TO EACH FLIGHT PER SPECIFICATION REQUIREMENTS.	RL01034 RL00050-04 OMRSD V41BS0.045
		THE OXIDIZER SYSTEM IS PURGED PER SPECIFICATION REQUIREMENTS.	OMRSD S00FB0.300 OMRSD S00FM0.250 OMRSD V41CB0.080 OMRSD V41CB0.081
		AN INTERNAL BOROSCOPE INSPECTION IS PERFORMED EACH FLIGHT FLOW.	OMRSD V41BU0.065
		THE ENGINE SYSTEM IS VERIFIED TO BE DRY PER OMRSD REQUIREMENT: - POST LANDING AT LAUNCH SITE - ADDITIONAL DRYNESS VERIFICATION AS REQUIRED	 OMRSD V41CB0.080 OMRSD V41CB0.081
		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	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	14-17,46	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	I	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	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 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	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	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	X	
HOUSING	RS007745	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		

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
FAIRING	RS007774	25-36	GTAW	I		X		
FAIRING	RS007774	74	GTAW	I				
FAIRING	RS007774	75,76	GTAW	II	X			
STRUT	RS007779	23-44, 143-164	GTAW	II	X			
STRUT	RS007779	45-66, 165-186	GTAW	II	X			
STRUT	RS007779	67	GTAW	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	GTAW	II				
SHIELD	RS007781	2,3,4	GTAW	II				
SEAL	RS008848	1 PLC	GTAW	I				
SEAL	RS008857	1 PLC	GTAW	I		X	X	

CIL ITEMS: B400-XX	HPOTP		P/N RS007701
BASE LINE RATIONALE	**VARIANCE**	**CHANGE RATIONALE**	**VARIANT DASH NUMBER**
1. B400-02, B400-03 SECOND STAGE NOZZLE CASTING IS NOT 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 EXTENDED 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

CIL ITEMS: B400-RK	HPOTP		P/N RS007701
BASE LINE RATIONALE	VARIANCE	CHANGE RATIONALE	VARIANT DASH NUMBER
3. B400-21 HOUSING DETAILS ARE ULTRASONIC INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS. (ECP 680)	HOUSING DETAILS HAVE NOT BEEN ULTRASONIC INSPECTED PER DRAWING AND SPECIFICATION REQUIREMENTS.	THE ADDED NDE PROVIDES ADDED CONFIDENCE THAT THE CRITICAL FLAW SIZE IS DETECTED IN THE PARENT MATERIAL OF THE HOUSING DETAILS. USE AS IS RATIONALE: 1. HOUSING DETAILS ARE ACCEPTABLE WITHOUT ULTRASONIC INSPECTION DUE TO A PENETRANT INSPECTION OF THE HOUSING DETAILS. THE PENETRANT INSPECTION IS ADEQUATE TO DETECT CRITICAL INITIAL FLAWS WHICH ARE THROUGH CRACKS.	-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, -471, -481, -491, -501
4. B400-21 FITTING MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS (INCONEL 718, RB0170-153).	RS007729-059 TEE-FITTING IS MANUFACTURED FROM AIR MELT 321 CRES BAR (QQ-S-763 CL321 COND A).	INCONEL 718 MATERIAL DOES NOT EXHIBIT INCLUSION STRINGERS WHICH ARE SUSCEPTABLE TO CHEMICAL ATTACK AND MAY RESULT IN LEAKAGE. USE AS IS RATIONALE: 1. FITTINGS ARE LEAK CHECKED FOLLOWING PROOF PRESSURE TEST PER RL00387. 2. LOADS INDUCED BY FABRICATION (WELDING AND PROOF PRESSURE TESTING) ARE HIGHER THAN OPERATIONAL LOADS AND SUFFICIENT TO SCREEN -059 FITTINGS FOR LEAKAGE.	-171, -181