1) CIL ITEM : 6400-13
2) FMEA CODE : B400
3) COMPONENT : HPOTP
4) PART NUMBER : RS007701
5) SYSTEM/SUBSYSTEM : PUMPS/BXXX (FASCOS REDLINE ACTIVE)
6) FAILURE MODE : LOSS OF SUPPORT, POSITION CONTROL, OR ROTORDYNAMIC STABILITY

7) PREPARED : SSME RELIABILITY
8) APPROVED :
9) DATE : 04-19-96
10) REVISION/CHANGE : -001/0
11) EFFECTIVITY : -501
12) HAZARD REFERENCE : SEE LISTINGS BELOW
13) CCBD # : ME3-01-3285

PHASE	FAILURE DESCRIPTION/EFFECT	CRITICALITY
SNC	BEARING FAILURE RESULTS IN EXCESSIVE AXIAL OR RADIAL DISPLACEMENTS WHICH LEADS TO RUBBING OF TURBINE OR PUMP COMPONENTS, DISINTEGRATION OF ROTATING PARTS; RESULTING IN AN OXIDIZER FIRE OR EXPLOSION. LOSS OF VEHICLE. REDUNDANCY SCREENS: SINGLE POINT FAILURE: N/A	1 HAZARD REF: ME-C1S,M, ME-C1A,C
S	INCREASED VIBRATION LEVELS RESULTS IN CONTROLLER INITIATED SHUTDOWN WHEN FASCOS REDLINE LIMIT IS EXCEEDED. MISSION SCRUB. LOSS OF VEHICLE DUE TO TURBOPUMP FAILURE MAY RESULT IF EXCESS VIBRATION IS 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
M	INCREASED VIBRATION LEVELS RESULTS IN CONTROLLER INITIATED SHUTDOWN WHEN FASCOS REDLINE LIMIT IS EXCEEDED. MISSION ABORT. 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

CIL ITEM: B6OD-13	DESIGN	DOCUMENT REF.
	FAILURE CAUSE A: BEARING FAILURE DUE TO SPALLING, PITTING, WEAR OR CORROSION OF BALLS OR RACES; LOSS OF RADIAL CLEARANCE; CAGE FAILURE; LOSS OF COOLANT; OR CONTAMINATION IN BEARINGS	
	THE HIGH PRESSURE OXIDIZER TURBOPUMP USES TWO SETS OF DUPLEX BEARING PAIRS PRELOADED IN THE EXTERNALLY CONVERGING CONTACT ANGLE CONFIGURATION. ONE SET OF 57mm BORE ANGULAR CONTACT BEARINGS ARE USED AT THE TURBINE END (1) AND ANOTHER SET OF 45mm BORE BEARINGS ARE LOCATED AT THE PUMP END (2) OF THE TURBOPUMP. BOTH SETS PROVIDE RADIAL POSITIONING OF THE SHAFT DURING ALL PHASES OF OPERATION. IN ADDITION, THE TURBINE END BEARINGS PROVIDE AXIAL RESTRAINT DURING THE START AND SHUTDOWN TRANSIENTS. THE BALLS AND RACES ARE MANUFACTURED UTILIZING 440C CRES, FOR ITS HARDNESS AND LOAD CARRYING ABILITY (3). THE ALLOY IS SINGLE VACUUM MELTED TO MINIMIZE IMPURITY FORMATION (1) (2). IT IS AUSTENIZED, QUENCHED, AND DOUBLE COLD STABILIZED AND TEMPERED FOR ADDITIONAL HARDNESS AND MATERIAL DIMENSIONAL STABILITY (1) (2). 440C CRES IS LOX COMPATIBLE (3). THE BALLS ARE POSITIONED BY A MANDREL WRAPPED GLASS FABRIC/TFE (TEFLON) RESIN IMPREGNATED CAGE, WHICH IS BATCH TESTED FOR LOX COMPATIBILITY (3). TEFLON (TFE) WAS SELECTED FOR ITS HIGH LUBRICITY, WEAR RESISTANCE AND REQUIRED MECHANICAL PROPERTIES (3). DRY-FILM LUBRICATION IS APPLIED TO THE CAGE AND RACES WHILE THE BALLS ARE SPUTTER COATED FOR LUBRICATION (1) (2). THE CLEANING (4), PACKAGING, AND STORAGE SPECIFICATIONS (5) ENSURE CORROSION-FREE BEARINGS PRIOR TO SERVICE. ENGINE DRYING AND PURGING PROVIDE A POSITIVE PRESSURE BARRIER FROM AMBIENT MOISTURE ENTRY INTO THE TURBOPUMP. COOLANT TO THE PUMP END BEARINGS IS SUPPLIED BY THE LEAKAGE FLOW OF THE REAR PREBURNER PUMP DAMPING SEAL ELEMENTS AND IS CONTROLLED BY DRAWING DIMENSIONS (6) (7). AN ANTI-VORTEX DESIGN INCORPORATED INTO THE SUPPORT REDUCES THE COOLANT FLOW SWIRL UPSTREAM OF THE BEARINGS (8). COOLANT FOR THE TURBINE END BEARINGS IS SUPPLIED BY THE DIVERTER RING (9). THE COOLANT ORIGINATES FROM THE PREBURNER IMPELLER INLET WHICH IS METERED BY THE HOLLOW PREBURNER IMPELLER BOLT (10). THE COOLANT FLOWS INTERNALLY THROUGH THE SHAFT TOWARDS FOUR RADIAL PASSAGES WHICH FEEDS THE MANIFOLD OF THE DIVERTER RING. THE RING HAS MULTIPLE DISCHARGE JETS TO PREVENT TOTAL BLOCKAGE OF FLOW (9). CLEANLINESS REQUIREMENTS DURING ASSEMBLY (11) AND AT THE VEHICLE PROPELLANT CLEANLINESS (12) LEVEL MINIMIZES THE POTENTIAL OF COOLANT PASSAGE BLOCKAGE, RUBBING AT SEAL CLEARANCES, AND BEARING SURFACE DEGRADATION FROM CONTAMINATION. A TWO-LOBED BEARING RETENTION NUT (13) IS UTILIZED DOWNSTREAM OF THE NO. 3 BEARING FOR OPTIMIZATION OF THE PRESSURE ENVIRONMENT FOR CAGE LIFE. THE INCREASED INNER RACE SHOULDERS PERMIT HIGH CONTACT ANGLE LOADING FOR IMPROVED AXIAL THRUST CAPABILITY (1) (2). THE BEARINGS ARE WEAR LIFE LIMITED BY MAJOR WAIVERS (14). CONTINUED USE WITH ALLOWABLE DISCREPANCIES RESULTING FROM OPERATION IS EVALUATED AND CONTROLLED PER THE REQUIREMENTS OF THE MAINTENANCE CONTROL DOCUMENT (15).	(1) RS007955 (2) RS007958 (3) RSS-8578-11 (4) RA1610-051 (5) RL00916 (6) RS007723 (7) RS007766 (8) RS007937 (9) RS007953 (10) RS007726 (11) RL10001 (12) ICD 13M15000 (13) RS007715 (14) DAR 2054 DAR 2082 (15) RSS-8793

CIL ITEM: 6400-13	DESIGN	DOCUMENT REF.
	FAILURE CAUSE B: EXCESSIVE PBP DAMPING SEAL CLEARANCE	
	THE FRONT (1) AND REAR PREBURNER PUMP DAMPING SEALS (2) PROVIDE DAMPING AND STIFFNESS TO THE ROTOR ASSEMBLY AT THE PREBURNER PUMP IMPELLER (3) LOCATION. THE FRONT DAMPING SEAL IS PILOTED BY THE FRONT RETAINER RING (4) AND THE PREBURNER PUMP VOLUTE HOUSING (5). THE REAR DAMPING SEAL IS PILOTED BY THE SUPPORT (6) AND REAR RETAINER RING (7). THESE SUBASSEMBLIES ARE SECURED BY BOLTS (8) WITH LOCKWASHERS (9). THE DAMPING SEALS ARE MANUFACTURED UTILIZING SILVER, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, IGNITION RESISTANCE, THERMAL CONDUCTIVITY, WEAR RESISTANCE, AND FRETTING CHARACTERISTICS (10). THE RETAINER RINGS ARE MANUFACTURED UTILIZING K-MONEL, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, IGNITION RESISTANCE, DUCTILITY, AND TOUGHNESS CHARACTERISTICS AT CRYOGENIC TEMPERATURES, AND CORROSION RESISTANCE (10). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (4) (7). THE BOLTS AND LOCKWASHERS ARE MANUFACTURED UTILIZING A-286 CRES, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, DUCTILITY, ELASTIC MODULUS, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (10). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (8) (9). THE LOCKWASHERS ARE ANNEALED FOR THIS BENDING APPLICATION (9). DRY-FILM LUBRICATION IS APPLIED TO THE BOLTS AND WASHERS TO RELIEVE FRICTION AND ALLOWS EQUAL LOAD DISTRIBUTION TO THE THREADED SURFACES (8) (9). THE LOCKWASHERS ARE SECURED DURING ASSEMBLY TO PREVENT BOLT DISENGAGEMENT DURING OPERATION. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (11). THE SEALS ARE MACHINED WITH ACCOMMODATIONS FOR PRESSURE DEFLECTIONS TO ACHIEVE THE DESIRED TAPER AND CLEARANCE DURING OPERATION (1) (2). AN INTERNAL KNURLED DIAMOND-SHAPED PATTERN IS INCORPORATED ON THE SEALING SURFACE TO MINIMIZE THE TANGENTIAL VELOCITY COMPONENT FOR ENHANCED ROTORDYNAMIC STABILITY. THE DAMPING SEALS PROVIDE SUFFICIENT LOAD CARRYING CAPABILITY TO PREVENT SHAFT CONTACT DURING OPERATION. CLEANLINESS REQUIREMENTS DURING HANDLING AND ASSEMBLY (12) AND AT THE VEHICLE PROPELLANT CLEANLINESS (13) LEVEL MINIMIZES THE POTENTIAL OF CONTAMINATION INDUCED RUBBING OF THE SEALS. CONTAMINATES ENTRAINED IN THE FLOW STREAM ARE ACCELERATED CENTRIPETALLY FROM THE IMPELLER DISCHARGE INTO THE VOLUTE.	(1) RS007764 (2) RS007766 (3) RS007723 (4) RS007758 (5) RS007739 (6) RS007937 (7) RS007761 (8) RS007792 (9) RS007794 (10) RSS-8578-11 (11) RL00814 (12) RL10001 (13) ICD 13M15000
	FAILURE CAUSE C: LOSS OF BEARING RETAINING BOLT PRELOAD	
	PUMP END BEARING LOADS ARE TRANSMITTED THROUGH THE ISOLATOR (1) TO THE SUPPORT STRUCTURE (2). THE ISOLATOR IS RADIALLY PILOTED TO THE SUPPORT AND IS RETAINED BY NINE BOLTS (3) WITH LOCKWASHERS (4). THE BOLTS ARE MANUFACTURED UTILIZING A-286 CRES, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, DUCTILITY, AND ELASTIC MODULUS (5). THE ALLOY IS SOLUTION HEAT TREATED (5). DRY-FILM LUBRICATION IS APPLIED TO THE THREADS TO MINIMIZE FRICTION WHILE ALLOWING EQUAL LOAD DISTRIBUTION TO ALL THE THREADED SURFACES (3). THE LOCKWASHERS ARE YIELDED AGAINST THE BOLT HEADS TO PREVENT DISENGAGEMENT DURING OPERATION. THE LOCKWASHERS ARE MANUFACTURED UTILIZING 321 CRES (4). THE ALLOY IS DUCTILE AND RESISTANT TO CORROSION AND STRESS CORROSION CRACKING (5). IT RECEIVES A SOLUTION HEAT TREATMENT AND IS DRY-FILM LUBRICATED (4). ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (6). THE BOLTS AND LOCKWASHERS ARE ASSESSED TO HAVE INFINITE LIFE (7) AND ARE NOT TRACKED BY SERIALIZATION. LOSS OF SUPPORT AND POSITION CONTROL WOULD REQUIRE LOSS OF PRELOAD TO ALL NINE BOLTS, SINCE THE ISOLATOR IS RADIALLY PILOTED TO THE SUPPORT.	(1) RS007933 (2) RS007937 (3) R0011320 (4) R0017251 (5) RSS-8578-11 (6) RL00814 (7) RL00532, CP320B0003B

CIL ITEM: B400-13	DESIGN	DOCUMENT REF.
	FAILURE CAUSE D: CARTRIDGE WEB FAILURE OR LOSS OF SUPPORT	
	TURBINE END BEARING LOADS ARE TRANSMITTED THROUGH THE CARTRIDGE (1) TO THE SUPPORT STRUCTURE (2). THE CARTRIDGE IS RADIALLY PILOTED BY THE SUPPORT, WHICH IS SECURED TO THE MAIN PUMP HOUSING BY 18 BOLTS (3) AND LOCKWASHERS (4). THE CARTRIDGE IS SLOTTED BETWEEN THE BEARING CARRIER AND THE MOUNTING FLANGE AND ACTS AS A LIGHT SPRING (1) TO ACCOMMODATE SHAFT MOVEMENT. AXIAL SHOULDERS ARE PROVIDED BY THE SUPPORT AND ANTI-VORTEX RING (5) TO CONTROL SHAFT AXIAL MOVEMENT. THE CARTRIDGE IS MANUFACTURED UTILIZING AN INCONEL 718 FORGING, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH AND DUCTILITY OVER A WIDE TEMPERATURE RANGE, HIGH MODULUS OF ELASTICITY, AND CORROSION RESISTANCE (6). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (1). THE JOURNALS FOR THE BEARING RACES AND SUPPORT PILOT, AND THE BEARING PRELOAD SPRING LIP, ARE CHROME PLATED TO MINIMIZE FRETTING AND GALLING POTENTIALS (1). DRY-FILM LUBRICATION IS APPLIED THROUGHOUT THE PART TO MINIMIZE FRETTING AND RELIEVE FRICTION AT THE SLIDING INTERFACES (1). THE SUPPORT BOLTS ARE MANUFACTURED UTILIZING A-286 CRES, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, DUCTILITY, ELASTIC MODULUS, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (6). THE ALLOY IS SOLUTION HEAT TREATED, COLD WORKED, AGED, AND COLD WORKED AGAIN (3). THE THREADS ARE DRY-FILM LUBRICATED TO RELIEVE FRICTION AND ALLOW EQUAL LOAD DISTRIBUTION TO THE THREADED SURFACES (3). THE LOCKWASHERS ARE MANUFACTURED UTILIZING 321 CRES, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, DUCTILITY, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (6). THE LOCKWASHERS ARE SOLUTION HEAT TREATED AND ANNEALED FOR THIS BENDING APPLICATION (4). THE LOCKWASHERS ARE YIELDED AT ASSEMBLY TO PREVENT BOLT DISENGAGEMENT DURING OPERATION. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (7). THE CARTRIDGE IS HIGH CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (9). THE BOLTS AND LOCKWASHERS ARE ASSESSED TO HAVE INFINITE LIFE (8) AND ARE NOT TRACKED BY SERIALIZATION.	(1) RS007974 (2) RS007975 (3) RS007945 (4) R0017647 (5) RS007973 (6) RSS-8578-11 (7) RL00814 (8) RL00532, CP32DR0003B (9) DAR 2293
	FAILURE CAUSE E: LOSS OF BEARING RETAINER NUT PRELOAD	
	THE PUMP BEARING RETAINER NUT (1) PROVIDES AXIAL RETENTION OF THE PUMP BEARING INNER RACES AND SPACER TO THE PREBURNER PUMP IMPELLER (2). THE NUT IS SECURED FROM ROTATION BY THE PUMP BEARING LOCKWASHER (3), WHICH IS YIELDED DURING ASSEMBLY. THE PUMP BEARING NUT IS MANUFACTURED UTILIZING INCONEL 718, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH AND DUCTILITY OVER A WIDE TEMPERATURE RANGE (4). THE ALLOY IS SOLUTION TREATED AND AGE-HARDENED (1). THE TURBINE BEARING RETAINER NUT (5) PROVIDES AXIAL RETENTION OF THE TURBINE BEARING INNER RACES, SPACER, DIVERTER, LABYRINTH SEAL, MATING RING, AND INNER HEAT SHIELD TO THE SHAFT (6). THE NUT IS SECURED FROM ROTATION BY FOUR "T" LOCKS (7), ONE OF WHICH IS YIELDED DURING ASSEMBLY. THE TURBINE BEARING NUT IS MANUFACTURED UTILIZING K-MONEL, WHICH WAS SELECTED FOR ITS RESISTANCE TO IGNITION, TENSILE STRENGTH, DUCTILITY AND TOUGHNESS AT CRYOGENIC TEMPERATURES, AND CORROSION RESISTANCE (4). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (5). THE PUMP BEARING LOCKWASHER AND THE TURBINE BEARING "T" LOCKS ARE MANUFACTURED UTILIZING 302 CRES, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, DUCTILITY, AND RESISTANCE TO CORROSION AND STRESS CORROSION CRACKING (4). THE ALLOY IS ANNEALED FOR THIS BENDING APPLICATION (4). DRY-FILM LUBRICATION (1) (2) (3) (5) (6) (7) IS USED ON ALL OF THE NOTED PARTS TO RELIEVE FRICTION AND ALLOW EQUAL LOAD DISTRIBUTION TO THE THREADED SURFACES. THE THREADS ON THE RETAINER NUTS (1) (5) ARE FABRICATED TO DRAWING REQUIREMENTS FOR INCREASED INSTALLATION CLAMPING FORCE. ASSEMBLY PROCEDURES FOR LOCKING DEVICES ENSURE DEFECT-FREE INSTALLATION (8). THE NUTS AND LOCKS ARE ASSESSED TO HAVE INFINITE LIFE (9) AND ARE NOT TRACKED BY SERIALIZATION.	(1) R0017254 (2) RS007723 (3) RS007722 (4) RSS-8578-11 (5) RS007715 (6) RS007703 (7) RS007716 (8) RL00814 (9) RL00532, CP32DR0003B

CIL ITEM: 8400-13	DESIGN	DOCUMENT REF.
	FAILURE CAUSE F: BEARING PRELOAD SPRING FAILURE	
	THE BEARING PRELOADS ARE SUPPLIED BY STEP SPRINGS (1) (2) ACTING ON THE OUTER RACES OF THE PUMP AND TURBINE END BEARINGS. THE SPRINGS ARE MANUFACTURED UTILIZING INCOLOY 903. INCOLOY 903 IS AN IRON BASE ALLOY WHICH EXHIBITS A LOW THERMAL EXPANSION COEFFICIENT AND AN INTERMEDIATE ELASTIC MODULUS, BOTH OF WHICH ARE NEARLY CONSTANT OVER A WIDE TEMPERATURE RANGE, THUS AFFORDING A NEARLY CONSTANT SPRING STRENGTH (3). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (1) (2). THE MATERIAL IS RESISTANT TO STRESS CORROSION CRACKING (3). THE AMOUNT OF PRELOAD IS SET BY CUSTOM GRINDING THE THICKNESS OF THE SPACERS WHICH SEPARATE THE INNER RACES. TO MAINTAIN THE DESIRED OPERATIONAL PRELOAD, COMPENSATION IS MADE FOR THERMAL AND CENTRIFUGAL DIFFERENTIAL GROWTH OF THE INNER RACES, SHAFT, AND OUTER RACES. THE TURBINE END PRELOAD SPRING IS HIGH CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (4).	(1) R0012228 (2) R0012230 (3) RSS-8578-11 (4) DAR 2033
	FAILURE CAUSE G: EXCESSIVE TURBINE INTERSTAGE SEAL CLEARANCE	
	THE INTERSTAGE SEAL CONTRIBUTES DAMPING AND STIFFNESS TO THE ROTOR AT THE TURBINE LOCATION. 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 (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 STRESS CORROSION CRACKING AND HYDROGEN ENVIRONMENT EMBRITTLEMENT (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 PILOTED 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 HIGH PRESSURE GASEOUS HYDROGEN (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 INDUCED RUBBING. THE SECOND-STAGE NOZZLE MEETS CEI REQUIREMENTS FOR HIGH CYCLE FATIGUE LIFE (6), BUT IS LOW CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (7).	(1) RS007957 (2) R0016027, RS007752 (3) RSS-8578-11 (4) RS007705 (5) RS007703 (6) RL00532, CP320R0003B (7) DAR 2147

CIL ITEM: B400-13	DESIGN	DOCUMENT REF.
	FAILURE CAUSE H: EXCESSIVE PRIMARY AND SECONDARY TURBINE SEAL CLEARANCE	
	DAMPING AND STIFFNESS ARE CONTRIBUTED BY THE TURBINE SEAL ELEMENTS TO THE ROTOR. THE DEGREE OF CONTRIBUTION IS BASED ON THE OPERATING CLEARANCE ESTABLISHED BETWEEN THE SEALS AND THE SHAFT SLEEVE. THE TURBINE SEAL ASSEMBLY CONSISTS OF A HOUSING AND TWO SEAL ELEMENTS. THE HOUSING IS FABRICATED IN THREE PIECES (HOUSING, RETAINER, END PLATE) UTILIZING INCOLOY 903. INCOLOY 903 IS AN IRON BASE ALLOY WHICH WAS SELECTED FOR ITS TENSILE STRENGTH, AND RESISTANCE TO STRESS CORROSION CRACKING AND HYDROGEN ENVIRONMENT EMBRITTLEMENT (1). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (2). SIX NAS1102E04-16 SCREWS ARE USED TO ASSEMBLE THE HOUSING. THE SCREW THREADS ARE DRY-FILM LUBRICATED FOR EQUAL LOAD DISTRIBUTION AND FRETTING PROTECTION, AND THE HEADS ARE STAKED TO PREVENT SCREW DISENGAGEMENT (2). DRY-FILM LUBRICATION IS ALSO UTILIZED AT THE SEALING SURFACES WHERE THE NOSE PADS OF THE SEAL ELEMENTS CONTACT THE HOUSING FOR EASE OF SEAL MOVEMENT (2). THE SEALING SURFACE IS GROUND TO ACHIEVE A MICROFINISH SURFACE (2). MULTIPLE RADIAL PASSAGES ARE MACHINED FROM THE PRIMARY AND SECONDARY CAVITIES FOR REDUNDANT PARALLEL DRAIN PATHS TO THE MAIN PUMP HOUSING DRAINS (2). THE HOUSING ASSEMBLY IS RADIALLY AND AXIALLY PILOTED TO THE MAIN PUMP HOUSING AND IS SECURED BY 18 BOLTS. THE SEAL ELEMENTS ARE RADIALLY FREE-FLOATING TO ACCOMMODATE SHAFT DYNAMIC DEFLECTIONS AND UTILIZES A DUAL NOSE PAD DESIGN ON THE DOWNSTREAM FACE FOR BYPASS LEAKAGE PREVENTION (2). THE PADS ARE GROUND TO ACHIEVE A MICROFINISH SURFACE (2). THE SEAL ELEMENTS CONTAIN AN OUTER ADAPTER RING MANUFACTURED UTILIZING INCOLOY 903 AND AN INNER RING OF CARBON P-5N. THE ADAPTER RING PROVIDES AN INTERFERENCE FIT TO THE CARBON RING AND HAS ANTI-ROTATION TANGS ON THE OUTER DIAMETER TO LIMIT TANGENTIAL MOVEMENT (2). THE CARBON RINGS ARE MANUFACTURED UTILIZING PURE CARBON GRAPHITE, WHICH IS SINTERED IN A PREFORM SHAPE. THE MATERIAL IS THEN IMPREGNATED WITH LITHIUM-FLOURIDE TO ENHANCE WEAR RESISTANCE (1). ITS WEAR RESISTANCE, COEFFICIENT OF FRICTION, AND LIGHTWEIGHT RESPONSE ABILITY TO SHAFT MOVEMENT ARE SUITED FOR THIS APPLICATION (1). DURING OPERATION, THE SEAL RINGS ARE HYDRODYNAMICALLY CENTERED BY PRESSURE LOADING ON THE CONVERGING TAPER DESIGN OF THE INNER JOURNAL DIAMETER (2). THE SLEEVE IS ALSO FABRICATED UTILIZING INCOLOY 903 AND IS SOLUTION HEAT TREATED AND AGE-HARDENED (3). THE SLEEVE IS FLAME-SPRAY COATED WITH TUNGSTEN CARBIDE AND THEN FINAL FINISH GROUND ON THE SHAFT TO ACHIEVE A MICROFINISH SURFACE (3). THE TUNGSTEN CARBIDE PROVIDES A HARD FINISH FOR ENHANCED WEAR RESISTANCE. THE SLEEVE IS RADIALLY POSITIONED BY TWO PILOTS ON THE SHAFT WHICH ALSO PROVIDE AN AXIAL SHOULDER.	(1) RSS-8578-11 (2) RS007966 (3) RS007703
	FAILURE CAUSE I: FRETTING OF BEARING AND/OR CARTRIDGE OR ISOLATOR	
	PUMP END BEARING (1) RADIAL LOADS ARE TRANSMITTED THROUGH THE ISOLATOR (2), WHICH IS PILOTED AND RETAINED BY THE SUPPORT (3) BY 9 BOLTS (4) AND LOCKWASHERS (5). THE OUTER RACES OF THE PUMP END BEARINGS ARE DESIGNED TO SLIDE AXIALLY TO ACCOMMODATE SHAFT MOTION. THE ISOLATOR IS MANUFACTURED UTILIZING FORGED INCONEL 718, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH AND DUCTILITY OVER A WIDE TEMPERATURE RANGE, HIGH MODULUS OF ELASTICITY, AND CORROSION RESISTANCE (6). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (2). THE BORE DIAMETER IS CHROME PLATED (2) TO PROVIDE DISSIMILAR HARDNESS AS COMPARED TO THE BEARING MATERIAL. DRY-FILM LUBRICATION IS UTILIZED AT THE BORE TO FURTHER MINIMIZE FRETTING POTENTIALS WHILE ALLEVIATING FRICTION (2). THE TURBINE END BEARING (7) RADIAL AND AXIAL LOADS ARE TRANSMITTED THROUGH THE CARTRIDGE (8) TO THE SUPPORT (9). THE CARTRIDGE IS PILOTED BY THE SUPPORT WHICH IS SECURED TO THE MAIN HOUSING BY 18 BOLTS (10) AND LOCKWASHERS (11). THE CARTRIDGE IS MANUFACTURED UTILIZING FORGED INCONEL 718. THE CARTRIDGE IS SOLUTION HEAT TREATED AND AGE-HARDENED (8). THE CARTRIDGE IS HIGH CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (14). CHROME PLATING IS UTILIZED AT THE BEARING BORES AND THE CARTRIDGE TO SUPPORT INTERFACE TO PROVIDE	(1) RS007958 (2) RS007933 (3) RS007937 (4) R0011520 (5) R0017251 (6) RSS-8578-11 (7) RS007955 (8) RS007974 (9) RS007975 (10) RS007945 (11) R0017647

CIL ITEM: B400-13	DESIGN	DOCUMENT REF.
	DISSIMILAR SURFACE HARDNESS (8). DRY-FILM LUBRICATION IS APPLIED TO THOSE LOCATIONS TO MINIMIZE FRETTING POTENTIALS WHILE ALLEVIATING FRICTION (8). THE BEARING BALLS AND RACES ARE MANUFACTURED UTILIZING 440C CRES, WHICH WAS SELECTED FOR ITS HARDNESS AND LOAD CARRYING ABILITY (6). THE ALLOY IS SINGLE VACUUM MELTED TO MINIMIZE IMPURITY FORMATION (1) (7). IT IS AUSTENIZED, QUENCHED, DOUBLE COLD STABILIZED, AND TEMPERED FOR ADDITIONAL HARDNESS AND DIMENSIONAL STABILITY (1) (7). TWO SPRINGS (12) ARE USED TO PROVIDE PRELOAD TO THE TURBINE END BEARINGS, WHILE A SINGLE SPRING (13) IS UTILIZED BETWEEN THE PUMP END BEARINGS. THE SPRINGS ARE MANUFACTURED UTILIZING INCOLOY 903. INCOLOY 903 IS AN IRON BASE ALLOY WHICH WAS SELECTED FOR ITS LOW THERMAL EXPANSION COEFFICIENT, INTERMEDIATE ELASTIC MODULUS, AND RESISTANCE TO STRESS CORROSION CRACKING (6). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (12) (3). ROTATING LOADS ARE DAMPENED IN THE PHASE II DESIGN. COMPONENT AND ROTATING ASSEMBLY DYNAMIC BALANCE FURTHER REDUCES SYNCHRONOUS UNBALANCE. FAILURE CAUSE J: LOSS OR INCREASE OF DEADBAND DEADBAND IS DEFINED AS THE RADIAL CLEARANCE BETWEEN THE BEARING OUTER RACES (1) (2) AND THE ISOLATOR (3) AND CARTRIDGE (4) BORES. THE CLEARANCE PERMITS NON-RESTRICTIVE BEARING MOVEMENT AND IS ESTABLISHED TO ACCOUNT FOR OUTER RACE TILT DUE TO LOADING, AND GROWTH DUE TO THERMAL HEATING. THE ISOLATOR AND CARTRIDGE ARE MANUFACTURED UTILIZING FORGED INCONEL 718, WHICH WAS SELECTED FOR ITS TENSILE STRENGTH AND DUCTILITY OVER A WIDE TEMPERATURE RANGE, HIGH MODULUS OF ELASTICITY, AND CORROSION RESISTANCE (5). THE ALLOY IS SOLUTION HEAT TREATED AND AGE-HARDENED (3) (4). THE BORE DIAMETERS OF THE ISOLATOR AND CARTRIDGE ARE CHROME PLATED TO PROVIDE A HARD CONTACT SURFACE FOR THE BEARING OUTER RACE, AND DRY-FILM LUBRICATED TO MINIMIZE FRETTING AND FRICTION (3) (4). THE ISOLATOR AND CARTRIDGE INCORPORATE A THICK CYLINDRICAL BORE DESIGN WHICH MINIMIZES OUT OF ROUNDNESS DUE TO RADIAL LOADS (3) (4). THE LENGTH OF THE BORE IS INCREASED TO ELIMINATE OUTER RACE OVERHANG DURING SHAFT AXIAL EXCURSIONS (3) (4). THE CARTRIDGE IS HIGH CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (7). FOR THE ISOLATOR, THE LEG WHICH CONNECTS THE CYLINDRICAL BORE TO THE MOUNT FLANGE PROVIDES ISOLATION FOR THE BORE FROM FLANGE BENDING AND RADIAL DISPLACEMENTS (3). TO MINIMIZE THE THERMAL GRADIENT BETWEEN THE UPSTREAM AND DOWNSTREAM SURFACES OF THE ISOLATOR, APPROXIMATELY 3 PERCENT OF THE BEARING COOLANT IS METERED THROUGH NINE EQUALLY SPACED ORIFICES IN THE ISOLATOR FLANGE AND DISCHARGED INTO A CAVITY FORMED BETWEEN THE THERMAL SHIELD (6) AND THE ISOLATOR. THE LEAKAGE IS ACCOUNTED FOR IN THE DAMPING SEAL DESIGN. THE THERMAL SHIELD IS MANUFACTURED UTILIZING INCONEL 718, WHICH IS SOLUTION HEAT TREATED AND AGE-HARDENED (6). THE BEARING RACES ARE MANUFACTURED UTILIZING 440C CRES, WHICH WAS SELECTED FOR ITS HARDNESS AND LOAD CARRYING ABILITY (5). THE ALLOY IS SINGLE VACUUM MELTED TO MINIMIZE IMPURITY FORMATION (1) (2). IT IS AUSTENIZED, QUENCHED, DOUBLE COLD STABILIZED, AND TEMPERED FOR ADDITIONAL HARDNESS AND DIMENSIONAL STABILITY (1) (2).	(12) R0012230 (13) R0012228 (14) DAR 2293 (1) RS007958 (2) RS007955 (3) RS007933 (4) RS007974 (5) RSS-8578-11 (6) R0017242 (7) DAR 2293

CIL ITEM: B400-13	DESIGN	DOCUMENT REF.
	ALL CAUSES: SILVER, K-MONEL, A-286 CRES, 302 CRES, 321 CRES, 440C CRES, INCOLOY 903, AND INCONEL 718 SATISFY LOX COMPATIBILITY REQUIREMENTS (1). HIGH CYCLE AND LOW CYCLE FATIGUE LIFE OF THE FRONT AND REAR DAMPING SEALS, BEARING RETAINING BOLTS AND LOCKWASHERS, BEARING RETAINING NUTS AND LOCKS, SUPPORT, ISOLATOR, PRELOAD SPRINGS, INTERSTAGE SEAL, TURBINE SEAL, AND SHAFT MEET CEI REQUIREMENTS (2) WITH THE EXCEPTION OF THE TURBINE END PRELOAD SPRING, WHICH IS HIGH CYCLE FATIGUE LIFE LIMITED (3), AND THE CARTRIDGE, WHICH IS HIGH CYCLE FATIGUE LIFE LIMITED BY MAJOR WAIVER (7). THE MINIMUM FACTORS OF SAFETY FOR THESE PARTS, ALONG WITH THE PUMP END BEARING, TURBINE END BEARING AND SECOND-STAGE NOZZLE, MEET CEI REQUIREMENTS (4). THE HARDWARE PARENT MATERIALS WERE CLEARED FOR FRACTURE MECHANICS/NDE FLAW GROWTH SINCE THEY ARE NOT FRACTURE CRITICAL PARTS, EXCEPT FOR THE PREBURNER PUMP BEARING ISOLATOR, AND SUPPORT WHICH WERE CLEARED BY CRITICAL INITIAL FLAW SIZE DETECTABILITY, THE SECOND-STAGE NOZZLE WAS CLEARED BY RISK ASSESSMENT (5). REUSE OF PARTS DURING OVERHAUL ARE CONTROLLED BY THE REQUIREMENTS OF THE OVERHAUL SPECIFICATION (6).	(1) RSS-8578-11 (2) RL00532, CP320R00038 (3) DAR 2033 (4) RSS-8546-16, CP320R0003B (5) NASA TASK 117 (6) RL00874 (7) DAR 2293

CIL ITEM: B400-13	INSPECTION AND TEST		
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
FAILURE CAUSE A:	RS007958 - PUMP END BEARING RS007955 - TURBINE END BEARING		RS007958 RS007955
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0160-064 RB0130-013
		BEARING RACES ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		BEARING BALLS ARE EDDY CURRENT INSPECTED PER SPECIFICATION REQUIRMENTS.	RL00564
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS FOR THE BALLS AND RACES.	RA1611-005
	SURFACE FINISH	BEARING DRY-FILM LUBRICATION IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1609-039 RA1609-040 RA1612-002
	ASSEMBLY INTEGRITY	BEARINGS ARE EDDY CURRENT INSPECTED PER SPECIFICATION REQUIREMENTS.	RL00743
		THE BALLS AND RACES ARE INSPECTED TO AFBMA STANDARDS FOR SIZE AND GRADE PER DRAWING REQUIREMENTS.	RS007958 RS007955

CIL ITEM: B400-11		INSPECTION AND TEST	
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
		RACES ARE VERIFIED TO BE COPLANAR PER DRAWING REQUIREMENTS.	RS007958 RS007955
		CAGE FABRIC LAYERS ARE INSPECTED PER DRAWING REQUIREMENTS.	RS007958 RS007955
		BEARINGS ARE ASSEMBLED AND DISASSEMBLED PER SPECIFICATION REQUIREMENTS.	RL00916
	CLEANLINESS OF COMPONENTS	BEARINGS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS.	RL10001 RA1610-051
		BEARINGS ARE INSPECTED FOR CORROSION PRIOR TO PACKAGING, BEFORE ASSEMBLY, AND BEFORE INSTALLATION PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007958 RS007955 RL00916 RL00814
FAILURE CAUSE B:	RS007723 - PREBURNER PUMP IMPELLER		RS007723
	RS007764 - FORWARD PREBURNER DAMPING SEAL		RS007764
	RS007766 - AFT PREBURNER DAMPING SEAL		RS007766
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RB0170-155 RS007764 RS007766
		IMPELLER CASTING IS RADIOGRAPHIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-006
		IMPELLER IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-155
		IMPELLER IS HOT ISOSTATIC PRESSED PER SPECIFICATION REQUIREMENTS.	RL00314
	ASSEMBLY INTEGRITY	SILVER SEALS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116

CIL ITEM: B400-13		INSPECTION AND TEST	
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
		SEAL AND IMPELLER SEALING DIAMETERS ARE INSPECTED PER DRAWING REQUIREMENTS.	RS007723 RS007764 RS007766
		RADIAL AND AXIAL CLEARANCES BETWEEN THE SILVER SEALS AND THE IMPELLER IS INSPECTED PER SPECIFICATION REQUIREMENTS.	RL00814
		CONCENTRICITY OF THE SILVER SEALS AND THE ISOLATOR IS INSPECTED PER SPECIFICATION REQUIREMENTS.	RL00814
FAILURE CAUSE C:	R0011320 - BOLTS RS007937 - SUPPORT RS007739 - VOLUTE		R0011320 RS007937 RS007739
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING REQUIREMENTS.	R0011320 RS007937 RS007739
		BOLTS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT AND ANNEALING ARE VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RS0160-014 RA0611-020 R0017251
	SURFACE FINISH	BOLT DRY-FILM LUBRICATION IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0112-003
	ASSEMBLY INTEGRITY	BOLT INSTALLATION AND STRETCH ARE VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007701 RL00814
		LOCKWASHER DEFORMATION IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007701 RL00814
	CLEANLINESS OF COMPONENTS	COMPONENTS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS.	RL10001

CIL ITEM: 8400-13		INSPECTION AND TEST	
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
FAILURE CAUSE D:	RS007974 - CARTRIDGE RS007975 - SUPPORT RS007973 - VORTEX RING R0017647 - LOCKWASHER RS007945 - BOLT		RS007974 RS007975 RS007973 R0017647 RS007945
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RB0170-153 RS007973 R0017647
		CARTRIDGE IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116 RA0115-012
		SUPPORT IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT AND ANNEALING ARE VERIFIED PER SPECIFICATION AND DRAWING REQUIREMENTS.	RA0611-020 RS007973 R0017647
	SURFACE FINISH	CARTRIDGE BORE CHROME PLATING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1609-002
		CARTRIDGE AND SUPPORT DRY-FILM LUBRICATION IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0112-003
FAILURE CAUSE E:	R0017254 - NUT RS007715 - NUT RS007722 - LOCKWASHER RS007716 - LOCK		R0017254 RS007715 RS007722 RS007716
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007715 RS007716 RS007722 RB0170-153
		NUTS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0611-020

CIL ITEM: B400-13		INSPECTION AND TEST	
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
	SURFACE FINISH	NUT DRY-FILM LUBRICATION IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0112-003
	ASSEMBLY INTEGRITY	NUT INSTALLATION AND TORQUE ARE VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007701 RL00814
		LOCK AND LOCKWASHER DEFORMATION IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007701 RL00814
FAILURE CAUSE F:	R0012228 - PUMP END SPRING R0012230 - TURBINE END SPRING		R0012228 R0012230
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0170-196
		SPRINGS ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENT.	RA0611-020
	ASSEMBLY INTEGRITY	SPRINGS CHARACTERISTICS ARE VERIFIED PER SPECIFICATION REQUIREMENTS.	RL00410 RL00814
		SPRINGS STEP LANDS ARE INSPECTED PER DRAWING REQUIREMENTS.	R0012228 R0012230
FAILURE CAUSE G:	RS007752 - SECOND-STAGE NOZZLE R0016027 - NOZZLE ASSEMBLY RS007957 - INTERSTAGE SEAL		RS007752 R0016027 RS007957
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENT.	RS007752 RB0170-197
		SEAL IS PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		NOZZLE IS PENETRANT AND ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116 RA0115-012

CIL ITEM: B400-13		INSPECTION AND TEST	
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
	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 AND NOZZLE SEALING DIAMETERS ARE INSPECTED PER SPECIFICATION REQUIREMENTS.	RL00814
		ROTATING ASSEMBLY IS BALANCED PER SPECIFICATION REQUIREMENTS.	RL00816
FAILURE CAUSE H:	RS007966 - TURBINE SEAL ASSEMBLY		RS007966
	RS007703 - SHAFT (SLEEVE)		RS007703
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENT.	RB0170-186 RB0130-115
		SHAFT SLEEVE IS ULTRASONIC INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-012
	SURFACE FINISH	SHAFT SLEEVE TUNGSTEN CARBIDE FLAME SPRAY IS VERIFIED PER DRAWING REQUIREMENTS.	RS007703
	ASSEMBLY INTEGRITY	SEAL AND SHAFT SEALING DIAMETERS ARE INSPECTED PER DRAWING REQUIREMENTS.	RS007966 RS007703
		CLEARANCE BETWEEN THE SEAL AND SLEEVE IS VERIFIED PER DRAWING REQUIREMENTS.	RS007703 RS007966
		PRIMARY AND SECONDARY TURBINE SEALS ARE LEAK TESTED PER SPECIFICATION REQUIREMENTS.	RL00814 RL00461
FAILURE CAUSE I, J:	RS007955 - TURBINE END BEARING		RS007955
	RS007958 - PUMP END BEARING		RS007958
	RS007933 - ISOLATOR		RS007933
	RS007974 - CARTRIDGE		RS007974
	MATERIAL INTEGRITY	MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RB0160-064 RB0130-013 RB0170-153

CIL ITEM: B400-13		INSPECTION AND TEST	
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
		BEARING RACES ARE PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-116
		BEARING BALLS ARE EDDY CURRENT INSPECTED PER SPECIFICATION REQUIREMENTS.	RL00564
		CARTRIDGE AND ISOLATOR ARE ULTRASONIC AND PENETRANT INSPECTED PER SPECIFICATION REQUIREMENTS.	RA0115-012 RA0115-116
	HEAT TREAT	HEAT TREAT IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1611-005 RA0611-020
	SURFACE FINISH	CARTRIDGE AND ISOLATOR BORE CHROME PLATING IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA1609-002
		CARTRIDGE AND ISOLATOR DRY-FILM LUBRICATION IS VERIFIED PER SPECIFICATION REQUIREMENTS.	RA0112-003
	ASSEMBLY INTEGRITY	BEARINGS ARE EDDY CURRENT INSPECTED PER SPECIFICATION REQUIREMENTS.	RL00473
		BEARINGS ARE ASSEMBLED AND DISASSEMBLED PER SPECIFICATION REQUIREMENTS.	RL00916
		BEARING OUTER RACE OUTSIDE DIAMETERS, AND ISOLATOR AND CARTRIDGE BORE DIAMETERS ARE INSPECTED PER DRAWING REQUIREMENTS.	RS007933 RS007955 RS007958 RS007974
	CLEANLINESS OF COMPONENTS	BEARINGS ARE VERIFIED CLEANED PER SPECIFICATION REQUIREMENTS.	RL10001 RA1610-051
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.	RL00874 RA0115-116
		OPERATION/PERFORMANCE IS VERIFIED BY ENGINE HOT FIRE TESTING AND 2ND E & M INSPECTIONS.	RL00050-04 RL00056-06 RL00056-07 RL00461

CIL ITEM: 8400-13		INSPECTION AND TEST	
POSSIBLE CAUSES	SIGNIFICANT CHARACTERISTICS	INSPECTION(S)/TEST(S)	DOCUMENT REF.
		FASTENER INSTALLATION AND TORQUE ARE VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007701 RL00814
		LOCK AND LOCKWASHER DEFORMATION IS VERIFIED PER DRAWING AND SPECIFICATION REQUIREMENTS.	RS007701 RL00814
		NO. 3 BEARING IS BORESCOPE INSPECTED AFTER EACH HOT FIRE PER SPECIFICATION REQUIREMENTS.	RL00050-04 RL00814 OMRSD V41BU0.065
		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 V41B50.045
		DATA FROM PREVIOUS FLIGHT OR HOTFIRE 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 (PRACA).
REFERENCE: NASA LETTER SA21/88/308 AND ROCKETDYNE LETTER B8RC09761.

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

FIELD CONFIGURATION VARIANCES FROM CIL RATIONALE

CIL ITEMS: 8400-RK		HPOTP	P/N RS007701
BASE LINE RATIONALE	VARIANCE	CHANGE RATIONALE	VARIANT DASH NUMBER
3. 8400-21 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 NDI 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. 8400-21 FITTING MATERIAL INTEGRITY IS VERIFIED PER SPECIFICATION REQUIREMENTS (INCONEL 718, #80170-153).	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 RL00587. 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