Critical Item List

Subsystem\Item No.\Part No.:	HPFTP/AT\B300\4700000	**Prepared by:**	D.F. Clark	**Page:**	16
Functional Assy:	Pump Section 01	**Approved by:**	A.J. Slone	**Issue Date:**	October 28, 1986
		CIL Item:	0103	**Rev. Date:**	April 16, 2001

CIL Item Code:	0103	Analyst:	D.F. Clark
FMEA Item Code:	0103	Approved by:	A.J. Slone
Function:	Direct coolant flow	Rev. No.:	
Subsystem\Item No.\Part No:	HPFTP/AT\B300\4700000	Rev. Date:	April 16, 2001
		Effectivity:	
		Hazard Ref.:	See Listings Below

Operating Phase	Failure Mode, Description and Effect	Criticality
Operating Phase: s,m,c	**Failure Mode:** Loss of coolant flow control and supply.	**Criticality:** 1
	Failure Cause(s)	**Hazard Ref:**
	A. f/n 106 & 118 Fracture or wear of the Discharge Housing or Turbine Housing due to vibration, contamination, rub, or material/manufacturing defect.	A) D1S/A/M/C (AT): 1A1.7.2.2, 1A1.7.3, 1A1.8.2.1.2.1, 1A1.8.2.1.2.3, 1A1.8.2.1.2.4, 1A1.8.2.1.2.5, 1A1.8.2.2.2.1 D3P/D(A/T); 1B4.2.1
	B. f/n 044 Fracture of the Tube Shaft due to vibration, excessive load, material/mfg defect,or contamination.	B) D1S/A/M/C (AT): 1A1.7.2.2, 1A1.8.2.1.2.1, 1A1.8.2.1.2.3, 1A1.8.2.1.2.4, 1A1.8.2.1.2.5, 1A1.8.2.1.2.6, 1A1.8.2.2.2.1
	C. f/n 040 Fracture or blockage of the lift-off seal assembly, due to vibration, flow instability, contamination, material /manufacturing defect, or ice blockage.	C) D1S/A/M/C (AT): 1A1.7.1.2, 1A1.7.2.2, 1A1.7.2.1, 1A1.8.2.1.2.1, 1A1.8.2.1.2.3, 1A1.8.2.1.2.4, 1A1.8.2.1.2.5 A1P/A(AT): 1B4.1
	D. f/n 082 & 241 Fracture or plugging of the Cooling Tube assemblies due to vibration, thermals, material/mfg. defects, braze, seal failure, ice plugging or contamination.	D) D1S/A/M/C (AT): 1A1.7.1.1, 1A1.7.1.2, 1A1.7.2.2, 1A1.8.2.1.2.1, 1A1.8.2.1.2.3, 1A1.8.2.1.2.4, 1A1.8.2.1.2.5
	E. f/n 117 Fracture or wear of the Lift-off seal Retainer due to vibration, contamination, rub, or material/mfg. defect.	E) D1S/A/M/C (AT): 1A1.7.2.2, 1A1.8.2.1.2.1, 1A1.8.2.1.2.3, 1A1.8.2.1.2.4, 1A1.8.2.1.2.5
	F. f/n 097 Fracture or wear of the Inlet Seal due to vibration, contamination, rub, or material/mfg. defect.	F) D1S/A/M/C (AT): 1A1.8.2.1.2.1, 1A1.8.2.1.2.3, 1A1.8.2.1.2.4, 1A1.8.2.1.2.6, 1A1.8.2.1.2.2.1
	G. f/n 046 & 054 Fracture or wear of the roller brg seal ring or roller bearing seal due to vibration, contamination, rub, or material/mfg. defect.	G) D1S/A/M/C (AT): 1A1.8.2.1.2.1, 1A1.8.2.1.2.3, 1A1.8.2.1.2.4, 1A1.8.2.1.2.5
	H. f/n 080 Fracture of the turbine inlet housing due to vibration, thermal growth, excessive loads, or material/mfg. defect.	H) D1S/A/M/C (AT): 1A1.7.3, 1A1.8.2.1.2.1, 1A1.8.2.1.2.4, 1A1.8.2.1.2.5
	Failure Effect: Loss of coolant through the bearings results in bearing failure, rotor instability, pump failure, causing a LOX rich condition and fire.Loss of turbine cooling could result in an uncontained failure.	
	System: Uncontained failure	

Mission/Vehicle:

Pump failure,
Loss of vehicle

Redundancy Screens:

Does not apply since it is a single point failure

Find Number Find Name	Design Considerations
f/n 106, 118 Hsg. Assy. Dischrg, Turb	

FAILURE CAUSE A: Fracture or wear of the Discharge Housing or Turbine Housing due to vibration, contamination, rub, or material/manufacturing defect.

The Discharge Housing (FN 106) is a hot isostatically pressed INCO 718 investment casting. This material is used for its' cryogenic strength and toughness. It contains the flow path geometry for the exiting fuel and provides a primary structural support for the overall assembly. It is one of the three primary structural elements and is fastened between the inlet housing at the pump end and the turbine housing at the turbine end. The discharge housing also referred to as the main housing provides the exit flow path from the third and final impeller to the collecting duct on the main engine. Internally, the housing supports the third impeller pump side tip seal and the 2-3 diffuser and provides anti-rotation for the latter. The flow path itself contains ten short airfoil shaped vanes and two flow splitters directing flow from the third impeller into the collecting volute. The splitters cover a much longer circumferential arc than do the vanes, and exist as structural ribs preventing excessive load through the smaller vanes. All vanes and the leading part of the flow splitters receive a shot peen and the housing receives a proof pressure test. Eight coolant holes extend from the collection volute to the mating turbine housing providing coolant flow for distribution to the necessary hot section components. The housing contains a threaded region on the ID side of the main flange to retain the main inverted nut and a ribbed transition between the ID of the barrel portion and the volute. Externally, the housing is covered with a fiber filled urethane insulation system designed to prevent the formation of liquid air on the exterior surface of the pump.
The housing is fracture critical and meets all the requirements of the SSME ATD fracture control plan FR-19793-5
DVS 4.1.2.9 Structural design analysis to verify that the pump discharge housing has adequate margin is complete. The results can be found in FR-20715-02 and -06 and FR-20716-02 and -07. The VCR is in FR-20715-105, -106, -107, and -115.
DVS 4.1.4.1.1.1 Strain gage pressure testing on the pump discharge housing to define high stress concentration locations is complete. The results are included in VCR documents FR-20715-105, -106, -107 and -115.
DVS 4.1.4.1.1.2 Vibration tests to define mode shapes and frequencies for the pump discharge housing are complete. The results are included in VCR documents FR-20715-105, -106, -107 and -115.

The Turbine Housing assembly (FN 118) consists of the housing detail (made of forged IN100 PWA-SP 1074 for its' strength and low cycle fatigue), key locked self locking inserts to retain the impeller rub stop, and six interference fit tapered plugs which seal the various machined flow passages within the housing. The turbine housing includes gold plating on the barrel to diaphragm radius and diaphragm to reduce the possibility of life reduction due to hydrogen rich environment effects and to increase LCF life.
The turbine housing (FN 118-05) outer barrel section serves as the primary turbine pressure vessel, containing high hot gas pressure levels during mainstage operation, as well as carrying high axial loads generated by diaphragm loads throughout the turbopump which are introduced by the 32 studs joining the turbine and pump discharge housings, and the turbine exit diffuser support. The load is ultimately transferred to the SSME hot gas manifold at the G-6 flange. The radial diaphragm portion of the housing serves as the turbine end roller bearing radial support structure. The radial diaphragm also serves as a pressure bulkhead separating the pump 3rd impeller backface region from the turbine hot gas environment. The diaphragm is also a key component in the turbopump thrust balance system providing attachment of the 3rd impeller's turbine side tip seal and ID axial rub stop and lab seals. In addition, flow straightening vanes on the pump side of the diaphragm serve to maximize the pressure available on the impeller backface for thrust balance.
The housing G6 flange provides the primary turbopump mount to the engine, and utilizes a cantilevered flange to prevent flange separation and minimize bending in the engine G6 studs. The turbine housing has an axial step between the flange ID (heel) and the OD (toe). The use of a shim permits minor adjustments to be made to compensate for flange or HGM warping rather than producing the final cantilever gap with the housing step only.
The axial load from the turbine static structure is transferred to the turbine housing from the turbine exit diffuser support (spool piece) at a full circumference load shelf directly inboard from the G6 flange.
To accommodate the large relative radial deflections without inducing large radial loads or applying significant radial deflection limitations on the TED, the spool piece is radially splined through eight lugs on the ID of the barrel which mate with the slots in the eight axial load arms on the spool piece. The radial spline maintains concentricity control while permitting relative radial motion, and also serves to react the turbine static structure torque, originating primarily from the turbine vanes, into the turbine housing. The eight spline lugs were also sized to permit the entire axial load from the spool piece to be reacted into the turbine side end of the lugs in the event of a failure of the spool piece axial load carrying arms.
Eight structural ribs span between the barrel and the diaphragm to limit bending induced by the axial load couple between the discharge housing studs and the barrel. These ribs control the stress in the barrel to diaphragm fillet, outboard of the studs, as well as control axial deflections of the diaphragm due to the Delta P from the 3rd impeller backface. Shallow, round bottomed, axial clearance scallops align with the cooled ribs to provide clearance with the turbine coolant tubes attached to the turbine exit diffuser.
Four of the eight turbine housing ribs contain integral coolant passages which provide hydrogen coolant to the tubes assembled on the turbine exit diffuser which ultimately route the coolant to chambers 2 and 48. To close the flow circuit inboard of the cross drill intersection in the radial passage, plugs are used at each of four passage locations. To verify integrity of the plug installation, the plugs are leak checked after assembly as well as being pressure tested during the housing proof test. Hydrogen enters the annulus formed by a groove in the turbine housing and the LOS OD flange through 68 holes in the LOS flange. Three holes transfer the coolant from the annulus to each radial passage and on to the awaiting coolant tube.

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	Eight cross drilled passages deliver roller bearing coolant from a supply annulus fed by eight holes in the discharge housing. The roller bearing receives approx. 35% of the total flow delivered from the annulus through holes in the rub stop lab seal, with the remaining flow bypassing the bearing through the axial hole or recirculating back to the pump through the rub stop lab seals. The housing is a fracture critical part and meets all the requirements of the SSME ATD fracture control plan FR-19793-5. On the Turbine Housing (F/N 118) a life limit has been imposed per DAR PW0267 DVS 4.1.2.9 Structural design analysis to verify that the turbine housing assembly has adequate margin is complete. The results are documented in FR-20715-02 and -06 and FR-20716-02 and -07. The VCR is in FR-20715-105, -106, -107 and -115. DVS 4.1.4.1.1.1 Strain gage pressure testing on the turbine housing assembly to define high stress concentration locations is complete. The results are included in VCR documents FR-20715-105, -106, -107 and -115. DVS 4.1.4.1.1.2 Vibration tests to define mode shapes and frequencies for the turbine housing assembly are complete. The results are included in VCR documents FR-20715-105, -106, -107 and -115.
f/n 044 Shaft Tube Assy	FAILURE CAUSE B: Fracture of the Tube Shaft due to vibration, excessive load, material/mfg defect,or contamination. The Boretube (FN 044) provides coolant flow for the pump end ball bearing. The coolant flow inside the shaft beneath the roller bearing also serves to minimize the axial thermal gradient under the bearing. The boretube (fabricated from 347 stainless steel tube per AMS 5571 for its' strength), ferrule, and spacers are brazed together using PWA-SP 19 gold-nickel braze. The boretube has 3 equally spaced lugs at the pump end which fit into slots in the end of the shaft, preventing boretube rotation during turbopump operation. The boretube is retained in the shaft by the end cap, which also locks the main stack nut and serves as a speed pickup wheel. A classified spacer (FN 226) between the end cap and the boretube is selected to provide the proper fit with rotor stack-up tolerances. DVS 4.1.4.4.1.5 Duty cycle and LCF life capabilities of the boretube which supplies coolant flow to the pump end ball bearing are being verified during engine testing at SSC. The results will be included in the engine testing VCR FR-20904-500 and -501
f/n 040 Seal Assy Lift-Off	FAILURE CAUSE C: Fracture or blockage of the lift-off seal assembly, due to vibration, flow instability, contamination, material /manufacturing defect, or ice blockage. The Lift-Off Seal (LOS, FN 040) is a machined bellows-type carbon face seal assembly consisting of a spring made of MP 35N PWA-SP 1171 for its' stiffness strength, a seal made of Carbon P5N PWA-SP 1148 for its' wear resistance and friction coefficient and a ring made of A286 AMS 5732 or 5737 for its' strength and thermal expansion. Its function is to contain hydrogen in the pump prior to engine start and after shutdown while opening during engine operation to provide hydrogen flow to cool the turbine. This seal is a diaphragm supported seal which lifts off the shaft seat as the pump internal pressure increases at start-up. This seal moves toward the turbine as the pump pressure increases until it contacts a stop. The liftoff seal opens during the engine start transient as the differential pressure across its bellows reaches a certain level. This opening of the seal occurs midway through the engine start transient. During shutdown the reverse occurs with the seal closing as the differential pressure across its bellows decays to the actuation level. Closing of the seal occurs approximately half way between the shutdown command and the end of turbopump rotation. Blueprint spring rate and leak check requirements ensure that the seal operates at desired pressure levels. After contacting the stop, a plenum is created by an integral labyrinth seal and a seal land on the shaft seal face. Since the turbine disk does not have a hole through the bore, a means must be provided to supply coolant flow to the turbine and front disk face. There are 16 holes through the liftoff seal face seal just rear of the face. When the pressure causes the face seal to liftoff the shaft seal, the flow goes through these holes and into passages and tubes that conduct the coolant to the turbine disk front face. Part of the flow leaks past the integral lab seal and cools the turbine disk rear face and turnaround duct. The Lift-off Seal Gasket (FN 050) is made of PWA-SP 1146 nickel alloy with a teflon coating. The Lift-off Seal Ring or runner (FN 047) made from PWA-SP 1074 (IN100) provides the mating seal surface for the LOS. It is shot peened and Chrome Carbide provides the hard wear surface. Four vents are incorporated to prevent pressure buildup behind the disk coverplate. The lift-off seal is a fracture critical part and meets all the requirements of the SSME ATD fracture control plan FR-19793-5. DVS 4.1.4.1.4.2 Vibration tests for the current liftoff seal configuration are in works. The results will be documented in FR-20715-108 DVS 4.1.4.3.1.5 Monitoring of the LOS cooling passage pressures can not be accomplished at the component level. This DVS item is covered in VCR FR-20904-352.
f/n 082, 241 Coolant Tube Assy Turb	FAILURE CAUSE D: Fracture or plugging of the Cooling Tube assemblies due to vibration, thermals, material/mfg. defects, braze, seal failure, ice plugging or contamination. Cooling is provided for turbine components to reduce operating temperatures and maintain structural margins and cyclic life thru Tube assy's (FN's 082, 241). Hydrogen

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	coolant is transported from Turbine Housing N-11 chamber passages to the Turbine Inlet through four coolant tube circuits. The coolant is supplied to mixing chambers inside the Turbine Exit Diffuser and Turbine Inlet. The Turbine Exit Diffuser chamber (Ch 48) supplies coolant to the Vane Supports and Blade Outer Gas Seals for temperature and tip clearance control, and to Chamber 243 for temperature control. The Turbine Inlet chambers supply coolant to the disk rim behind the blade platforms, conditioning the blade attachments and disk rim. Each individual circuit contains two coolant tube assemblies that are bolted together at the Turbine Exit Diffuser inner shell inside of a strut, and a third tube assembly that is bolted to the Inlet Housing. The coolant tubes are made from 0.250-inch diameter, 0.020-inch wall thickness, 347 stainless steel seamless tubing for its' strength. The tube end ferrules and the Turbine Inlet tube elbow, also made of 347 stainless steel, are brazed to the tubes using Au-Ni braze. The elbows at the Exit Diffuser interface are made of A-286 for, and are also Au-Ni brazed to the tubes. These elbows required the higher strength of A-286 to carry the tube pressure loads. Each tube is designed with one guided end to allow unconstrained shrinkage, minimizing tube and elbow thermal stress. Coolant tube pressure at the bolted joints and slip joints is contained by several Kel-F jacketed spring seals and piston ring seals. The coolant elbow assy-of (FN 082) is made up of 4 parts brazed together, an elbow, ferrule, tube, and plug, all of AISI 347 material. Four are used in each pump assembly. It receives the disk coolant flow from the turbine exit diffuser (TED) tubes and transports it through the fat struts of the turbine inlet housing into the liner. The assembly has two seals, one at the ferrule to prevent hot gas inside the dome from entering the liner and another on the elbow to prevent the hot gas inside the strut from entering Chamber 50. A plastic jacketed seal (FN 076) is used where the coolant tube assembly plugs into the turbine housing. The bolt (FN 257) and cupwasher (FN 266) are used to clamp the cooling tube assembly into the turbine exit diffuser. DVS 4.1.3.3.5.1 Requirement deleted. This Item is no longer required. The adequacy of the turbine coolant system is being verified during engine testing at SSC. The results will be included in the engine testing VCR FR-20904-500 and -501
f/n 117 Lift-off Seal Retainer	FAILURE CAUSE E: Fracture or wear of the Lift-off seal Retainer due to vibration, contamination, rub, or material/mfg. defect. The LOS Retainer (FN 117) is made of A286 (AMS 5732) for its' strength and thermal expansion. It serves three functions; retention of the LOS and heatshield to the Turbine Housing, backstop for LOS I.D., and metering of coolant flow up the disk. The retainer threads on the housing using left-hand threads, tightening in the direction of pump rotation. The I.D. of the retainer limits the travel of the LOS when the seal swings open. This limits the stress in the bellows and forces the flow split between the disk flow and coolant tube flow. A set screw (FN 251) is threaded into one of 7 holes in the heatshield which aligns with one of 24 slots in the retainer. Installation of the Turnaround Duct then traps the lock. On the Lift-Off Seal Retainer (F/N 117) a life limit and inspection limit has been imposed per DAR PW0316. DVS 4.1.4.4.1.5 Duty cycle and LCF life capabilities of the lift off seal retainer are being verified during engine testing at SSC. The results will be included in the engine testing VCR FR-20904-500 and -501
f/n 097 PEBB K.E. Seal	FAILURE CAUSE F: Fracture or wear of the Inlet Seal due to vibration, contamination, rub, or material/mfg. defect. The pump end ball bearing (PEBB) lab seal (FN 097) is made of AMS 4127 aluminum alloy. It isolates the PEBB compartment from the 1st stage impeller inlet. The KE clearances are set to provide the proper coolant flowrate from the bearing compartment through the PEBB while minimizing leakage to the 1st stage. The seal OD is snapped to the pump inlet housing and is held in place axially by a retainer (FN 207). The PEBB lab seal has eccentric KE's. A puller groove is provided for removal of the seal from the inlet housing. The A-286 screws (FN 206) retain the L-ring which traps the ball bearing knife edge seal in the inlet housing. DVS 4.1.4.4.1.5 Duty cycle and LCF life capabilities of the pump end ball bearing lab seal are being verified during engine testing at SSC. The results will be included in the engine testing VCR FR-20904-500 and -501
f/n 054, 046 Brg-KE Seal, Ring	FAILURE CAUSE G: Fracture or wear of the roller brg seal ring or roller bearing seal due to vibration, contamination, rub, or material/mfg. defect. The Thrust Piston Turbine-side Bearing Seal Ring (FN 046) and rub stop (FN 252) counteract thrust inbalance loads towards the turbine. During the start and shutdown transients, the mating faces act as a rub stop, physically bearing the load unbalance. During mainstage, the axial gap between the rotating face and static face meters flow from the impeller back face to the bore. The Bearing Seal Ring (FN 046), made from forged IN 100 PWA-SP 1074 for its' strength and low cycle fatigue, serves two functions. It provides the lands for the Roller Bearing Lab Seal (FN 054) as well as the mating hard face for the Thrust Piston Face Seal. It is anti-rotated to the 3rd impeller by two tangs positioned in slots in the impeller balance area. The Monel K500 AMS 4676 Roller Bearing Lab Seal (FN 054) serves several functions. It meters recirculation flow from the bearing cavity back to the impeller bore, provides axial support for the rub load, provides anti-rotation to the Roller Bearing Outer Race Sleeve and axial retention of the outer race. The seal itself is anti-rotated in the Turbine Housing by use of a tab. The bolts (FN 151) retain the rub stop plate (FN 152) which retains the rub stop (FN 252) and roller bearing knife edge seal (FN 054) to the main turbine housing (FN

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	168). The bolts are made from A-286 which is a very ductile material with good cryogenic strength. They are threaded into INCO 718 self-locking inserts. These inserts are threaded into the main turbine housing and locked in place with 302 CRES keys. The inserts provide the locking for the bolts via beams which are deformed radially inward thus causing an interference with the bolt. The beam lock design provides high reuse capability. The rotating seal ring is a fracture critical part and meets all the requirements of the SSME ATD fracture control plan FR-19793-5. DVS 4.1.4.4.1.5 Duty cycle and LCF life capabilities of the rotating seal ring and lab seal on the turbine side of the thrust balance piston are being verified during engine testing at SSC. The results will be included in the engine testing VCR FR-20904-500 and -501
f/n 080 Turbine Inlet Housing	FAILURE CAUSE H: Fracture of the turbine inlet housing due to vibration, thermal growth, excessive loads, or material/mfg. defect. The Turbine Inlet Housing Set (TIH, FN 080) is an assembly of seven parts which make up the load carrying structure of the turbine inlet housing assembly. These include the liner (inner dome) (FN 080-02), manifold (FN 080-04), mixing chamber OD wall (FN 080-05), 2-tooth knife edge seal (FN 080-01), the inlet housing (FN 080-03), and the two sets of damper springs (FN 080-06 and 080-07) between the double walls on either side of the flow path through the housing. They are put together in a set to facilitate line drilling the four tube clearance holes through the turbine inlet housing and into the liner with a minimum of circumferential stack-up tolerance. The 2-tooth knife edge seal is machined concentric to the pump-side inlet housing snap at this set level. The turbine inlet housing (FN 080-03) is made from a thin-walled investment casting of PWA-SP 1135 Microcast MAR-M 247 for its' high temperature strength. The housing provides the flow path structure for the hot preburner gases entering the turbine and transfers all diaphragm pressure loads associated with the turbine inlet assembly into the turbine exit diffuser (TED) flange. It is attached to the TED structure through the turbine inlet housing spacer and vane supports with 48 T-head bolts and is held concentric with the pump centerline by the turbine inlet spacer which is snapped at its OD to the TED. The outer wall of the TIH is a full hoop ring and is the main structure of the part. The pump side flange provides a means to hold the part in place and contains the seal for the joint with the spacer. The turbine side flange provides for the attachment of the bellows, the four coolant elbow assemblies, and the seal for this joint. The outer wall also acts as a pressure vessel between the main flow path and Chamber 50. The OD's of the 16 cantilevered struts attach to this wall and transfer the axial loads and related moments from the internal structure. The next wall inboard of the outer wall is the outer flow path wall which is cylindrical in shape. It is attached to the rest of the structure by the struts and is slotted axially between each strut to form 16 individual sections. This wall serves two functions, the first being the OD flow guide, and the second serving as a heat shield for the outer wall. The slots in the outer flow path wall absorb the relative circumferential thermal growth between the two walls caused by their different bulk temperatures. A damper spring is wedged between the two walls at the slot to add support for the thin outer flow path wall and to prevent vibratory problems from occurring. There are 16 struts connecting the inner structure of the turbine inlet housing to the outer walls. Four of the struts are wider in cross section than the other twelve to allow for the cooling elbow assemblies to pass through them. These struts are cantilevered from their outer edge and act as 16 individual beams with a common axial deflection on their ID end. Integral with the ID end of the struts is a double wall structure which provides for the inside surface of the flow path and attachment of the inner cooling manifold structure. The outermost wall is slotted axially between struts, for thermal growth relief, to form 16 individual sections. It serves as the ID side of the main flow path and acts as a scrub liner similar to the outer flow path wall. The innermost wall of the turbine inlet housing provides structure to position the manifold parts and transfer all the ID loads into the struts. It is also elliptical in shape and is slotted axially between the struts for thermal growth relief. The axial slots in both inner walls allow each strut to be independent and cantilevered from its outer end. At the inlet end of this wall is a pilot diameter that positions the ID support ring during operation. This ring grows tight within the first four seconds of operation to provide a radial load and CCW moment at the ID of the struts to reduce the axial deflection of the 2-tooth knife edge seal and CW bending moments at the OD end of the cantilevered struts caused by the axial load. In the middle of the inner wall are 32 lugs positioned one on either side of each strut core breakout. These lugs transfer the axial load from the inside manifold and liner structure through a bayonet lock flange which holds all 32 lugs and 16 struts at the same axial deflection. A damper spring is wedged between the two inner walls at the free edges along the axial split in the walls (32 places) to tie them together radially and provide stiffening and damping for vibrations. The 16 OD damper springs (FN 080-06) have a V shaped cross section and run straight through the full length of the turbine inlet housing and are sized to fit snugly between the two outer walls of the turbine inlet housing to provide damping and to seal along the axial slot in the outer flow path wall. The 32 ID damper springs (FN 080-07) are assembled as pairs at the 16 inner wall axial slots and are circular in the lengthwise direction with a question mark shaped cross section. The profile is symmetrical around the center of their length so that they can be used on either side of the back to back pairing. The springs are assembled with a tight fit and effectively form a box structure with the two walls for increased stiffness and vibratory damping. The liner (FN 080-02) is machined from a solid PWA-SP 1143 INCO 909 forging used for its' thermal expansion and hydrogen resistance and serves three main functions. It serves as the inner dome of the turbine separating the turbine inlet flow from Chamber 3 at the back of the disk with its spherical diaphragm forming the inside of the structure. It has four passages to accept the disk coolant flow from the coolant elbow assemblies and pass it on to the manifold. Its last function is to provide one side of the coolant distribution manifold while accepting all the axial loads from the internal manifold structure and the inlet dome and spring and transferring them to the lugs of the TIH. It is held in place axially by a bayonet lock formed by the TIH lugs and a matching set of lugs on its OD. A key tab is provided on the OD flange that interfaces with one of the slots on the inner wall of the TIH to ensure circumferential alignment. The manifold (FN 080-04), made from a PWA-SP 1143 (INCO 909) forging, receives the disk coolant flow from the liner into its annular chamber and distributes it in two

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	directions. An E-seal (FN 153) ensures no coolant flow from the manifold will be diverted into the hot gas path. The mixing chamber OD wall (FN 080-05) is an L shaped part machined from a PWA-SP 1143 (INCO 909) forging and serves as the outer boundary of the disk coolant mixing chamber. The 2-tooth knife edge seal (FN 080-01), also made from a PWA-SP 1143 (INCO 909) forging, has three main functions. One function is to provide the remaining wall of the mixing chamber and to distribute the flow from this chamber to two other areas near the disk. The other functions of the 2-tooth knife edge seal are to reduce the amount of disk coolant flow that escapes back to the main flow path and to prevent main flow bypass under the 1st vane inner platform. The 2-tooth knife edge seal is held in place with 16 bolts (FN 157), one offset for angular positioning, which pass through the flange and manifold and into the threaded holes in the liner. The bolts are locked into place with cup washers (FN 255) that key off slots machined on the ID of the flange. The outer flow guide (FN 353), made of PWA-SP 1103 (A286), acts as a continuation of the inner flow guide directing the flow from Chamber 3 toward the disk surface outward until it is picked up by the 2-tooth knife edge seal (K. E. seal). It also shields the bolt heads from the rotating flow field next to the disk and fills the cavity between the K. E. seal and manifold reducing the volume for swirling fluid. It is held in place by the 16 manifold bolts. The flow guide is a full hoop part with cylindrical stand-offs around the bolt holes to soften the flange. It has 16 counterbores to accommodate the bolt heads, and cup washer features for locking the bolts. Three holes are provided for jackscrew access to disassemble the manifold structure. The housing is a fracture critical part and meets all the requirements of the SSME ATD fracture control plan FR-19793-5. On the Turbine Inlet Housing Liner (F/N 080-02) a life limit and inspection limit has been imposed per DAR PW0313. On the Turbine Inlet Housing (F/N 080-03) a life limit and inspection limit has been imposed per DAR PW0255. On the Turbine Inlet Damper (F/N 080-07) a life limit and inspection limit has been imposed per DAR PW0314. DVS 4.1.4.1.5.1 Proof tests of the turbine inlet duct to show that plastic strain requirements are not exceeded are complete. The results are included in VCR document FR-20715-112. DVS 4.1.4.1.5.2 Vibration tests to determine the resonant frequencies of the turbine inlet housing set are complete. The results are documented in FR-20716-11 with the VCR in FR-20715-112.

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Failure Mode: Loss of coolant flow control and supply.		**CIL Item:** 0103	**Rev. Date:** April 16, 2001

Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
Failure Cause A f/n 106 Housing Assy,Dischrg	Material Integrity	Shot peen of housing (f/n 106-03) is verified per specification requirements	AMS 2430
		Material integrity of casting (f/n 106-03-1) is verified per specification requirements	PWA-SP 1490-2
		Weld repair integrity (to vanes and splitters on casting) (f/n 106-03-1) is verified per specification requirement	PWA-SP 36158
	Raw Material	FPI- per- QAD (casting) (f/n 106-03-1)	SP-FPM Master
		Xray- per- QAD (casting) (f/n 106-03-1)	SP-XRM Master
	Finished Material	Proof pressure test of A/O (f/n 106) is verified per specification requirements	REI 017
		FPI- per- QAD (A/O) (f/n 106)	SP-FPM Master
	Assembly Integrity	Part Seating is verified per REI	REI 012
		Inspection of F4 Pump Discharge Flange interface seal surface finish is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause A f/n 118 Housing Asyo,Turbine	Material Integrity	Material integrity of pin (f/n 118-02) is verified per specification requirements	QQ-N-281
		Material integrity of plug (f/n 118-01) is verified per specification requirements	QQ-N-281
		Material integrity of housing (f/n 118-05-1) is verified per specification requirements	PWA-SP 1074
		Material integrity of pin (f/n 118-04) is verified per specification requirements	QQ-N-281
		Material integrity of plug (f/n 118-03) is verified per specification requirements	QQ-N-281
		Material integrity of insert (f/n 118-06) is verified per drawing and specification requirements	AMS 5662 & PWA-SP 11-17
		Contamination control of insert (f/n 118-06) is verified per specification requirements	PWA-SP 36180-4

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Inspection	Minimum plating thickness of gold is verified per drawing requirements	
		Integrity of Gold Plating is verified per specification requirements	PWA-SP 36966-2
	Raw Material	Sonic- per- QAD (housing) (f/n 118-05)	SP-SIM 1
	Finished Material	ECI-per-QAD	TDM-1 per NDTM 99-1
		FPI- per- QAD (housing) (f/n 118-05)	SP-FPM Master
		FPI- per- QAD (A/O) (f/n 118)	SP-FPM Master
		EDM and removal of recast are verified per specification requirements	PWA-SP 97-5 and PWA-SP 105
		Proof pressure test of A/O (f/n 118) is verified per specification requirements	REI 017
		Sonic- per- QAD (A/O (f/n 118) - Shearwave insp)	SP-SIM 1
	Assembly Integrity	Inspection of F20 Balance Cavity Pressure interface seal surface finish (on housing and on plate) is verified per REI	REI 012
		Inspection of N11 Turbine Area Drying Purge interface seal surface finish (on housing (f/n 118), on cover & on plugs at N11.3 & N11.4) is verified per REI	REI 012
		Inspection of G6 Pump Mounting Flange interface seal surface finish is verified per REI	REI 012
		Part Seating is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause B f/n 044 Tube Asyo,Shaft	Material Integrity	Braze integrity is verified per drawing and specification requirement	PWA-SP 19
	Finished Material	Xray- per- QAD	SP-XRM Master
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
Failure Cause b f/n 226 Washer,Bore Tube	Material Integrity	Material integrity is verified per specification requirements	AMS 5737
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part seating of DIM R9 is verified per REI	REI 012
		Selection of classification of part is verified per assembly drawing requirements	
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause C f/n 040 Seal Asyo,Lift-Off	Material Integrity	Material integrity of spring (f/n 040-01-1) is verified per specification requirements	PWA-SP 1171
		Material integrity of rivet (f/n 040-04) is verified per specification requirements	AS 7233 per MS9318B
		Material integrity of seal (f/n 040-02) is verified per specification requirements	PWA-SP 1148
		Material integrity of ring (f/n 040-03) is verified per specification requirements	AMS 5732 or AMS 5737
	Raw Material	Sonic- per- QAD (spring) (f/n 040-01)	SP-SIM 1
	Finished Material	FPI- per- QAD (spring) (f/n 040-01)	SP-FPM Master
		FPI- per- QAD (ring) (f/n 040-03)	SP-FPM Master
		Sonic- per- QAD (semi-finished spring) (f/n 040-01)	SP-SIM 1
	Assembly Integrity	Flow Check of lift-off seal (f/n 040) is verified per REI and TOL	REI 012
Failure Cause c f/n 047 Ring,Sealing,Lft-Off	Material Integrity	Hardface is verified per drawing and specification requirements	PWA-SP 288-2
		Shot peen is verified per specification requirements	AMS 2430
		Material integrity is verified per drawing and specification requirements	PWA-SP 1074

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Inspection	Inside diameter is verified per drawing requirements	
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	FPI- per- QAD	SP-FPM Master
		ECI- per- QAD	SP-ECM Master
Failure Cause c f/n 050 Gasket,Lift-Off Seal	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1146
		Teflon Coating is verified per drawing and specification requirements	HPS-655
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause D f/n 082 Tube Asyo,Coolant	Material Integrity	Material integrity is verified per specification requirements	AMS 5571
		Braze integrity is verified per specification requirements	PWA-SP 19
	Finished Material	Xray- per- QAD (tube A/O) (f/n 082)	SP-XRM Master
		Leak test is verified per drawing requirement	
		FPI- per- QAD (fittings) (f/n 082)	SP-FPM Master
		FPI- per- QAD (tube A/O) (f/n 082)	SP-FPM Master
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause D f/n 241 Tube Asyo,Coolant	Material Integrity	Material integrity of the elbow (f/n 241-04) is verified per specification requirements	AMS 5731
		Material integrity of the tube (f/n 241-05) is verified per specification requirements	AMS 5571
		Material integrity of the ferrule (f/n 241-02) is verified per specification requirements	AMS 5646

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Material integrity of the tube (f/n 241-06) is verified per specification requirements	AMS 5571
	Finished Material	Proof pressure test of the A/O (f/n 241) is verified per drawing requirement	
		FPI- per- QAD (A/O) (f/n 241)	SP-FPM Master
		Xray- per- QAD (A/O) (f/n 241)	SP-XRM Master
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause d f/n 076 Seal,Turbine Hsg.	Material Integrity	Jacket material integrity is verified per specification requirements	AMS 3650
Failure Cause d f/n 257 Bolt,Tubes,T.E.D.		Material integrity is verified per specification requirements	AS 7477
	Finished Material	FPI- per- QAD	SP-FPM master
Failure Cause d f/n 266 Washer,Key,Ted Tubes	Material Integrity	Material integrity is verified per specification requirements	AMS 5599
	Assembly Integrity	Locking feature inspected is verified per REI	REI 012
Failure Cause E f/n 117 Retainr,Lft-Off Seal	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1103
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part Seating of DIM S2 is verified per REI	REI 012
		Penetrant inspect per DAR	PW0316
		Selection of classification of part is verified per assembly drawing requirements	

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause e f/n 251 Pin,L.O.S.Retainer	Material Integrity	Material integrity is verified per specification requirements	AMS 5732
Failure Cause F f/n 097 Seal,Inlet		Material integrity is verified per specification requirements	AMS 4127
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part seating of DIM S14 is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause f f/n 206 Screw,Seal Retainer	Material Integrity	Material integrity is verified per specification requirement	AS 7477
	Raw Material	Sonic- per- QAD	SP-SIM 314
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause f f/n 207 Ring,Sealing,Inlet	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1146
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part seating of DIM S15 is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause G f/n 046 Ring,Sealing,Bearing	Material Integrity	Hardface is verified per drawing and specification requirements	PWA-SP 288-1
		Material integrity is verified per drawing and specification requirement	PWA-SP 1074

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Shot peen is verified per specification requirement	AMS 2430
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	ECI- per- QAD	SP-ECM Master
		FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part seating is verified per REI	REI 012
Failure Cause G f/n 054 Seal, Roller Bearing	Material Integrity	Heat treatment and hardness are verified per drawing & specification requirements	PWA-SP 11-17 & AMS 4676
		Material integrity is verified per specification requirements	AMS 4676
	Finished Material	FPI- per- QAD	SP-FPM Master
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause g f/n 151 Bolt,Turbine Housing	Material Integrity	Material integrity is verified per specification requirement	AMS 5731-85 per MS9558
	Raw Material	Sonic- per- QAD	SP-SIM 314
Failure Cause g f/n 152 Plate,Retaining,Brg.	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1146
	Finished Material	FPI- per - QAD	SP-FPM Master
	Assembly Integrity	Part Seating is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause H f/n 080 Liner & Housing Set	Material Integrity	Shot peen of housing assembly (f/n 080) is verified per specification requirements	AMS 2430

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Material integrity of spacer (f/n 080-05) is verfied per specification requirements	PWA-SP 1074
		Material integrity of housing casting (f/n 080-03-1) is verified per specification requirements	PWA-SP 1135
		Material integrity of seal (f/n 080-01-1) is verfied per specification requirements	PWA-SP 1143
		Heat treatment of housing casting (f/n 080-03-1) is verified per drawing and specification requirements	PWA-SP 11-19 and PWA-SP 1135
		Material integrity of manifold/liner (f/n 080-04-1/080-04-2) is verified per specification requirements	PWA-SP 1143
		Material integrity of liner (f/n 080-02-1) is verified per specification requirements	PWA-SP 1143
	Raw Material	Xray- per- QAD (housing casting) (f/n 080-03-1)	SP-XRM Master
		Sonic- per- QAD (liner) (f/n 080-02)	SP-SIM 1
		Sonic- per- QAD (spacer) (f/n 080-05)	SP-SIM 1
		Sonic-per-QAD(manifold if, 2S4700153) (f/n 080-04-1)	SP-SIM 1
	Finished Material	FPI-per-QAD (manifold/liner) (f/n 080-04/080-04-2)	SP-FPM Master
		FPI-per-QAD (housing set, after proof test) (f/n 080)	SP-FPM Master
		Penetrant inspect per DAR(s)	PW0313, PW0255, PW0277, PW0314
		FPI-per-QAD (liner) (f/n 080-02)	SP-FPM Master
		ECI-per-QAD (housing set, after proof test) (f/n 080)	SP-ECM Master
		Proof pressure test of housing set (f/n 080) is verified per specification requirement	REI 017
		FPI-per-QAD (spacer) (f/n 080-05)	SP-FPM Master
		FPI-per-QAD (seal) (f/n 080-01)	SP-FPM Master

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Recycled Hardware	FPI-per-PWA-SP 36187 (seals) (f/n 080-01)	PWA-SP 36187 & SP-FPM Master
		FPI-per-PWA-SP 36187 (manifold/liner) (f/n 080-04)	PWA-SP 36187 & SP-FPM Master
		FPI-per-PWA-SP 36187 (spacer) (f/n 080-05)	PWA-SP 36187 & SP-FPM Master
		FPI-per-PWA-SP 36187 (housings) (f/n 080-03)	PWA-SP 36187 & SP-FPM Master
		FPI-per-PWA-SP 36187 (liner) (f/n 080-02)	PWA-SP 36187 & SP-FPM Master
Failure Cause h f/n 153 Gasket,Trbn.Inlet	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1143
Failure Cause h f/n 157 Bolt,Turbine Inlet		Material integrity is verified per specification requirements	AS 7468
	Raw Material	Sonic- per- QAD	SP-SIM 314
	Finished Material	ECI - per- QAD	SP-ECM Master
		FPI - per- QAD	SP-FPM Master
Failure Cause h f/n 255 Washer,Key,Trbn.Inlt	Material Integrity	Material integrity is verified per specification requirements	AMS 5599
	Assembly Integrity	Locking feature inspected is verified per REI	REI 012
Failure Cause h f/n 353 Guide,Flow	Material Integrity	Material integrity is verified per specification requirements	AMS 5732
	Finished Material	FPI -per -QAD	SP-FPM Master
	Assembly Integrity	Part Seating is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
All Cause	Assembly Integrity	Shipping container; cleanliness control of closures, desiccant material and GN2 purge are verified per specification requirements	PWA-SP 80, MIL-D-3464, MIL-P-27410C
		Cleanliness control of all parts during final assembly are verified per specification requirement	PWA-SP 80
	Acceptance	Acceptance test will be conducted as required by contract, to demonstrate specified performance.	FR24542