Critical Item List

Subsystem\Item No.\Part No.: HPFTP/AT\B300\4700000	**Prepared by:** D.F. Clark	**Page:** 33
Functional Assy: Turbine Section 02	**Approved by:** A.J. Slone	**Issue Date:** October 28, 1986
	CIL Item: 0201	**Rev. Date:** April 16, 2001

CIL Item Code: 0201

FMEA Item Code: 0201

Function: Direct hot gases

Subsystem\Item No.\Part No: HPFTP/AT\B300\4700000

Analyst: D.F. Clark

Approved by: A.J. Slone

Rev. No.:

Rev. Date: April 16, 2001

Effectivity:

Hazard Ref.: See Listings Below

Operating Phase	Failure Mode, Description and Effect	Criticality
Operating Phase: s,m	**Failure Mode:** Loss of flow control with energy loss in the turbine.	**Criticality:** 1R
	Failure Cause(s)	**Hazard Ref:**
	A. f/n 080 & 253 Fracture of the turbine inlet housing or deflector due to vibration, thermals, FOD, inlet distortion, excessive loads, or materials/mfg. defect.	A) D1S/A/M/C (AT): 1C2.1.1.2.3, 1C2.1.1.3.1
	B. f/n 083 Fracture of inlet bellows due to vibrations, over temp, over pressure, thermal growth, mount loads, or materials/mfg. defect.	B) D1S/A/M/C (AT): 1C2.1.1.2.1
	C. f/n 090 & 350 Fracture of the bellows heat shield or the adaptor due to vibrations, over pressure, thermal shock, thermal growth, or materials/mfg. defect.	C) D1S/A/M/C (AT): 1C2.1.1.2.1
	D. f/n 038 Fracture of the turbine outlet duct due to vibration, thermal growth, loss of cooling, or material/mfg. defect.	D) D1S/A/M/C (AT): 1C2.1.1.3.3
	E. f/n 077 & 240 Fracture of the diffuser or diffuser support, due to vibration, thermal growth, loss of cooling, or material/mfg. defect.	E) D1S/A/M/C (AT): 1C2.1.1.2.3
	F. f/n 113 & 114 Wear or erosion of the B.O.G. Seals due to rub, contamination, vibrations, thermals, or material/mfg. defect.	F) D1S/A/M/C (AT): 1C2.1.1.2.2, 1C2.1.1.3.2
	G. f/n 110 & 109 Fracture of the 1st or 2nd Stator Supports due to vibration, thermal growth or material or manufacturing defect.	G) D1S/A/M/C(AT): 1C2.1.1.2.3

Failure Effect:

Loss in turbine power results in decreased flow sensed by the controller which increases oxidizer flow. Excess turbine discharge temp will cause redline shutdown.

System:

Engine shutdown

Mission/Vehicle:

Mission scrub/abort

Loss of vehicle due to HPFTP turbine failure may result if not detected

Redundancy Screens:

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.

Find Number Find Name	Design Considerations
f/n 080, 253 Hsg. Turb. Inlet, Dome	FAILURE CAUSE A: Fracture of the turbine inlet housing or deflector due to vibration, thermals, FOD, inlet distortion, excessive loads, or materials/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 also 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 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.

Find Number Find Name	Design Considerations
	The turbine inlet dome (FN 253), also known as the "hubcap dome", is a spherically shaped, radially free floating flow guide, made of AMS 5608 cobalt alloy (HAYNES 188) for its' high temperature creep strength, which turns the flow from the fuel preburner into an annular flow stream for entry into the turbine inlet housing. It is trapped within the turbine inlet housing assembly between a conical surface on the ID wall of the inlet housing and the ID support ring (FN 254) in a sandwich with the dome spring. The dome is pressure balanced by leakage around its flange and through the inlet housing inner walls as well as 53 holes distributed in four concentric circles in the center of the dome. The dome spring (FN 256) is a machined spring washer with three equally spaced standoffs on each side set up in a circumferentially alternating pattern forming a ring of six fixed-guided leaf springs. It is made from a PWA-SP 1074 (IN100) forging. It serves as a gap filler between the ID support ring and the turbine inlet dome and absorbs the axial movement of the dome. It also provides damping for the dome during periods when there is no contact at the conical interface and prevents any tendency for the dome to rotate due to vibrations and flow swirl effects. The bolt (FN 079) & nut (FN 134) retain the turbine inlet housing, spacer, 1st and 2nd vane supports, and turbine exit diffuser inner shell liners to the turbine exit diffuser. The bolt has a T-Head which leans against the turbine exit diffuser to provide torque restraint for assembly / disassembly. The bolt is made of Astroloy, a nickel alloy that has high strength and good ductility in the hydrogen environment. 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. On the Turbine Inlet Deflector (F/N 253) a life limit and inspection limit has been imposed per DAR PW0319. 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 and dome are complete. The results are included in VCR document FR-20716-11.
f/n 083 Inlet Bellows	FAILURE CAUSE B: Fracture of inlet bellows due to vibrations, over temp, over pressure, thermal growth, mount loads, or materials/mfg. defect. The Turbine Bellows (FN 083) provides a flexible coupling between the fuel preburner and the turbine inlet housing to allow for thermal and mechanical deflections of the turbine and preburner components. The bellows is bolted to the turbine inlet housing at one end; the other bears against the hot gas manifold at the G5 interface. The bellows is made of Inconel 909 PWA-SP 1143 for its low modulus of elasticity to give it more deflection capability with less stress, and for its hydrogen resistance. When the HPFTP/AT is mounted to the hot gas manifold, the bellows is axially loaded in compression to force the free end to remain in contact with the G5 interface. During operation, the bellows is a pressure vessel that contains approximately 60 percent of the delta pressure from turbine inlet to turbine discharge causing additional load for sealing the G5 interface. The Bellows Inner Liner (FN 084) acts as a turbine inlet heatshield for the ID of the bellows. It is also made of Inconel 909 for its alpha match to the bellows. The liner blocks hydrogen coolant and turbine inlet flow from impinging directly on the ID of the bellows. The bellows inner liner is snapped with a tight fit to the bellows at both the turbine and pump ends. The liner is splined to the bellows to prevent rotation of the liner and it is axially trapped between the bellows lugs and the turbine inlet housing when the bellows is snapped to the turbine inlet housing. The cavity between the bellows and inner liner is vented to turbine inlet pressure via vent holes in the inner liner. The inner liner and bellows have small thumb nail slots that run axially along the ID to allow unrestricted coolant flow that is provided by the hot gas manifold. The bolt (FN 081) and nut (FN 138) retain the bellows to the turbine inlet housing. The bellows is a fracture critical part and meets all the requirements of the SSME ATD fracture control plan FR-19793-5. DVS 4.1.4.1.10.1 A proof pressure test of the turbine bellows and inner liner assembly is complete. The results are documented in FR-20715-01 and FR-20716-101 with the VCR in FR-20715-111. DVS 4.1.4.1.10.2 Tests to determine resonant frequencies for the bellows and inner liner have been completed. The results are documented in FR-20716-101 with the VCR in FR-20715-111.
f/n 090, 350 Bellows Heat Shld, Ring	FAILURE CAUSE C: Fracture of the bellows heat shield or the adaptor due to vibrations, over pressure, thermal shock, thermal growth, or materials/mfg. defect. The Bellows Heatshield (FN 090) forms a cavity for mixed gasses (coolant and turbine inlet) to bathe the OD surfaces of the turbine inlet housing and bellows. Its OD forms the discharge side of the flowpath. It is a pressure vessel that contains the remaining 40 percent of the turbine pressure drop. It is made of MAR-M-247 for its high temperature capability and its alpha match with the turbine exit diffuser. The bellows heatshield has a lip on the pump end that is fit into an Adaptor (FN 350) which fits into the snout of the turbine exit diffuser providing the seal at one end and is sealed at the turbine end via the bellows piston ring. Pressure forces the heatshield to move

Find Number Find Name	Design Considerations
	toward the preburner until it is stopped by the G5 interface. Chamber 51 flows out through flats in the piston ring and though large thumb nail cuts that are in the axial face of the heatshield that presses against the HGM. The bellows shield is a fracture critical part and meets all the requirements of the SSME ATD fracture control plan FR-19793-5. On the Turbine Bellows Adapter (F/N 350) a life limit and inspection limit has been imposed per DAR PW0327. DVS 4.1.4.1.10.2 Tests to determine resonant frequencies for the bellows and inner liner have been completed. The results are documented in FR-20716-101 with the VCR in FR-20715-111.
f/n 038 Turnaround Duct	FAILURE CAUSE D: Fracture of the turbine outlet duct due to vibration, thermal growth, loss of cooling, or material/mfg. defect. The Turbine Outlet Duct (FN 038) or Turnaround Duct (TAD) turns the flow exiting the second stage blades 180° into the Turbine Exit Diffuser (TED) and is made from Mar M 247 PEA-SP 1135 for its' high temperature strength. Structurally, the TAD only carries the aero-turning load and a slight Turbine Housing-to-flowpath pressure differential unlike the HPOTP/AT where the TAD carries the entire turbine static structure load. The TAD is removable with a turbine only teardown, allowing access to the Turbine Housing fasteners. The TAD slides onto the heatshield and is rotated to engage the bayonet. Slots in the Turbine Exit Diffuser Support then engage TAD O.D. lugs, retaining the TAD in position. The TAD fits radially tight to the heatshield during operation which prevents flow behind the TAD. An L-shaped seal ring snapped on the TAD O.D. provides an axial seal surface for the E-seal. An axial assembly gap between the ring and Turbine Exit Diffuser Support limits seal gland excursion as the TAD grows axially tight between the Turbine Exit Diffuser Support and heatshield. The TAD Heatshield (FN 037), made from Inconel 909 PWA-SP 1143 for its' thermal expansion and hydrogen resistance properties, protects the Turbine Housing from the radiant heat of the TAD and isolates the TAD from the coolant flowing from the LOS. It also provides support and positioning for the TAD. TAD axial loads are taken out at the I.D. bayonet and the O.D. through stand-offs on the Turbine Housing ribs. The heatshield is anti-rotated to the housing by a single lug and is loaded axially by a 200# wave washer trapped by the LOS Retainer. The TAD is is a fracture critical part and meets all the requirements of the SSME ATD fracture control plan FR-19793-5. On the Turbine Outlet Duct (F/N 038-02) a life limit and inspection limit has been imposed per DAR PW0264. On the Turbine Outlet Heat Shield (F/N 037) a Life limit and inspection limit has been imposed per DAR PW0312. DVS 4.1.2.9 Structural design analyses to verify membrane stresses for the turbine turnaround duct are complete with the results documented in FR-20715-01 and the VCR in FR-20715-109. DVS 4.1.4.1.6.2 Tests to verify vibration characteristics of the turbine turnaround duct are complete. The results are included in VCR document FR-20715-109.
f/n 077, 240 Turbine Diffuser, Spool	FAILURE CAUSE E: Fracture of the diffuser or diffuser support, due to vibration, thermal growth, loss of cooling, or material/mfg. defect. The Turbine Exit Diffuser (TED, FN 077) provides the primary load path for the Turbine Inlet and Turbine Vane loads. These loads include the Turbine Inlet axial loads, and the 1st and 2nd Stage Vane axial and tangential loads. In addition to its load carrying function, the TED also serves as a diffuser for the turbine exhaust, and creates part of the duct for turning the turbine exhaust gases 180°. The TED is a ring-strut-ring configuration. Loads are transferred from the inner ring to the outer ring through 16 axially oriented struts. The TED is machined from wrought IN-100, PWA-SP 1074, for its superior high temperature strength, ductility and LCF capability. The Turbine Exit Diffuser also serves as a pressure vessel, containing Chamber 48 fluid. Chamber 48 is a mixing chamber whose volume is created by the space between the TED inner shell and the 2nd Vane Support. This chamber provides conditioning fluid to the Vane Supports, Vane platforms, the Turbine Inlet flange, Bellows OD, and Chamber 243. Chamber 243 is conditioned with Chamber 48 fluid, and is required due to the sensitivity of this chamber to small changes in fluid flows into it. It is sealed from hot exhaust gases at the Flowblocker and TAD W-seals. The Chamber 48 conditioning fluid was added to provide a dominant flow of Chamber 48 fluid into Chamber 243, making it less sensitive to small leaks, and to maintain a tolerable bulk temperature and circumferential temperature gradient for the TED and TED support. Turbine secondary coolant flow provides cooling to the blade attachments, disk rim and turbine inlet inner structure. Coolant is transported to the turbine inlet through tubes that cross the flowpath through the Turbine Exit Diffuser struts. All joints in the TED plumbing circuit are hermetically sealed with AuNi braze. The Flowblocker is a sleeve seal (FN 210) that is snapped to the TED, and is assembled loose at the TED Support. During the start transient, the Flowblocker grows tight to the Support, while remaining tight at the TED snap. This seal minimizes turbine exhaust blow-by and recirculation outboard of the TED. It is also machined from wrought IN-100, Spec PWA-SP 1074, for compatibility with the TED, and for its superior elevated temperature material properties. The Turbine Exit Diffuser Support (FN 240), in combination with the TED, serves as the main load path for the turbine loads. It carries the TED axial, radial and circumferential loads and transfers them to the Turbine Housing. The Support consists of two ring sections, connected to each other with eight axially oriented arms. The

Find Number Find Name	Design Considerations
	TED axial load is input at the face of the pump-end ring, and reacted by the Turbine Housing at the turbine-end ring. The TED circumferential load is input at slots in the pump-end ring that mate with axially oriented TED torque lugs. The circumferential load is reacted by radial spline lugs in the Turbine Housing that mate with slots in the Support arms. TED radial loads are reacted by the hoop stiffness of the Support pump-end ring. The Support is machined from wrought IN100, PWA-SP 1074, for its high strength and ductility throughout its operating temperature range, as well as for thermal expansion compatibility with the TED. The TED is retained in the Support by four radially oriented Pins (FN 261) that are press fit to the Support, and protrude into the TED strut core openings in the TED outer shell. The pins are made of A-286, AMS 5732, for its high strength at elevated temperatures and its superior ductility. The TED is a fracture critical part and meets all the requirements of the SSME ATD fracture control plan FR-19793-5. On the Turbine Exit Diffuser (F/N 077) a life limit and inspection limit has been imposed per DAR PW0268. On the Turbine Diffuser Support (F/N 240) a life limit and inspection limit has been imposed per DAR PW0318. On the Seal - Sleeve (F/N 210) a life limit and inspection limit has been imposed per DAR PW0331. DVS 4.1.2.11 Turbine exit flowpath analyses to verify that requirements are being met has been completed. The results are documented in FR-20710-01 through -06 with the VCR in FR-20712-27. DVS 4.1.3.2.5.1 Water flow visualization model tests of the turbine exit diffuser and support are complete. The results are documented in FR-20833-03 with the VCR in FR-20712-27. DVS 4.1.4.1.6.2 Tests to verify vibration characteristics of the turbine exit diffuser are complete. The results are included in VCR document FR-20715-109.
f/n 113, 114 Seal B.O.G. Stg. 1, 2	FAILURE CAUSE F: Wear or erosion of the B.O.G. Seals due to rub, contamination, vibrations, thermals, or material/mfg. defect. The 1st BOGS Set (FN 113), made up of 13 equally sized 1st BOGS segments (short for Blade Outer Gas Seal), also commonly called tip shrouds, are machined from PWA-SP 1135 Microcast MAR-M-247 for its' high temperature strength. The basic cross section is cut into 13 equal segments resulting in segments that can be mixed with segments made from other rings when making up a set. These cuts form straight radial sides on the segments. The individual segments are then shot peened all over to improve life characteristics. On the inlet end of the BOGS is a flange and a hook which attaches it to the 1st vane support. It is trapped in place axially between a full circular hook on the support and the 1st vane spacer with the BOGS hook riding in an annular slot. All the axial load from the 1st vanes and 1st vane spacer is transferred through the BOGS flange and into the end of the support hook. Axial load generated by pressure differentials across the BOGS is also taken out at this flange. Protruding out the end of the support hook are 13 tangs that locate the BOGS circumferentially within the support and provide anti-rotation features to remove any torque imparted into the BOGS from the main flow or by a rarely encountered blade tip rub. Another hook is machined on the exit end of the BOGS that fits on the outside of the 2nd vane outer platform leading edge. The BOGS act as a beam spring trapped between the vane platform and the hook on the 1st vane support to add some softness to the system to help absorb the loads. The 2nd BOGS Set (FN 114), made up of 18 2nd BOGS segments (short for Blade Outer Gas Seal), also commonly called tip shrouds, are machined from PWA-SP 1135 Microcast MAR-M-247 for its' high temperature strength. The class of the part is chosen during assembly based on measurements of the longest 2nd blade tip in the rotor while they are mounted in the disk. The tip clearance is set radially by the class selection. The edges of the BOG segments are machined to form a shiplap joint with the outer shiplap on one edge and the inner shiplap on the other so that a full joint is realized when the segments are mated together in sets. Due to the machined shiplapped edges, a full set of parts cannot be made from a single ring. The tolerances on the shiplaps are designed so that the segments used to make up a set can be picked from a mixture of segments manufactured from different rings. Once they are picked for a set, are numbered and the classified machining done, they must remain in that set. While still in the detail stage the individual segments are shot peened all over to improve life characteristics. On the exit end of the BOGS is a flange and a hook which attaches it to the 2nd vane support. It is trapped in place axially between a full circular hook on the support and the turbine exit diffuser (TED) curl with the BOGS hook riding in an annular slot. Axial load generated by pressure differentials across the BOGS is taken out at this flange. Protruding out the end of the support hook are 18 tangs that locate the BOGS circumferentially within the support and provide anti-rotation features to remove any torque imparted into the BOGS from the main flow or by a rarely encountered blade tip rub. Another hook is machined on the inlet end of the BOGS that fits on the outside of the 2nd vane outer platform trailing edge. The BOGS will act as a beam spring when trapped between the vane platform and the hook on the 2nd vane support to add some softness to the system to help absorb the loads. On the 1st Stage Duct Segment (F/N 113-01) a life limit and inspection limit has been imposed per DAR PW0330. On the 2nd Stage Duct Segment (F/N's 114-01, 114-02) a life limit and inspection limit has been imposed per DAR PW0315. DVS 4.1.2.6 Turbine internal flow management analysis is complete with the results documented in FR-20712-01 and FR-20713-16 and the VCR in FR-20712-01A, 11A and 11B.

Find Number Find Name	Design Considerations
	DVS 4.1.2.9 Structural design analysis to verify margins is complete, and can be found in FR-20711-01and -03 and FR-20716-03 with the VCR in FR-20715-114. DVS 4.1.3.2.4.1 The demonstration of aerodynamic turbine performance at MSFC is complete. The results are documented in FR-20833-03 with the VCR in FR-20712-27. DVS 4.1.4.1.9.1 The turbine vane vibration tests to determine resonant frequencies are complete. The results are documented in FR-20716-21 with the VCR in FR-20715-114. DVS 4.1.4.1.9.2 The turbine vane LCF tests at MSFC are complete. The results are documented in FR-20711-05 with the VCR in FR-20715-114. DVS 4.1.4.2.5.1 Requirement deleted. Structural resonance tests for the turbine inlet duct and vane assembly are no longer required.
f/n 110, 109 Stator Supports 1, 2	FAILURE CAUSE G: Fracture of the 1st or 2nd Stator Supports due to vibration, thermal growth or material or manufacturing defect. The 1st Vane Support Housing (FN 110), made from a PWA-SP 1143 (INCO 909) forging, is a full hoop, multi-functional part. It is located axially and circumferentially by a flange in the main turbine exit diffuser (TED) bolted joint. Radially it is snapped at either end to the ID side of the 2nd vane support housing and maintains its centering along with the 2nd support through splines at the TED bolted joint. The main function of the 1st vane support housing is to transfer all the axial and tangential and part of the radial loads from the 1st vane segments into the TED flange joint. At the rear of the cylindrical part of the 1st vane support housing is a PWA-SP 288-2 hardcoated surface that radially supports the leading edge hook of the 2nd vane segments. Hardcoating is required because the vane hooks must slide axially due to the relative thermal growths of the parts. The vane supports are made of low alpha INCO 909 to minimize radial expansion and maintain a desired blade tip clearance during operation. The flange has 48 bolt clearance holes for attachment at the TED joint. It also has four scallops to allow passage of the TED coolant tubes through the flange as well as the eight spline slots for centering and torque removal. The height of the torque lugs on the ID of the flange are sized to prevent radially trapping the front hook of the 1st vane between the support and the turbine inlet spacer. The spacer, made of IN 100, will try to thermally outgrow the support in operation, which could cause this gap to close, if the support slips radially within the joint. The Second Vane Support (FN 109) provides the structure from which the 2nd vanes and 2nd blade outer gas seals (BOGS) are cantilevered. The housing is machined from a PWA-SP 1143 (Inco 909) forging chosen for its low coefficient of thermal expansion (alpha), high tensile properties, and resistance to hydrogen embrittlement. The low alpha material is the key to maintaining low turbine radial clearances, as the cooled turbine disk does not result in large radial deflections of the turbine rotor. As the vane and BOGS segments are cantilevered from the housing, the low alpha material ensures that the segments are retained at the minimum radial position for any given temperature. The primary function of the vane support is to transfer all the axial and tangential loads from the second vane segments and BOGS into the TED flange joint. The second function of the vane support is to provide an intermediate pressure vessel for the turbine, separating the turbine flowpath from Chamber 48. The second vane support is snapped to the 1st vane support at both ends of the 1st support, and also contacts it at the mid span bumper during operation to provide additional hoop restraint to resist bending in the 1st support cylinder due to the radial load imparted at the 1st vane trailing edge hook. The pumpside of the housing cylinder is sealed to the TED curl by a W-seal to prevent excessive leakage which could bleed down the pressure from Chamber 48. The flange has 48 bolt clearance holes for attachment to the TED joint using the T head bolts. The flange is also interrupted by four equally spaced scallops to provide clearance for the TED coolant tubes to pass through the flange. Straddling the scallops are the eight equally spaced square slots for the radial spline.

Critical Item List

Subsystem\Item No.\Part No.:	HPFTP/AT\B300\4700000	**Prepared by:**	D.F. Clark	**Page:**	39
Functional Assy:	Turbine Section 02	**Approved by:**	A.J. Slone	**Issue Date:**	October 28, 1986
Failure Mode:	Loss of flow control with energy loss in the turbine.	**CIL Item:**	0201	**Rev. Date:**	April 16, 2001

Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
Failure Cause A f/n 080 Liner & Housing Set	Material Integrity	Material integrity of liner (f/n 080-02-1) is verified per specification requirements	PWA-SP 1143
		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) is verified per drawing and specification requirements	PWA-SP 11-19 and PWA-SP 1135
		Shot peen of housing assembly (f/n 080) is verified per specification requirements	AMS 2430
		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 manifold/liner (f/n 080-04-1/080-04-2) is verified per specification requirements	PWA-SP 1143
	Raw Material	Sonic- per- QAD (manifold, if 2S4700153) (f/n 080-04-1)	SP-SIM 1
		Xray- per- QAD (housing casting) (f/n 080-03-1)	SP-XRM Master
		Sonic- per- QAD (spacer) (f/n 080-05)	SP-SIM 1
		Sonic- per- QAD (liner) (f/n 080-02)	SP-SIM 1
	Finished Material	FPI- per- QAD (seal) (f/n 080-01)	SP-FPM Master
		FPI- per- QAD (spacer) (f/n 080-05)	SP-FPM Master
		FPI- per- QAD (liner) (f/n 080-02)	SP-FPM Master
		FPI- per- QAD (housing set, after proof test) (f/n 080)	SP-FPM Master
		FPI- per- QAD (manifold/liner) (f/n 080-04/080-04-2)	SP-FPM Master
		ECI- per- QAD (housing set, after proof test) (f/n 080)	SP-ECM Master

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Proof pressure test of housing set (f/n 080) is verified per specification requirement	REI 017
		Penetrant inspect per DAR(s)	PW0313, PW0255, PW0277, PW0314
	Recycled Hardware	FPI-per-PWA-SP 36187 (housings) (f/n 080-03)	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 (liner f/n 080-02)	PWA-SP 36187 & SP-FPM Master
		FPI-per-PWA-SP 36187 (seals) (f/n 080-01)	PWA-SP 36187 & SP-FPM Master
		FPI-per-PWA-SP 36187 (spacer f/n 080-05)	PWA-SP 36187 & SP-FPM Master
Failure Cause A f/n 253 Deflector,Trbn.Inlet	Material Integrity	Material integrity is verified per specification requirements	AMS 5608
	Finished Material	Penetrant inspect per DAR	PW0319
		FPI- per- QAD	SP-FPM Master
	Recycled Hardware	FPI-per-PWA-SP 36187	
Failure Cause a f/n 079 Bolt,Exit Diffuser	Material Integrity	Material integrity is verified per specification requirement	PWA-SP 1149
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause a f/n 134 Nut,Exit Diffuser	Material Integrity	Material integrity is verified per specification requirements	AMS 5732
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause a f/n 254 Ring,Turbine Inlet	Material Integrity	Material integrity is verified per drawing and specification requirements	PWA-SP 1135

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Heat treatment is verified per drawing and specification requirements	PWA-SP 11-19 & PWA-SP 1489
	Raw Material	Xray- per- QAD	SP-XRM Master
	Finished Material	FPI- per- QAD	SP-FPM Master
		Penetrant and Dimensional inspect per DAR	PW0265
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause a f/n 256 Damper,Spring	Material Integrity	Material integrity is verified per drawing and specification requirements	PWA-SP 1074
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	FPI- per- QAD	SP-FPM Master
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause B f/n 083 Bellows,Turbine	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1143
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	ECI- per- QAD	SP-ECM Master
		FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Inspection of G5 Turbine Inlet 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 b f/n 081 Bolt,Turbine Inlet	Material Integrity	Material integrity is verified per specification requirement	PWA-SP 1149
	Finished Material	FPI- per- QAD	SP-FPM Master

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
Failure Cause b f/n 084 Liner,Trbn.Bellows	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1143
	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 b f/n 138 Nut,Inlet Bellows	Material Integrity	Heat treatment is verified per specification requirements	AMS 5732
		Material integrity is verified per specification requirements	AMS 5732
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause C f/n 090 Shield,Heat,Bellows	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1074
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	Proof pressure test is verified per specification requirements	REI 017
		FPI- per- QAD	SP-FPM Master
		ECI- per- QAD	SP-ECM Master
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause C f/n 350 Adaptor,Shld,Bellows	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1074
	Raw Material	Sonic -per -QAD	SP-SIM 1
	Finished Material	Penetrant inspect per DAR	PW0327

Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Sonic-per-QAD (Shearwave)	SP-SIM 1
		FPI -per -QAD	SP-FPM Master
	Recycled Hardware	ECI- per- PWA-SP 36187	PWA-SP 36187 & SP-ECM Master
		FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause D f/n 038 Duct Set,Trbn Outlet	Material Integrity	Material integrity of duct (f/n 038-02-1) is verified per drawing and specification requirements	PWA-SP 1074
		Material integrity of ring/duct (f/n 038-03-1/038-03-2) is verified per drawing and specification requirements	PWA-SP 1074
	Finished Material	FPI- per- QAD (duct) (f/n 038-02)	SP-FPM Master
		FPI- per- QAD (ring) (f/n 038-03)	SP-FPM Master
		FPI- per- QAD (A/O) (f/n 038)	SP-FPM Master
	Assembly Integrity	Penetrant inspect per DAR	PW0264
		Part Seating is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause d f/n 037 Shield,Heat,Turbine	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1143
	Finished Material	Penetrant inspect per DAR	PW0312
		FPI- per- QAD	SP-FPM Master
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause E f/n 077 Diffuser,Trbn.Exit	Material Integrity	Shot peen is verified per drawing and specification requirements	AMS 2430

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Material integrity is verified per specification requirements	PWA-SP 1074
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	Penetrant inspect per DAR	PW0268
		FPI- per- QAD	SP-FPM Master
		ECI- per- QAD	SP-ECM Master
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause E f/n 240 Support,Diffuser	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1074
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Penetrant inspect per DAR	PW0318
		Part Seating is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause e f/n 210 Seal,Sleeve	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1074
	Finished Material	Penetrant inspect per DAR	PW0331
		FPI- per- QAD	SP-FPM Master
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause e f/n 261 Pin,Exit Diffuser	Material Integrity	Material integrity is verified per specification requirements	AMS 5666

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Assembly Integrity	Locking feature inspected is verified per specification requirements	REI 012
Failure Cause F f/n 113 Seal,Stage 1,B.O.G.	Material Integrity	Heat treatments are verified per drawing and specification requirements	PWA-SP 11-19 & PWA-SP 1135
		Material integrity is verified per specification requirements	PWA-SP 1135
	Raw Material	Xray- per- QAD (duct segment) (f/n 113-01)	SP-XRM Master
	Finished Material	FPI- per- QAD (duct set) (f/n 113)	SP-FPM Master
		FPI- per- QAD (duct segment) (f/n 113-01)	SP-FPM Master
	Assembly Integrity	Penetrant inspect per DAR	PW0330
		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 F f/n 114 Seal,Stage 2,B.O.G.	Material Integrity	Heat treatments are verified per drawing and specification requirements	PWA-SP 11-19 & PWA-SP 1135
		Material integrity is verified per specification requirement	PWA-SP 1135
	Raw Material	Xray- per- QAD (duct segment) (f/n 114-01/114-02)	SP-XRM Master
	Finished Material	FPI- per- QAD (duct segment) (f/n 114-01/114-02)	SP-FPM Master
		FPI- per- QAD (duct set) (f/n 114)	SP-FPM Master
	Assembly Integrity	Selection of classification of part is verified per assembly drawing requirements	
		Penetrant inspect per DAR	PW0315
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
Failure Cause G f/n 109 Support,Stg.2,Stator	Material Integrity	Leading edge vane hook ring thickness is verified per drawing requirements	
		Material integrity is verified per specification requirements	PWA-SP 1143
		EDM and recast layer are verified per drawing and specification requirements	PWA-SP 97-2
	Raw Material	Sonic- per- QAD	SP-SIM 1
	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 110 Support,Stg.1,Stator	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1143
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	Trailing edge vane hook groove dimension is verified per drawing requirements	
		FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part Seating of DIM S18 is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
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
	Maintenance	Post Flight borescope pump out inspection of the Turbine Bellows Internal Heatshield and 1st and 2nd Stg. BOGS is verified per OMRSD.	OMRSD V41BU0.137

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Post Flight borescope inspection of the Turbine Inlet Gaspath and Bellows External Heatshield is verified per OMRSD.	OMRSD V41BU0.135