Critical Item List

Subsystem\Item No.\Part No.: HPFTP/AT\B300\4700000 | **Prepared by:** D.F. Clark | **Page:** 1

Functional Assy: Pump Section 01 | **Approved by:** A.J. Slone | **Issue Date:** October 28, 1986

CIL Item: 0101 | **Rev. Date:** April 16, 2001

CIL Item Code: 0101

FMEA Item Code: 0101

Function: Increase flow stream

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 impeller head rise.

Failure Cause(s)

A. f/n 032, 033 & 034 Damage, fracture or erosion of the impellers due to vibration, thermals, contamination or material/mfg defects.

B. f/n 062, 071, 072, 073, 093 & 108 Fracture or wear of the dampers or knife edge seals due to vibration, thermal growth, contamination or material/mfg. defect.

Criticality:

1R

Hazard Ref:

A) D1 S/A/M/C (AT):1B2.1.2.1.1.1.1, B2.1.2.1.1.2, 1B2.1.2.1.1.3, 1B2.1.2.1.1.4, 1B2.1.2.1.1.5, 1A1.9.1.1

B) D1 S/A/M/C (AT): 1B2.1.2.1.2.2.1, 1B2.1.2.1.2.2.2, 1B2.1.2.1.2.3, 1B2.1.2.1.2.5

Failure Effect:

Reduced pump output would be sensed by the controller which increases fuel preburner oxidizer flow. Excessive turbine discharge temperature will cause a 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 032, 033, 034 Impellers Stg. 1, 2, 3	FAILURE CAUSE A: Damage, fracture or erosion of the impellers due to vibration, thermals, contamination or material/mfg defects. The pump incorporates three Impeller stages (F/N's 032, 033 & 034) to increase the pressure of the liquid hydrogen supplied to the powerhead. The Impellers are machined from PWA-SP 1240 (A110 ELI) Titanium forgings for its specific strength and cryo toughness. All three stages are shrouded designs using six full length blades, six mid length splitters and twelve short splitters to do the work. Each impeller is piloted to the shaft and to its adjacent impeller with tight radial snaps and each has a unique spline feature carrying the torque for assembly foolproofing. The first and second stages incorporate lab seal lands for controlling leakage flows and pressures. The third stage acts as a double acting thrust piston. Tip seals at the discharge, a corner seal at the inlet and a face seal on the back side, vary front and back face pressures with shaft position. To improve HCF margin, all three impellers are media finished and shot peened and highly stressed corners are rounded. Individual impeller balance is achieved by material removal from lowly stressed areas of a front and rear balance plane. The 2nd impeller additionally accommodates two 180° counterweights for pump-end rotor stack balance. Material is removed from the segments for balance and each segment has a different size alignment lug to foolproof assembly. All three impellers are fracture critical parts and meet all the requirements of the SSME ATD fracture control plan FR-19793-5. DVS 4.1.2.3 Pump hydrodynamics analysis to verify pump performance is complete. The results are documented in FR-20709-01 and -02 with the VCR in FR-20712-27 and FR-23231-107. DVS 4.1.4.1.3.1 Strain gaged spin tests for the pump impellers are complete. The results are documented in FR-20715-25, FR-20715-27 and FR-20715-28 for impellers 1, 2 and 3, respectively. The VCR is in FR-20715-102. DVS 4.1.4.1.3.2 Spin burst tests for the pump impellers are complete. The results are documented in FR-20715-25, FR-20715-27 and FR-20715-28 for impellers 1, 2 and 3, respectively. The VCR is in FR-20715-102. DVS 4.1.4.1.3.3 Vibration tests to determine resonant frequencies for impeller 1 are complete. Vibration tests are not required for impellers 2 and 3. The results are documented in FR-20716-18 with the VCR in FR-20715-102. DVS 4.1.4.1.3.4 Adequate impeller rub margin has been substantiated by lack of wear during engine level testing at SSC. No report to be issued. DVS 4.1.4.1.3.6 Photoelastic test stress analysis of first stage impeller has been completed. The results are documented in FR-20715-20 with the VCR in FR-20715-102.
f/n 071, 072, 093, 108, 073, 062 Seal, Damper & Knife Edge	FAILURE CAUSE B: Fracture or wear of the dampers or knife edge seals due to vibration, thermal growth, contamination or material/mfg. defect. The Impeller Lab Seals are made from AMS 4127 Aluminum forgings. The 1st impeller inlet Lab Seal (FN 093) provides leakage control between the 1st stage impeller inlet and discharge on the pump side of the impeller. The seal is snapped to a seal carrier on the OD of the two hooks at assembly. After chilldown and during operation, the seal is snapped on the ID of the hooks. The seal is held in place axially by a retaining Nut (FN 095) which is locked by a Keywasher (FN 094). The nut loads the Labyrinth Seal Housing trapping the knife edge seal and providing a redundant axial constraint for the Vane Ring. The 1st impeller discharge Lab Seal (FN 108) minimizes leakage from the 1st stage discharge to the seal leakage sump (cavity surrounding the diffusers which drains into the inlet volute). The seal is snapped to the 1-2 diffuser on the OD and is bolted in place. The seal KE's are machined eccentrically to prevent a rub at operation due to the tendency of the rotor to run off center due to a rotor side load. The side load is caused by circumferential pressure gradients in the turbine and pump discharge volute. The 2nd impeller inlet Lab Seal (FN 073) provides leakage control between the 2nd stage impeller inlet and discharge on the pump side of the impeller. The seal is snapped to the 1-2 diffuser on the OD and is bolted in place. The seal KE's are machined eccentrically to prevent a rub at operation due to the tendency of the rotor to run off center due to a rotor side load. The side load is caused by circumferential pressure gradients in the turbine and pump discharge volute. The 2nd impeller discharge Lab Seal (FN 062) minimizes leakage from the 1st stage discharge to the seal leakage sump. The seal is snapped to the 2-3 diffuser on the OD and is bolted in place. This seal does not require eccentric KE's. The lab seal clearances are optimized to minimize leakage from stage to stage while providing enough operating clearance to preclude a rub. The lab seals are arranged to develop a net axial load in the turbine direction which helps to balance the axial thrust load delivered to the rotor by the turbine. The Damper Seals (FN's 071 & 072) made from AMS 4219 cast Aluminum, are high pressure annular interstage seals with a deliberately roughened surface which enhances rotor stability through damping. The surface roughness is achieved by machining 396 flat bottomed holes into the seal wall . The annular passages formed by the seals and rotors have convergent clearances. The convergent flow also enhances rotor stability. In order to prevent rubs and maintain proper annular flow areas, it is necessary to machine the 2-3 damper seal with eccentricity. Eccentric machining of the 1-2 damper is not required. The seals are bolted into the diffusers and are snapped on the OD to the diffusers. The Screws (FN's 136, 243, 244, 246 & 264), made from A-286 (AMS 5732 for strength and thermal expansion characteristics) are threaded into 304 CRES self-locking helical wire inserts which are installed into the pump interstage diffusers. They retain the impeller knife edge seals, the damper seals, and the corner seal to the diffusers. The screws contain vespel inserts installed in a hole that is drilled through the end of the screws to provide a redundant self-locking to the self-locking inserts. On the Second Stage Knife Edge Seal (F/N 073) a life limit and inspection limit has been imposed per DAR PW0322.

Critical Item List

Subsystem\Item No.\Part No.: HPFTP/AT\B300\4700000	**Prepared by:** D.F. Clark	**Page:** 3
Functional Assy: Pump Section 01	**Approved by:** A.J. Slone	**Issue Date:** October 28, 1986
Failure Mode: Loss of impeller head rise.	**CIL Item:** 0101	**Rev. Date:** April 16, 2001

Find Number Find Name	Design Considerations
	DVS 4.1.2.3 Pump hydrodynamics analysis to verify pump performance is complete. The results are documented in FR-20709-01 and -02 with the VCR in FR-20712-27 and FR-23231-107.

Critical Item List

Subsystem\Item No.\Part No.: HPFTP/AT\B300\4700000 | **Prepared by:** D.F. Clark | **Page:** 4

Functional Assy: Pump Section 01 | **Approved by:** A.J. Slone | **Issue Date:** October 28, 1986

Failure Mode: Loss of impeller head rise. | **CIL Item:** 0101 | **Rev. Date:** April 16, 2001

Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
Failure Cause A f/n 032 Impeller,Stage 1	Material integrity	Material integrity is verified per specification requirements	PWA-SP 1240
	Inspection	Pump end pilot diameter is verified per drawing requirements	
		Spline data is verified per drawing requirements	
		Blade leading edge thickness verified per drawing requirements	
		Shroud thickness is verified per drawing requirements	
		Turbine end pilot diameter is verified per drawing requirements	
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	Proof spin test is verified per specification requirements	REI 018
		ECI- per- QAD	SP-ECM Master
		FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part seating is verified per REI	REI 012
		Maximum temperature limit if part is subjected to heat to facilitate assembly is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause A f/n 033 Impeller,Stage 2	Material integrity	Material integrity is verified per specification requirements	PWA-SP 1240
	Inspection	1st Stage pilot diameter is verified per drawing requirements	
		Shroud thickness is verified per drawing requirements	
		Turbine end pilot diameter is verified per drawing requirements	

Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Blade leading edge thickness verified per drawing requirements	
		Spline data is verified per drawing requirements	
		Pump end inside diameter is verified per drawing requirements	
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	Proof spin test is verified per specification requirements	REI 018
		ECI- per- QAD	SP-ECM Master
		FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part seating is verified per REI	REI 012
		Maximum temperature limit if part is subjected to heat to facilitate assembly is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause A f/n 034 Impeller,Stage 3	Material integrity	Material integrity is verified per specification requirements	PWA-SP 1240
	Inspection	Turbine end pilot diameter is verified per drawing requirements	
		2nd Stage pilot diameter is verified per drawing requirements	
		Shroud thickness is verified per drawing requirements	
		Spline data is verified per drawing requirements	
		Pump end inside diameter is verified per drawing requirements	
		Blade leading edge thickness verified per drawing requirements	
	Raw Material	Sonic- per- QAD	SP-SIM 1

Critical Item List

Subsystem\Item No.\Part No.: HPFTP/AT\B300\4700000 | **Prepared by:** D.F. Clark | **Page:** 6

Functional Assy: Pump Section 01 | **Approved by:** A.J. Slone | **Issue Date:** October 28, 1986

Failure Mode: Loss of impeller head rise. | **CIL Item:** 0101 | **Rev. Date:** April 16, 2001

Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Finished Material	ECI- per- QAD	SP-ECM Master
		Proof spin test is verified per specification requirements	REI 018
		FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Maximum temperature limit if part is subjected to heat to facilitate assembly is verified per REI	REI 012
		Part seating is verified per REI	REI 012
		Part alignment onto shaft is verified per Assembly Drawing requirements	
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause B f/n 062 Seal,Stage 2,Rear	Material Integrity	Material integrity is verified per specification requirements	AMS 4127
	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 071 Damper,Stage 1	Material Integrity	HIP is verified per drawing requirements	
		Heat treatment is verified per drawing and specification requirements	PWA-SP 11-32
		Material integrity is verified per specification requirements	AMS 4219
	Raw Material	Xray- per- QAD	SP-XRM Master
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part seating of DIM S10 is verified per REI	REI012

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 B f/n 072 Damper,Stage 2	Material Integrity	Material integrity is verified per specification requirements	AMS 4219
		Heat treatment is verified per drawing and specification requirements	PWA SP 11-32
		HIP is verified per drawing requirements	
	Raw Material	Xray- per- QAD	SP-XRM Master
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part seating of DIM S7 is verified per REI 012	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause B f/n 073 Seal,Stage 2,Front	Material Integrity	Material integrity is verified per specification requirements	AMS 4127
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part seating of DIM S12 is verified per REI	REI012
		Penetrant inspect per DAR	PW0322
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause B f/n 093 Seal,Stage 1,Front	Material Integrity	Material integrity is verified per specification requirements	AMS 4127
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part Seating of DIM S13 is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master

Critical Item List

Subsystem\Item No.\Part No.: HPFTP/AT\B300\4700000 | **Prepared by:** D.F. Clark | **Page:** 8

Functional Assy: Pump Section 01 | **Approved by:** A.J. Slone | **Issue Date:** October 28, 1986

Failure Mode: Loss of impeller head rise. | **CIL Item:** 0101 | **Rev. Date:** April 16, 2001

Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
Failure Cause B f/n 108 Seal,Stage 1,Rear	Material Integrity	Material integrity is verified per specification requirements	AMS 4127
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Part seating of DIM S11 is verified per REI	REI 012
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause b f/n 094 Washer,Key,Stg.1	Material Integrity	Material integrity is verified per specification requirements	AMS 5512
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Locking feature inspected is verified per REI	REI 012
Failure Cause b f/n 095 Ring,Seal,Ext.Thread	Material Integrity	Material integrity is verified per specification requirements	PWA-SP 1146
	Finished Material	FPI- per- QAD	SP-FPM Master
	Recycled Hardware	FPI-per-PWA-SP 36187	
Failure Cause b f/n 136 Screw,Rear Diffuser	Material Integrity	Material integrity is verified per specification requirements	AS 7477
	Raw Material	Sonic- per- QAD	SP-SIM 314
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause b f/n 243 Screw,Fwd.Diffuser	Material Integrity	Material integrity is verified per specification requirements	AS 7477
	Raw Material	Sonic- per- QAD	SP-SIM 314

Critical Item List

Subsystem\Item No.\Part No.: HPFTP/AT\B300\4700000 | **Prepared by:** D.F. Clark | **Page:** 9

Functional Assy: Pump Section 01 | **Approved by:** A.J. Slone | **Issue Date:** October 28, 1986

Failure Mode: Loss of impeller head rise. | **CIL Item:** 0101 | **Rev. Date:** April 16, 2001

Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause b f/n 244 Screw,Fwd.Diffuser	Material Integrity	Material integrity is verified per specification requirements	AS 7477
	Raw Material	Sonic- per- QAD	SP-SIM 314
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause b f/n 246 Screw,Rear Diffuser	Material Integrity	Material integrity is verified per specification requirements	AS 7477
	Raw Material	Sonic- per- QAD	SP-SIM 314
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause b f/n 264 Screw,Fwd.Diffuser	Material Integrity	Material integrity is verified per specification requirements	AS 7477
	Raw Material	Sonic- per- QAD	SP-SIM314
	Finished Material	FPI- per- QAD	SP-FPM Master
All Cause	Assembly Integrity	Cleanliness control of all parts during final assembly are verified per specification requirement	PWA-SP 80
		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
	Acceptance	Acceptance test will be conducted as required by contract, to demonstrate specified performance.	FR24542
	Maintenance	Shaft rotation torque check is verified per OMRSD.	OMRSD V41BS0.060