Subsystem: HPOTP B500 - 4750000-700	**Critical Item List**	Page: 60	
Functional Assy: Drive Turbine Section B50002	Prepared by: M.T. Spencer	Issue Date: December 23, 1993	
	Approved by: R.L. Pugh	Rev. Date: December 08, 1995	
	CIL Item: 0205		

CIL Item Code: 0205		Analyst: M.T. Spencer	
FMEA Item Code: 0205		Approved by: R.L. Pugh	
Function: Direct H2 Coolant		Rev. No.:	
System/Subsystem: HPOTP B500 - 4750000-700		Rev. Date: December 08, 1995	
		Effectivity:	
		Hazard Ref.: See Listings Below	

Operating Phase	Failure Mode, Description and Effect	Criticality
s,m	**Failure Mode:** Loss of coolant flow control. **Failure Cause/s:** A. I/n 107, 143, or 188. Fracture or plugging of manifold due to vibration,thermal growth, material/braze/mfg defect, or contamination. B. I/n 109 Fracture of the Deflector due to vibration, thermal growth, excessive loads, or material/mfg defect C. I/n 022-08 Wear or plugging of the K.E Seal or loss of the I/n 22-23 ring braze due vibration, thermal growth, contamination, or material/mfg defect. D. I/n 059 Fracture of the main turbine housing due to vibration, thermal growth, excessive loads, or material/mfg defect E. I/n 022 Fracture of Main Pump Housing due to vibration, over pressure, thermals, plumbing loads, or material/weld/mfg defects F. I/n 22-29-10 Fracture of sleeve housing due to vibration, thermal growth, excessive loads, or material/mfg. defects **Failure Effect:** Loss of cooling flow or excessive hot gas ingestion could result in icing or rotor shift, brg failure, or turbine/ airfoil failure leading to fire, or case penetration **System:** Uncontained failure **Mission/Vehicle:** Loss of vehicle **Redundancy Screens:** Does not apply since it is a single point failure	**Criticality:** 1 **Hazard Ref:** A) C1S/A/M/C (AT) 1A1.1.6.1.1, 1A1.1.6.1.2 B) C1S/A/M/C (AT) 1A1.1.6.1.2 C) C1S/A/M/C (AT) 1A1.1.6.1.2 D) C1S/A/M/C (AT) 1A1.1.6.1.2 E) C1S/A/M/C (AT) 1A1.1.6.1.2 F) C1S/A/M/C (AT) 1A1.1.6.1.2

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Part Name/No.	Design Considerations	Document Ref
f/n 107, 143, and 188 Manifold	FAILURE CAUSE A. Four (4) sets of transfer tubes route coolant through the TIH and feed the deflector assembly for turbine disk cooling. The flow metering orifice was located in the supply exit to provide margin for leakage. The tubes are brazed into ferrules per PWA-SP Spec 19 as specified in the Materials Control Plan FR-19673-4 Sealing and damping is provided with piston rings, and by support brackets that are bolted or allowed to slide in retainers. Four separate tubes are utilized to provide cooling flow thru the outlet duct and to the IPS package for roller and bumper ball brg cooling, and the back side of the turbine disk. These tube sizes were increased from .250 diameter to .375 diameter to provide additional coolant pressure margin against hot gas ingestion at the roller bearing 4 tooth knife edge seal. These tubes interface with the cored passages in the turbine outer case and main housing with appropriate seals. All tubes are fabricated from AMS 5571 and 5572, which are excellent in the H2 environment. The tubing design wall thickness and brackets have been analyzed for both LCF, and HCF. Life margins were well in excess of requirements. These parts are manufactured with a process which is gold-nickel braze (PWA-SP 19). These parts meet CEI requirements.	
f/n 106 Deflector	FAILURE CAUSE B. This assembly is retained by 24 bolts which manifolds two of the four cooling tubes to provide an even distribution to the turbine disk, and control thermal growth of the fwd rim seal. The dual function pins transfer loads, and hold the seal concentric with the seal land. The seal material is PWA-SP 1143 and was selected for its high temperature strength and ductility in hydrogen. The mission life of the seal is greater than 1000 cycles. DVS 4.1.3.3.5.1 Turbine coolant system evaluation has been completed, and can be found in FR-20726-35.	
f/n 22-08, 22-23 K.E. Seal Set	FAILURE CAUSE C. This seal in combination with the 11 and 72 seals, controls the flow to the backside of the disk. Material used for the K.E. is PWA -SP 1074 (IN 100) which was selected for its strength resistance to hydrogen embrittlement. The seal ring is an (spec) A 286 support with brazed-on nickel land (PWA-SP 6000-1) and plated silver AMS 2410. The A286 was selected for its high strength and resistance to hydrogen embrittlement, and the silver for rub tolerance, and the nickel for its resistance to ignition in LOX. The braze is PWA-SP 19. Mission life for the seal is greater than 1000 cycles. This part meets CEI requirements.	
f/n 059 Main turbine housing	FAILURE CAUSE D. This housing (which is also referred to as the Turbine Outer Vane Support (TOVS)) transfer the loads from the inlet housing and turbine vanes to the outlet duct.	

This housing provides four passages for coolant transfer to the roller bearing and IPS package. In four locations cooling hole meters are provided for blade tip control.

Three pins are used to align the housing circumferentially to position the cooling passage juncture between the TOVS housing and the bellows housing. The coolant passage mates with a coolant transfer tube on the other end.

Material used is PWA-SP 1074 (IN 100) which was selected for its high strength in elevated temperature hydrogen.

This part does not meet CEI requirements, so life and inspection limits have been imposed (DAR 0184). DAR NO. 0184

I/n 22
Main pump hsg

FAILURE CAUSE E. The main housing provides coolant transfer passages to the roller bearing and IPS. The main housing is made up of a welded assembly of the left, center, and right castings of Inconel 718, and the turbine side housing which is made of PWA-SP 1052 (A-286) chosen for its high strength and LOX compatibility.

Materials Control Plan FR-19673-6 describes the EB Weld Development Program which will demonstrate the process to ensure the successful fabrication/assembly of this housing.

This part on the pump side sees LOX, and on the turbine side H2 .

The housing provides the LOX flowpath geometry for the inlet independently for the inducers and main impeller, and discharge.

This structure also provides the backbone for the pump to transmit induced loads to the hot gas manifold. It also provides support for the various seals, roller brg, passages for the interpropellant seals, and maintains the required clearance for the inducers, main impeller, and thrust balance system thru support of the inner hsg. assembly.

The preburner hsg and the seal support are bolted to this housing, as well as the turbine discharge duct.

This part does not meet CEI LCF Life, but does meet Fracture Mechanics Life, so no life or inspection limits have been imposed (DAR 0189). DAR NO. 0189

DVS 4.1.2.9 Structural design analysis can be found in FR-20729-09, and FR-20730-01.

I/n 22-29-10
Housing

FAILURE CAUSE F. Provides support for the static components of the seal assembly, and the turbine end bearings.

Passages machined into the forged housing allow coolant flow to the roller bearing and TEBB. A spring assisted Teflon seal located in a seal gland between the borescope hole and primary Hydrogen seal drain prevents leakage flow through the borescope hole and into the primary drain. The snap fit between the IPS Housing and Sleeve near the borescope is maintained as a back-up to the Teflon seal.

To maintain the tight Sleeve-to-Housing fits, cooling slots, a redesigned heatshield, and a tight fit between the flow guide I/n 282, and seal I/n 011 have been incorporated along with the Teflon seal between the sleeve and housing. These features all contribute to avoiding ice in this area.

The IPS seal package is assembled into the sleeve prior to installation of the sleeve into the Main Housing Assembly. Bearing deadband diameters are machined with the sleeve installed to eliminate the assembly load's effect on the deadband.

The IPS Sleeve (housing) retaining nut also serves as part of the inlet flowpath wall, directing flow to the turbine side inducer. In addition, deswirl vanes are incorporated on the back side of the nut to improve vaporizer performance.

A cup washer is used to lock the retaining nut due to the concern that the vaporizer could excite a tab, and cause it to be released into the flowstream. Locking is per PWA-SP 320.

Material is PWA-SP 1146(Inconel 718) which was selected for its LOX compatibility.

This part meet CEI requirements.

DVS 4.1.3.2.1 & .2 has been completed, and can be found in FR-20904-1, and FR-20728-2, -3.

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		Inspection and Test	
Possible Causes	**Significant Characteristics**	**Inspection and Test**	**Document Ref**
Failure Cause A f/n 107, 143, & 188 Manifold	Material Integrity	Material integrity is verified per specification requirements for the various tube assemblies.	AMS 5571, AMS 5772, AMS 5731, and AMS 5646
	Heat Treat	Heat treat is verified per specification , and drawing requirements.	PWA-SP 11-32
	Braze Integrity	Braze integrity is verified per specificaton requirements. Au-Ni	PWA-SP 19
	INSPECTION		
	Finished Material	FPI - f/n 143, f/n 188 elbow per QAD FPI - f/n 188 tube detail, f/n 107 assy. per QAD X-ray - f/n 188 assy per QAD Leak test is verified per print requirements.	SP-FPM Master SP-FPM Master SP-XRM Master
Failure Cause B f/n 106 Deflector	Material Integrity	Material integrity is verified per specification requirements.	PWA-SP 1143
	Heat Treat	Heat treat is verified per specification, and drawing requirements.	PWA-SP 1143
	INSPECTION		
	Finished Material	FPI per QAD	SP-FPM Master
Supporting hardware 0205b f/n 129 Bolt	Material Integrity	Material integrity is verified per specification.	AMS 5731-85 per MS 9556
	INSPECTION		
	Raw Material	Sonic per QAD	
	Finished Material	FPI per QAD	SP-FPM Master
Failure Cause C f/n 1. 22-09, 2. 22-23 1. K.E. Seal, 2. Seal Ring	Material Integrity	Material integrity is verified per specification requirements.	1. PWA-SP 1074 2. PWA-SP 8000-1, AMS 5731

	Heat Treat	Heat treat is verified per specification , and drawing requirements.	2. PWA-SP 11, and 11-32
	Plating Integrity	Plating integrity is verified per specification	AMS 2410
	Braze Integrity	Braze integrity is verified per specification requirements.	PWA-SP 19
	INSPECTION		
	Raw Material	1. Sonic per QAD	
	Finished Material	2. FPI - Assembly and detail ring and support per QAD 1. ECI per QAD 1. X-ray per QAD	2. SP-FPM Master 1. SP-ECM Master 1. SP-XRM Master
	Assembly Integrity	Part seating is verified per assembly drawing.	REI 013
Failure Cause D f/n 059 Main turbine hsg	Material Integrity	Material integrity is verified per specification requirements.	PWA-SP 1074
	INSPECTION		
	Raw Material	Sonic - housing per QAD	
	Finished Material	ECI - assembly per QAD	SP-ECM Master
		FPI at the detail or assembly level per QAD	SP-FPM Master
Supporting hardware 0205d f/n 060 1.Tubes 2. Elbows, Ferrule	Material Integrity	1. & 2. Material integrity is verified per specification. Proof and Leak test verified per print requirements.	1. AMS 5571 2. AMS 5648
	INSPECTION		
	Finished Material	1. FPI - tubes per QAD 2. FPI - elbows per QAD	1. SP-FPM Master 2. SP-FPM Master
Failure Cause E f/n 022 Main hsg	Material Integrity	Material integrity is verified per specification requirements for 22-28-02, 03, and 04 Material integrity is verified per specification requirements for 22-28-09 Contamination control is verified per specification for item 22-28-12, -18, & 22, and 22-28-11.	PWA-SP 1490-1 PWA-SP 1052 PWA-SP 36150-4

		EDMR	PWA-SP 97-5
	Heat Treat	Heat treat is verified per specification requirements for 22-28-02, 03, and 04. Heat treat is verified per specification for and drawing requirements for item 22.	PWA-SP 11-31 PWA-SP 11, 11-17, and 1490
	Weld Integrity	Weld integrity is verified per specification requirements. Weld repair is verified per specification for fins 22-28-02, 03, & 04.	PWA-SP 16-22, PWA-SP 31-158, PWA-SP 16-2233 PWA-SP 35158
	INSPECTION		
	Raw Material	Sonic - housing item 22-28-09 per QAD X-ray - housing item nos. 22-28-02, 03, and 04 per QAD	 SP-XRM Master
	Finished Material	X-ray - item 22 per QAD ECI - item 22-28-02, 03, 04 per QAD ECI - item 22-28-09 before proof test per QAD ECI - item 22-28-09 after proof test per QAD FPI - Cast material item nos. 22-28-02, 03, and 04 per QAD FPI - Wrought material item no. 22-28-09 per QAD FPI - Unmachined welds item no. 22 per QAD FPI - Machined welds item no. 22 per QAD Coolant passage min wall thickness is verified per drawing requirements.	SP-XRM Master SP-ECM Master SP-ECM Master SP-ECM Master SP-FPM Master SP-FPM Master SP-FPM Master SP-FPM Master
	In-Process Testing	Proof pressure test to reflect the proof factors and conditions specified in the reference documents.	REI 005
	HIP	HIP is verified per specification.	PWA-SP 4, & 1490
Failure Cause F f/n 22-29-10 Sleeve Hsg	Material Integrity	Material integrity is verified per specification	PWA-SP 1146
	INSPECTION		
	Raw Material	Sonic per QAD	
	Finished Material	FPI per QAD	SP-FPM Master
	Assembly Integrity	Part seating and torque will be verified per assembly drawing. Cleanliness of components will be verified per specification.	REI 013 PWA-SP 60

All Cause	General Quality Requirements:	Supplier Quality Assurance requirements are included in PW-QA-6076, and include such requirements as first piece layouts. This requires the documentation of dimensions on all characteristics represented on the delivered article. Inspection Methods Sheets for use in the inspection of purchased parts and assemblies contain the necessary information to insure that the requirements of the QADs, engineering drawings, and referenced documents are satisfied. For shop fabricated parts, the sheets are audited by Inspection Methods. The purchase orders for vendor supplied parts must comply with PWA-SP 300, 'Control of Materials Processes and Parts', which requires the vendor to provide material, process, and dimensional information to the Quality Department.	PWA-SP 300
	Acceptance	Acceptance test will be conducted as required by contract, to demonstrate specified performance.	DR SE-13
	Cleanliness	Cleanliness of components will be assured by compliance to Contamination Control Specification.	PWA-SP 60
All Cause f/n : 059 TOVS, 022 Main Housing	Waivers	The TOVS does not meet CEI life, so a life limit and inspection requirement has been imposed (DAR 0184). The Main Housing does not meet CEI LCF life requirements, but does meet Fracture Mechanics life, so no limits have been imposed (DAR 0189).	DAR NO. 0184 DAR NO. 0189