Subsystem: HPOTP B500 - 4750000-700	**Critical Item List**	Page: 32	
Functional Assy: Drive Turbine Section 850002	Prepared by: M.T. Spencer	Issue Date: December 23, 1993	
	Approved by: R.L. Pugh	Rev. Date: December 08, 1995	
	CIL Item: 0201		

CIL Item Code: 0201		Analyst: M.T. Spencer	
FMEA Item Code: 0201		Approved by: R.L. Pugh	
Function: Direct Hot Gases		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	Loss of flow control with energy loss in the turbine due to mis-direction, or blockage.	1R

Failure Cause(s):

A. f/n 114-02 Fracture of turbine inlet hsg due to vibration, thermal growth, over temp, excessive loads, or material/mfg defect.

B. f/n 60 Fracture of bellows due to vibration, thermal growth, over temp, excessive loads, or material/mfg defect.

C. f/n 115 Fracture of bellows shield due to vibration, thermal growth, over temp, excessive loads, or material/mfg defect.

D. f/n 13 Fracture of outlet duct due to vibration, thermal growth, over temp, excessive loads, turbine blade failure, or material/mfg defect.

E. Failure Cause Deleted.

F. f/n 112 or 113 Wear or erosion of the turbine tip seals due to vibrations, thermal growth, rub, material/mfg defect, corrosion, or FOD.

Hazard Ref:

A) B3S/A/M/C (AT) 1B2.1.1.1, 1B2.1.1.2, 1B2.1.5, 1B2.1.6

B) C1S/M (AT) 1B2.1.1.1.1.1, 1B2.1.1.1.3, 1B2.1.1.1.4

C) C1S/M (AT) 1B2.1.1.1.1.1, 1B2.1.1.1.3, 1B2.1.1.1.4

D) B3S/A/M/C (AT) 1B2.1.1.1, 1B2.1.1.2, 1B2.1.5, 1B2.1.6

F) B3S/A/M/C (AT) 1B2.1.1.2

Failure Effect:

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

System:

Engine shutdown

Mission/Vehicle:

Mission scrub.

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

Debris generated in failing could cause damage to the GOX HEX downstream of the turbine exhaust.

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.

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		Approved by:	R.L. Pugh	Rev. Date:	December 06, 1995
		CIL Item:	0201		

Operating Phase:
m

Failure Mode:
Loss of flow control with energy loss in the turbine due to mis-direction, or blockage.

Failure Cause(s):
A. f/n 114-02 Fracture of turbine inlet leg due to vibration, thermal growth, over temp, excessive loads, or material/mfg defect.

B. f/n 60 Fracture of bellows due to vibration, thermal growth, over temp, excessive loads, or material/mfg defect.

C. f/n 115 Fracture of bellows shield due to vibration, thermal growth, over temp, excessive loads, or material/mfg defect.

D. f/n 13 Fracture of outlet duct due to vibration, thermal growth, over temp, excessive loads, turbine blade failure, or material/mfg defect.

E. Failure Cause Deleted.

F. f/n 112 or 113 Wear or erosion of the turbine tip seals due to vibrations, thermal growth, rub, material/mfg defect, corrosion, or FOD.

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

System:
Engine shutdown

Mission/Vehicle:
Mission abort

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

Debris generated in failing could cause damage to the GOX HEX downstream of the turbine exhaust.

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.

Criticality:
1R

Hazard Ref:
A) B3S/A/M/C (AT) 1B2.1.1.1, 1B2.1.1.2, 1B2.1.5, 1B2.1.6
B) C1S/M (AT) 1B2.1.1.1.1.1, 1B2.1.1.1.3, 1B2.1.1.1.4
C) C1S/M (AT) 1B2.1.1.1.1.1, 1B2.1.1.1.3, 1B2.1.1.1.4
D) B3S/A/M/C (AT) 1B2.1.1.1, 1B2.1.1.2, 1B2.1.5, 1B2.1.6
F) B3S/A/M/C (AT) 1B2.1.1.2

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Part Name/No.	Design Considerations	Document Ref
f/n 114-02 Inlet hsg.	FAILURE CAUSE A. The turbine inlet hsg defines the inner and outer flowpath walls.	
	The thin outer wall is a full hoop carrying shell which provides a support wall for the 12 cantilevered struts. The struts are all the same size for even load distribution and have the O.D. of the core closed off by the outer wall to eliminate core breakout KTs. Outer wall thickened areas at the leading and trailing edges are optimized to reduce the concentrated stresses. The inner flowpath was split between struts and is supported by the struts. These features are all incorporated to eliminate the cracking experienced during development.	
	Vent holes in the outer flow path wall allow hot gas path bleed into the nose cavity to reduce thermal stress, and reduce the delta P on the inner support. The holes have been sized to allow sufficient flow while being small enough to prevent the ingestion of bolts or nuts.	
	Dual function pins transfer the load from the inner dome to the inlet case, and hold the seal concentric with the seal land.	
	The inlet hsg is bolted to the outer case, and is made of PWA-SP 1489 (Micro-Cast Mar-M-247) which was selected for its strength in elevated temperature hydrogen, and thermal shock. The inner dome (heatshield) is PWA-SP 1143 (Incoloy 909), which was selected for its resistance to hydrogen embrittlement, and low alpha which reduces thermal stresses.	
	In response to the thermal cracking experienced in development, an O.D. load ring made of PWA-SP 1074 (IN 100) material has been incorporated which provides a preload compression on the outer wall of the turbine inlet housing at the strut trailing edge. While this becomes an non separable piece once installed, it is identified as f/n 114-02-02.	
	To uncouple thermally driven stresses from the turbine inlet housing, the inlet dome utilizes a radially free dome and wave washer spacer configuration.	
	The inlet housing LCF life is less than CEI requirements, but Fracture Mechanic Life is greater than CEI, so no inspection limits are imposed (DAR 0161).	DAR NO. 0161
	LCF life of the I.D. load ring (f/n 114-04) also does not meet CEI life, but the Fracture Mechanics Life is greater than CEI, so no inspection limits are imposed (DAR 0162).	DAR NO. 0162
	DVS 4.1.4.1.5.1, and .2 tests which require proof pressure, and vibration tests have been completed, and can be found in FR 20729-50 and 20730-49.	
	DVS 4.1.4.2.5.1 test which requires resonance testing has not yet been started.	
	DVS 4.1.2.9 which requires structural design analysis of the inlet was completed in 4/89 (FR 20729-06, and 06A)	
f/n 060 Inlet bellows	FAILURE CAUSE B. The primary function of the bellows is to compensate for the relative deflections between the preburner and turbine inlet due to thermals, pressure, and mechanical loads. The heatshield is attached to the bellows.	
	Keylock stud orientation is provided to reduce KI's in high stress areas.	
	The bellows material is PWA-SP 1143 (Incoloy 909) which was selected for its resistance to hydrogen embrittlement, and low alpha which reduces thermal stress. This is a fully machined bellows to eliminate welds and improve life.	
	This part meets CEI LCF requirements, but does not meet Fracture Mechanics life, and a life limit and inspection requirement	

is imposed (DAR 0183).

DAR NO. 0183

DVS 4.1.4.1.10.1 turbine bellows pressure test to 1.2 times the maximum operating pressure has been, completed, and can be found in FR-20729-47.

DVS 4.1.4.1.10.2 which require bellows and shield resonant frequencies had been completed 12/89. (FR 20730-17)

f/n 118
Bellows shield

FAILURE CAUSE C. The function of the bellows shield is to provide a smooth flowpath along the outside of the HPOTP. Material used is Haynes 188 (AMS 5772) forging which was chosen for its high temperature strength and ductility in hydrogen.

Vent holes have been incorporated to reduce the delta P and therefore buriging potential.

This part meets CEI requirements.

f/n 013
Outlet Duct

FAILURE CAUSE D. The outlet duct (TAD) is a one piece casting that directs the turbine discharge to the hot gas manifold. 22 struts are provided for support; 14 for studs to attach to the pump hsg.

The midspan splitter is cast as a full ring and then sliced between each strut to eliminate thermally induced stress in the splitter fillet radii. The turbine-side endwall is also sliced radially between each strut and then cut circumferentially to create a thermally compliant flow guide

Experience has demonstrated a cracking condition of the integral TAD forward outer flowpath wall due to thermals. To correct this condition, an independent ring has been incorporated as part of the upper level assembly.

Development testing demonstrated a loose snap condition, between the tap curl and the turbine discharge inner wall, as well as a cracking condition. To correct this, the curl (flowguide) has been separated from the outlet duct by making it an independent piece. This curl is identified as f/n 282, and is made of PWA-SP 1143 (Incoloy 909) material. Gaskets are provided at both the forward and aft joints (f/ns 283 & 284) which are made of AMS 5544 material.

The seal (f/n 11) provides a portion of the inner flowpath wall between the 3rd blade exit and the duct.

The TAD must transmit the thrust and torque from the turbine stators to the pump hsg.

Engine level testing revealed a downstream impact on the engine turning vane durability. A redesign to the TAD airfoil was accomplished to eliminate this problem.

Material used is PWA-SP 1486 (mar-m-247) for its strength in elevated temperature hydrogen.

This part does not meet CEI requirements, and inspection limits have been imposed (DAR 0188).

DAR NO. 0188

DVS 4.1.2.9 which requires structural design analysis of the TAD can be found in FR-20729-07A.

DVS 4.1.2.11 which requires a turbine exit flowpath analysis was completed, and is documented in FR-20904-91.

DVS 4.1.3.2.4.2 which requires a turbine exit air flow characterization has been partially completed, and the test plan can be found in FR-20666-4, and FR- 20833-4, and 20833-5.

DVS 4.1.4.1.6.2 requires proof pressure test, and vibration tests, has been completed, and can be found in FR-20729-07A.

f/n N/A N/A	FAILURE CAUSE E. Failure cause deleted.
f/n 112 & 113 Turbine tip seals	FAILURE CAUSE F. The turbine blade tip seals which are supported by the inner vane support (TIVS f/n 097), and the outer vane support (TOVS f/n 059), define the flow path O.D. The solid outer blade tip seal (OS) ring is integral with the vane assy.
	The TIVS does not meet CEI life so an inspection limit has been imposed (DAR 0193). DAR NO. 0193
	The 2nd vane carries the 1st and 2nd OS, and the 3rd vane carries the 3rd OS. These vane assemblies are segmented, and feather seals are used between segments to control leakage.
	The 2nd vane does not meet CEI LCF life, so life limits have been imposed (DAR 0186). DAR NO. 0186
	The 3rd vane does not meet CEI LCF life, but does meet Fracture Mechanics life, so no limits have been imposed (DAR 0187). DAR NO. 0187
	Material is microcast PWA-SP 1489 (mar-m-247) which was selected for its strength in elevated hydrogen temperatures.
	These parts are manufactured with a process to control low melt alloy contamination (PWA-SP 109).

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		Inspection and Test	
Possible Causes	**Significant Characteristics**	**Inspection and Test**	**Document Ref**
Failure Cause A f/n 114-02 Inlet hsg	Material Integrity	Material integrity is verified per specification requirements.	PWA-SP 1489
	Heat Treat	Heat treat is verified per specification requirements.	PWA-SP 11-19, PWA-SP 1499
	INSPECTION		
	Raw Material	X-Ray per QAD	SP-XRM Master
	Finished Material	FPI - housing per QAD	SP-FPM Master
	Assembly Integrity	Locating pins for inner wall are drilled at assembly. Fits and clearances of axial dimensions verified per the assembly drawing.	REI 013
Supporting hardware 0201a f/n 114-02-02 Ring	Material Integrity	Material integrity is verified per specification requirements.	PWA- SP 1074
	INSPECTION		
	Raw Material	Sonic per QAD	
	Finished Material	FPI per QAD ECI per QAD	SP-FPM Master SP-ECM Master
Supporting hardware 0201a f/n 114-4 Ring	Material Integrity	Material integrity is verified per specification.	PWA-SP 1074
	INSPECTION		
	Raw Material	Sonic per QAD	
	Finished Material	FPI per QAD	SP-FPM Master

Supporting hardware 0201a f/n 114-6 Ring	Material Integrity	Material integrity is verified per specification and drawing requirements.	PWA-SP 1074
Supporting hardware 0201a f/n 114-7 Heatshield		Material integrity is verified per specification. EDMR	PWA-SP 1143 PWA-SP 97-8
	INSPECTION		
	Raw Material	Sonic per QAD	
	Finished Material	FPI per QAD	SP-FPM Master
Supporting hardware 0201a f/n 278 Deflector	Material Integrity	Material integrity is verified per specification.	AMS 5608
	INSPECTION		
	Finished Material	FPI per QAD	SP-FPM Master
Failure Cause B f/n 060 Bellows	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 11-32, PWA-SP 1143
	Braze Integrity	Braze integrity is verified per specification.	PWA-SP 19
	INSPECTION		
	Raw Material	Sonic - detail level per QAD	
	Finished Material	X-ray - Assembly level per QAD	SP-XRM Master
		ECI - Assembly level per QAD ECI - Detail level per QAD	SP-ECM Master SP-ECM Master

		Sonic - Cross Drilled Holes Only per QAD	
		FPI - Detail and assembly level per QAD Produce slots for locking keys per drawing requirements. Proof and leak test of coolant tubes verified per drawing requirements.	SP-FPM Master
	In-Process Testing	Proof pressure test at room temperature to reflect proof factor called out in Engineering Instructions.	REI 005
Failure Cause C f/n 115 Shield	Material Integrity	Material integrity is verified per specification requirements.	AMS 5772
	INSPECTION		
	Finished Material	FPI per QAD	SP-FPM Master
Failure Cause D f/n 013 Outlet Duct	Material Integrity	Material integrity is verified per specification requirements. Ring material integrity is verified per specification requirements.	PWA-SP 1489 PWA-SP 1074
	Heat Treat	Heat treat is verified per specification, and drawing requirements.	PWA-SP 11-19, PWA-SP 1489
	INSPECTION		
	Raw Material	X-ray per QAD Ring Sonic per QAD	SP-XRM Master
	Finished Material	FPI per QAD ECI per QAD Ring FPI per QAD Ring ECI per QAD	SP-FPM Master SP-ECM Master SP-FPM Master SP-ECM Master
Supporting hardware 0201d f/n 262 Flowguide	Material Integrity	Material integrity is verified per specification requirements.	PWA - SP 1143
	INSPECTION		
	Raw Material	Sonic per QAD	

	Finished Material	FPI per QAD	SP-FPM Master
Failure Cause E		Failure cause deleted	
Failure Cause F f/n 112, & 113 Tip seals	Material Integrity	Material integrity is verified per specification requirements. Control of low melt alloys	PWA-SP 1469, AMS 5536 PWA-SP 109
	Heat Treat	Heat treat is verified per specification and drawing requirements	PWA-SP 11-17, PWA-SP 18, PWA-SP 1469
	Braze Integrity	Braze integrity is verified per specification requirements.	PWA-SP 10
	INSPECTION		
	Raw Material	X-ray per QAD	SP-XRM Master
	Finished Material	FPI - Vane set per QAD FPI - Vane assembly before braze per QAD FPI - Vane assembly after braze per QAD	SP-FPM Master SP-FPM Master SP-FPM Master
		X-ray - Vane set per QAD	SP-XRM Master
		ECI - Vane set per QAD	SP-ECM Master
		Vane wall thickness verified per drawing.	
Supporting hardware 0201f f/n 097 Support	Material Integrity	Material integrity is verified per specification.	PWA-SP 1143
	INSPECTION		
	Raw Material	Sonic per QAD	
	Finished Material	FPI per QAD	SP-FPM Master
All Cause	General Quality Requirements:	Supplier Quality Assurance requirements are included in PW-QA-6078, and include such requirements as first piece layouts. This requires the documentation of dimensions on all characteristics represented on the delivered article.	PWA-SP 300

		Inspection Methods Sheets for use in the inspection of purchased parts and assemblies contain the necessary information to insure that the requirements of the CADs, 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.	
	Acceptance	Acceptance test will be conducted as required by contract, to demonstrate specified performance.	DR SE -13
	Maintenance	On a contingency basis, perform a turbine inlet borescope on Post Fit thru part G1 and G1.1.	V41BUC.128
All Cause f/n : 013 TAD, 060 Bellows, 097 TIVS, 112 2nd Vane, 113 3rd Vane, 114-02 Inlet Housing, 114-04 Load Ring	Waivers	The inlet housing does not meet CEI LCF life but does meet Fracture Mechanics life so no limits are imposed (DAR 0181).	DAR NO. 0181
		The load ring does not meet CEI LCF life but does meet Fracture Mechanics life so no limits are imposed (DAR 0182).	DAR NO. 0182
		The bellows meets CEI LCF life but does not meet Fracture Mechanics life so a life limit and inspection requirement is imposed (DAR 0183)	DAR NO. 0183
		The 2nd Vane does not meet CEI LCF life so life limits have been imposed (DAR 0186)	DAR NO. 0186
		The 3rd Vane does not meet CEI LCF life but does meet Fracture Mechanics life so no limits are imposed (DAR 0187).	DAR NO. 0187
		The TAD does not meet CEI requirements so life and inspection limits have been imposed (DAR 0188).	DAR NO. 0188
		The TIVS does not meet CEI requirements so an inspection limit has been imposed (DAR 0193).	DAR NO. 0193