Critical Item List

Subsystem:	HPOTP B500 - 4750000-700	Prepared by:	M.T. Spencer	Page:	47
Functional Assy:	Drive Turbine Section B50002	Approved by:	R.L. Pugh	Issue Date:	December 23, 1993
		CIL Item:	0203	Rev. Date:	December 08, 1995

CIL Item Code:	0203	Analyst:	M.T. Spencer
FMEA Item Code:	0203	Approved by:	R.L. Pugh
Function:	Convert Gas to Mechanical Energy	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
Operating Phase: s,m,c	**Failure Mode:** Loss of control of the expanding gases.	**Criticality:** 1

Failure Cause(s):

A. f/n 32, 33, 34, 121, or 122 Fracture of turbine blades due to vibrations, rub, thermal growth/shock, over temp, material/mfg defect, overspeed, erosion, or FOD.

B. f/n 48, 112, or 113 Fracture of turbine vanes due to vibrations, thermal growth, over temp, material/mfg defect, corrosion, or FOD.

C. f/n 112 or 113 Fracture of blade tip seals due to vibrations, thermal growth, over temp, material/mfg defect, corrosion, or FOD.

Hazard Ref:

A) C1S/A/M/C (AT) 1A1.1.1.1, 1A1.1.1.2, 1A1.1.3, 1A1.1.4, 1A1.1.5, 1A1.1.6.1.1, 1A1.1.6.1.2, 1A1.1.6.2, 1A1.1.7.1.1, 1A1.1.8.1.1, 1A1.1.8.1.2

B) B3S/A/M/C (AT) 1B2.1.1.1, 1B2.1.1.2, 1B2.1.2, 1B2.1.3, 1B2.1.5, 1B2.1.6, 1B2.1.7

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

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Failure Effect:

Failure of airfoils could result in damage to GOX heat exchanger with downstream fire. Severe unbalance could result in rotor unbalance and pump failure.

System:

Uncontained engine damage

Mission/Vehicle:

Loss of vehicle

Redundancy Screens:

Does not apply since it is a single point failure

Part Name/No.	Design Considerations	Document Ref
f/n 32, 33, 34, 121, or 122 Turbine blades	FAILURE CAUSE A. Three rows of hollow contoured blades with 54 blades per row are utilized to convert the expanding hot gas to rotary motion of the shaft through the blade slots. Use of the 3 stage turbine maintains the turbine efficiency with unshrouded blades and reduced rotor speeds. Platforms at the blade inner shroud form the gas path I.D. Blade tip gap is controlled to provide the required level of performance. Hollow foils significantly improve thermal shock life. The blades are cast PWA-SP 1493 single crystal nickel alloy material for improved thermal shock life, creep capability, and melt margin. Attachment stresses are reduced due to lower pull of hollow airfoils. Preliminary stress summary indicates > 1,000 LCF cycle life for the outer and inner necks. The disk, spacers, and retaining rings are PWA-SP 1074 (IN 100) parts are uncoated, and the blade attachments, spacers and disk attachments are shot peened for improved surface stress capability. Blade damping is provided by cast stiff/light weight dampers located in pockets under the blade L.E. platform, and trapped by the blade root and spacers. The material used is PWA-SP 1494 (IN 100), which is a common blade damper material with proven wear characteristics. The coolant mixing chamber formed by the seal on the flow guide and the 1st blade stop provides a optimum coolant temperature for disc attachments. This blade stop serves as a classified spacer to control the overall length of the disc stack. The blades are fracture critical and will meet the requirements of the fracture control plan FR-19793-2. Safe life fracture mechanics requirements will be properly traced throughout the life of the part. These parts are manufactured with processes which control low melt alloy contamination (PWA-SP 109), and shot peening (AMS 2430). These parts meet CEI requirements. DVS 4.1.2.9 which requires structural design analysis of the blades was completed in 5/90, and can be found in FR-20729-08, and FR-20730-07. DVS 4.1.4.1.6.1 Photoelastic stress analysis of the 3rd blade had been completed in 1/89, and can be found in FR 20729-23. DVS 4.1.4.1.6.2 Vibration testing of the 1st, 2nd, and 3rd blades has been completed, and can be found in FR 20730-52. DVS 4.1.4.1.6.3 Low cycle fatigue test at MSFC has been completed, and can be found in FR 20725-07.	
f/n 48, 112, or 113 Turbine vanes	FAILURE CAUSE B. Three stages of vanes with 82 1st, 64 2nd, and 78 3rd vanes per stage provide the correct angle of attack for the following blade row. Hollow foil design has good thermal shock capability, while the large leading and trailing edge diameters make the vanes more tolerant to excessively hot, but brief start transients. Use of the disk supported interstage seals eliminates the high vane diaphragm loads at the vane ID endwall that would be encountered otherwise. The inner shrouds of the 2nd and 3rd stage provide an abradable material to control the stage leakage at the blade platforms without damage to the spacer K.E.s. The honeycomb is brazed to the vane with the joint combination being Mar-M 247/Hastelloy X using Au-Ni (AMS 4786) per PWA-SP 10. The mission life of the 3rd vane is 900 cycles.	

The 1st stage vane is retained at the I.D.by the inlet duct load ring and at the O.D. by the Outer Turbine Case, a ring (f/n 100), and an anti-rotation ring (f/n 99), both of PWA 1103 material.

The 2nd and 3rd vanes are retained by the (TIVS) inner and outer (TOVS) turbine housings, which are secured by bolts to the TAD.

In response to testing which demonstrated gas path in-flow, the TIVS forward edge thickness was modified to increase the surface area to provide better sealing of the f/n 101 seal.

Coolant is supplied to the 3rd vane hooks from metering holes in the TIVS.

Material used is micro cast PWA-SP 1469 (mar-m-247) selected for its strength in elevated temperature hydrogen.

These parts are manufactured with a process which controls low melt alloy contamination (PWA-SP 109).

These parts are fracture critical and will meet the requirements of the fracture control plan FR-19793-2. Safe life fracture mechanics requirements will be properly traced throughout the life of the part.

The 1st vane does not meet CEI LCF requirements, but does meet Fracture Mechanic Life, so no limits have been impdsed (DAR 0185). DAR NO. 0185

The 2nd vane does not meet CEI LCF requirements, so life limits have been imposed (DAR 0186). DAR NO. 0186

The 3rd vane does not meet CEI LCF requirements, but does meet Fracture Mechanic Life, so no limits have been imposed (DAR 0187). DAR NO. 0187

DVS 4.1.2.9 which requires structural design analysis of the vanes was completed in 5/90, and can be found in FR-20730-06.

DVS 4.1.4.1.9.1 Vibration testing of the vanes has been completed, and can be found in FR 20730-23, & 51.

DVS 4.1.4.1.9.2 Low cycle fatigue test at MSFC has been completed, and can be found in FR 20725-07.

DVS 4.1.3.1.1 requires flow calibration of the 1st, 2nd, and 3rd vanes, and had been completed, and can be found in FR 20724-10.

f/n 112 & 113
Turbine tip seals

FAILURE CAUSE C. The 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 is integral with the vane assy.

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 3rd vane does not meet CEI LCF requirements, but does meet Fracture Mechanics Life, so no limits have been imposed (DAR 0187). DAR No. 0187

Material used is micro cast PWA-SP 1469 selected for its strength in elevated temperature hydrogen.

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Inspection and Test

Possible Causes	Significant Characteristics	Inspection and Test	Document Ref
Failure Cause A f/n 32, 33, 34, 121, or 122 Blades	Material Integrity	Material integrity is verified per specification requirements. Shot peening Control of low melt alloys Profile of blade root coating verified per drawing requirements.	PWA-SP 1493 AMS 2430 PWA-SP 109
	Heat Treat	Heat treat is verified per specification and drawing requirements. Stress relief heat treat is verified per specification and drawing requirements..	PWA-SP 11-17 PWA-SP 11-15
	INSPECTION		
	Finished Material	X-ray per QAD Blade wall thickness concave, convex sides, and surface profile requirements are verified per drawing requirements.	SP-XRM Master
		FPI per QAD	SP-FPM Master
	Assembly Integrity	Rotor balance is verified per assembly drawing. Blade lock fit is verified per assembly drawing.	REI 013
Supporting hardware 0203 a f/n 086, 087, 088, 089, 251 Spacers, and retainers	Material Integrity	Material integrity is verified per specification. Shot peening - f/ns 86, 87 & 88 Control of low melt alloys - f/ns 86, 87, & 88 EDMR - f/ns 86, 87 & 88	PWA-SP 1074 AMS 2430 PWA-SP 109 PWA-SP 97-9
	Heat Treat	Heat treat is verified per specification, and drawing requirements, f/ns 89, & 251.	PWA-SP 11-19, & 1074
	INSPECTION		
	Raw Material	Sonic - all per QAD	
	Finished Material	FPI - all per QAD	SP-FPM Master
Supporting hardware 0203 a f/n 254, 255, 065 Dampers	Material Integrity	Material integrity is verified per specification.	PWA-SP 1494
	Heat Treat	Heat treat is verified per specification, and drawing requirements.	PWA-SP 11-32, & 1494

INSPECTION

	Raw Material	X-ray casting per QAD	SP-XRM Master
Failure Cause B and C I/n 48, 112, or 113 Turbine tip seals	Material Integrity	Material integrity is verified per specification requirements. Control of low melt alloys.	PWA-SP 1489, AMS 5536 PWA-SP 109
	Heat Treat	Heat treat of the castings is verified per specification, and drawing requirements. Heat treat of the assemblies is verified per specifications.	PWA-SP 11-18, & 1489 PWA-SP 11-17, & 1489
	Braze Integrity	Braze integrity of items I/n 112 and 113 is verified per specifications. Au-Ni	PWA-SP 10 AMS 4786
	INSPECTION	Vane wall thickness is verified per drawing requirements for I/n 113 only.	
	Raw Material	X-ray - at the detail level per QAD	SP-XRM Master
	Finished Material	X-ray - vane set I/n 112, 113, vane assy I/n 48 per QAD	SP-XRM Master
		FPI - vane assembly (I/ns 112, & 113) after braze per QAD FPI - vane assy- I/n 112 and 113 before braze per QAD FPI - vane sets 112, 113, and vane assy 48 per QAD	SP-FPM Master SP-FPM Master SP-FPM Master
		ECI - vane set I/n 112, 113, vane assy I/n 48 per QAD	SP-ECM Master
All Cause	General Quality Requirements:	Supplier Quality Assurance requirements are included in PW-QA-6075, and include such requirements as first place 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

	Maintenance	Shaft rotation torque check is performed after engine operation, or HPOTP installation/reinstallation.	OMRSD - V41BS0.050
	Cleanliness	Cleanliness of components will be assured by compliance to Contamination Control Specification.	PWA-SP 36180-1
All Cause Vn : 048 1st Vane, 112 2nd Vane, 113 3rd Vane	Waivers	The 1st Vane does not meet CEI LCF life, but does meet Fracture Mechanics life, so no limits have been imposed (DAR 0185).	DAR NO. 0185
		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