Critical Item List

Subsystem\Item No.\Part No.: HPFTP/AT\B300\4700000	**Prepared by:** D.F. Clark	**Page:** 48
Functional Assy: Turbine Section 02	**Approved by:** A.J. Slone	**Issue Date:** October 28, 1986
	CIL Item: 0202	**Rev. Date:** April 16, 2001

CIL Item Code: 0202
FMEA Item Code: 0202
Function: Convert gas to mechanical energy
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,c	**Failure Mode:** Loss of control of the expanding gases.	**Criticality:** 1
	Failure Cause(s)	**Hazard Ref:**
	A. f/n 058, 059, 165 & 352 Fracture or wear of Blades or blade retainers due to vibrations, thermal growth/shock, inlet distortion/overtemperature, overspeed, rub, FOD, or material/mfg. defect.	A) D1S/A/M/C (AT): 1A1.1.1, 1A1.1.2, 1A1.4, 1A1.5, 1A1.8.1.1, 1A1.8.1.2, 1A1.8.2.4
	B. f/n 041 & 042 Fracture of the Vanes due to vibrations, thermal distortion, FOD, or material/mfg. defect.	B) D1S/A/M/C (AT): 1C2.1.1.3.2
	C. f/n 113 & 114 Fracture, of the B.O.G. Seals due to rub, contamination, vibrations, thermals, or material/mfg. defect.	C) D1S/A/M/C (AT): 1C2.1.1.3.2
	D. f/n 105 Fracture of the Vane Seal due to rub, corrosion, material defect, or manufacturing defect.	D) D1S/A/M/C (AT): 1C2.1.1.3.2

Failure Effect:

Failure of airfoils 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

Find Number Find Name	Design Considerations
f/n 058, 059, 165, 352 Blade 1,2-Fwrd. Retainers	FAILURE CAUSE A: Fracture or wear of Blades or blade retainers due to vibrations, thermal growth/shock, inlet distortion/overtemperature, overspeed, rub, FOD, or material/mfg. defect.

The two stage turbine utilizes unshrouded, uncoated, Alloy 454 PWA-SP 1493 single crystal Turbine Blades (FN's 058 & 059) which provide superior thermal shock resistance and the optimal combination of LCF and HCF capability, melt margin, and elevated temperature strength when compared to other single crystal, directionally solidified, or equiaxed blade alloys. The thermal shock resistance of the blades is enhanced by the use of hollow, thin-walled airfoils and media finished (REM processed) flowpath surfaces to reduce thermally induced strains. The blades utilize two-tooth attachments with compound fillet radii for improved attachment lives and more predictable load sharing. To enhance the fatigue capability of the attachments, the blade is shot peened on all surfaces inboard of the platform, including the root, extended neck, gussets, and the leading and trailing edge attachment faces. Gold plating is used as an anti-gallant on the 1st and 2nd stage blade attachments to mitigate initiation of microfissures.
The front retaining ring (FN 056) axially rertains the first stage blades(FN 058) and forms 'windows' that reduce variability of the fluid temperature scrubbing of the blade backface. The rear retaining ring (FN 057), trapped in an annular cavity between the retainers (FN 165, 352) and the disk, holds the blades in the proper axial location for operation, and reacts the axial blade stack loads into the disk. The retainers (FN 165, 352), machined from an IN-100 forging, are radially retained by a single tooth (dovetail) attachment which rides in the inner tooth of the disk broach slot at the pump side of the disk. Axially, the retainers (FN 165, 352) are retained by a split IN-100 ring (FN 057) which is depressed into a circumferential slot in the disk as the retainers are installed onto the disk. The axial load from the entire blade and spacer stack is transferred aft where it is reacted in double shear through the ring to the disk lugs. Blade seal dampers (FN 356, 371), made of Haynes 188 material for its superior ductility, high temperature capability and friction damping characteristics, are employed in the shank cavity formed by the suction and pressure sides of the blades to reduce dynamic blade stress and blade attachment coolant leakage between the platforms.
The classified Blade Spacers (FN 120) account for the accumulation of tolerances within the rotor stack to maintain the proper axial stack length to minimize leakage of coolant between the details while providing sufficient clearance for growths of the hardware during operation. The spacer is machined from IN-100 forgings and is radially retained by a single tooth, "dovetail" attachment which rides in the outer tooth pair of the disk broach slot.
A contoured pocket on the upstream side of the spacer OD forms, with its neighboring spacer and the OD of the disk lug, a residence for the 1st stage blade damper (FN 104). The contoured pocket maintains the damper in the proper orientation until centrifugals during operation load the dampers outward against the blade platforms. A tab on the ID of the spacer performs an assembly foolproofing function to ensure the proper orientation of the spacer and the 1st blade dampers by creating an axial interference with the mating tab of the trailing edge attachment face of the 1st blade when improperly installed.
Two different types of dampers (FN 236, 338) are used to reduce vibratory stress in the second stage turbine blades. Both dampers are machined from IN-100 (PWA 1074) forgings. A symmetrical 'blade to blade' damper (FN 236) bridges between the platforms of adjacent blades to provide damping primarily for the easywise bending mode. A second 'blade to ground' damper (FN 338) is located between the 'blade to blade' dampers and contacts the center of the blade platform. This "blade to ground" damper provides damping primarily for the stiffwise bending mode.
The turbine blades are fracture critical parts and meet all the requirements of the SSME ATD fracture control plan FR-19793-5.

On the 1stage Turbine Blades (F/N 058) a life limit has been imposed per DAR PW0278.
On the 2nd Stage Turbine Blades (F/N 059) a life limit has been imposed per DAR PW0279.
On the Turbine Spacers (F/N 120) a life limit has been imposed per DAR PW0317.

DVS 4.1.2.4 The turbine aerodynamic analysis to verify efficiency is complete. The results are documented in FR-20710-01 thru -06 with the VCR in FR-20712-27.
DVS 4.1.2.5 Turbine airfoil durability analyses to verify that the airfoils meet creep, LCF and HCF requirements are complete. The results are documented in FR-20711-01 and -03 and FR-20716-03 with the VCR in FR-20715-114.
DVS 4.1.2.6 Turbine internal flow management analysis is complete. The results are documented in FR-20712-01 and FR-20713-16 and the VCR is in FR-20712-01A, 11A and 11B.
DVS 4.1.2.9 Structural design analysis to verify turbine margins is complete. The results are documented in FR-20716-03 and the VCR in FR-20715-104.
DVS 4.1.2.12 The turbine foreign object analysis to estimate impact stress concentrations resulting from FOD is complete. The results are in FR-20715-07 and -07A and the VCR is in FR-20710-07A
DVS 4.1.3.2.4.1 The aerodynamic test at MSFC to demonstrate turbine performance has been completed. The results are documented in FR-20833-03 and the VCR is in FR-20712-27.
DVS 4.1.4.1.8.1 The photoelastic test of the 2nd blade has been completed with the results documented in FR-20716-08 and the VCR in FR-20715-104..
DVS 4.1.4.1.8.2 Vibration testing of the turbine blades has been completed. The results are documented in FR-20716-08 and the VCR is in FR-20715-104.
DVS 4.1.4.1.8.3 LCF tests have been completed at MSFC on the turbine blades. The results are documented in FR-20716-08 with the VCR in FR-20715-104.
DVS 4.1.4.4.1.3 Creep tests of precalibrated turbine blades in an engine at SSC are complete. Detailed thermal and strain analyses show that the blades exceed design requirements. The results are documented in FR-20711-02 and -04 with the VCR in FR-20715-104. The design of the turbine blades has been reviewed relative to TDM-

Find Number Find Name	Design Considerations
	2090-S 'Compressor and Turbine Blade Containment Design Procedure'. Based on this assessment, it is felt that the turbine design meets the criteria for containment.
f/n 041, 042 Vane Stages 1, 2	FAILURE CAUSE B: Fracture of the Vanes due to vibrations, thermal distortion, FOD, or material/mfg. defect.

The 1st Vane Set (FN 041) is made up of 25 three vane segments, 75 vanes total, which are held in place circumferentially by tangs on the 1st vane support and axially by the 1st vane spacer. The 1st vane segments are made of PWA-SP 1493 (Single Crystal Alloy) castings and consist of three airfoils and their platforms. Their only function is to take the straight axial annular turbine main flow and turn it circumferentially to impinge on the 1st blades at the proper incidence angle for the most efficient operation at all flight points throughout the mission. The material has its primary crystallographic orientation aligned radially through the middle vane stacking line. The secondary orientation is parallel to the engine centerline. This orientation was chosen to align the material properties efficiently with the stress patterns in the part. The airfoils have hollow cores that are open to the ID side of the inner platform. The vanes are uncooled and rely on the core openings at the ID of the part to equalize temperatures and pressures across the walls to reduce thermal gradients and internal loads during transient conditions. The material properties are sufficient for the airfoils to handle the full steady state temperatures at operation without cooling. On both sides of the outer platform are rails that extend from the front hook to the rear hook. These add stiffening to the outer wall as well as provide material to contain the feather seals. The feather seal grooves are EDM'd into the sides of the outer platform within these rails.
The 1st vane segment set is included in the turbine inlet housing assembly because its ID platform foot is trapped between the mixing chamber OD wall and the TIH. It is assembled into the pump with the rest of this subassembly including its 'W'-seal and the piston ring seal. The gas loads are taken out of the vane segments by the 1st vane support (FN 110) through the front and rear hooks. The rear hook radial loads are transferred directly into the 1st vane support (FN 110) while the front hook loads are taken out by the turbine inlet housing spacer. The ID of the trailing edge of the inner platform has a seal land that mates with a piston ring seal on the turbine inlet housing inner manifold structure. This prevents the main flow from bypassing the ID of the vanes.
The 1st Vane Feather Seal (FN 237) is made from PWA-SP 1042 (Cobalt Alloy) sheet bent into an approximate L shaped. The small or vertical part is straight whereas the long part has a slight S-curve in the radial direction and another S-curve in the circumferential direction to match the shape of the gaps between the vane segments. There are 25 feather seals per pump build, one installed at each gap. They fit within the feather seal groove in the sides of the outer platform rails of the segments and split their width between the groove on either side of the gap. The function of the feather seal is to reduce the amount of leakage going in or out of the outer platforms, bypassing the airfoils and causing disturbances in the main flow path.
The Turbine Inlet Housing Spacer (FN 112) is a full ring located within the flange stack between the vane supports and the turbine inlet housing (TIH). It provides the centering for the TIH and acts as a flow restrictor between Chambers 48 and 50 as well as the hot gas distributor for mixing in Chamber 48. It also provides radial support for the 1st vane front hook.
The 1st Vane Spacer (FN 293) is a full circumferential split ring made from a PWA-SP 1143 (INCO 909) forging. It is located axially between the 1st vane segments and the 1st BOGS and snaps radially into the ID of the cylindrical part of the 1st vane support. Its function is to transfer the axial load from the 25 1st vane segments to the 13 1st BOGS segments. In the process, it also provides axial positioning of the 1st vane.

The 2nd Vane Set (FN 042) is made up of 26 three vane segments, 78 vanes total, and are made from PWA-SP 1493 single crystal alloy and consist of three airfoils and their platforms. They function to redirect the flow to the 2nd blades at the proper incidence angle for the most efficient operation at all flight points throughout the mission. The material has its primary crystallographic orientation aligned radially through the middle vane stacking line. The secondary orientation is parallel to the engine centerline. This orientation was chosen to align the material properties efficiently with the stress patterns in the part. The airfoils have hollow cores that are open to the OD side of the outer platform. The vanes are uncooled and rely on the core openings at the OD of the part to equalize temperatures and pressures across the walls to reduce thermal gradients and internal loads during transient conditions. The material properties are sufficient for the airfoils to handle the full steady state temperatures at operation without cooling. The vane segment is cantilevered from the 2nd vane support (FN 109) using retention hooks which axially protrude from the leading and trailing edge rails which span the segment circumferentially. The hooks and rails are split by axially cut slots which mate with radial lugs on the ID of the 2nd vane support (FN 109) to provide anti-rotation for resisting the segment airfoil circumferential load.
The 2nd Vane Feather Seal (FN 111) is made from PWA-SP 1042 (Cobalt Alloy) and has a S-curve in the circumferential direction to match the shape of the gaps between the vane segments. There are 26 feather seals per pump build, one installed at each gap. They fit within the feather seal groove EDM'd into the sides of the outer platform rails of the segments and split their width between the groove on either side of the gap. The function of the feather seal is to reduce the amount of leakage going in or out of the outer platforms, bypassing the airfoils and causing disturbances in the main flow path.
The vanes are fracture critical parts and meet all the requirements of the SSME ATD fracture control plan FR-19793-5.
Report FR-20711-01 & 03 states that a detailed thermal and strain analysis shows that the vanes exceed the design requirements.

On the 1st Stage Vane Cluster (F/N 041) a life limit has been imposed per DAR PW0263.
On the 1st Stage Turbine Support Spacer (F/N 112) a life limit and inspection limit has been imposed per DAR PW0251.

DVS 4.1.2.6 Turbine internal flow management analysis is complete. The results are documented in FR-20712-01 and FR-20713-16 with the VCR in FR-20712-01A, 11A

Find Number Find Name	Design Considerations

and 11B.
DVS 4.1.2.9 Structural design analyses to verify margins for the turbine vanes are complete. The results are documented in FR-20711-01 and -03 and FR-20716-03 with the VCR in FR-20715-114.
DVS 4.1.3.2.4.1 The aerodynamic test on the turbine at MSFC to demonstrate turbine performance has been completed. The results are documented in FR-20833-03 with the VCR in FR-20712-27.
DVS 4.1.4.1.9.1 Vibration tests to determine resonant frequencies for the turbine vanes are complete. The results are documented in FR-20716-21 with the VCR in FR-20715-114.
DVS 4.1.4.1.9.2 LCF tests have been completed at MSFC on the turbine vanes. 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 113, 114

Seal B.O.G. Stg. 1, 2

FAILURE CAUSE C: Fracture, 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 (FN 110) to add some softness to the system to help absorb the loads. Gas loads are taken out of the vane segments by the 1st vane support (FN 110) through the front and rear hooks. The rear hook radial loads are transferred directly into the 1st vane support (FN 110) while the front hook loads are taken out by the turbine inlet housing spacer.

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 (FN 109) to add some softness to the system to help absorb the loads. The vane segment is cantilevered from the 2nd vane support (FN 109) using retention hooks which axially protrude from the leading and trailing edge rails which span the segment circumferentially. The hooks and rails are split by axially cut slots which mate with radial lugs on the ID of the 2nd vane support (FN 109) to provide anti-rotation for resisting the segment airfoil circumferential load.

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. The results are documented in FR-20712-01 and FR-20713-16 with the VCR in FR-20712-01A, 11A and 11B.
DVS 4.1.2.9 Structural design analyses to verify margins for the turbine vanes are complete. The results are documented in FR-20711-01 and -03 and FR-20716-03 with the VCR in FR-20715-114.
DVS 4.1.3.2.4.1 The aerodynamic test on the turbine at MSFC to demonstrate turbine performance has been completed. The results are documented in FR-20833-03 with the VCR in FR-20712-27.
DVS 4.1.4.1.9.1 Vibration tests to determine resonant frequencies for the turbine vanes are complete. The results are documented in FR-20716-21 with the VCR in FR-20715-114.

Find Number Find Name	Design Considerations
	DVS 4.1.4.1.9.2 LCF tests have been completed at MSFC on the turbine vanes. 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 105 Vane Seal Stage 2	FAILURE CAUSE D: Fracture of the Vane Seal due to rub, corrosion, material defect, or manufacturing defect. Vane Seals (FN 105) provide sealing against leakage at the I. D. of the second vanes and they act as interstage spacers to provide axial spacing of the blades in the disk assembly. The Vane Seals are machined from IN -100 (PWA 1074) forgings and are radially retained by a single tooth (dovetail) attachment which rides in the outer tooth of the disk broach slot. Axial load generated by the first stage turbine blade is passed through this vane seal dovetail attachment into the second blade. To insure this axial load path is isolated to a single row, a small recess is machined into the forward face of the vane seal to provide clearance with the classified spacer from adjacent disk rows. Six axial rows of knife edges are machined on the O.D. of the vane seals which align with the honeycomb lands on the I.D. of the second vane segments after pump assembly. These knife edges provide sealing against leakage around the I.D. of the second vanes. By locating the rotating knife edges at the disk rim, the diaphragm area at the vane ID is greatly reduced, minimizing the bending moment applied to the vane airfoils. Pockets for turbine blade dampers are machined into the trailing edge face of the spacers. A center pocket provides both containment for a 'blade to ground' damper and radial surfaces for the damper to contact. The interstage seal spacer functions as a stationary object relative to the second stage turbine blade--providing the 'ground' for this damper. Pockets on the right and left corners of the spacer provide containment for a 'blade to blade' damper. Slots machined into the vane seals which intersect the damper pockets provide 'windows' for inspection of the dampers following pump assembly. The seal is a fracture critical part and meets the requirements of the SSME ATD fracture control plan FR-19793-5.

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
Failure Cause A f/n 058 Blade, Stage 1	Material Integrity	Precipitation heat treatment is verified per specification requirements	PWA-SP 11-17 & PWA-SP 1493
		Stress relieve is verified per drawing and specification requirements	PWA-SP 11-15
		Shot peen is verified per specification requirements	AMS 2430
		Material integrity of casting (f/n 058-1) is verified per drawing and specification requirement	PWA-SP 1493
		Control of the presence of low melt alloys is verified per specification requirements	PWA-SP 109
	Inspection	Airfoil casting (f/n 058-1) concave (6 pl) and convex (6 pl) minimum wall thicknesses are verified per drawing requirements	
		Blade (f/n 058) root surface profile (2 pl) is verified per drawing requirement	
		Airfoil casting (058-1) section data (2 pl at U) are verified per drawing requirements	
	Finished Material	Xray- per- QAD (At GESP)	SP-XRM Master
		FPI- per- QAD	SP-FPM Master
		Frequency Check-per-QAD	REI029
	Assembly Integrity	Blade frequency check per REI029 is within limits and verified complete per drawing requirements	REI029
	Recycled Hardware	Xray- per- PWA-SP 36187	PWA-SP 36187 & SP-XRM Master
		FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause A f/n 059 Blade, Stage 2	Material Integrity	Material integrity of casting (f/n 059-1) is verified per drawing and specification requirements	PWA-SP 1493
		Stress relieve is verified per drawing and specification requirements	PWA-SP 11-15
		Control of the presence of low melt alloys is verified per specification requirements	PWA-SP 109

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Shot peen is verified per specification requirements	AMS 2430
		Precipitation heat treatment is verified per specification requirements	PWA-SP 11-17 & PWA-SP 1493
	Inspection	Blade (f/n 059) root surface profile (2 places) is verified per drawing requirements	
		Airfoil casting (f/n 059-1) concave (6 pl) and convex (6 pl) wall thicknesses are verified per drawing requirements	
		Airfoil casting (f/n 059-1) section data (2 pl U) are verified per drawing requirements	
	Finished Material	Frequency Check-per-QAD	REI029
		Xray- per- QAD (At GESP)	SP-XRM Master
		FPI- per- QAD	SP-FPM Master
	Assembly Integrity	Blade frequency check per REI029 is within limits and verified complete per drawing requirements	REI029
	Recycled Hardware	Xray- per- PWA-SP 36187	PWA-SP 36187 & SP-XRM Master
		FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause A f/n 165 Retainer,Blade	Material Integrity	Control of the presence of low melt alloys is verified per specification requirements	PWA-SP 109
		EDM and removal of recast layer is verified per drawing and specification requirements	PWA-SP 97-8
		Shot peen is verified per specification requirements	AMS 2430
		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

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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 A f/n 352 Retainer,Blade	Material Integrity	EDM and removal of recast layer are verified per drawing and specification requirements	PWA-SP 97-8
		Control of the presence of low melt alloys is verified per specification requirements	PWA-SP 109
		Shot peen is verified per specification requirements	AMS 2430
		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
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause a f/n 056 Ring,Retaining	Material Integrity	Heat treatment is verified per drawing and specification requirements	PWA-SP 11-19 & PWA-SP 1074
		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	Selection of classification of part is verified per assembly drawing requirements	
Failure Cause a f/n 057 Ring,Retaining	Material Integrity	Heat treatments are verified per specification requirements	PWA-SP 11-19 & PWA-SP 1074
		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

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Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
Failure Cause a f/n 104 Damper,Turbine	Material Integrity	Material integrity is verified per drawing requirements	PWA-SP 1074
	Finished Material	Sonic- per- QAD	SP-SIM 1
		FPI- per- QAD	SP-FPM Master
Failure Cause a f/n 120 Spacer,Turbine	Material Integrity	EDM and removal of recast layer is verified per specification requirement	PWA-SP 97-8
		Material integrity is verified per specification requirements	PWA-SP 1074
		Control of the presence of low melt alloys is verified per specification requirements	PWA-SP 109
		Shot peen is verified per specification requirement	AMS2430
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	FPI- per- QAD	SP-FPM Master
	Assembly Integrity	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 a f/n 236 Damper,Turbine	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
Failure Cause a f/n 338 Damper,Turbine	Material Integrity	Material itegrity is verified per specification requirements	PWA-SP 1074
	Raw Material	Sonic- per- QAD	SP-SIM 1

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause a f/n 356 Seal,Stg.2	Material Integrity	Heat treatment is verified per drawing and specification requirements	PWA-SP 11-31
		Material integrity is verified per drawing requirements	PWA-SP 1042 or AMS 5608
Failure Cause a f/n 371 Damper,Seal,Stg.1		Material integrity is verified per specification requirements.	AMS 5608 or PWA-SP 1042
		Solution heat treatment is verified per specification requirements.	PWA-SP 11-31
Failure Cause B f/n 041 Vane Set,Stage 1		Material integrity of casting (f/n 041-01) is verified per drawing and specification requirements	PWA-SP 1493
		Stabilization heat treatment of vane cluster (f/n 041) is verified per drawing & specification requirements	PWA-SP 11-18
		Control of the presence of low melt alloys is verified per specification requirements	PWA-SP 109
		Precipitation heat treatment of vane cluster (f/n 041) is verified per drawing & specification requirements	PWA-SP 11-17 and PWA-SP 1493
	Inspection	Vane segment casting (f/n 041-01) concave (12 pl) and convex (12 pl) minimum wall thicknesses are verified per drawing requirements	
		Vane segment casting (f/n 041-01) wall thicknesses (8 pl x 3 airfoils) are verified per drawing requirements	
	Finished Material	CTM-per-QAD (casting) (f/n 041-01)	SP CTM-1
		FPI- per- QAD (vane cluster) (f/n 041)	SP-FPM Master
		Xray- per- QAD (casting) (f/n 041-01)	SP-XRM Master
		FPI- per- QAD (vane cluster set) (f/n 041)	SP-FPM Master

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Assembly Integrity	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 B f/n 042 Vane Set,Stage 2	Material Integrity	Material integrity of casting (f/n 042-01-01) is verified per drawing and specification requirements	PWA-SP 1493
		Braze of vane cluster (f/n 042) is verified per drawing specification requirements	PWA-SP 10 & PWA-SP 11
		Precipitation heat treatment of vane cluster (f/n 042) is verified per drawing and specification requirements	PWA-SP 11-17 & PWA-SP 1493
		Stabilization heat treatment of vane cluster (f/n 042) is verified per drawing and specification requirements	PWA-SP 11-18
		Material integrity of honeycomb seal is verified per specification requirements	AMS 5536
		Control of the presence of low melt alloys is verified per specification requirements	PWA-SP 109
	Inspection	Convex leading edge vane hook thickness on vane cluster (f/n 042) is verified per drawing requirements	
		Profile of vane honeycomb diameter on vane cluster (f/n 042) is verified per drawing requirements	
		Vane segment casting (f/n 042-01-01) wall thicknesses (8 pl x 3 airfoils) are verified per drawing and specification requirements	
		Trailing edge vane hook groove dimension on vane cluster (f/n 042) is verified per drawing requirements	
		Vane segment casting (f/n 042-01-01) concave (12 pl) and convex (12 pl) minimum wall thickness is verified per drawing requirements	
	Raw Material	Xray- per- QAD (casting) (f/n 042-01-01)	SP-XRM Master
	Finished Material	FPI- per- QAD (vane cluster set) (f/n 042)	SP-FPM Master
		FPI- per- QAD (vane cluster assembly of) (f/n 042-01)	SP-FPM Master

Inspection and Test

Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Assembly Integrity	Penetrant inspect per DAR	PW0272
		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 b f/n 109 Support,Stg.2,Stator	Material Integrity	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
		Leading edge vane hook ring thickness is verified per drawing requirements	
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	FPI- per- QAD	SP-FPM Master
Failure Cause b 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
Failure Cause b f/n 111 Seal,Stage 2,Stator	Material Integrity	Heat treatment is verified per drawing and specification requirements	PWA-SP 11-31
		Material integrity is verified per drawing requirements	PWA-SP 1042 or AMS 5608
Failure Cause b f/n 112 Spacer,Stg.1,Stator		Material integrity of (Spacer or Adapter) (f/n 112-01-1 or 112-01-2) is verified per specification requirements	PWA-SP 1074
		Material integrity of Pin (f/n 112-02) is verified per specification requirements	AMS 5732 per MS 9390

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Raw Material	Sonic- per- QAD	SP-SIM 1
	Finished Material	Penetrant inspect per DAR	PW0251
		FPI- per- QAD (Spacer) (f/n 112-01)	SP-FPM Master
		ECI- per- QAD (Spacer) (f/n 112-01)	SP-ECM Master
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause b f/n 237 Seal,Stg. 1,Stator	Material Integrity	Material integrity is verified per specification requirements	AMS 5608 or PWA-SP 1042
		Heat treatment is verified per drawing and specification requirements	PWA-SP 11-31
Failure Cause b f/n 293 Spacer,Stage 1 Vane		Material integrity is verified per specification requirements	PWA-SP 1143
	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 C 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 segment) (f/n 113-01)	SP-FPM Master
		FPI- per- QAD (duct set) (f/n 113)	SP-FPM Master
	Assembly Integrity	Selection of classification of part is verified per assembly drawing requirements	

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
		Penetrant inspect per DAR	PW0330
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & SP-FPM Master
Failure Cause C f/n 114 Seal,Stage 2,B.O.G.	Material Integrity	Material integrity is verified per specification requirement	PWA-SP 1135
		Heat treatments are verified per drawing and specification requirements	PWA-SP 11-19 & 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
Failure Cause c 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
Failure Cause c 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

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Possible Causes	Significant Charactertistics	Inspection and Test	Document Ref
	Finished Material	Trailing edge vane hook groove dimension is verified per drawing requirements	
		FPI- per- QAD	SP-FPM Master
Failure Cause D f/n 105 Seal,Vane	Material Integrity	EDM and removal of recast layer are verified per drawing and specification requirements	PWA-SP 97-8
		Control of the presence of low melt alloys is verified per specification requirements	PWA-SP 109
		Shot peen is verified per specification requirements	AMS2430
		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
	Recycled Hardware	FPI- per- PWA-SP 36187	PWA-SP 36187 & 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
		Post Flight borescope inspection of the 1st Stg. Vane Segments, 1st and 2nd Stg. Turbine Blades and the Turbine Discharge gaspath is verified per OMRSD.	OMRSD V41BU0.135