# Critical Item List

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|---|---|---|---|
| **Subsystem:** HPOTP B500 - 4750000-700 | **Prepared by:** M.T. Spencer | **Page:** 102 | |
| **Functional Assy:** Structural Section B50004 | **Approved by:** R.L. Pugh | **Issue Date:** December 23, 1993 | |
| | **CIL Item:** 0403 | **Rev. Date:** December 08, 1995 | |

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|---|---|
| **CIL Item Code:** 0403 | **Analyst:** M.T. Spencer |
| **FMEA Item Code:** 0403 | **Approved by:** R.L. Pugh |
| **Function:** Load Transmission | **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:**
e,m,c

**Failure Mode:**
Loss of load transfer capability.

**Failure Cause(s):**

A. f/n 232 or 234 Fracture of the preburner hag or inner hag due to vibration, over pressure, thermals, plumbing loads, or material/mfg defect.

B. f/n 22 ASO, Fracture of the main pump hag due to vibration, over pressure, thermals, plumbing loads, or material/weld/mfg defect.

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

D. f/n 058 Fracture of the main turbine housing (TOVS) due to vibration, thermal growth, excessive loads, or material/mfg defect

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

F. f/n 35 Fracture or loss of torque of any of the following threaded fasteners due to excessive load, thermal growth, corrosions, or material/mfg defect.
f/n 14 Nut
f/n 82 Nut
f/n 67 Nut
f/n 62 Nut
f/n 117 Nut
f/n 160 Nut
f/n 98 Nut
f/n 55 Nut
f/n 28 Nut
f/n 91 Nut
f/n 169 Nut
f/n 73 Deflector
f/n 177 Bolt
f/n 235 Nut
f/n 116 Bolt
f/n 127 Bolt
f/n 128 Bolt
f/n 40 Bolt
f/n 245 Bolt
f/n 129 Bolt
f/n 131 Bolt
f/n 132 Bolt

**Criticality:**
1

**Hazard Ref.**
A) C1S/A/M/C (AT) 2A1.1
B) C1S/A/M/C (AT) 1A1.1.8.2.4
C) C1S/A/M/C (AT) 1A1.1.8.2.4
D) C1S/A/M/C (AT) 1A1.1.8.2.4
E) C1S/A/M/C (AT) 1A1.1.8.2.4
F) C1S/A/M/C (AT) 1A1.1.8.2.4, 4A1.2, 4A2, 4A3, 4A4, 4A6.2

B - 519

f/n 134 Bolt
f/n 139 Bolt
f/n 145 Bolt
f/n 176 Bolt
f/n 181 Bolt
f/n 190 Bolt
f/n 199 Bolt
f/n 252 Bolt
f/n 035 Tiebolt
f/n 130 Screw
f/n 22-28-14 Stud
f/n 22-28-15 Stud
f/n 287 Bolt
f/n 080 Stud
f/n 22-28-18 Stud
f/n 22-28-12 Insert
f/n 22-28-13 Insert
f/n 24-02-03 Insert
f/n 244-03 Insert
f/n 080 Insert
f/n 013 Nut

**Failure Effect:**

Rotor shift with rub in the pump or turbine stages with possible uncontained failure and/or fire.

**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 |
|---|---|---|
| I/n 232<br>Preburner hsg | FAILURE CAUSE A. The Preburner pump hsg is forged Inconel 718 (PWA-SP 1146), which was selected for its high cryogenic strength, ductility, and experience in a LOX environment. This housing provides the inlet area to the impeller, the exit area to the preburner pump, support for the various seals, and maintains the required clearance for the impeller.<br><br>Race track slots engage pins in the main pump housing for alignment of the preburner and main pump housings.<br><br>This part is a pressure vessel, and the mission life is 350 cycles.<br><br>The cast discharge volute inner housing which is utilized as a flow guide only is Micro-Cast Inconel 718 (PWA-SP 1490-2) for its high strength and experience in a LOX environment, and is supported by a spanner nut fit to the P/B housing.<br><br>This part meets CEI requirements.<br><br>DVS 4.1.2.9 Structural design analysis can be found in FR-20729-02, and FR-20730-02. | |
| I/n 022<br>Main pump hsg | FAILURE CAUSE B. The main hsg is made up of a welded assembly which includes the left, center, and right side parts made of cast PWA-SP 1490 (Microcast Inconel 718) which was chosen for it's high strength, and experience in a LOX environment. This material has a proven history in a LOX environment, LOX testing of this material appears in Appendix 52 of the P&W MCL Manual. The welded on turbine side housing is wrought super A286, and was chosen for it's high strength and resistance to hydrogen embrittlement.<br><br>The four main pump welds are all fully inspectable, as well as the core support welds.<br><br>Materials Control Plan FR-19673-5 describes the EB Weld Development Program which will demonstrate the process to ensure the successful fabrication/assembly of this housing.<br><br>The part on the pump side sees LOX, and on the turbine side H2.<br><br>The housing provides the LOX flowpath geometry for the inlet independently for the inducers and main impeller, and discharge.<br><br>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 bearing, TEBB, 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.<br><br>To retain radial and circumferential positioning of the pre burner structural housing, 5 pins are tight fit into the main pump housing, and fit into the race track holes in the pre burner housing.<br><br>The preburner housing and the damper/PEBB support are bolted to this housing, as well as the turbine discharge duct.<br><br>The Main Housing does not meet CEI LCF life limits, but does meet Fracture Mechanics life, so no life or inspection limits have been imposed (DAR 0189).<br><br>DVS 4.1.2.9 Structural design analysis can be found in FR-20729-09, and FR-20730-01. | DAR NO. 0189 |

I/n 114-02
Turbine inlet hsg.

FAILURE CAUSE C. The turbine inlet hsg defines the inner and outer flowpath walls, and provides the passage as well as the support for the hydrogen cooling transfer tubes to the inner support and turbine disk.

The thin outer wall (deflector I/n 278) which is AMS 5608 (Haynes 188) is a full hoop carrying shell which provides a support wall for the 12 cantilevered struts which 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 is split radially 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 material (Micro-Cast Mar-M-247) and was selected for its strength in elevated temperature hydrogen, and thermal shock. This is essentially a spherical shell that is split along it's length in 12 places between the struts. The inner dome (heatshield I/n 114-07) is PWA-SP 1143 (Incoloy 909), and was selected for its resistance to hydrogen embrittlement, and low alpha which reduces thermal stresses.

To uncouple thermally driven stresses from the turbine inlet housing, the inlet dome utilizes a radially free dome and wave washer spacer (I/n 279) configuration.

The inlet housing LCF life is less than CEI requirements, but Fracture Mechanics Life is greater than CEI, so no inspection limits are imposed (DAR 0181). DAR NO. 0181

LCF life of the I.D. load ring (I/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 0182). DAR NO. 0182

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 FR-20730-49.

DVS 4.1.4.2.5.1 test which requires resonance testing has been completed, and is documented in FR-20730-53, 54, 55, 66, and 80.

DVS 4.1.2.8 which requires structural design analysis of the inlet was completed in 4/89, and is documented in FR-20729-08A.

I/n 059
Main turbine housing

FAILURE CAUSE D. This housing transfers the loads from the inlet housing and turbine vanes to the outlet duct. This housing also provides four cooling passages for transfer to the roller bearing and IPS package. In four locations cooling hole meters are provided for blade tip shroud position control.

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

This is a fracture critical part, and will meet the requirements of the fracture control plan FR-19793-2 and safe life fracture mechanics requirements and be properly traced throughout the life of the part.

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

DVS 4.1.2.9 requires structural design analysis of the main turbine housing, and has been completed and is documented in FR-20729-08.

f/n 013 Outlet Duct

FAILURE CAUSE E. The outlet duct assembly is a one piece casting with an attached IN-100 flowpath ring that directs the turbine discharge to the hot gas manifold. 22 struts are provided for support with 14 for studs to attach to the pump hsg, and 4 with tubes and seals for cooling H2 flow which mates with the cored passages of the turbine case.

The midspan splitter is cast as a full ring and then sliced between each strut to eliminate thermally induced fatigue 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.

Development testing has demonstrated a loose snap condition , between the flow guide and the turbine discharge inner wall, as well as a cracking condition. To correct this, the flowguide has been separated from the outlet duct by making it an independent piece. This flowguide 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 (Waspaloy).

The duct 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 duct airfoil was accomplished to eliminate this problem.

Material is PWA-SP 1469.

This is a fracture critical part and will meet the requirements of the fracture control plan FR-19793-2 and safe life fracture mechanics requirements and be properly traced throughout the life of the part.

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 Outlet Duct can be found in FR-20729-07.

DVS 4.1.2.11 which requires a turbine exit flowpath analysis was completed in 6/87, and is documented in FR-20904-91.

DVS 4.1.3.2.4.2 which requires a turbine exit air flow characterization has been completed, and is documented in FR-20833-4 & -5.

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

f/n 131 (typical) Threaded fasteners

FAILURE CAUSE F. Adequate function of the beam lock insert locking feature will be assured by the Fastener Reuse Plan. This plan requires thread gaging per MIL-S-8879, replacement of lubricants, and inspection of locking features. Rejected fasteners will be mutilated.

Deformed thread nuts are used because they provide adequate locking for single use applications.

Threaded fasteners utilized in the pump end were selected for their strength and compatibility in a LOX environment. These include find numbers 40, 022-28-18, 134, 128, and 138 which are all AMS 7468 which is MP35N. The tiebolt f/n 035 is PWA-SP96 (Inco 718) which was also selected for cryogenic capability.

Find numbers 127, 245, and 267 are all AMS 5731 which is A-286, and was selected for it's ductility and cryogenic strength.

PWA 1146 which is Inco 718 was selected for it's proven history in LOX, and is utilized for find numbers 28, 55, 91, and 235.

Threaded fasteners utilized in the turbine section were selected for their strength and ductility, and good resistance to hydrogen embrittlement. These include find numbers 022-28-15, 116, 129, 130, 131, 132, 190, and 252, all of which are made of AMS 5731 which is A286. AMS 5732 (also A-286) is utilized for f/ns 87, 96, 014, 117, 150, and 169, while AMS 7462 is used for f/n 022-28-14.

The external threaded fasteners are also AMS 5731 for it's strength and ductility, and include find numbers 145, 176, 177, and 199, except nut f/n 082 which is AMS 5844 (MP35N).

Analysis of the major fastener torque values was completed using a spreadsheet and friction factor test results. The torque ranges are incorporated on the top assembly drawing to preclude joint loosening .

The Inconel 718 inserts are used in oxygen and below -260 degs F in H2 to avoid embrittlement.

The A-286 insert used in the turbine has a fine external thread to avoid misassembly.

The materials used for the nuts include AMS 5732, AMS 5664, and PWA-SP 1146. Each material was selected for its strength in the environment used.

The bolt materials include AMS 7466, and AMS 5731. As with the nuts, the materials were selected relative to strength and environment.

Tab and cup washers are used primarily to lock spanner nuts. Tab washers were not used in the primary flow path to eliminate the possibility that a liberated tab could enter the flow path.

Interference fit thread studs are used where there are small differences in the coefficient of thermal expansion, and assures a reasonably consistent fit over the operating range of the pump. Key locked studs were used where a low alpha of the housing coupled with the high alpha of the stud did not lend itself to interference fit.

These parts meet CEI requirements.

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**Inspection and Test**

| Possible Causes | Significant Characteristics | Inspection and Test | Document Ref |
|---|---|---|---|
| Failure Cause A<br>f/n 1, 232 P/B hsg 2, 234<br>Inner hsg<br>P/B hsg | Material Integrity | Material integrity is verified per specification requirements.<br><br>Contamination control is verified per specification.<br>Weld repair per specification. | 1. PWA-SP 1146<br>2. PWA-SP 1490-2<br>1. PWA-SP 36180-4<br>2. PWA-SP 36158 |
| | INSPECTION | | |
| | Raw Material | Sonic - f/n 232 per QAD<br>X-ray f/n 234 per QAD | <br>SP-XRM Master |
| | Finished Material | FPI - f/n 232 per QAD<br>FPI - f/n 234 per QAD<br>ECI - f/n 232 per QAD | SP-FPM Master<br>SP-FPM Master<br>SP-ECM Master |
| | Assembly Integrity | Torques are verified per assembly drawing.<br>Cleanliness of components is verified per specification.<br><br>Leak check of preburner housing with GHe verified per assembly drawing. | REI 013, & 016<br>PWA-SP 60 |
| | In-Process Testing | Proof pressure test at room temperature per specification. | REI 005 |
| Failure Cause B<br>f/n 022<br>Main hsg and volute | Material Integrity | Material integrity is verified per specification requirments for 22-28-02, 03, and 04<br>Material integrity is verified per specifications for 22-28-09.<br><br>Contamination control is verified per specification for item 22-28-12, 16, & 22, and item 22-29-11 | PWA-SP 1490<br>PWA-SP 1052<br><br>PWA-SP 36180-4 |
| | Heat Treat | Heat treat is verified per specification, and drawing requirements.<br>Heat treat is verified per specification and drawing note | PWA-SP 11-31, & 1490<br>PWA-SP 11 and note |
| | Weld Integrity | Weld integrity is verified per specification requirements. EDMR<br>Weld repair is verified per specification for f/ns 22-28-02, 03, & 04. | PWA-SP 16-22, PWA-SP 16-33,<br>PWA-SP 16-2233, PWA-SP 97-5<br>PWA-SP 36158-4 |
| | INSPECTION | | |
| | Raw Material | Sonic - housing 22-28-09 per QAD<br>X-ray - housings 22-28-02, 03, & 04 per QAD | <br>SP-XRM Master |

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| | Finished Material | FPI - Cast material - t/ns. 22-28-02, 03, and 04 per QAD<br>FPI - Wrought material - t/n 22-28-09 per QAD<br>FPI - Unmachined welds - t/n 22 per QAD<br>FPI - Machined welds - t/n 22 per QAD | SP-FPM Master<br>SP-FPM Master<br>SP-FPM Master<br>SP-FPM Master |
| | | ECI - t/ns. 22-28-02, 03, and 04 per QAD<br>ECI - t/n 22-28-09 per QAD<br>Coolant passage min wall thickness is verified per drawing requirements. | SP-ECM Master<br>SP-ECM Master |
| | | X-ray - t/n 22 per QAD | SP-XRM Master |
| | Assembly Integrity | Cleanliness of components is verified per specification. | REI 013<br>PWA-SP 90 |
| | In-Process Testing | Proof pressure test to reflect the proof factors per specification. | REI 005 |
| | HIP | HIP is verified per specification | PWA-SP 4, PWA-SP 1490 |
| Failure Cause C<br>t/n 114-02<br>Turbine inlet hsg | Material Integrity | Material integrity is verified per specification requirements. | PWA-SP 1469 |
| | Heat Treat | Heat treat is verified per specification, and drawing requirements | PW 11-19, & 1469 |
| | INSPECTION | | |
| | Raw Material | X-ray per QAD | SP-XRM Master |
| | Finished Material | FPI per QAD | SP-FPM Master |
| | Assembly Integrity | Locating pins for inner wall are drilled at assembly. | REI 013 |
| Supporting hardware<br>0403c<br>t/n 114-02-02<br>Ring | Material Integrity | Material integrity is verified per specification. | PWA-SP 1074 |
| | INSPECTION | | |
| | Raw Material | Sonic per QAD | |
| | Finished Material | FPI per QAD<br>ECI per QAD | SP-FPM Master<br>SP-ECM Master |

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| Supporting hardware<br>0403c<br>f/n 114-4<br>Seal | INSPECTION | | |
| | Finished Material | FPI per QAD | SP-FPM Master |
| Supporting hardware<br>0403c<br>f/n 114-5<br>Seal | Material Integrity | Material integrity is verified per specification. | PWA-SP 1143 |
| Supporting hardware<br>0403c<br>f/n 114-6<br>Ring | | Material integrity is verified per specification and drawing requirements. | PWA-SP 1074 |
| Supporting hardware<br>0403c<br>f/n 114-7<br>Heatshield | | Material integrity is verified per specification.<br>EDMR | PWA-SP 1143<br>PWA-SP 97-6 |
| | INSPECTION | | |
| | Raw Material | Sonic per QAD | |
| | Finished Material | FPI per QAD | SP-FPM Master |
| Supporting hardware<br>0403c<br>f/n 278<br>Deflector | Material Integrity | Material integrity is verified per specification requirements. | AMS 5608 |
| | INSPECTION | | |
| | Finished Material | FPI per QAD | SP-FPM Master |
| Failure Cause C<br>f/n 059<br>Turbine case | Material Integrity | Material integrity is verified per specification requirements. | PWA-SP 1074 |
| | INSPECTION | | |

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| | 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 |
| Failure Cause E<br>f/n 013<br>Outlet duct | Material integrity | Material integrity is verified per specification requirements. | PWA-SP 1469, PWA-SP 1074 |
| | Heat Treat | Heat treat is verified per specification, and drawing requirements. | PWA-SP 11-19, & 1469 |
| | INSPECTION | | |
| | Raw Material | X-ray per QAD | SP-XRM Master |
| | | Sonic per QAD | |
| | Finished Material | FPI per QAD | SP-FPM Master |
| | | ECI per QAD | SP-ECM Master |
| Supporting hardware<br>0403e<br>f/n 262<br>Flowguide | Material Integrity | Material integrity is verified per specification | AMS 1143 |
| | INSPECTION | | |
| | Raw Material | Sonic per QAD | |
| | Finished Material | FPI per QAD | SP-FPM Master |
| Failure Cause F<br>f/n 131 (typical)<br>Fasteners | Material integrity | Material integrity is verified per specification and drawing requirements.<br>1. Find nos. 177, 116, 127, 128, 245, 131, 132, 145, 176, 181, 190, 199, 267, 252, 130, or 22-29-15.<br>2. Find nos. 13, 14, 60, 67, 160, 96, 117 or169.<br>3. Find no. 82<br>4. Find no. 65, 26, 82, 73, 91, 235, 062, or 073<br>5 . Find nos. 126, 40, 134, 136, or22-26-16<br>6. Find nos. 35<br>7. Find nos. 22-29-12, 22-29-13, 24-02-03, 60, or 244-03<br>8. Find no . 60 | 1. AMS 5731<br>2. AMS 5732, or 5737<br>3. AMS 5844<br>4. PWA 1146<br>5. AMS 7468<br>6. PWA-SP 96<br>7. AMS 5662<br>8. AMS 7482<br><br>10. AMS 7482 |

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| | | 9. Deleted<br>10. Find no. 22-28-14 | |
| | Heat Treat | Heat Treat I/n 13 is verified per drawing requirements. | |
| | INSPECTION | | |
| | Raw Material | Sonic - Find nos. 14, 55, 91,189, , 177, 128, 035, 245, 129, 134, 145, 176, 190, 199, 267 per QAD<br>Sonic - Find nos.073 per QAD<br>Sonic - Find no. 22-28-14 per QAD | |
| | Finished Material | FPI - Find nos. 177, 118, 127, 40, 245, 131, 129, 132, 134, 138, 176, 199, 190, 267, 252, 60, 22-28-14, 22-28-15, 22-28-18, 130, 181. per QAD<br>FPI -Find nos. 14, 62, 82, 067, 180, 96, 189, 145, 062 per QAD<br>FPI - Find nos. 28, 91, 073, 235, 55 per QAD<br>ECI - Find nos. 91, 128, 035, 134, 55 per QAD | SP-FPM Master<br>SP-FPM Master<br>SP-FPM Master<br>SP-ECM Master |
| | Assembly Integrity | Torque values for the following find numbers will be verified per drawing requirements: Find Nos. - 062, 067, 134, 145, 138, 035, 235, 040, 082, 128, 199, 176, 177, 035 | REI 013 |
| | | All fasteners shall be installed in accordance with REI 016 to insure joint integrity. | REI 013 |
| | | Where accessible, the locking features of the locking devices shall be visually inspected for evidence of cracks, tears creases, or steps. | REI 013 |
| 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 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. | |
| | 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 - V41CBO050 |

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| | | Turbine end ball bearing, pump end ball bearing, and roller bearing inspection is performed on a contingency basis as a result of any anomaly experienced during engine operation, or as a consequence of handling. | |
| | | Turbine end bearing drying is initiated within 48 hours of landing or test termination. | OMRSD - V41CBO.065 |
| | Cleanliness | Cleanliness of components will be assured by compliance to Contamination Control Specification. | PWA-SP80 |
| All Cause<br>f/n : 059 TOVS, 013 TAD | Waivers | The TOVS does not meet CEI life requirements, so a life limit and inspection requirement has been imposed (DAR 0184) | DAR NO. 0184 |
| | | The TAD does not meet CEI requirements, so life and inspection limits have been imposed (DAR 0189). | DAR NO. 0189 |