FINAL REPORT

AAIU Synoptic Report No: 2007-026
AAIU File No: 2006/0084
Published: 9/11/07

In accordance with the provisions of SI 205 of 1997, the Chief Inspector of Accidents, on 1/11/06, appointed Mr. John Hughes as the Investigator-in-Charge to carry out a Field Investigation into this Incident and prepare a Synoptic Report.

Aircraft Type and Registration:	ATR 42, EI-CVS
No. and Type of Engines:	2 x PW 120
Aircraft Serial Number:	033
Year of Manufacture:	1986
Date and Time (UTC):	1 November 2006 @ 14.45 hrs
Location:	Enroute Kerry to Dublin
Type of Flight:	Public Transport
Persons on Board:	Crew - 4 Passengers - 33
Injuries:	Crew - Nil Passengers - Nil
Nature of Damage:	No. 1 Engine internal damage only
Commander's Licence:	ATPL
Commander's Details:	Male, aged 48 years
Commander's Flying Experience:	5,523 hours of which 2,748 were on type
Notification source:	Shannon Duty Airport Manager
Information Source:	Aircraft Operator

SYNOPSIS

The aircraft had taken off from Farranfore Airport, Co. Kerry and was in the climb when the port engine (No.1) Inter Turbine Temperature (ITT) exceded 1200°C. The Captain immediately shut down that engine and made a "Mayday" call. He decided to divert to Shannon Airport where full emergency procedures were implemented. The aircraft landed safely at 15.11 hrs and proceeded to Taxiway A where the passengers disembarked in the normal way.

FINAL REPORT

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft had taken off from Farranfore Airport, Co. Kerry at 14.35 hrs on track for Dublin via waypoint RANAR. During the climb out to FL170, approaching FL120, the crew heard a loud bang and felt a jolt. The aircraft was 5 NM southwest of Shannon at this time. The flight crew noted that engine No.1 ITT was indicating over 1200°C. The cabin crew also reported that they had observed flames and smoke coming from No.1 engine. The crew shut down No.1 engine and carried out the in-flight engine fire drills. The flight crew reported that after shutting down the engine the propeller appeared to feather as no drag was noticed. It was noted that the propeller was not rotating. The Captain reported that there was no engine fire warning in the cockpit. During the fire drill Agent 1 extinguisher was fired. A "Mayday" call was made to Shannon ATC. The Captain decided to divert to Shannon Airport and briefed the cabin crew to prepare the cabin for a planned emergency landing at Shannon. A single engine approach was carried out and a normal single engine landing was made on RWY 24. Full emergency procedures were implemented at Shannon and the aircraft landed safely at 15.11 hrs. Having ascertained that there were no further flames or smoke from the engine, the Captain taxied the aircraft off the runway to Taxiway A, where the passengers disembarked in the normal way. The aircraft was then towed to Stand 25B.

1.2 Damage to The Aircraft

Licensed engineers at Shannon Airport inspected the aircraft. The No.1 propeller could not be turned. A borescopic examination of the engine was carried out. It appeared that at least one of the blades in the Low Pressure Turbine (LPT) detached and lodged in the adjacent stators. As a result the complete row of blades in the LPT appeared to be 50% missing over their length. The 1st stage Power Turbine (PT) rotor and stator were also damaged. The engine was removed to the Manufacturer's facility in the UK for teardown to determine the cause of the failure.

1.3 Aircraft Information

1.3.1 Aircraft and Engine Details

Details of the No.1 engine are as follows:

Serial No:	120983
Installed:	30/10/2005
Time Since New (TSN):	24,240 hours
Cycles Since New (CSN):	27,506 cycles
Time Since Overhaul (TSO):	9,300 hours
Cycles Since Overhaul (CSO):	12,419 cycles
Time Since Hot Section Inspection:	1,775 hours
Cycles Since Hot Section Inspection:	2,606 cycles

Details of most recent aircraft servicing**:**

Time since last A Check:	73.18 hours
Landings since last A Check:	111 landings

1.3.2 Engine Operation (Appendix A & B)

The PW120 is a "Free Turbine" design featuring three independent shafts, each rotating at an individual speed. Each vane and corresponding turbine converts energy from the combustion gas to a mechanical rotational force. The high pressure turbine turns the high pressure impeller and accessory gearbox. The LPT turns the low pressure impeller. The two stage power turbines provide rotational force to the reduction gearbox through the Power Turbine (PT) shaft and torque shaft. The two-stage reduction gearbox reduces the input speed from the torque shaft (20,000 RPM) to the propeller shaft (1,200 RPM).

The Auto-feather logic detects an engine failure, signals the opposite engine to up-trim and the electrical auxiliary engine pump to supply oil to feather the failed engine's propeller.

1.4 Engine Strip and Inspection

The engine was stripped down at the Manufacturer's facility in the UK. Prior to engine strip the following was noted:

The power turbine (PT) rotor was locked.
The high-pressure (HP) rotor was free to rotate.
The low- pressure (LP) rotor was stiff to rotate with intermittent locking.
There was a heavy rub to the LP impeller at the inducer area.
There was impact damage to the second stage PT blades and stator.
The pressure, vent, and scavenge tubes to the No. 6 & 7 roller bearing housing had sheared.

1.5 Manufacturers Initial Report

Disassembley of the turbo-machinery revealed that a quantity of two LP blades had liberated from the LPT Disc (**Appendix C**). The remains of the two blades were retrieved from the engine. A section consisting of one fir tree segregation (so called as it resembles a fir tree) of the LPT disc, was found to be sheared at the base of the fir tree area, which released the two blades. The liberated part of the disc was not found.

Severe intershaft rubbing was observed to the LPT shaft corresponding to the rear of the HP Impeller and High Pressure Turbine (HPT) disc. Intershaft rubbing was also observed to the outside diameter of the PT shaft at various positions. This rubbing shows that the PT shaft had "whipped" inside the LP shaft. Both the LP and HP Impellers were found to have heavy rubbing to the inducer and exducer areas.

The number 6 & 7 bearing retaining bolts had sheared, the pressure, vent, and scavenge oil tubes were sheared. The rollers of the No. 6 bearing had become fused to the outer race of the bearing. There was severe down stream bombardment damage to the 1st stage PT stator and 1st stage PT blades.

The primary cause of this event was considered to be the failure of the LP turbine disc assembly. However, the mode of the failure needed to be established. The intershaft rubbing observed to the engine was considered to be caused by the induced vibration caused by the unbalance of the LP disc assembly, post the disc failure. Induced vibration caused the retaining bolts of the No. 6 & 7 housing to shear, allowing the housing to rotate, fretting and shearing the pressure, vent, and scavenge oil tubes. The loss of oil to the No. 6 bearing over heated the bearing and the rollers became fused to the outer race of the bearing. The sheared bolt caused the impact damage to the 1st stage PT stator and the 1st stage PT blades.

However, it could not be determined if the bearing failed first, causing the blades to lift or whether the out of balance on blade departure caused sufficient vibration to destroy the bearing. It was decided to return all the dynamic components to the manufacturer's Canadian laboratory for further testing and analysis.

1.6 Service Investigation

The LPT disc and stator assemblies were sent to the Manufacturers Service Investigation in Canada. They reported as follows:

1.6.1 History

ESN 120983 was a leased engine and entered Operator service with EI-BYO, another aircraft of the fleet. Records show that the subject engine had two previous shop visits.

In May 2004, at Time Since New (TSN) of 19,934 hours, a Hot Section Inspection (HSI) repair was conducted. Inspection records show that the LPT disc assembly had been debladed. The disc was found serviceable after NDT (Non Destructive Test) inspection. However, the blades were scrapped due to being undersize and were replaced with 53 serviceable blades. The LPT stator and seal assembly were also replaced.

In October 2005, at TSN of 22,465 hours an internal oil leak was repaired. At the same time, the LPT disc assembly was again debladed and the disc found serviceable. It was found that the 53 blades were corroded and 6 of these had to be replaced. Due to major erosion, the LPT stator and seal assembly were again replaced, this time, to Mod Post- SB21555/21659 standard.

On investigation of the LPT disc following this incident, records show that it had 24,240 flight hours and 27,506 flight cycles in service. (The life of the disc is 30,000 flight cycles.)

The modification standard[1] was as follows:

The LPT disc assembly was a Pre-SB No. 21555 configuration.
6 blades were to post-SB 21601 standard,
40 blades were to post -SB 21312 standard, and
7 blades were to post -SB 20645 standard.

1.6.2 Service Bulletin SB 21555

This SB, issued in November 1997, states:

"*Service experience on some engines has shown that hot corrosion can occur on the low pressure turbine disc fixing serrations. This could be caused by a leak of hot gas into the disc fixing area. To decrease the amount of hot gas leakage into this area, the sealing configuration at the low pressure turbine vane is improved.*"

[1] SB 20645 Replacement of jet oil nozzle, issued 1/1990, compliance category B6 (for record purposes).
SB 21312 Replacement of LPT blades, issued 4/1994, compliance category 7.
SB 21555 Replacement of LPT blades and stator/seal assembly, issued 11/1997, compliance category 7.
SB 21601 Replacement of LPT blades, issued 2/1999, compliance category 7.
SB 21659 Replacement of LPT stator and abradable seals, issued 4/2001, revision 4/2003, compliance category 7.

The SB Description states:

"Replace the low pressure stator and seal assembly with a new one. Also, replace the low pressure turbine blades with ones that have a redefined profile at the root fixing."

Service Bulletin SB 21555 is a Category 7 SB. Category 7 has a low priority (accomplish when all pre-SB parts are used up). This SB is not included in the minimum SB list recommended by the engine manufacturer. Because of this, the installed LPT disc is allowed to run to its full cyclic life, whether pre-or post SB 21555.

(A Category 6 SB, however, recommends compliance when the sub-assembly is disassembled and access is available to the necessary part.)

1.6.3 Examination

Examination of the LPT disc assembly and the two blades confirmed a complete rupture of one fixing at the bottom serration (rivet slot vicinity) releasing two blades.

- The blade airfoils were battered and fractured from debris impact at various heights above the platform.
- The disc balancing rims as well as the balancing rivets and the disc centre hub were rubbed on a 120-degree arc from orbiting.
- Several blade platform edges were rubbed and worn due to an axial contact with the upstream LPT vane ring assembly.
- The No. 6 bearing inner ring and cage (**Appendix D**) were still mounted on the disc. Both bearing components were rubbed, smeared and deformed. The No. 6 bearing air-seals were unevenly rubbed and worn.
- Examination of the LP stator assembly confirmed it was a Post-Service Bulletin (SB) No. 21555/21659 configuration. Battering damage was noted to the vanes on the downstream side. The retaining rivets for the baffle retaining plate were sheared. The vane-ring retaining-plate outer-rim downstream edge was significantly rubbed and worn from axial contact with the LPT blade platforms. The stator labyrinth and abradable seals were significantly rubbed and worn.

1.6.4 Materials Investigation Laboratory (Appendix D)

The LPT disc assembly was sent to the manufacturer's laboratory for further analysis. Cracking of the LPT disc fixing occurred at the bottom serration, pressure side, near the upstream face. The crack exhibited river lines at grain facets and showed evidence of an intergranular fracture. The fractured disc fixing area revealed microvoids at the grain boundaries indicative of advanced stage of creep.

Fracture of three consecutive LPT blade airfoils just above the platform occurred by tensile overload due to impact.

The disc average "K" diameter was measured at 7.6488" compared to the original diameter of 7.6523".

A variation in the average hardness of the disc fixings adjacent to the fractured fixing was noted. The maximum difference in average hardness between the upstream and downstream faces was 60 HB. The hardness of the fixings located at 90º and 180º of the fractured fixing both showed no significant difference between the upstream and downstream faces.

Semi-quantitative energy dispersive spectroscopy (EDS) analysis of the LPT disc indicated that the major alloying elements of the material were consistent with the compositional requirements.

1.6.5 Manufacturer's Materials Investigation Conclusion

- The fracture mechanism of the LPT disc fixing was creep assisted by fatigue.
- There were no metallurgical anomalies noted on the LPT disc material.
- Damage to the submitted adjacent hardware was secondary as a consequence of the rupture of the LPT disc fixing.

1.6.6 Manufacturer's Concluding Remark

SB No. 21555 introduced an LPT vane assembly with improved sealing configuration and a new LPT blade with a redefined root fixing profile to decrease the amount of hot gas leakage into the disc fixing area.

1.7 <u>Additional Information</u>

1.7.1 Creep

Creep is the term used to describe the tendency of a material to move or to deform permanently to relieve stresses. Material deformation occurs as a result of long term exposure to levels of stress that are below the yield or ultimate strength of the material. Creep is more severe in materials that are subjected to heat for long periods and near material melting point. Creep of a turbine blade will cause the blade to contact the casing, and may result in the failure of the blade. Because of the high gas temperatures and pressures involved creep can also affect the turbine disc.

1.7.2 Fatigue

Fatigue is the progressive and localised structural damage that occurs when a material is subjected to cyclic or fluctuating strains at nominal stresses that cause structural failure. The maximum values are often significantly less than the ultimate tensile stress, and may be below the yield stress of the material.

2. ANALYSIS

Although the cabin crew reported that they had observed flames and smoke coming from the No. 1 engine, the Captain reported that there was no engine fire warning in the cockpit. There was little evidence of fire during the engine strip and it can be concluded that the products of combustion were contained within the No.1 engine power plant. It was agreed that the quick action of the Captain in shutting down the engine saved the engine from further internal damage.

SB No. 21555 introduced a LPT vane assembly with improved sealing configuration and a new LPT blade with a redefined root fixing profile to decrease the amount of hot gas leakage into the disc fixing area. In 2005, the LPT stator and seal were replaced to this modification standard but 47 blades installed were all to an older standard. The modification was issued in May 1997 and consideration might have been given to replacing all the blades in 2005 to the latest standard considering that the engine was stripped down at the time. Had the modification been classified initially as a Category 6 "Recommended" service bulletin, greater emphasis would have been placed on renewing the blades to the higher standard thus protecting the disc fixing areas from hot gas corrosion. The disc had reached 91% of its flight cycle life. This engine component failure contributed to an in-flight engine shut down and the Investigation recommends that the SB compliance be made more urgent.

3. CONCLUSIONS

(a) Findings

1. Two LPT blades liberated from the LPT disc and were found within the engine. A section which separates two adjoining fir tree blade fixings was found to be sheared at the base of the fir tree area, which released the above two blades.

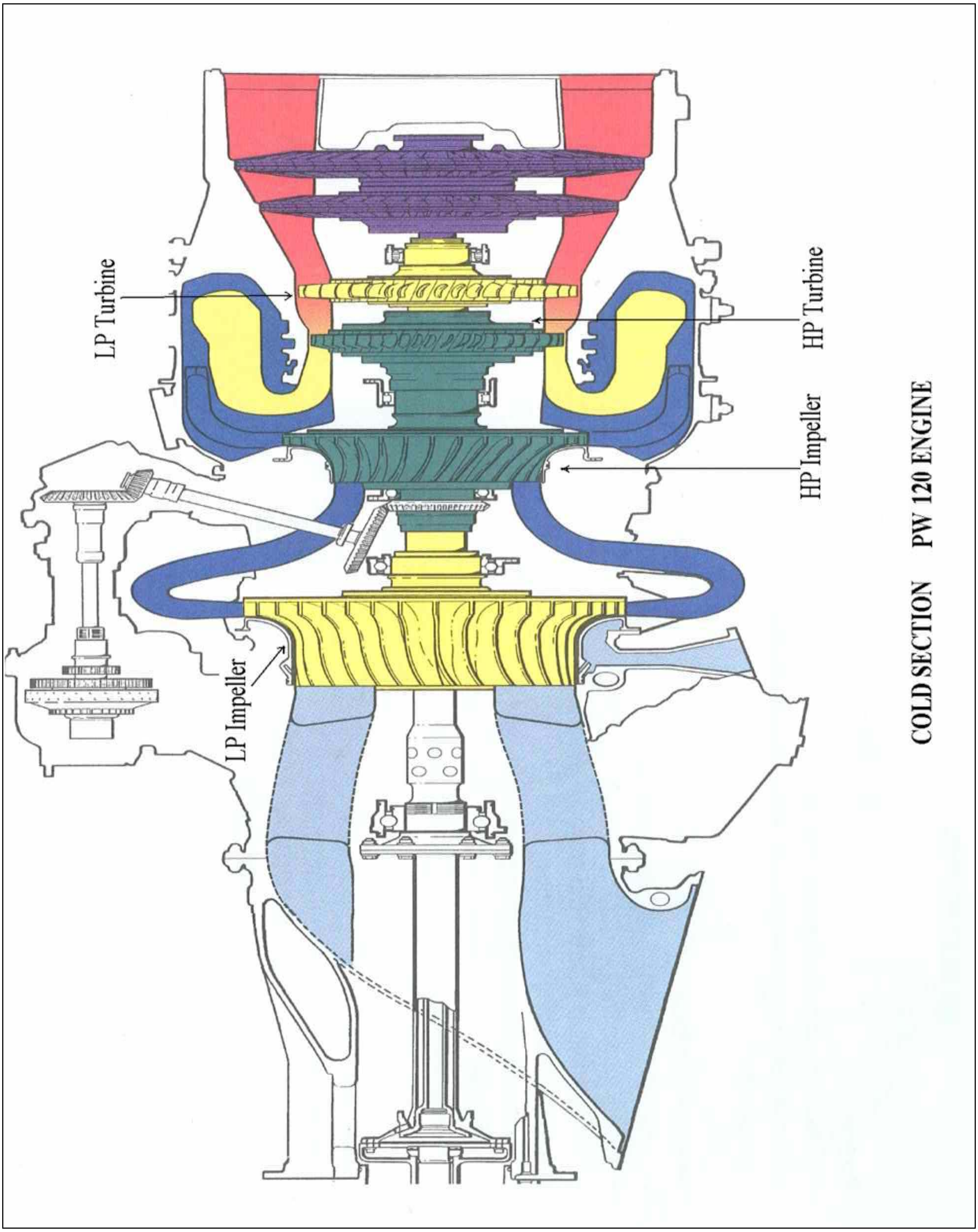
(b) Cause

1. The fracture mechanism of the LPT disc fixing was creep assisted by fatigue.

4. SAFETY RECOMMENDATIONS

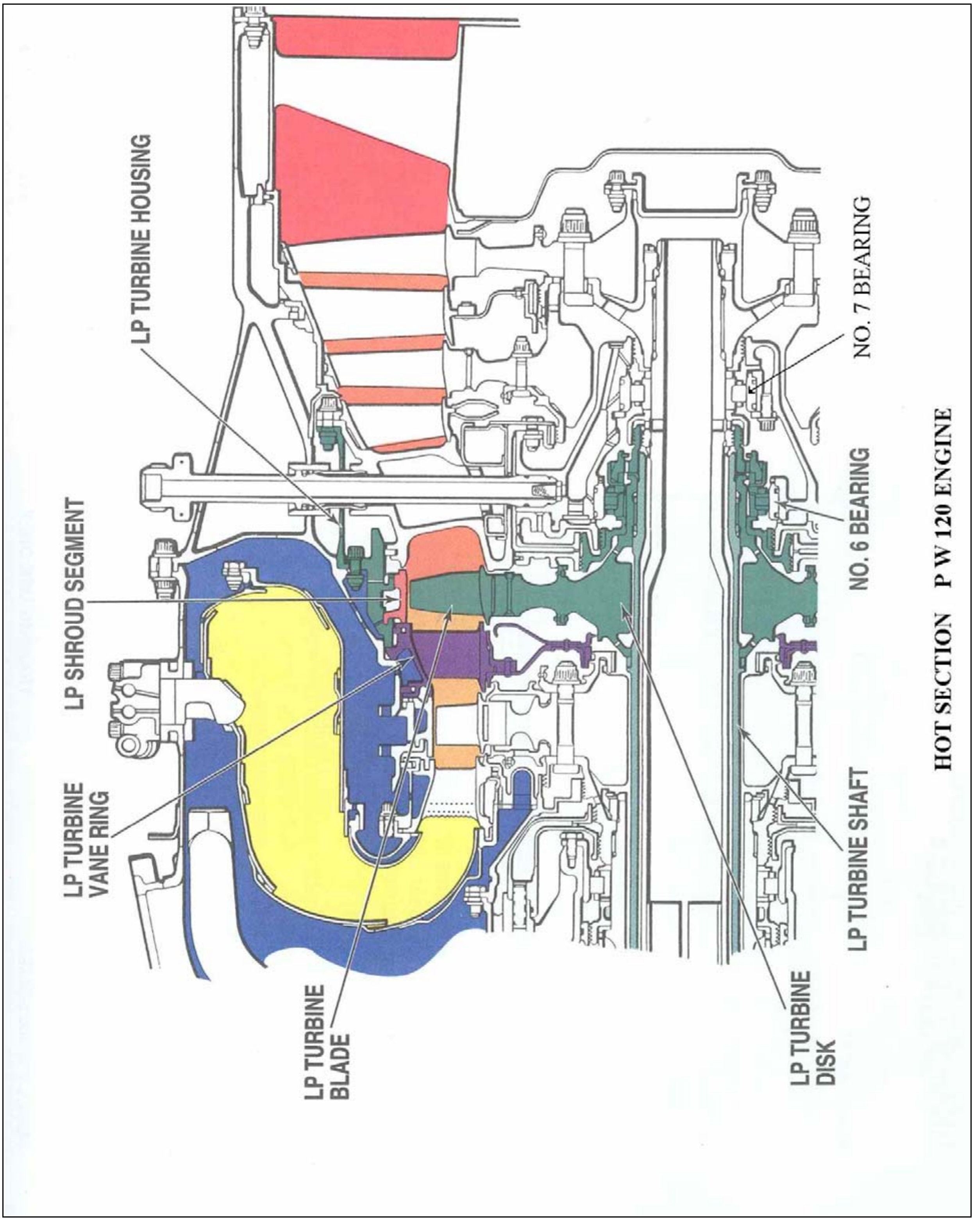
The manufacturer should give more urgency to the implementation of Service Bulletin No.21555 by changing the Compliance Category from 7 to 6. **(SR 18 of 2007).**

APPENDIX A


LP Turbine
HP Turbine
HP Impeller
LP Impeller
COLD SECTION PW 120 ENGINE

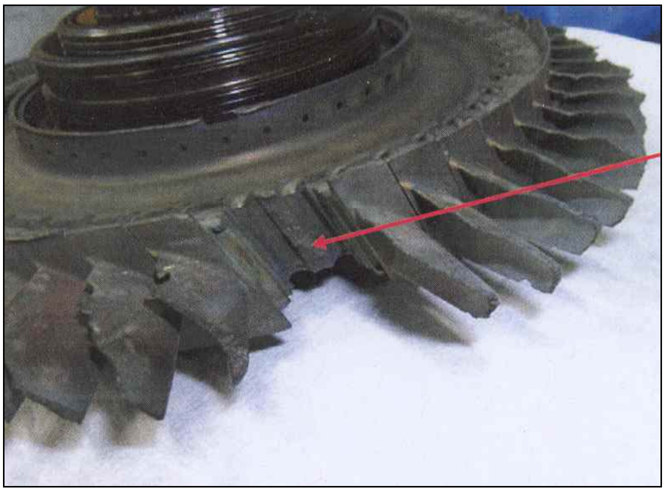
FINAL REPORT

APPENDIX B



APPENDIX C

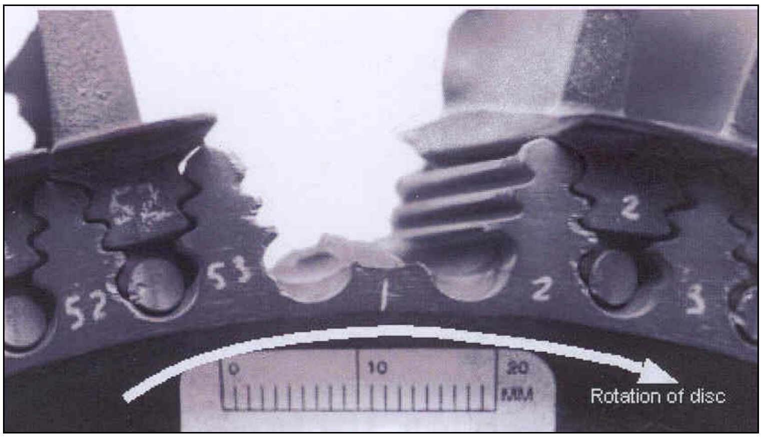
Shown above (*LH picture*) is the LP turbine disc missing two complete blades with a section of disc which liberated from the disc body. Three blades fractured above the disc platform, with the remaining blades suffering severe impact damage. The other picture (*RH),* shows severe intershaft rubbing and heat discoloration of the LPT shaft from contact with the rear end of the HP impeller and the bore of the HP Turbine disc.

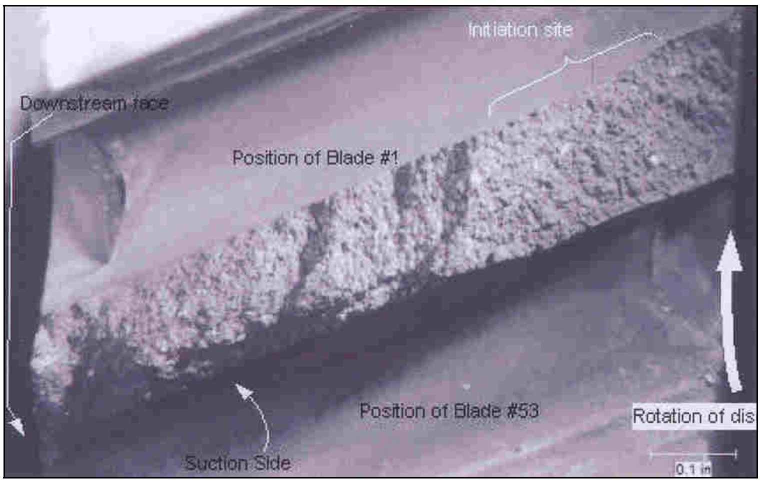


The arrow indicates where one complete fir tree area liberated from the LP disc. The remains of the blades as shown were retrieved from the area of the 1st stage PT stator. The missing section from the disc body was not found within the engine.

APPENDIX D

Above, the deformed and fused No.6 bearing





A close-up of the fractured surface shows an intergranular topography. The crack initiation site is at the upstream face, pressure side. *(Photo Courtesy of the Engine Manufacturer)*