AAIB Bulletin No: 8/95 **Ref: EW/C95/1/3** **Category: 1.1**

INCIDENT

Aircraft Type and Registration:	BAe ATP, G-MANA
No & Type of Engines:	2 Pratt & Whitney (PW)126 turboprop engines
Year of Manufacture:	1994 (first Certificate of Airworthiness)
Date & Time (UTC):	20 January 1995 at 1408 hrs
Location:	Manchester International Airport
Type of Flight:	Scheduled Public Transport
Persons on Board:	Crew - 4 Passengers - 15
Injuries:	Crew - None Passengers - 1 Minor
Nature of Damage:	Severe internal damage to right engine
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	47 years
Commander's Flying Experience:	7,700 hours (of which 455 were on type) Last 90 days - 155 hours Last 28 days - 52 hours
Information Source:	AAIB Field Investigation

History of the flight

The aircraft and crew had flown an uneventful 45 minute sector from their base to Manchester. After embarking the passengers, the engines were started and the aircraft taxied to Runway 24. The co-pilot took control for a rolling takeoff which was carried out at full power in the normal manner at 1405 hrs. After takeoff, landing gear and flaps were retracted and engine power was reduced to the climb rating. Later, at 1,000 feet in the climb on runway heading, the propeller speed was reduced to 85% on both powerplants. When the aircraft was about three miles from the airport, climbing through 2,700 feet altitude, the cabin and flight crew felt and heard a distinct thud as the aircraft yawed. The co-pilot applied rudder to correct the yaw and the commander noticed that right-hand engine torque had reduced from about 90% to 20%. The commander asked ATC if they could maintain heading and climb to safety altitude whilst they addressed an engine problem. Shortly after receiving the desired ATC clearance, there was a second thud and the right engine fire warning bell sounded. The

commander shut down the right engine and carried out the 'Engine Fire' immediate actions. The warning did not cease within 45 seconds of discharging the first fire extinguisher shot but it went out shortly after the second extinguisher discharge. After extinguishing the fire, the commander declared an emergency using the 'MAYDAY' prefix and asked for radar vectors back to Manchester. He then took control from the co-pilot and spoke to the passengers on the cabin Public Address (PA) system.

By this time the Senior Cabin Crew Member (SCCM) had made her way to the flight deck to report the noise she had heard, the sudden yaw and an unusual smell in the cabin which she likened to the smell of exploded caps from a toy cap gun. The flight crew were obviously busy so she waited behind them. Whilst she was waiting, the second cabin crew member came to the flight deck to inform the SCCM that she and the passengers could see flames coming from the right engine and that there was smoke in the cabin.

The flight crew had not been aware of any smoke until the flight deck door was opened whereupon an acrid smoke haze was obvious. The SCCM asked the commander to ventilate the cabin whilst she went aft to attend to the passengers. As she went aft, she could still see the length of the cabin but the smoke was noticeably worse aft of row eight. Some passengers seated on the side nearest the engine fire were trying to move to seats on the other side so she asked them to return to their seats and fasten their seat belts, which they did. By the time she reached the rear of the cabin, the engine fire was no longer visible but she did see the jet-pipe change colour from orange to black and she noticed that the propeller was rotating very slowly. The SCCM identified one man seated at the rear who was calm and had a good view of the right engine. She asked him to monitor the engine and to press his call bell if he saw the engine on fire again, but not to press it for any other reason. She then went forward to attend to passengers at the front of the aircraft including one person whose eyes were irritated by the smoke. This person, who was blind, had recently received hospital treatment for an eye condition but apparently none of the other passengers suffered any respiratory or ocular discomfort. Oxygen was not used on the flight deck or in the cabin.

The smoke gradually cleared as the commander manually flew the aircraft towards the downwind leg for Runway 24 with vector assistance and priority from ATC. Whilst positioning for a visual approach, the flight crew reviewed and carried out the remaining fire drill actions from the emergency checklist and completed the approach and landing checklists just before they landed at 1420 hrs, eight minutes after the fire warning. Both pilots stated after the incident that the aircraft performed better than they had expected on one engine, and that they had not experienced any control difficulties.

Meanwhile ATC at Manchester had brought the airport emergency services to full alert and the fire service were watching the aircraft as it approached to land. There were no signs of fire and the aircraft landed normally on Runway 24 in benign weather conditions. The commander taxied off the runway

via rapid exit turnoff 'X' and brought the aircraft to a halt on taxiway number 4 with the right-hand engine downwind of the cabin. There the fire service vehicles surrounded the aircraft. Because the fire was now out and there were only 15 passengers, one of whom was blind, the commander ordered the SCCM to evacuate the aircraft via the normal stairs at the forward left door. This was achieved a few seconds after the left engine was shut down but, despite earlier requests to evacuate without their belongings, several passengers tried to carry them off the aircraft. The SCCM and a further PA call from the commander succeeded in encouraging them to leave their belongings on the aircraft.

The passengers were assembled and counted upwind of the aircraft on the tarmac. Having shut down the engine the commander left the co-pilot to complete the remaining actions whilst he satisfied himself that the passengers were safe. Airport buses arrived and conveyed the passengers to the terminal. One person required minor medical attention.

Engine shutdown drills

The QRH (Quick Reference Handbook) for the ATP contained two engine shutdown drills: one for 'ENGINE FIRE OR SEVERE MECHANICAL FAILURE IN FLIGHT' and another for 'ENGINE IN-FLIGHT SHUTDOWN' which was applicable to 'MECHANICAL FAILURE', 'AUTO-FEATHERING', 'LOW OIL PRESSURE' and general aircraft safety reasons. The memorised actions for shutting down the engine were very similar for each drill with, for the fire drill, the additional actions of cancelling the fire warning bell and discharging the fire extinguisher. The 'IN-FLIGHT SHUTDOWN' memorised actions required the pilot to establish whether the propeller had feathered satisfactorily before proceeding with the remainder of the drill. There was no mention of any requirement to check that the propeller had feathered in the 'ENGINE FIRE OR SEVERE MECHANICAL FAILURE IN FLIGHT' drill. In both cases it is important to check that the propeller has feathered before attempting 'normal' single-engined flight. The AAIB has brought this anomaly to the attention of Jetstream Aircraft Limited and the operator. Jetstream Aircraft Limited has proposed an amendment to the Flight Manual, currently under consideration by the CAA, which requires the pilot to establish that the propeller has feathered satisfactorily in both engine shutdown drills.

Flight Recorders

The Flight Data Recorder (FDR), a Fairchild F1000 was down loaded by Jetstream Aircraft Limited, and the raw data supplied to the AAIB. The Cockpit Voice Recorder was removed and returned to the AAIB for replay, the 30 minute recording contained the final approach and landing, but the period of the engine fire had been overwritten.

Figure 1 shows some of the recorded engine data during the incident; the aircraft also carried an engine health monitoring system which recorded exceedance information as well as trend data. Engine No 2 showed a sudden drop in Torque from 100% to around 30% as the aircraft was climbing through 2,750 feet on 1013 mb at 172 kt. This was followed by a rise in Inter-stage Turbine Temperature (ITT) recorded by the health monitoring system, which contained 20 seconds of data on both engines triggered by the ITT exceedance. The maximum ITT was 975°C. There was a second drop in Torque 40 seconds later to around zero, and then 10 seconds later the No 2 engine fire warning illuminated. There was then a reduction in power lever angle and the propeller RPM reduced. The fire warning lasted for 8 seconds on the FDR and the engine was shut down.

There were some problems in the recorded information after the incident when spurious readings were recorded for No 2 engine following the engine shutdown. The Propeller RPM appeared to increase to an overspeed condition (max 110%), and the Low Pressure Turbine (NL2) RPM also appeared to increase despite the engine being shut down. Both indications then decreased, but then showed spikes to higher values (85% Prop RPM and 25% NL) intermittently. Both parameters then stabilised at the same high values that were previously indicated during the spikes. These values made it appear that the engine was running, however other engine parameters show the engine shutdown.

Jetstream conducted further data retrievals from G-MANA after the incident when the engine and wiring harness had been changed, these showed that the data spikes still occurred, data retrievals from other aircraft where the engines were shut down showed no such anomalous readings. The Flight Data Acquisition Unit (FDAU) was fitted to another aircraft without reproducing the fault. The FDAU was returned to the manufacturer, and in the presence of the AAIB and the aircraft manufacturer was tested to the design test specification, with no faults found. Further extensive testing was carried out. These tests in some cases were outside the normal test envelope, and still no faults were found with the FDAU. When the FDAU was returned to G-MANA the spikes and spurious data were again in evidence on down loading the FDR data.

The fault in the FDR system has not yet been identified but Jetstream Aircraft Limited are continuing to troubleshoot the aircraft system; any further information will be published in a later Bulletin.

Engineering Investigation

The aircraft was examined by the AAIB on the evening of the incident at Manchester International Airport. The only obvious external signs of problems with the right engine were that a considerable quantity of oil had flowed back from the Low Pressure Compressor Shroud Bleed outlet on the outboard side of the nacelle and there was evidence of oily soot deposits on the right tailplane. Closer inspection revealed numerous hard object impacts on the right tailplane leading edge de-icing boot, one or two of which had penetrated the rubber. The right engine propeller was found fully feathered.

The long exhaust duct was badly distorted through excessive heat and some metallic debris was lying in the duct. Using a torch, it was possible to see that the Second Stage Power Turbine (PT2) had suffered massive damage with sections missing from almost all of the blades. Once the engine forward cowling was opened it was possible to see that there was no evidence of fire inside the nacelle and the quantity of oil leaked around the engine bay area was described by maintenance personnel as "normal". The casing around the power turbine had numerous bulges where high-energy impacts had occurred inside but none had penetrated the casing. It was later discovered that the three oil transfer tubes associated with the No 6 and 7 bearings were loose, being effectively only located by their pipework (see diagram).

The engine was stripped at the Manufacturer's local overhaul facility under AAIB supervision. In addition to the damage to the PT2 stage previously noted, it was found that the PT1 stage had lost all of its blades. Most had fractured immediately above the platform but a total of twelve had been liberated from their fir tree roots in three locations spaced at 120° around the disc circumference. The low pressure turbine (LPT) had impact damage but was mostly intact. The High Pressure Turbine (HPT) was scarcely damaged, as was the rest of the engine forward of this location. Some abnormal seal rubbing and bearing deterioration was found in the compressor stages but, as discussed later in this bulletin, this was considered consequential to the primary problems which had occurred in the power turbine area. It was also found that the No's 6 and 7 bearing housing had come adrift from its location in the Inter-Turbine Case (ITC) and rotated a small amount due to failure of the twelve bolts securing it. This dislocation of the housing had led to failure of the oil transfer tubes mentioned above. The No's 6 and 7 bearings themselves were intact but devoid of any lubricant and were very badly worn and overheated - the No 7 bearing being worse than the No 6.

A complete description of the rest of the damage and fractures found in the turbine area is not required in this bulletin as it was secondary to the primary sequence of events which was arrived-at following metallurgical examination of the parts. It should, however, be noted that a considerable quantity of oil had been released into the LP and HP compressor areas due to consequential seal degradation and that this was considered to be responsible for the smoke reported in the passenger cabin.

Metallurgical Examination

The affected parts were examined at the engine Manufacturer's main facility in Canada. The No's 6 and 7 bearing housing bolts were found to have fractured by a fatigue mechanism, as had the oil transfer tubes. Other indications were found which supported a mechanism of severe vibration over an extended period of time having occurred in the power turbine rotor.

Unfortunately, little remained of the PT1 blade aerofoils and shrouds apart from one almost intact blade and two pieces of two others. The PT1 disc itself had suffered severe overheating on the upstream face, suggesting an oil fire in that area, although the recovered blades did not show such damage. The one intact blade had lost the leading edge of its platform and some material was missing from the frontal root surface - similar wear being noted on the other two fragments. This was interpreted as indicating that these blades, at least, had migrated forward and made contact with the stator vanes in front.

For reasons given in the 'Discussion' paragraph of this bulletin, the Reduction Gearbox (RGB) oil scavenge filter was subjected to a check on the pressure drop across its element. This was found to be 50 psid above 90% High Pressure rotor speed. The filter should bypass at 45 psid and an amber cockpit warning should have been generated at 25 psid indicating an impending bypass.

Engine History

The engine fitted in the right-hand position on G-MANA was not that which had been installed at delivery. The latter had been removed for incorporation of Pratt & Whitney Canada Service Information Letter (SIL) 323 which involved rework of the power turbine blades. The subject engine, S/No PCE 124179, had 6,931 total flying hours and 8,048 cycles since new but had only some 142 hours/180 cycles since its last workshop visit. This visit was also for incorporation of SIL 323 and the power turbine stages were new.

On the two sectors prior to the incident takeoff, the technical log contained two maintenance entries for apparent oil loss on the right engine. The first reported that the oil level was below the sight glass and, after replenishment and a check for leaks, the engine was ground-run with no abnormalities observed. However a Special Inspection (SI) was raised to monitor oil uplifts for 48 hours. After the next sector the SI was performed and it was found that 2 quarts were required to restore the oil level. The next sector involved the incident takeoff.

Discussion

The engine manufacturer's report into the engine failure concluded that it was "*a result of first stage PT blades fracture initiated by blade shift*". However, due to extensive resultant damage the cause for blade shift could not be established.

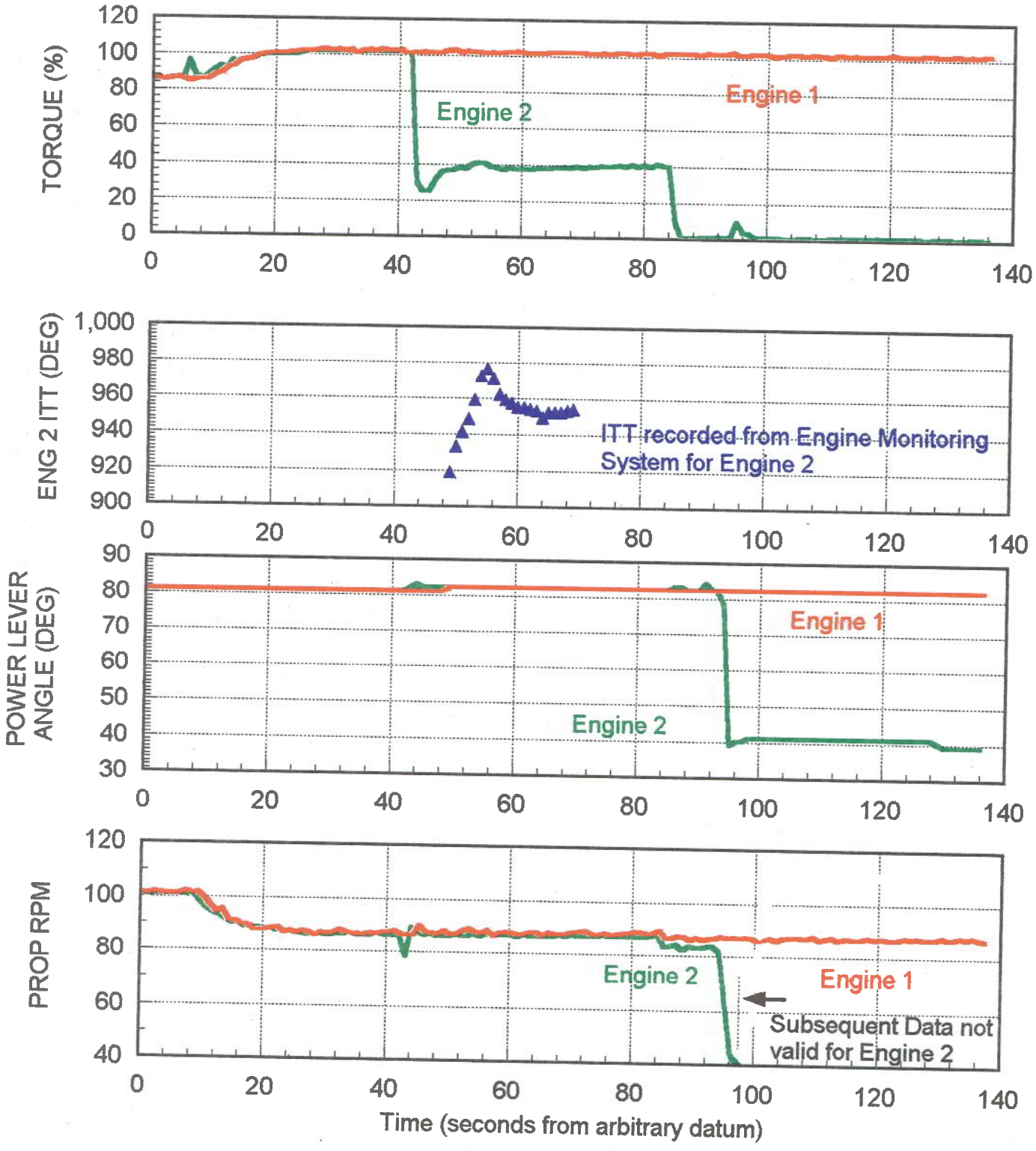
The phenomenon of blade shift, whilst evidently experienced on the lower-powered versions of the PW100 family of engines, is not believed to have been a problem on the PW126. SIL PW-055, issued in October 1988, drew attention to Service Bulletin 2003 Rev.5 which incorporated instructions

for borescope inspection for axial blade shift on the smaller engines, but does not discuss possible causes, which would imply some failure of the retaining rivets or mal-assembly. An additional mechanism could be softening of the disc material due to overheating. This certainly occurred at some point with the incident engine, although it was not possible to say whether the overheating originated as a result of seal deterioration due to blade shift or for some other mechanical reason.

The evidence of overheating of the PT1 disc suggested an oil fire in the region of the 6/7 bearing housing. Again this could have been due to seal degradation due to extreme vibratory stresses in the power turbine but it is also known, by the engine manufacturer, that over-replenishment of the oil quantity can lead to oil leakage from this and other areas. It has recently been established that a partially blocked RGB scavenge filter can result in misleading indications of total oil quantity, particularly if readings are taken at different times after engine shutdown. Another PWC SIL, No 322 dated September 1994, drew attention to the possibility of a partially blocked RGB scavenge filter and its ability to cause fluctuating cockpit readings of oil pressure. The question of over-servicing of the system by maintenance crews was not mentioned. The SIL called for checks and cleaning/replacement of the RGB scavenge filter following crew reports of abnormal engine oil indications. It also advocated a 1,200 flying-hour interval between scheduled cleaning and replacement of the main and RGB scavenge filters, whereas the unit was listed as 'On Condition' in maintenance planning documents. This recommendation was to be reviewed following completion of the manufacturer's investigation of the problem. The RGB filter on the incident engine had accumulated some 1,500 hours since it was last serviced, since no additional instruction appeared in the approved maintenance schedule for the aircraft.

As stated previously, an 'impending by-pass' amber caption should have illuminated in the cockpit when the pressure drop across the filter reached 25 psid. This did not appear to have happened and a check on the aircraft revealed a wiring anomaly which rendered the system inoperative. All ATP aircraft were subsequently found to be incorrectly wired and Jetstream Aircraft issued Service Bulletin ATP-79-25-10382A on 10 February 1995, detailing re-wiring to correct the fault. The manufacturer asked the Civil Aviation Authority to mandate this SB for all aircraft on the UK register and on 1 May 1995 the CAA agreed that the Bulletin be revised and re-issued with mandatory status.

Figure 1 G-MANA FDR data



G-MANA: PW126 Engine Turbine Cutaway Diagram