ACCIDENT

Aircraft Type and Registration:	ATR 72-201, EI-REH
No & Type of Engines:	2 Pratt & Whitney Canada PW 124B turboprop engines
Year of Manufacture:	1990
Date & Time (UTC):	21 October 2009 at 1030 hrs
Location:	Stand 7, Manchester Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 33
Injuries:	Crew - None Passengers - None
Nature of Damage:	Significant damage to propeller blades and stand infrastructure
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	30 years
Commander's Flying Experience:	3,790 hours (of which 1,425 were on type) Last 90 days - 225 hours Last 28 days - 60 hours
Information Source:	AAIB Field Investigation

Synopsis

Following an uneventful flight, the aircraft came to a halt on stand and the crew applied the parking brake. However, the aircraft subsequently started to move forward once more and, despite attempts to stop the aircraft by using the brakes, it continued to move until it struck a stand guidance mirror assembly. The investigation determined that a failure of a hydraulic fuse in the parking/emergency brake line had led to a loss of the brake accumulator hydraulic pressure.

History of the flight

The crew were operating the first of four scheduled sectors. Following an uneventful flight from Galway, Ireland to Manchester, the commander taxied the aircraft towards Stand 7. Before turning onto the stand centreline, the flight crew checked that all brake pressures were indicating normally. Having drawn up to the correct stopping position on the stand, the commander set the parking brake before feathering both propellers. Ground crew approached the aircraft whilst the anti-collision lights were flashing and attached the fixed electrical power[1] cable. Although their procedures required them to insert chocks immediately on approaching the aircraft, they did not do so.

Footnote

[1] The fixed electrical power cable provides ground based electrical power for the aircraft.

The aircraft then started moving slowly forwards, so the ground crew ran clear. Both pilots attempted to stop the aircraft by applying the toe brakes, without success, after which the commander exercised the parking/emergency brake lever.

Recognising that the aircraft was not under control, the commander gave an 'alert call' to the cabin crew, and instructed the co-pilot to shut the engines down. The co-pilot shut the engines down, transmitted to ATC that the aircraft was in difficulties and requested the attendance of the fire and rescue service.

The aircraft rolled forward until the No 2 engine propeller struck a stand guidance mirror, provided to enable pilots to see the stop lines on the stand centreline. Both the mirror and propeller were damaged, with one propeller blade becoming lodged in the mirror assembly as the aircraft stopped moving. The fire and rescue service responded after a short delay, which was due to training exercises being conducted at the time of the accident.

Analysing the event later, both pilots recalled considering the possibility of using reverse thrust to attempt to halt the aircraft's movement and perhaps back away from the stand. However, they recognised that before reverse thrust was achieved, the propellers would produce forward thrust for a short period; they considered that this strategy had the potential to make the situation worse.

Recorded information

The Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) were successfully downloaded. The FDR recording did not include any parameters relating to hydraulics, brakes or ground speed and was therefore of limited benefit to this investigation. The CVR provided good quality audio of crew communications and the ambient noise.

The recordings showed that 3 minutes and 20 seconds after touchdown, the propeller pitch parameter changed from LOW to NORMAL and the engine torque values and propeller speeds dropped to a recorded value of 0% (propeller speeds are not computed below 25% of the nominal propeller rpm; this also prevents torque values from being calculated). Approximately 35 seconds later, the CVR recorded impact sounds that were consistent with propeller blades striking the stand guidance mirror with an initial propeller speed of 75 rpm. This was followed by a short period without any propeller blade impact and then by rumbles consistent with the propeller blades striking and rubbing the mirror mounting pole. This second set of blade strikes also correlated with small amounts of accelerometer activity recorded on the FDR. During this time, the data showed the fuel flow for both engines reduce to zero at which point no more data was recorded.

Description of the aircraft hydraulic systems

The ATR 72 has two hydraulic systems, Green and Blue, which between them supply services such as landing gear actuation, nosewheel steering, wing flaps, spoilers and the braking system. Each system is pressurised to a nominal 3,000 psi by an AC electric pump, which in turn is powered by a frequency-wild AC generator mounted on each propeller reduction gearbox. A single hydraulic fluid reservoir is used for both systems, with separation provided by means of a partition within the tank. The partition extends to approximately two thirds the height of the tank; a sight glass, together with a fill line, is positioned above the top of the partition. Thus, in the event of a leak, the fluid level will drop below the sight glass to the top of the partition, before continuing to fall on the Green or Blue side, depending on which system is being depleted.

The Blue system is equipped with an auxiliary DC pump that runs automatically under certain conditions, including when the main system pump pressure falls below 1,500 psi, the landing gear is down and at least one engine is running. The frequency-wild generators drop off line when the propeller rpm falls below 70%. In operational terms, this means that when the propellers' rpm are reduced prior to feathering following the aircraft's arrival on stand, the Green and Blue system AC pumps will cease operating. This will cause the DC pump, powered from starter/generators on the high-speed engine spools, to cut in, thus maintaining pressure in the Blue system. When the engines are shut down the DC pump can operate from a ground electrical supply, or directly from the battery bus via a button on the pedestal.

Each hydraulic system is provided with a 0.2 litre accumulator, which damps out pressure surges and compensates for pump response time in the event of high demand. In addition, there is a 1.2 litre parking/emergency braking accumulator that maintains brake pressure when the aircraft is parked, or, via an emergency brake metering valve, provides brake pressure in the event of failure of the main hydraulic system. Each brake line contains a hydraulic fuse to limit the loss of fluid in the event of a leak downstream. These six fuses are mounted close to the anti-skid manifold in the hydraulic bay, which is located in the lower fuselage aft of the main landing gear.

A schematic diagram of the hydraulic system is shown at Figure 1.

Examination of the aircraft

The aircraft was examined briefly on the evening of the day of the accident, and in detail during daylight on the following day.

It was apparent that the aircraft had moved between 10 and 14 metres beyond the usual stop position area, with a trail of hydraulic fluid under the fuselage that extended a similar distance behind the aircraft, indicating that significant leakage had occurred as the aircraft came to its initial stop. The right hand propeller had struck the first of two poles on which were mounted the stand guidance mirrors. Significant damage had occurred to the propeller blades, which were of composite construction. The impact had caused the mirror to rotate around its pole so that it faced towards the terminal; the aircraft had come to rest with the propeller blades trapped in the gap between the pole and the mirror.

The left main landing gear aft fairing was removed in order to gain access to the hydraulic system components. It was apparent that the floor of the bay was wet with hydraulic fluid and that no fluid was visible in the reservoir sight glass. After removing the filler cap it was found that the Blue system side of the reservoir was empty. The reservoir was refilled; approximately 5 litres were required to achieve the 'Full' indication on the sight glass. The park brake lever was set to off and the DC pump was operated for a few seconds using the pedestal button; this pressurised the Blue system to approximately 3,000 psi, as indicated on the Blue and Emergency Brake accumulator gauges. However, the Blue system pressure decayed rapidly, as fluid was seen to leak from the rearmost of two hydraulic fuse assemblies attached to the anti-skid manifold; the location is shown schematically in Figure 1.

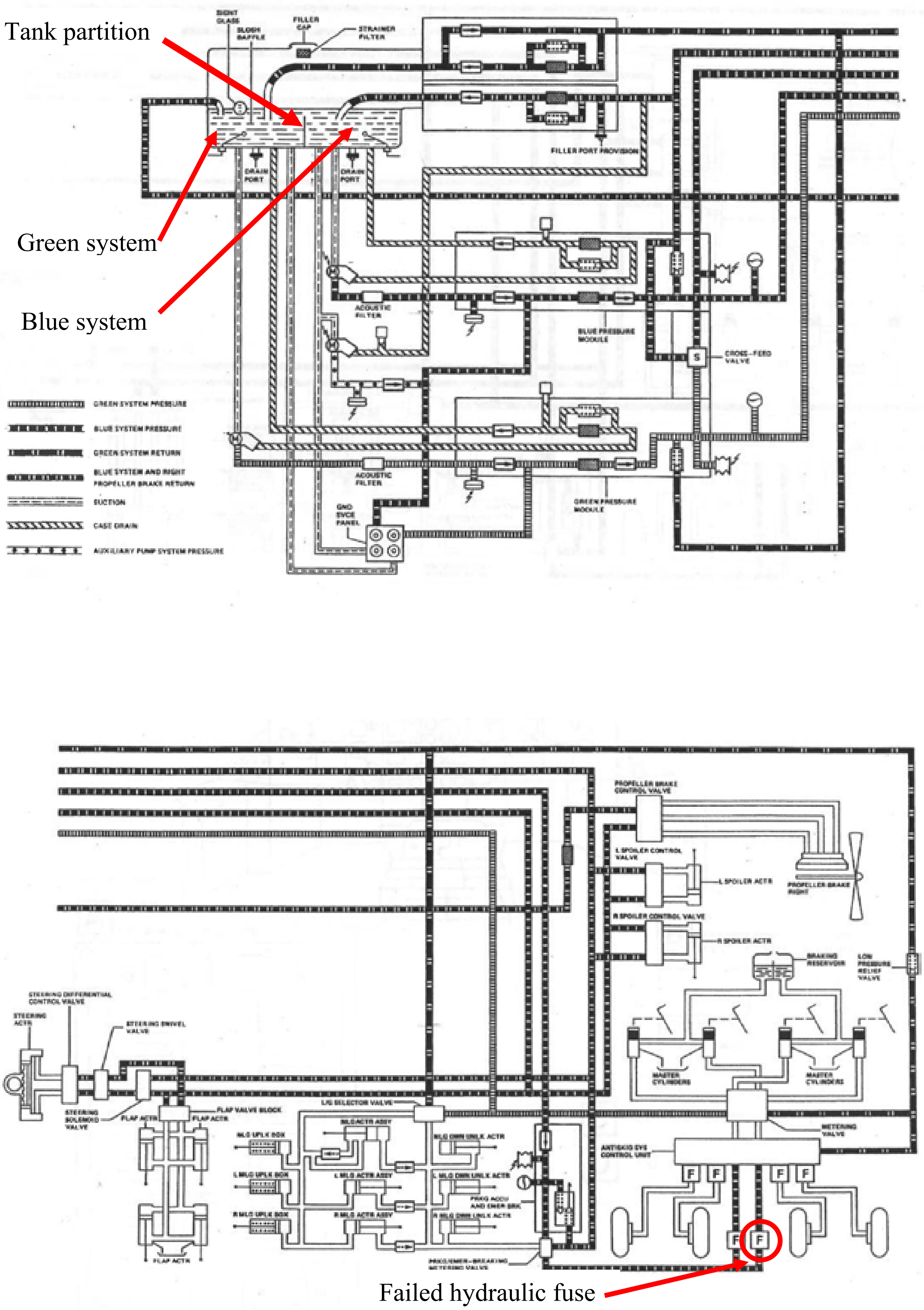

Figure 1

Hydraulic system schematic diagram

The defective hydraulic fuse was removed and was observed to have a crack in its valve body; this can be seen in Figure 2.

Examination of the hydraulic fuse

The function of a hydraulic fuse is to limit the loss of fluid in the event of a downstream leak, such as could be caused by the failure of a pipe or a union. It operates by means of a flow rate sensing valve mechanism that moves to close off the fluid flow. In the case of the failed component, the crack was effectively upstream of the valve mechanism, which was rendered ineffective as a result.

Figure 2

Visible crack on surface of valve body

The valve body bore a data plate that indicated the Part Number was 6279-1, with a serial number of 398. It was date-stamped 15 November 1988 and, in the absence of any records indicating to the contrary, is likely to have been on the aircraft since initial build. This being the case the total hours and flight cycles achieved by the aircraft, and hence the hydraulic fuse, were 30,854 hours and 54,385 cycles, up to the date of the accident. The hydraulic fuses are not 'lifed' items and are maintained 'on condition'.

The component was subjected to a metallurgical examination. The existence of the crack in the valve body, which was manufactured from cast aluminium alloy, was confirmed by means of fluorescent dye penetrant. It was also found that the crack ran along the wall between the two internal chambers within the body. The valve body was subsequently broken open; examination of the fracture surface revealed that it was primarily brittle overload with two small areas of fatigue growth either side of a channel connecting the two chambers, as indicated in the photograph at Figure 3. It was additionally noted that the fracture surface exhibited evidence of shrinkage porosity along its entire length. This is a feature that can occur as a result of non-uniform solidification during the casting process. It takes the form of voids within the material, the irregular shapes of which can result in stress concentrations from which fatigue cracks grow. An example of a void is shown in Figure 3.

The fatigue had initiated from multiple origins in the bore of the channel, with initiation appearing to be influenced by the presence of shrinkage porosity. The crack growth extended to a maximum length of around 4.5 mm before the final brittle overload failure occurred; this resulted in the observed crack, which accounted for approximately 50% of the total cross-sectional area of the component along the fracture plane. The brittle nature of the material was such that the critical crack length required before a final overload failure occurred would be relatively short. There was no evidence of any mechanical or corrosion damage that could have influenced the observed failure.

It was not possible to establish when the crack initiated or how quickly it progressed. However, it probably did not reach the surface of the valve body until the final,

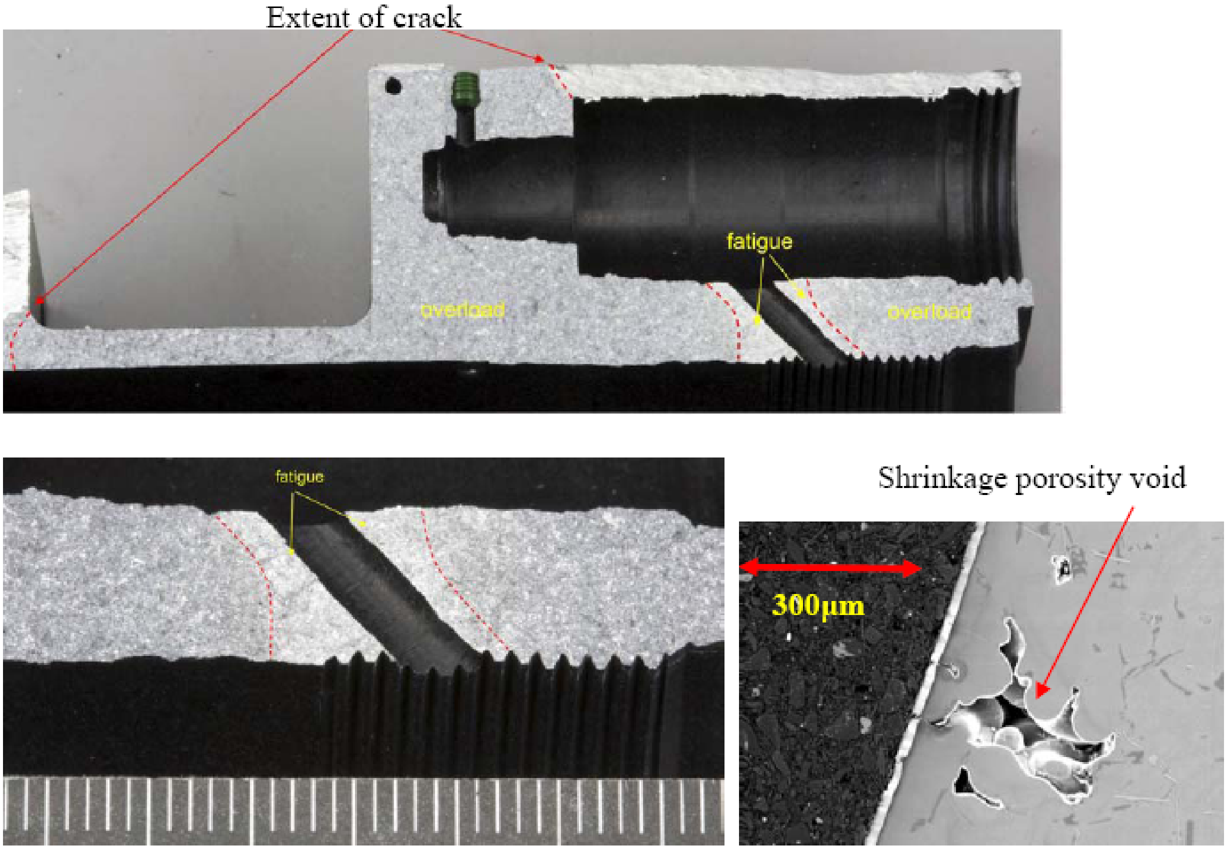

Figure 3

View of sectioned fuse body showing extent of the crack

brittle overload failure, which most probably occurred as the aircraft arrived on stand. Thus, it is unlikely that there would have been any fluid leakage prior to this. In support of this, the technical log contained no record of any top-up of the hydraulic reservoir for three weeks prior to the accident. Information from the operator indicated that one quart of fluid was uplifted on 24 July 2009 and a leaking tee fitting in the left landing gear well was replaced on 29 September 2009. There was no recent maintenance activity on the hydraulic fuses or the immediate area.

Other hydraulic fuse failure events

The aircraft manufacturer stated that the subject event was the third known failure of a hydraulic fuse. The first occurred in Vietnam on 29 March 2007 on an aircraft that was delivered in 2001 and had achieved 11,500 hours and 12,100 flight cycles. Control of the aircraft was lost on the runway after landing due to the loss of nosewheel steering; the Green hydraulic system was already disabled due to an inoperative pump. The failed fuse, located in the Blue hydraulic line between the parking and emergency brake metering valve (ie the same location as EI-REH), was manufactured in 2000 and is likely to have been fitted to the aircraft since it was built. Although the incident narrative described the fuse as “fractured”, the subsequent investigation of the component was inconclusive. Following this incident the aircraft manufacturer revised the Master Minimum Equipment List (MMEL) to require a check of the hydraulic reservoir contents prior to despatch with one hydraulic pump inoperative.

The second event occurred in Venezuela on 7 October 2009. Details are scarce, but the aircraft reportedly lost "all systems" pressure while taxiing to the runway prior to departure. The aircraft had achieved 28,300 hours and 52,920 cycles, with the inference that the same figures applied to the life of the failed fuse.

Analysis

The investigation showed that the aircraft overran its intended stop position following a failure of a hydraulic fuse in the Blue hydraulic system.

When the brakes failed with the aircraft stationary on the parking stand, the flight crew were presented with a situation beyond their training, and for which the manufacturer had not provided a procedure in the flight crew operating manual. Their actions alerted the cabin crew and emergency services, and by shutting down the engines, they minimised the extent of the damage.

Although required by their procedures, the ground crew did not place chocks under the wheels of the aircraft before attaching the fixed electrical power. The insertion of the chocks may have prevented the aircraft from moving forward, after it had initially come to a halt. This put the ground crew into a hazardous situation as the aircraft began to move forward whilst they were attaching the fixed electrical power.

As a result of this accident the airport operator, several ground handling companies, the CAA, the Health and Safety Executive, and airline representatives, have instigated a series of discussions about ground crew activities around aircraft with engines running. In light of these discussions, no safety recommendation is made regarding ground handling.

The FDR parameters did not include the operation of the parking/emergency brake lever. The crew had brought the aircraft to a halt before applying the parking brake and feathering the propellers. The last action caused the Green hydraulic system to cease operating, but, by this stage, the Blue hydraulic system would have been supplying the brake pressure. Since no leakage is possible from the failed fuse unless the parking/emergency brake lever is operated, it is probable that the crack in the valve body finally progressed to failure as a result of being exposed to Blue hydraulic system pressure. The crew's operation of the parking/emergency brake lever resulted in the contents of the Blue hydraulic system accumulator being discharged via the crack. It is possible that, until the contents were exhausted, some braking effect against the decaying propeller thrust was achieved from the residual pressure.

The metallurgical examination revealed that the failure was caused by a fatigue crack in the hydraulic fuse body. Whilst the fatigue crack growth would have been driven by the repetitive pressure cycles, the initiation appeared to be influenced by the presence of shrinkage porosity within the casting. Whilst this might pose a question on the quality of the casting, there have been only two similar events reported across the ATR 42/72 fleet and the fact that one of them occurred to a relatively recently manufactured component suggests a random nature to the failures.