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ADDENDA and CORRECTIONS

(ALL TIMES IN THIS BULLETIN ARE UTC)

ACCIDENT

Aircraft Type and Registration:	Boeing 777-236ER, G-YMMM
No & Type of Engines:	2 Rolls-Royce RB211 Trent 895-17 turbofan engines
Year of Manufacture:	2001
Date & Time (UTC):	17 January 2008 at 1242 hrs
Location:	Runway 27L, London Heathrow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 16 Passengers - 136
Injuries:	Crew - 4 (Minor) Passengers - 1 (Serious) 8 (Minor)
Nature of Damage:	Aircraft damaged beyond economic repair
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	12,700 hours (of which 8,500 hours were on type) Last 90 days - 85 hours Last 28 days - 52 hours
Information Source:	Inspectors Investigation
	All times in this report are UTC

The investigation

The Air Accidents Investigation Branch (AAIB) was informed of the accident at 1251 hrs on 17 January 2008 and the investigation commenced immediately. The Chief Inspector of Air Accidents has ordered an Inspectors' Investigation to be conducted into the circumstances of this accident under the provisions of The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996.

In accordance with established international arrangements, the National Transportation Safety Board (NTSB) of the USA, representing the State of Design and Manufacture of the aircraft, has appointed an Accredited Representative to participate in the investigation. The NTSB Accredited Representative is supported by a team which includes additional investigators from the NTSB, the Federal Aviation Administration and Boeing; Rolls-Royce, the engine manufacturer, is also participating fully in the investigation. British Airways, the operator, is cooperating with the investigation and providing expertise as required. The Civil Aviation Authority (CAA) and the European Aviation Safety Agency (EASA) are being kept informed of developments.

In view of the sustained interest within the aviation industry, and amongst the travelling public, it is considered appropriate to publish an update on the continuing investigation into this accident. This report is in addition to the Initial Report, published on 18 January 2008, a subsequent update published on 23 January 2008 and Special Bulletins published on 18 February 2008 and 12 May 2008.

History of the flight

The flight from Beijing to London (Heathrow) was uneventful and the operation of the engines was normal until the final approach. The aircraft was correctly configured for a landing on Runway 27L and both the autopilot and the autothrottle were engaged. The autothrottles commanded an increase in thrust from both engines and the engines initially responded. However, at a height of about 720 ft the thrust of the right engine reduced to approximately 1.03 EPR (Engine Pressure Ratio); some seven seconds later the thrust on the left engine reduced to approximately 1.02 EPR. The reduction in thrust on both engines was the result of less than commanded fuel flows and all engine parameters after the thrust reduction were consistent with this. Parameters recorded on the Quick Access Recorder (QAR), Flight Data Recorder (FDR) and Non-Volatile Memory (NVM) from the Electronic Engine Controllers (EECs) indicate that the engine control system detected the reduced fuel flows and commanded the Fuel Metering Valves (FMVs) to open fully. The FMVs responded to this command and opened fully but with no appreciable change in the fuel flow to either engine.

The aircraft had previously operated a flight on 14 January 2008 from Heathrow to Shanghai, with the return flight arriving on 15 January 2008. The aircraft was on the ground at Heathrow for 20 hours before the departure to Beijing on the 16 January 2008. Prior to these flights G-YMMM had been in maintenance for two days, during which the left engine EEC was replaced and left engine ground runs carried out.

Flight Data

In accordance with regulatory requirements, the aircraft was equipped with a 25 hour duration FDR and a 120 minute Cockpit Voice Recorder (CVR). The aircraft was also equipped with a QAR, which recorded data into a removable solid state memory device. These were successfully replayed.

The FDR provided a complete record of both the accident flight and the preceding flight; Heathrow to Beijing, which was operated on 16 January 2008. The FDR also contained the latter stages of the flight from Shanghai to Heathrow, which arrived on 15 January 2008.

The QAR record had ended about 45 seconds[1] prior to initial impact. Although the QAR record had not included the final seconds of the approach and touchdown, it recorded the position of both engine FMVs, a parameter not recorded on the FDR, and included the initial onset of the fuel flow reduction to both engines and the subsequent FMV movements to their fully open positions.

A time history of Total Air Temperature (TAT), Static Air Temperature (SAT), fuel temperature and other salient parameters during the accident flight are shown in Figure 1. Figure 2 shows a time history of the relevant parameters during the final approach and the accident sequence.

Whilst taxiing out at Beijing the TAT was -6°C (21°F), and the fuel temperature, measured in the left main fuel tank, was -2°C (28°F). The aircraft took off at 0209 hrs.

Footnote

[1] The loss of the 45 seconds of QAR data was accounted for due to the system being configured to buffer data in volatile memory before recording it onto the solid state memory.

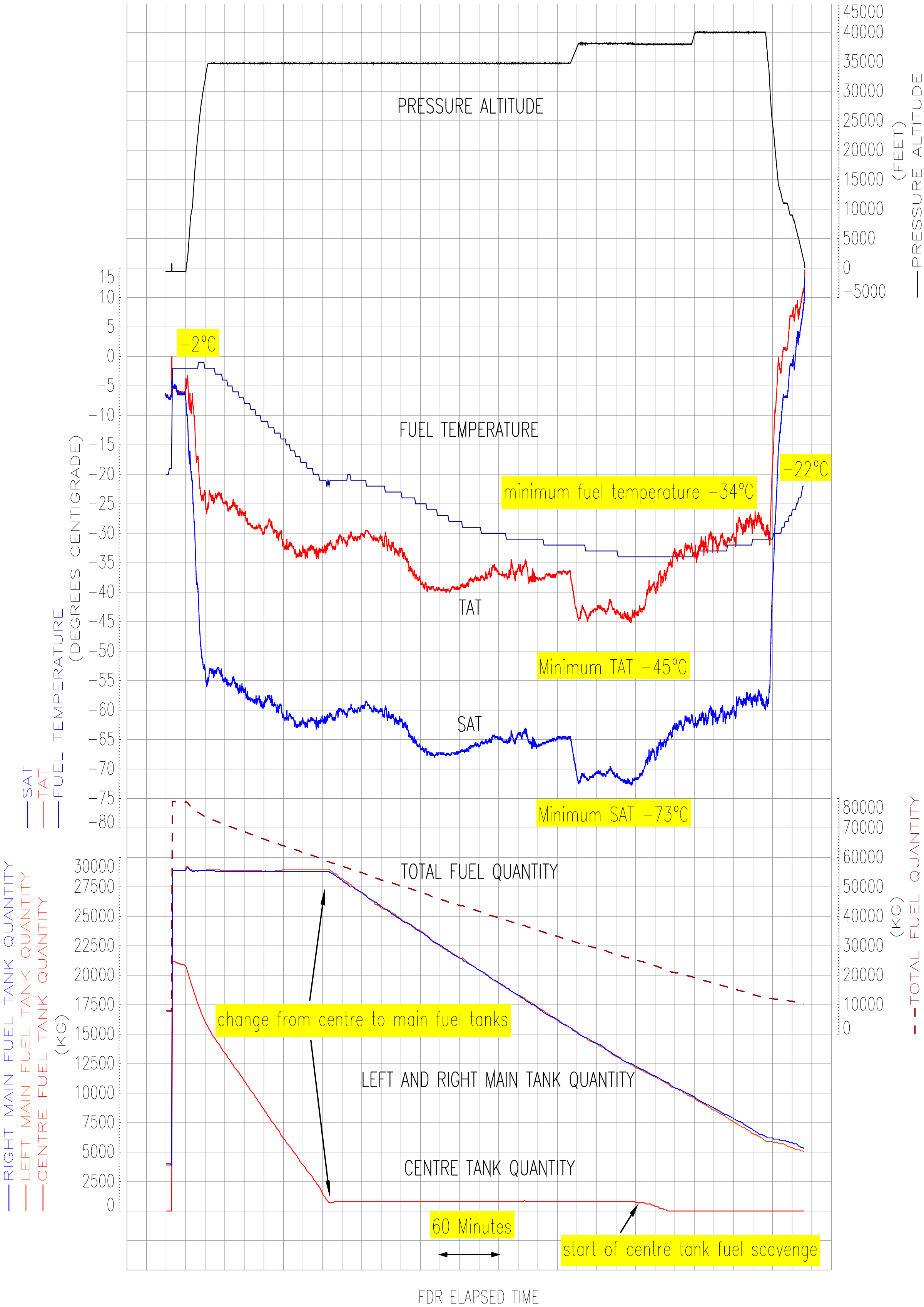


Figure 1

Temperatures

The total fuel quantity at takeoff was 78,700 kg, with 28,900 kg in both the left and right main tanks and 20,900 kg in the centre tank. The aircraft climbed to a pressure altitude of 10,590 m (34,750 ft), where, at 0232 hrs, it levelled off into the cruise portion of the flight. The TAT had reduced to -25°C (-13°F) with the fuel temperature remaining at -2°C (28°F) at this time. Engine fuel flows during the takeoff phase had peaked at 24,176 pounds per hour (pph) for the left engine and 23,334 pph for the right engine, with both engines being fed with fuel from the centre tank. This slight difference in fuel flows is not considered to be significant.

Two hours into the cruise the TAT had progressively reduced to -33°C (-27°F) and the left main tank fuel temperature was about -22°C (-8°F). At this point the engines fuel feed supply switched from the centre tank to their respective main fuel tanks; the total fuel quantity at this point was 58,600 kg, with fuel being distributed 29,000 kg, 800 kg and 28,800 kg across the left main, centre and right main fuel tanks respectively.

During the next three and a half hours the fuel temperature reduced further from -22°C (-8°F) to -32°C (-26°F), in line with further reductions in TAT.

At 0842 hrs the aircraft made the first of two cruise step climbs, climbing from 10,590 m (34,750 ft) to 11,610 m (38,100 ft). The step climb was managed using the vertical speed (VS) mode of the autopilot, with the vertical speed set at 400 fpm. The peak fuel flow during the step climb was 8,688 pph for the left engine and 8,512 pph for the right engine. Prior to the second step climb, the aircraft made a minor flight level change to FL380 as it crossed international air traffic control boundaries.

At 0931 hrs, fuel temperature reduced to its lowest recorded value of -34°C (-29°F). It remained there for about 80 minutes during which the lowest value of TAT of -45°C (-49°F) was recorded.

When the left and right main fuel tank quantities approached 12,200 kg, automatic scavenging of the fuel from the centre fuel tank to the main fuel tanks commenced, as designed, and over a period of half an hour the centre tank quantity indication reduced from 800 kg to zero.

Just over two hours from touchdown the TAT started to rise, in response to the increasing SAT; this was followed by an associated rise in fuel temperature. About twenty minutes later, the aircraft made its second and final step climb from FL380 to FL400. This was also completed using the VS mode of the autopilot, but with a slightly higher vertical speed of 600 fpm set. During this climb the peak fuel flow was 8,896 pph for the left engine and 8,704 pph for the right engine.

At 1202 hrs the aircraft commenced its descent before levelling at FL110, to enter the hold at Lambourne; it remained in the hold for about five minutes, during which it descended to FL90. In the first few minutes of the descent the fuel flows on both engines reduced to 970 pph, with two peaks to a maximum of 4,900 pph, until the aircraft entered the hold, when the fuel flows increased to 5,500 pph. The aircraft was then radar vectored for an ILS approach to Runway 27L. The aircraft subsequently stabilised on the ILS with the autopilot and autothrottle systems engaged and at a height of about 1,200 ft, the aircraft was configured for landing and 30º of flap was selected. By this time the fuel temperature had risen to -22°C (-8°F).

As the flaps reached the 30º position the airspeed had reduced to the target approach speed of 135 kt and the autothrottle commanded additional thrust to stabilise the

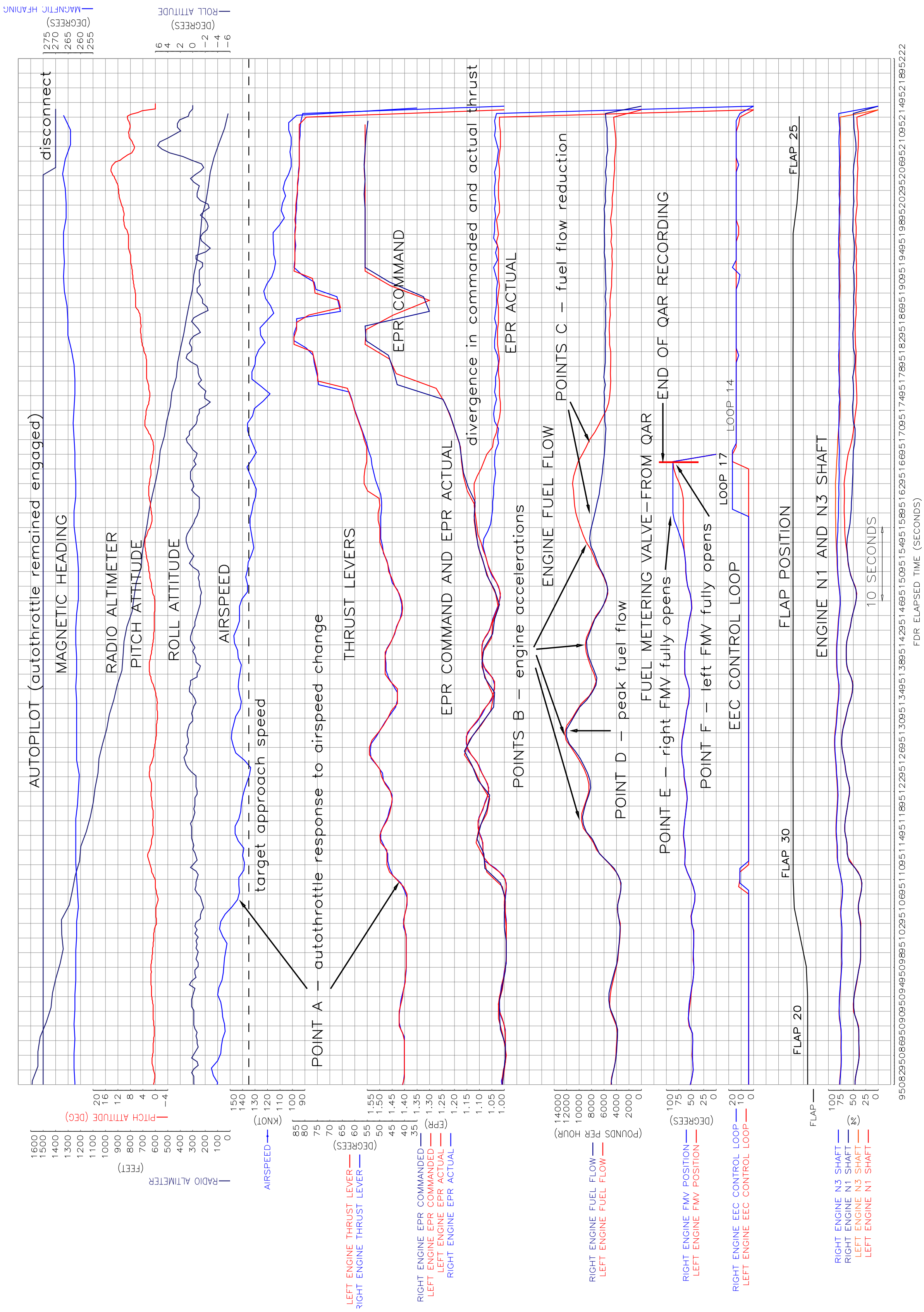


Figure 2

Final approach

airspeed (Figure 2 Point A). In response to variations in the wind velocity and associated airspeed changes, there followed a series of four, almost cyclic, thrust commands by the autothrottle (Figure 2 Points B). It was during the fourth acceleration, and as additional thrust was being commanded, that the right engine, followed some seven seconds later by the left engine, experienced a reduction in fuel flow (Figure 2 Points C). The right engine fuel flow reduction occurred at a height of about 720 ft and the left engine at about 620 ft.

Of the four thrust commands it was the second that resulted in the highest delivery of fuel flow, reaching a peak of 12,288 pph for the left engine and 12,032 pph for the right (Figure 2 Point D). These peaks occurred about 26 seconds prior to the reduction in fuel flow to the right engine. Peak fuel flows during the first and third thrust commands were lower, at about 9,500 pph and 9,000 pph respectively.

During the fourth thrust increase, the right engine fuel flow had increased to 8,300 pph before gradually reducing. The recorded EPR then started to diverge from the commanded EPR and the right engine FMV was then fully opened (Figure 2 Point E). Some seven seconds later, the left engine fuel flow, which had increased to 11,056 pph, also started to reduce and the left engine FMV was also moved to its fully open position (Figure 2 Point F). Following the reduction in fuel flow, the left engine fuel flow stabilised at about 5,000 pph and the right at about 6,000 pph. Both engines continued to produce thrust above flight idle. The autothrottle and the flight crew commanded additional thrust, with both thrust levers ultimately being placed fully forward, but there was no increased thrust available from either engine. The actual fuel flows continued to remain significantly below that being commanded.

At 240 ft the aircraft commander selected flap 25 in an attempt to reduce the drag. As the autopilot attempted to maintain the aircraft on the ILS glideslope the airspeed reduced and by 200 ft had reached 108 kt. The stick shaker activated at approximately 170 ft, and shortly afterwards the First Officer made a nose down pitch control input which reduced the aircraft pitch attitude and caused the auto pilot to disconnect. The aircraft's initial impact was at a descent rate of about 1,400 fpm and a peak normal load of about 2.9g. The aircraft then bounced, before commencing a ground slide, during which the FDR and CVR records ceased due to loss of electrical power.

The data indicated that throughout the flight, the fuel cross-feed valves were closed and the fuel spar valves open. There was no activation of a low pressure warning from the fuel boost pumps or any impending fuel filter blockage warning.

Fuel system description

The fuel on the Boeing 777-200ER is stored in three fuel tanks: a centre tank, a left main tank and a right main tank; see Figure 3. The centre tank contains two override / jettison pumps (OJ) and each main fuel tank contains two boost pumps, identified as forward (fwd) and aft. Each of the pump inlets is protected by a mesh screen and the pumps are also equipped with a check valve fitted in the discharge port, to prevent fuel in the fuel feed manifold flowing back through the pump. A pressure switch, mounted between the pump's impellor and check valve, monitors the fuel pressure and triggers a warning in the flight deck if the pressure rise across the pump drops to a value between 4 and 7 psi.

The fuel feed manifold runs across the aircraft and connects to the engine fuel feed lines. The manifold is split between the left and right system by two cross-feed

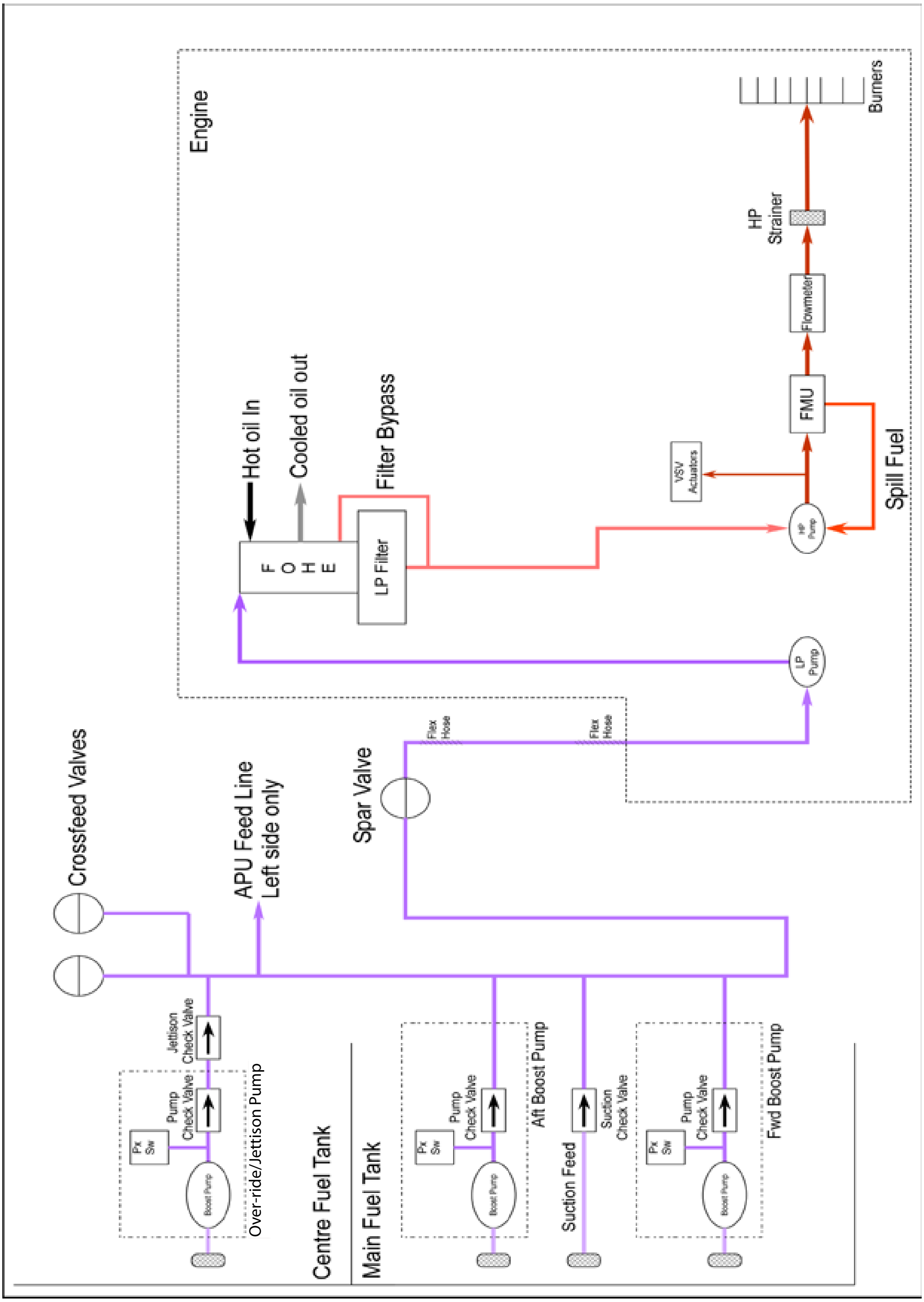


Figure 3

Boeing 777 / Rolls-Royce Trent 800 Fuel System valves. When these valves are closed, and the centre tank is the source of the fuel, the left OJ feeds the left engine and the right OJ feeds the right engine. The fuel from the left and right main tanks will supply their respective engines during main tank feed. Spar valves in the fuel manifold provide a means of shutting off the fuel supply to the engines, and they are controlled by the engine run / cutoff switches. The spar valves also move to the closed position when the fire switch is operated.

To prevent large amounts of free water building up in the fuel tanks the aircraft is fitted with a water scavenge system that uses jet pumps operated by motive flow from the OJ and boost pumps. One jet pump is located in each main tank and two in the centre tank. The jet pumps draw fluid from the lowest sections of each tank and inject it close to the inlet of each aft boost pump and both OJ inlets.

The aircraft is equipped with a centre tank fuel scavenge system, which increases the amount of useable fuel in this tank. The system uses jet pumps, provided with motive flow from the boost pumps, to draw fuel from the lowest part of the centre tank and feed it into both main fuel tanks. A float valve mounted in the centre tank turns on the motive flow when the centre tank content is below 15,800 kg. Float valves mounted in each of the main fuel tanks prevent fuel scavenge when the contents of these tanks are above 12,500 kg.

Each tank is vented to atmosphere through channels in the roof of the fuel tanks, which are connected to surge tanks mounted outboard of each of the main tanks. The surge tanks are vented to atmosphere through a flame arrestor and a scoop mounted on the lower surface of each wing. Should the flame arrestor or scoop become blocked, a pressure relief valve will operate and prevent the tanks from becoming over or under pressurised.

If fuel is loaded into the centre tank, the normal operation is to select all OJ and boost pumps ON at the start of the flight. As the OJs operate at a higher delivery pressure than the boost pumps the centre tank will empty first. During this period the boost pumps will provide fuel flow for their internal cooling and lubrication and supply motive flow to the jet pumps. When the centre tank is nearly empty, the pressure in the fuel feed manifold reduces and the main tank boost pump check valves open supplying fuel into the manifold. The flight crew then manually switch OFF the OJ pumps. In the event of low pressure from both the boost pumps in a main tank, the suction feed bypass check valve opens and fuel, via an inlet screen, is drawn from the main fuel tank by the engine Low Pressure (LP) pump.

The airframe fuel system supplies fuel to the LP engine-driven pump. This raises the fuel pressure (and fuel temperature slightly) and pumps the fuel through a Fuel/Oil Heat Exchanger (FOHE) which serves the dual purpose of cooling the engine lubricant and raising the temperature of the fuel such that ice does not affect the downstream components, including the LP filter. The FOHE is of a hybrid cross-flow / counterflow design. The fuel enters the top of the FOHE and passes downward, through a matrix of 1,180 small-diameter tubes that protrude through the inlet face. Hot oil enters the FOHE, just below the inlet face, before being directed to the bottom of the device. The oil then migrates upwards and around the fuel containing tubes. The temperature of the fuel after it has passed through the FOHE is considerably above its entry temperature. Should the LP filter become blocked, a bypass operates to allow unrestricted fuel flow around the filter; there is a flight deck indication if this occurs.

After the LP Filter, the fuel travels to the High Pressure (HP) pump where its pressure is raised higher still to the values needed for injection through the burners in the combustion chamber. The HP fuel is ported into the Fuel Metering Unit (FMU). The FMU contains a Fuel Metering Valve (FMV), which regulates the fuel flow to match a thrust demand and is commanded from the EEC. The fuel from the FMU is routed to the burners via a flowmeter and a relatively coarse HP strainer.

Aircraft examination

General

A comprehensive examination of all the aircraft systems revealed no pre-existing defects with the electrical systems, hydraulics, autoflight systems, navigation systems or the flying controls.

Spar Valves

The flight data shows that the spar valves remained open throughout the flight. Any uncommanded movement would have been recorded on the FDR and warnings would have been enunciated on the flight deck. A detailed examination of the spar valves and their control system revealed no pre-existing defects and a thorough review of the control system indicated that uncommanded and unrecorded movement of the spar valves was not possible. Extensive testing to induce an uncommanded movement, that remained unrecorded, could not identify any such failure modes.

High Intensity Radiated Field (HIRF) and Electro-Magnetic Interference(EMI)

Tests were conducted on the effects of HIRF and EMI on the spar valve control system up to power levels well in excess of published standards and no anomalous behaviour was experienced. In addition, the EECs were originally tested satisfactorily to power levels in excess of those that would have affected other more sensitive aircraft systems. During the accident flight no anomalies were evident with the electrical, navigation or communication systems, which are much more susceptible to such interference. There is therefore no evidence to suggest that HIRF or EMI played any part in this accident.

Fuel System

A pressure and vacuum check was carried out on the aircraft fuel feed system, and all of the pipelines were inspected by videoscope before the main mechanical and electrical components were removed for examination and testing. In addition, the entire left fuel feed system was removed from the aircraft, all the seals were inspected and the system was reassembled at the AAIB facility at Farnborough. The surge tank pressure relief valves, which had not operated in flight, were tested and found to be serviceable and there was no structural deformation to the fuel tanks which would have resulted from a blockage in the vent system.

The examination and testing found no faults in the aircraft fuel system that could have restricted the fuel flow to the engines.

Engines

With the exception of the two EECs and the FOHE/LP filter assemblies, most of the engine control system components, located beneath the engine, were too badly damaged or contaminated with dirt and fire fighting media to be functionally tested. However, all components were strip-examined and individual sub-assemblies tested where possible.

No pre-existing defects or evidence of abnormal operation were found with the exception of signs of abnormal cavitation erosion on the delivery side of both HP pumps. Some small debris was recovered from the left FOHE inlet chamber but this would not have restricted the fuel flow. Both of these observations have been reported in previous AAIB Special Bulletins, 01/2008 and 03/2008.

The EECs, whose NVM was successfully downloaded soon after the accident, have not been tested because to do so would require erasing the installed software and loading special test software. Since the recorded data and the NVM indicate that there were no anomalies with either EEC, testing of these units is not currently planned.

Fuel loading

G-YMMM was refuelled at Beijing with 71,401 kg of No 3 Jet Fuel (Peoples Republic of China), at a fuel temperature of 5°C (41°F); the refuelling was completed 30 minutes before the engines were started for the return flight to Heathrow and the total fuel load was 79,000 kg. At the start of the flight the recorded temperature of the fuel in the left main tank was -2°C (28°F). No 3 Jet Fuel complies with the UK and USA specifications for Jet A-1.

The FDR shows that at the time of the accident the total fuel on the aircraft was 10,500 kg, with 5,100 kg in the left main tank and 5,400 kg in the right main tank. Following the accident, approximately 6,500 to 7,100 kg of fuel had leaked out of fractured engine fuel pipes before the spar valves were manually closed.

Fuel testing

Following the accident, 66 fuel samples were taken from the aircraft and the engines. A number of these samples were tested and critical properties such as the freezing point, density, flash point, viscosity, contamination, fuel additives and presence of water were tested against DEF STAN 91-91 and ASTM D1655 requirements[2]. The fuel samples complied fully with the fuel specifications for Jet A-1. Additional tests were carried out to detect any unusual components that would not normally be found in aviation turbine fuels. No evidence of contamination was found. The water solubility, which is the fuel's ability to absorb and release water, was considered to be normal.

The properties of the sampled fuel were also consistent with the parameters recorded in the quality assurance certificate for the bulk fuel loaded onto G-YMMM at Beijing.

The fuel sampled from G-YMMM was compared with 1,245 batches of Jet A-1 tested in the UK during 2007. With regard to the distillation range, which is the boiling range of the fuel, the fuel from G-YMMM was approximately in the middle of the sampled range. The freezing point of the fuel sampled from G-YMMM was -57°C (-71°F), which was slightly below the average freezing point but within the normal range for Jet A-1.

Fuel waxing

The freezing point of aviation turbine fuel is established by cooling the fuel until wax has formed and then warming the fuel until the last crystal of wax is seen to disappear. The freezing point of the fuel sampled from G-YMMM was measured using both an automatic and a manual test. Neither test could detect any wax crystals in the fuel at temperatures warmer than -57°C (-71°F).

The Boeing 777 has a fuel temperature probe located in the inboard section of the left main tank. The aircraft manufacturer previously undertook tests to establish the effectiveness of the fuel temperature probe by fitting a number of racks of thermocouples along the inside of the main fuel tanks. The tests established that the coldest fuel in the main fuel tanks is at the inboard section. The tests also established that there was a close correlation between the temperature of the fuel measured by the temperature probe and the rack of thermocouples

Footnote

[2] DEF STAN 91-91 and ASTM D1655 contain the standard specifications for aviation turbine fuels.

mounted adjacent to the probe. On the accident flight, the temperature probe measured the minimum fuel temperature as -34°C (-29°F).

On long flights the temperature of the fuel in the main wing tanks will tend towards the temperature of the boundary layer around the wing, which can be up to 3°C lower than TAT. On the accident flight the minimum TAT was -45°C (-49°F). Because of the position of the centre fuel tank, the temperature of the fuel in this tank is warmer than the fuel in the main tanks.

In conclusion, the data indicates that the fuel did not reach a low enough temperature to cause the fuel to wax during the accident flight.

Water in fuel

Water is always present, to some extent, in aircraft fuel systems and can be introduced during refuelling or by condensation from moist air which has entered the fuel tanks through the tank vent system. The water can take the form[3] of dissolved water, entrained (suspended) water or free water. Dissolved water occurs when a molecule of water attaches itself to a hydrocarbon molecule. As the fuel is cooled the dissolved water is released and takes the form of either entrained or free water. Entrained water is water that is suspended in the fuel as tiny droplets and can, with time, settle out as free water. Free water takes the form of droplets, or puddles, which collect on the bottom of the fuel tanks or in stagnation points within the fuel delivery system.

The amount of free water is controlled by regularly draining the water out of the fuel tank sumps, an activity known as 'sumping'. Free water is also controlled on the Boeing 777 by the water scavenge system which feeds the free water at the rear of the tanks into the area above the fuel pump inlets as entrained water. Both of these activities rely on the free water not freezing.

Water ice in fuel

As the fuel temperature reduces to around -1°C to -3°C (31 to 27°F), entrained water in the fuel will start to freeze and form ice crystals. The density of the ice crystals is approximately the same as the fuel, so the crystals will generally stay in suspension and drift within the fuel. As the fuel temperature is further reduced, it reaches the Critical Icing Temperature, which is the temperature at which the ice crystals will start to stick to their surroundings. When the fuel temperature reduces to approximately -18°C (0°F), the ice crystals adhere to each other and become larger. Below this temperature little is known about the properties of ice crystals in fuel and further research may be required to enable the aviation industry to more fully understand this behaviour.

Fuel System Icing Inhibitor

Fuel System Icing Inhibitor (FSII) is a fuel additive that, when used in concentrations of 0.10% to 0.15% by volume, can prevent the formation of water ice down to a temperature of -40°C (-40°F). FSII is only effective on undissolved water (entrained and free) and, as it is approximately 500 times more soluble in water than fuel, it will migrate into the undissolved water and lower its freezing point. The mixture of water and FSII has a similar density to water and will be either consumed by the engines or can be removed from the fuel tank sumps during normal sumping operations.

FSII is not commonly used in large public transport aircraft and was not detected in the fuel samples taken from G-YMMM. However, aviation turbine fuel containing FSII has been used on aircraft flown by

Footnote

3 Aerospace Information Report AIR 790 Rev C.

the Royal Air Force, US Air Force and other military forces for about 50 years. The additive was introduced following accidents on the Boeing B-52 aircraft when engine fuel filter icing led to restricted fuel flow and subsequent engine rollbacks[4] and flame outs. FSII is also in use as an alternative to fuel heaters on many small civilian jet aircraft. The additive is approved for use on the Boeing 777 and the FAA has provided information on its use in aircraft through Advisory Circular 20-29B.

Estimated water content of the fuel

It is estimated that the fuel loaded at Beijing would have contained up to 3 ltr (40 parts per million (ppm)) of dissolved water and a maximum of 2 ltr (30 ppm) of undissolved water (entrained or free). In addition, it is estimated that a maximum of 0.14 ltr of water could have been drawn in through the fuel tank vent system during the flight to Heathrow. This water would have been evenly spread throughout the fuel and would have been in addition to any water remaining in the fuel system from previous flights. These quantities of water are considered normal for aviation turbine fuel.

Tests for the presence of water in the fuel

It was not possible to establish the condition of the fuel in the centre tank at the time of the accident as it had subsequently been grossly contaminated with fire fighting foam and water applied by the fire crews immediately following the accident.

A requirement in the fuel specification is that the fuel should be visually inspected to ensure that it is clear, bright and free of water and sediment. In addition to the appearance test, the Karl Fisher test, which uses a chemical method to establish the total amount of water (dissolved and entrained) in the fuel, was carried out on fuel samples taken from the left main tank sump, the APU fuel line and the right engine variable stator vanes.

With the exception of the samples taken from the engine fuel filters and housings, all the samples that were tested passed the appearance tests. The samples from the engine fuel filters and housings contained a small number of very small droplets of water. These droplets could have resulted from the ingress of fire fighting media through damaged engine components, or might have been free water, which naturally settles in these areas.

The Karl Fischer tests indicated that the total amount of water in the samples, dissolved and entrained, was below 40 ppm, which is a very low level.

During the inspection of G-YMMM approximately 0.25 and 0.1 ltr of free water was recovered from the left and right main fuel tanks respectively, from areas where it could not migrate to the tank sumps. It is normal for free water to collect in large aircraft fuel tanks, and this quantity was considered to be relatively low for a Boeing 777.

Sumping

G-YMMM was last sumped at London Heathrow on 15 January 2008 prior to the flight to Beijing. The aircraft's fuel tanks had also been sumped at London Heathrow whilst on maintenance, on the 14 January 2008.

Prior to the accident the operator had initiated a review of the effectiveness of their sumping programme, which was carried out during routine Daily and Transit checks. The results of the review indicated that the drain valves could freeze and, when the fuel was cold, the flow of fluid through the drains could be very slow. During the review, a number of aircraft were checked in a warm hangar where any ice in the fuel tanks would have melted

Footnote

4 Rollback - uncommanded reduction of engine thrust.

and migrated to the drains. G-YMMM was sumped in this manner on 14 December 2007.

The review established that whilst the free water does freeze, and could occasionally block the tank drains, there was no evidence of any significant quantities of free water having accumulated in any of the operator's 43 Boeing 777 aircraft.

Testing by aircraft manufacturer

As part of the investigation the manufacturer, under the direction of the AAIB, undertook small scale fuel testing in a climatic chamber and full scale testing on an adapted fuel rig.

Beaker tests

The small scale tests were known as Beaker tests and were undertaken to establish the behaviour of water when introduced into cold-soaked fuel. The test also used a number of simulated fuel system components to establish how ice might accumulate in a fuel system and restrict the fuel flow. The tests concluded that there was a 'stickier' range between -5°C (23°F) and -20°C (-4°F) when ice would more readily stick to its surroundings. The ice took on a more crystalline appearance at -20°C (-4°F) and at temperatures below -25°C (-13°F) the ice did not appear to have the mechanical properties required to bridge and plug orifices.

Fuel rig testing

The fuel rig consisted of a storage tank containing 3,520 ltr (930 US Gal) of Jet A[5] fuel, that could be cooled to -40°C (-40°F), and all the components in the aircraft fuel system from the boost pump inlet screen to the FOHE and engine driven LP pump. The flexible fuel feed pipes from G-YMMM were also fitted to the rig. A constraint of the rig was that the geometry and length of the pipe runs were not identical to the aircraft configuration.

The aim of the tests was to establish if ice could build up within the fuel delivery system and cause a restriction of the fuel flow. The tests were carried out using either fuel preconditioned with a known quantity of water, or by injecting quantities of ice or water directly into the boost pump inlet.

The tests established that under certain conditions ice can accrete on the inside of some of the fuel pipes and on the boost pump inlet screens. The thickness of this ice appeared to be dependent on the fuel temperature and the fuel flow, but accumulations generated so far have not been sufficient to restrict the flow. However, further testing is required to understand more fully the manner of this accretion.

Testing also established that, under certain conditions, it is possible to partially block the FOHE and restrict the fuel flow to the engine HP fuel pump. The blockages were achieved by injecting water directly into the boost pump inlet. As the water moved through the fuel system it formed ice crystals, which subsequently blocked the ends of a number of the tubes in the FOHE matrix. Smaller amounts of water caused a temporary restriction which quickly cleared as the ice melted, whereas the restriction persisted when larger quantities of water were used. However, this restriction could always be cleared by reducing the fuel flow, which changed the equilibrium between the cold fuel and hot oil in the heat exchanger, such that the ice melted on the inlet face of the FOHE, sufficient to restore the original fuel flow. Variation of the FOHE oil temperature between 75 and 95°C (167 and 203°F) made a small difference to the amount of

Footnote

[5] For the purposes of these tests Jet A and Jet A1 are considered to behave in a similar manner.

water required to restrict the FOHE, whereas variations in fuel temperature and fuel flow had a larger affect. During these tests the fuel flow never dropped below that required by the engine for operation at flight idle.

Further tests have shown that icing of the boost pump check valves is unlikely to result in restricted fuel flows. The possibility of air being introduced into the fuel has also been discounted as pressure responses seen on the fuel rig and during engine testing do not correlate with the engine response during the accident.

Tests were undertaken to establish if it was possible for pieces of ice to cause a restriction in the fuel delivery system. Such ice might have formed in the fuel tanks and been drawn into the boost pump inlet, or might have formed from water that had collected in the downstream side of the boost pump check valve housings. Ice injected directly into the boost pump inlet passed into the manifold as small ice particles. Ice was manufactured in a freezer, using the check valve housing as a mould, and positioned in front of the spar valve and close to the inlet of the LP pump in a way that could have caused a restriction to the fuel flow. The results of these limited tests suggest that ice formed in the fuel tank or check valve housings is unlikely to have caused the restricted fuel flow seen on the accident flight; however, further testing is required to confirm this.

Testing continues to investigate other icing scenarios and to establish if it is possible for ice to build up in the aircraft system in sufficient quantity to restrict fuel flow at the point of the build up, or release and thereby restrict fuel flow downstream in the fuel system. Whilst the water injection testing has demonstrated a high level of repeatability of delivering ice to the front face of the FOHE, attempts to generate ice repeatedly on other components in the fuel system have not been successful and have not created a detectable restriction. Problems have also been experienced in maintaining the water concentration in the fuel during the long duration tests as the fuel is recycled through the system.

Electronic Engine Control Unit (EEC)

Before examining the engine's behaviour during the latter stages of the flight, it is necessary to give a broad outline of the operation of the EEC. Since several parameters were both recorded on the QAR and stored in the NVM of the EEC, they provide some evidence of the event and confirm that the EEC was itself reacting correctly.

The most pertinent of the recorded parameters were the FMV commanded and actual positions. These showed that the EECs attempted to counter the shortfall in thrust demanded by the autothrottle by commanding the FMVs on both engines to open fully: the actual position showed that this was achieved. Prior to the rollback, the EECs had been operating in EPR mode. As the FMVs reached fully open, the EECs switched to Control Loop 17 (Absolute Maximum Fuel Flow Limit) as would logically be expected. The right engine remained at this unusual condition for more than the 2 seconds necessary to generate a fault code which was written to the NVM. After about 10 seconds from the start of the rollback of this engine, the EEC switched to Control Loop 14, which is a surge protection logic.

It is important to emphasise that neither engine had surged. Analysis and testing shows that the fluctuations in Burner Pressure (P30), caused by fluctuating fuel flow, would invoke the surge protection logic, which is triggered mostly by an excessive rate of change of P30. Applying Control Loop 14 causes the FMV to close to a lower value of fuel flow (but still significantly more than the fuel system was apparently capable of delivering). If the condition persists for more than 30 seconds, another fault code is generated: the right engine EEC logged such a code.

The left engine also switched to Control Loop 17 but it was not in control for more than 2 seconds before the P30 fluctuations triggered Control Loop 14 and so the fault code was not generated. The variability of this characteristic was reflected during the post-accident engine testing. The response of the EECs was considered to be quite explicable and no abnormalities were apparent.

HP Pump testing

The HP pump manufacturer conducted tests on a new pump in an attempt to replicate the cavitation marks seen on the accident flight pumps. The test revealed that running the pump with an abnormally low inlet pressure and a restricted fuel flow of 5,000 pph for 60 seconds gave identical cavitation marks to those seen on the pumps removed from G-YMMM. These cavitation marks have only been seen by the manufacturer, on one previous in-service pump, which was attributed to a failure of the LP pump drive shaft. The cavitation marks were not an indication of a fault in the pumps, but a symptom of either low inlet pressures or fuel aeration and would not have affected operation of the pump.

Engine testing

In order to validate how an engine reacts to a restricted fuel flow, two test facilities were used: firstly a Systems Test Facility (STF), and secondly a Trent 800 engine mounted in a fully-instrumented engine test cell.

The STF provided valuable data, particularly concerning the manner in which the EEC reacts to the FMV moving to fully open and the fluctuations in fuel flow and P30. However, it had limitations because, although it incorporated almost all of the components which comprise the engine fuel and control system, parameters such as spool speeds and burner pressure had to be synthesised from a mathematical model and the very dynamic conditions which followed the rollback could only be verified using an engine.

Accordingly, a development engine was prepared with the ability to restrict the fuel flow at various locations within the engine and the representative aircraft fuel system. After various iterations, it was found that the best way to apply the restriction was a metal plate with an orifice drilled in it, sized to pass a maximum fuel flow approximating to the average flow of both engines after the rollback.

The testing was accomplished in three distinct phases, the results of each phase informing the next as the overall aim was to match as closely as possible the recorded data from the accident flight. Although the components of the engine were fully representative of those fitted to G-YMMM (in particular the EEC software standard) it was acknowledged that the fuel used was at ambient temperature and, in addition, it was not possible to simulate the effects of airspeed.

Further refinements to the third phase of testing, included programming the power lever to move in a similar manner to the autothrottle thrust demands that preceded the rollback. This was because previous testing had shown that, with the restriction applied several metres upstream from the engine/airframe interface, the engine pump drew fuel from the pipework and thus delayed the onset of rollback, the position of the restriction also appeared to have some effect on the fuel flow and P30 oscillations after rollback. It was hypothesised that, with the restriction in place, it might be possible to achieve the three acceleration / deceleration cycles which preceded the final acceleration and rollback event as fuel in the aircraft pipework was depleted.

Engine Test Conclusions

Data collected during the course of the tests was exhaustive and is still being analysed. However, several important conclusions can be drawn:

- The behaviour of all the engine fuel system control components was consistent with a restriction in fuel flow occurring somewhere upstream of the HP pump.
- The further upstream the restriction was placed from the HP pump, the more acceleration/deceleration cycles could be completed following the introduction of the restriction, before the engine rolled-back.
- The reaction of the EEC to such an event was consistent with its programming logic.
- Upon removal of the restriction, the engine recovered quickly to normal operation.
- The engine and control system response indicated either a fixed restriction in the aircraft system or delivery of a restriction to a downstream fuel system component as the most likely scenarios, and excluded a gradual accretion on the front face of the FOHE or LP pump inlet.

Data mining

A team of statisticians from QinetiQ, together with specialists from the aircraft and engine manufacturer, the operator and the AAIB, are conducting a review of data from the accident flight and from other data sources.

Minimum fuel temperature data has been obtained from approximately 141,000 flights of Boeing 777 aircraft (approximately 13,000 Rolls Royce powered, 114,00 from Pratt and Whitney and 14,000 General Electric). The lowest recorded temperature during the accident flight was -34°C (-29°F). Of the flights sampled, less than 0.2% had fuel temperatures at or below this temperature. The lowest recorded temperature was -39°C (-38°F), which was on a GE powered aircraft, the lowest recorded temperature on a Rolls Royce powered aircraft was -37°C (-34°F). For fuel temperatures below -20°C (-4°F), there were 22,500 flights (approximately 17%).

In addition, data from approximately 13,000 flights on Boeing 777 Rolls Royce powered aircraft has been further analysed in detail. The fuel temperature at takeoff on the accident flight was -2°C (28°F); of the 13,000 flights 118 had takeoff fuel temperatures at or below -2°C (28°F), with the lowest being -11°C (12°F). On the approach prior to the accident the fuel temperature was -22°C (-8°F); 70 flights of the 13,000 flights had approach fuel temperatures at or below this temperature, with the lowest being -28°C (-18°F).

It is therefore clear that the fuel temperatures experienced during the accident flight were low, but were not unique, with other flights experiencing lower temperatures.

Analysis of fuel flow from the 13,000 flights shows that 10% had fuel flows less than 10,000 pph during step climbs (the accident flight did not exceed 8,896 pph), and 10% had had fuel flows greater than 10,000 pph during the approach phase (the accident flight was greater than 12,000 pph). Although these were not unique, they were at the edge of family for the data analysed. However, when analysed in conjunction with the fuel temperature data above, all of these factors make this flight unusual within the 13,000 flights analysed.

Following fuel flow reduction to the engines, the EEC control loop changed to Control Loop 17, an indication that the EEC was commanding maximum fuel flow. The FMV also moved to its fully open position without the expected increase in fuel flow. A retrospective analysis of the aforementioned 13,000 flights has been conducted for cases of EEC Control Loop 17 and for mismatches between the FMV position and the expected fuel flow. This has not revealed any previous occurrences. The aircraft manufacturer, however, has records of six occurrences of EEC Control Loop 17 during the previous 10 years. Explanations were available for all of the occurrences and they were all for reasons not relevant to the accident to G-YMMM.

The data mining work continues and is exploring further combinations of parameters to identify unique features from the accident flight. Included in this work is analysis of fuel flows and temperature.

Operational history of the Boeing 777

The Boeing 777 entered service in May 1995 and has since flown 17.5 million hours and 3.9 million flights. The Trent 800 powered Boeing 777 first entered service in March 1996 and has since flown 6.5 million hours and 1.4 million flights. These figures represent the operational history to July 2008.

Discussion

The examination of the aircraft has not revealed any pre-existing technical reason for the engine rollback and the subsequent lack of engine response. Following the rollback the fuel flow reduced to only 5,000 pph on the left engine and 6,000 pph on the right, whereas the expected fuel flow with the FMV in the fully open position should have been in excess of 38,000 pph. This indicates that the fuel flow was being restricted, and this restriction continued after the initial engine rollback and through to the ground impact.

The only physical evidence found following the accident was the cavitation marks on the pressure outlet ports of the HP pumps on both engines. From testing and in service experience it is concluded that these marks were fresh, and therefore most probably occurred on this flight, and were caused by a restricted fuel flow, leading to low inlet pressure at the HP pump.

The aircraft boost pumps that were supplying fuel from the main fuel tanks to the engine at the time of engine rollback, did not indicate a low pressure at any time during the flight. Subsequent tests of the indication system found it to be serviceable. Therefore, the restriction was most probably downstream of the boost pump low pressure switches and upstream of the HP pump inlet.

Had both boost pumps and suction feed check valves become restricted, then a low pressure in the fuel manifold would have led to air being drawn from the centre tank, via the jettison and override pump check valves. However, testing has shown that aeration causes a different response from the engine to that seen during the event. Furthermore, if a restriction occurred in the fuel manifold, between the centre tank feed and the point at which the boost pump feed lines connect into the manifold, then there would have been adequate fuel supply from the boost pumps downstream, or from the suction feed bypass. Thus, the restriction must have been downstream of the connection of the fwd boost pump feed line to the fuel manifold.

Examination of the fuel system did not reveal any physical restriction in the fuel system and the spar valves remained open throughout the flight. The fuel temperature had reached a low of -34°C (-29°F); whilst this is unusual it is not exceptional and the fuel temperature was not sufficiently low for the fuel to start to wax.

The fuel was tested and found to conform to all the required specifications. No significant quantities of water were found in either the fuel samples or in the aircraft's main fuel tanks.

Testing by the aircraft manufacturer, under the direction of the AAIB, has established that ice can accrete within the fuel system, and that the FOHE can become partially blocked with ice when water is injected into the boost pump inlet whilst cold fuel (below 0ºC) is circulated. However, injecting water in this manner results in concentrations of water that are considerably in excess of current certification requirements; moreover, the quantities of water used have not been quantified against the amount of ice that can form in the fuel system. Indeed, there have been difficulties in the repeatability of accruing ice on some of the fuel system components.

The investigation so far has established that there are two possible scenarios that could have led to a restriction of the fuel flow that match the known data from G-YMMM. The first is that ice accreted over a period of time, most probably at a location downstream of the fwd boost pump connection into the fuel manifold and upstream of the HP pump inlet. This ice would have had to have accrued to an extent to block approximately 95% of the cross sectional area to induce cavitation of the HP pump and result in the observed engine response. Testing by the engine manufacturer has shown that sufficient ice accretion could not have occurred on the face of the FOHE or the LP pump inlet, prior to the final series of accelerations. If it had, then the rollback would have occurred earlier during the first acceleration of the final approach series. A partial restriction upstream of the LP pump is consistent with the accident flight data, but testing has not yet been able to duplicate such a restriction with ice; nevertheless, this possibility is still being evaluated. Testing also established that ice on the face of the FOHE tends to melt at low fuel flows. As the event occurred after the aircraft had flown at a low fuel flow during the descent, it is unlikely, in this scenario, that enough ice had accreted on the face of the FOHE to cause the restriction.

The second scenario is that ice had accreted throughout the fuel feed system, and was then released during an increased fuel flow demand, such as the 12,000 pph achieved during the second acceleration on the final approach. In this case the ice might then travel and be 'caught' in the pipework, spar valve, LP pump inlet or on the face of the FOHE, thereby causing a restriction to the fuel flow.

For ice to accrete within the fuel system it requires long periods at low fuel flows and temperatures below the Critical Icing Temperature. It is known that ice behaves differently as the fuel temperature changes. However, at present it is not fully understood how the ice forms within the aircraft fuel system at different temperatures due to the variability in the results on the fuel rig and differences in the layout between the fuel rig and the actual aircraft fuel system.

Analysis of the flight data on G-YMMM indicated that the system had high fuel flows of 24,000 pph from the centre fuel tank during the takeoff from Beijing. However, when the fuel was being supplied by the boost pumps in the main fuel tanks the maximum fuel flow was 8,896 pph, until the final series of accelerations just prior to the rollback. The last high fuel flow demand on G-YMMM prior to the approach into Heathrow, and when the main fuel tanks were supplying the engines, was during a VNAV commanded step climb on the previous flight into Beijing when the fuel flow reached 10,700 pph. The step climbs on the accident flight had both been completed in VS mode with a low rate of climb selected, which resulted in lower fuel flows.

There has only been one other in-service event of HP pump cavitation, which was as a result of a failure of the LP pump drive. A review of previous recorded occurrences of the EEC entering Control Loop 17 has shown six previous cases, all of which were explicable. There has only been one previous recorded occurrence of the EEC entering Control Loop 14, and this was due to an engine surge. A review of available data has not revealed any other indication of a mismatch between FMV position and fuel flow, similar to that which occurred on the accident flight.

The accident flight was therefore unique in that this has been the only recorded case of a restricted fuel flow affecting the engine performance to the extent of causing HP pump cavitation, Control Loop 17, Control Loop 14 and a mismatch between FMV position and fuel flow demand, and this occurred on both engines within 7 seconds of each other. This is the first such event in 6.5 million flight hours and places the probability of the failure as being 'remote' as defined in EASA CS 25.1309.

Summary

The investigation has shown that the fuel flow to both engines was restricted; most probably due to ice within the fuel feed system. The ice is likely to have formed from water that occurred naturally in the fuel whilst the aircraft operated for a long period, with low fuel flows, in an unusually cold environment; although, G-YMMM was operated within the certified operational envelope at all times.

All aviation fuel contains water which cannot be completely removed, either by sumping or other means. Therefore, if the fuel temperature drops below the freezing point of the water, it will form ice. The majority of flights have bulk fuel temperatures below the freezing point of water and so there will always be a certain amount of ice in the fuel.

To prevent the ice causing a restriction requires either: the fuel system must be designed in such a way that the ice in the fuel does not pose a risk of causing an interruption of the fuel supply to the engine or; prevention of the water from becoming ice in the first instance. Changes to the fuel system design could make the system more tolerant, but would take time to implement and would certainly not be available within the near term. Therefore, to reduce the risk of recurrence interim measures need to be adopted until such design changes to the fuel system are available.

One option would be to prevent the water from becoming ice, such as through the use of FSII. Alternatively, operational changes to reduce the risk of ice formation causing a restricted fuel flow at critical stages of flight could be introduced. Such changes could be implemented quickly, but must not compromise the safe operation of the aircraft.

Although the exact mechanism in which the ice has caused the restriction is still unknown, in detail, it has been proven that ice could cause a restriction in the fuel feed system. The risk of recurrence needs to be addressed in the short term whilst the investigation continues. The FAA and EASA have been fully appraised of the outcome of all testing and analysis developed to date. Therefore:

Safety Recommendation 2008-047

It is recommended that the Federal Aviation Administration and the European Aviation Safety Agency, in conjunction with Boeing and Rolls-Royce, introduce interim measures for the Boeing 777, powered by Trent 800 engines, to reduce the risk of ice formed from water in aviation turbine fuel causing a restriction in the fuel feed system.

However, it should be recognised that throughout the investigation all of the testing and research into the root cause of this accident has been conducted on the Boeing 777 / Trent 800 aircraft engine combination, and it is unknown whether other aircraft / engine combinations that have already been certificated might also be vulnerable to this previously unforeseen threat. Therefore:

Safety Recommendation 2008-048

It is recommended that the Federal Aviation Administration and the European Aviation Safety Agency should take immediate action to consider the implications of the findings of this investigation on other certificated airframe / engine combinations.

Furthermore, the Boeing 777 was certificated in 1995 as meeting both the FAA federal aviation regulations and the JAA airworthiness requirements in force at the time. These regulations required that an aircraft and engine fuel system must be capable of sustained operation throughout its flow and pressure range, and at low temperatures, with a prescribed concentration of water. However, the current requirements do not appear to address the scenarios identified during this investigation, such as the sudden release of accrued ice, which could lead to a restricted fuel flow. Therefore:

Safety Recommendation 2008-049

It is recommended that the Federal Aviation Administration and the European Aviation Safety Agency review the current certification requirements to ensure that aircraft and engine fuel systems are tolerant to the potential build up and sudden release of ice in the fuel feed system.

Further work

The investigation into the cause of this accident continues. Further testing will be carried out to establish more clearly how ice forms within the fuel system and how it might cause the restricted fuel flows seen on this flight. An assessment of the fluid dynamics of the fuel system is also being conducted. The data mining activity is continuing to look at data from other Boeing 777 flights and a comprehensive study of the crashworthiness aspects of the accident is being undertaken.

ACCIDENT

Aircraft Type and Registration:	1) Boeing 737-33V, G-THOO 2) Boeing 737-36Q, G-THOJ
No & Type of Engines:	1) 2 CFM CFM56-3C1 turbofan engines 2) 2 CFM CFM56-3C1 turbofan engines
Year of Manufacture:	1) 1998 2) 1997
Date & Time (UTC):	28 June 2008 at 2130 hrs
Location:	South Apron, Coventry Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - Not Provided Passengers - Not provided
Injuries:	Crew - None Passengers - None
Nature of Damage:	1) Minor scratching to right winglet 2) Right elevator severely damaged
The following information relates to G-THOO	
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	47 years
Commander's Flying Experience:	9,370 hours (of which 4,166 were on type) Last 90 days - 155 hours Last 28 days - 28 hours
Information Source:	Aircraft Accident Report Form submitted by the commander, investigation reports submitted by the airfield

Synopsis

During pushback the right winglet of G-THOO struck and damaged the right elevator of G-THOJ.

History of the flight

G-THOO, a winglet-equipped 737-300, was scheduled to operate from Coventry to Palma de Mallorca. The aircraft was ready for departure and a pushback ground team consisting of a tug driver and a 'guideman', who was in headset communication with the flight deck crew, were available. At 2127 hrs G-THOO was pushed back from Stand One. The planned push would turn G-THOO tail towards the passenger terminal before pulling forward to permit engine start. G-THOJ, a 737-300, was parked on Stand Eight which placed it directly behind G-THOO. As G-THOO was turned tail towards the terminal, the right winglet struck the right elevator of G-THOJ. The ground crew then pulled G-THOO back onto Stand One. The incident was not reported to ATC, Rescue and Fire Fighting Service (RFFS) or airfield operations until approximately 45 minutes later when the aircraft operator's duty engineer telephoned the RFFS.

Damage

The right winglet of G-THOO suffered minor damage and the aircraft was returned to service shortly after the incident. The elevator of G-THOJ was almost completely cut through during the collision and required replacement.

Airfield investigation

Following the event, Coventry Airport conducted an investigation into the accident. This investigation identified a number of findings including the following:

1. Tactical changes to flight timing altered the planned stand usage at the time of departure.
2. The aircraft parking plan required to be produced as part of the airside safety manual appeared to be missing.
3. The procedure for pushbacks identified the 'guideman' as being in charge of the pushback procedure and responsible for ensuring that adequate people are available to monitor the wingtip clearance.
4. The pushback and operations personnel involved did not follow the airfield aerodrome manual procedure for notifying RFFS of a ground incident.

The airfield recommended that the company handling the pushback in this accident address all the above items in addition to conducting risk assessments on pushback procedures for all stands under all possible circumstances. All the Safety Recommendations have been accepted and are being implemented. Subsequently Stand Eight has been withdrawn from use and associated ground equipment parking areas have been removed. This provides a clear area for pushbacks from Stand One.

Conclusion

In this accident there was little risk to staff or passengers but the delay in reporting the event to the RFFS was a significant issue. This and the other findings have been addressed by the airfield's internal investigation report and therefore, no AAIB recommendations are made.

ACCIDENT

Aircraft Type and Registration:	American AA-5 Traveller, G-AZVG
No & Type of Engines:	1 Lycoming O-320-E2G piston engine
Year of Manufacture:	1972
Date & Time (UTC):	5 June 2008 at 1310 hrs
Location:	Cranfield Airfield, Bedfordshire
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Engine shock-loaded, damage to propeller, spinner, lower cowling and wing
Commander's Licence:	Private Pilot's Licence
Commander's Age:	67 years
Commander's Flying Experience:	1,215 hours (of which 48 were on type) Last 90 days - 19 hours Last 28 days - 12 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

On taxiing after start the pilot turned to the left and collided with an aircraft parked alongside.

History of the flight

The flight was intended as a recency check on the pilot by an instructor. On taxiing after start the pilot applied left brake and left rudder which turned the aircraft towards a Robin light aircraft parked alongside. The instructor warned the pilot that he was getting too close to the Robin, expecting him to steer to the right. Instead, the pilot increased power causing the aircraft to turn about its left wheel and collide with the Robin. The instructor stated he had attempted to prevent the collision by applying right brake and right rudder but could not counteract the inputs applied by the pilot in time.

ACCIDENT

Aircraft Type and Registration:	Cirrus SR22, N434A
No & Type of Engines:	1 Continental IO-550-N
Year of Manufacture:	2005
Date & Time (UTC):	5 July 2008 at 1154 hrs
Location:	Manchester/Barton Aerodrome
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor nicks to propeller and cracked wheel spat
Commander's Licence:	Private Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	790 hours (of which 280 were on type) Last 90 days - 11 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent AAIB enquiries

Synopsis

The aircraft departed its base at Stapleford and flew uneventfully towards Barton. The weather was generally good with clear visibility although this was significantly reduced in the scattered thundery showers.

The pilot contacted the FISO on duty at Barton by radio and was informed that Runway 27L was in use. Grass Runway 27L is 621 metres long and was wet; a heavy shower of rain was passing over the aerodrome. As the aircraft turned onto the final approach, the visibility deteriorated and the wind shifted, becoming a slight tail wind. The pilot lost sight of the far end of the runway in the poor visibility and touched down in the middle third of runway. Conscious of the risk of skidding on the "very wet" runway, he applied light braking. The aircraft ran off the end of the runway into a rough area of long grass. Both occupants vacated the aircraft without difficulty.

The pilot reported that, with the benefit of hindsight, a go-around would have been a safer course of action.

ACCIDENT

Aircraft Type and Registration:	DH82A Tiger Moth, G-ANMY
No & Type of Engines:	1 De Havilland Gipsy Major I piston engine
Year of Manufacture:	1942
Date & Time (UTC):	5 June 2008 at 0935 hrs
Location:	Land Mead Farm Strip, near Abingdon, Oxfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to propeller, engine cowling, tailplane and upper wings
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	66 years
Commander's Flying Experience:	15,748 hours (of which 29 were on type) Last 90 days - 16 hours Last 28 days - 11 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft encountered previously unnoticed standing water during its takeoff roll from a grass airstrip. The water and associated soft ground caused a marked deceleration and the aircraft pitched forward, coming to rest inverted. The pilot and his passenger were uninjured and there was no fire.

History of the flight

Aware that heavy rain had fallen two days before, the pilot examined the full length of the main east-west grass runway in preparation for a takeoff. Although there were patches of water at the extreme western end and around the periphery of the runway, he found that the central portion was well drained and firm.

By the time the aircraft was ready for departure the wind had changed and now favoured a takeoff to the south from an adjacent grass takeoff area. The pilot reported that the ground on this alternative area was firm underfoot and that looking ahead, as far as he could see, there appeared to be no problems with the surface conditions. Initially the takeoff run was normal but at about 35 kt the aircraft crested a small rise and encountered an area of previously unseen standing water. The water and associated soft ground caused a marked deceleration and the aircraft pitched forward, coming to rest inverted. The pilot and his passenger were uninjured and there was no fire.

In a commendably honest report, the pilot acknowledged that the accident could have been avoided if he had walked the entire length of the takeoff area and not relied on a visual assessment. Also, he considered that the aircraft might not have inverted if he had closed the throttle the moment that he sensed the deceleration.

ACCIDENT

Aircraft Type and Registration:	Mooney M20K 231, D-EKUR
No & Type of Engines:	1 Continental TSIO-360-B1 piston engine
Year of Manufacture:	1980
Date & Time (UTC):	25 July 2008 at 1300 hrs
Location:	Garston Farm Airstrip, Chippenham, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - None Passengers - None
Nature of Damage:	Right wing, landing gear and propeller blades
Commander's Licence:	Private Pilot's Licence
Commander's Age:	65 years
Commander's Flying Experience:	3,000 hours (of which 500 were on type) Last 90 days - 20 hours Last 28 days - 9 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

Shortly after becoming airborne, the aircraft stalled and landed in a field of standing crop. The four occupants were uninjured and were able to vacate the aircraft without assistance. The aircraft sustained significant damage. The pilot candidly notes that he inadvertently reduced power below that required for safe flight and did not notice the low power setting in time. He considers that this may have been due to the slightly bumpy runway and that his concentration was focused on the takeoff roll.

Another person, who had discussed the accident with the pilot, reported that he had been concerned with avoiding a propeller strike and was keeping the weight off the nosewheel during the takeoff run. This rearward pressure on the controls may have led to the aircraft lifting off earlier than intended. Once airborne at a low speed, the high drag of this configuration would have prevented the aircraft from accelerating and climbing normally, especially if less than full power was applied.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-140 Cherokee, G-AVRP
No & Type of Engines:	1 Lycoming O-320-E2A piston engine
Year of Manufacture:	1967
Date & Time (UTC):	5 August 2007 at 1100 hrs
Location:	0.5 nm south-west of Isle of Wight/Sandown Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - 1 (Fatal) Passengers - 3 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	687 hours (of which 143 were on type) Last 90 days - 12 hours Last 28 days - 6 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft departed from Runway 23, with four people on board, on a flight to Pontivy, France. Its takeoff ground roll was noticeably long and, having lifted off, G-AVRP climbed to about 50 ft agl and maintained that height as it flew over rising ground beyond the end of the runway. As it approached trees at the top of the rising ground, the aircraft was seen to pitch up and clear the trees before its nose dropped and it descended out of sight. The aircraft struck another line of trees and crashed into a field. The aircraft rapidly caught fire. The fire was extinguished by the Airport Fire-fighting and Rescue Service (FFRS). All the occupants of the aircraft died in the accident and the aircraft was destroyed.

It was established that the aircraft's predicted performance, at its estimated takeoff weight and in the prevailing conditions, should have enabled a successful departure. Its failure to do so may have been the result of reduced engine power, a tailwind component, a greater takeoff weight than estimated, an incorrect piloting technique during takeoff or a combination of some or all of these factors.

Two Safety Recommendations are made.

History of the flight

The aircraft's initial point of departure on the day of the accident was a private airstrip in Staffordshire, 7 nm south of Tatenhill Airfield. The pilot flew from there to Tatenhill, where he picked up three passengers, one of whom had recently bought the aircraft from the pilot and another co-owner. Then, without refuelling or any other delay, G-AVRP departed for Isle of Wight/Sandown Airport (referred to as Sandown Airport), arriving there at 0942 hrs after a flight lasting 1 hour 55 minutes. The aircraft was seen to touch down about halfway along Runway 05 and use most of the remaining runway to stop. With the surface wind from the south-east at 5 to 10 kt and the reciprocal Runway 23 providing an upslope, which favoured landing aircraft, the direction of the runway in use was changed.

While on the ground, the pilot completed a flight plan for an outbound flight to Pontivy, France (Brittany), and a customs declaration form for a return flight from Pontivy later that afternoon. He also enquired about refuelling but was told that there was no fuel available. When the pilot received confirmation that his flight plan had been filed, he and his passengers re-boarded the aircraft for their flight to France.

When the pilot of G-AVRP requested clearance to taxi he also requested a departure from Runway 05, stating that he had a full load. He was advised by the airfield air/ground radio operator that a number of aircraft were inbound to land on Runway 23 and that movements were restricted to that runway. G-AVRP taxied to the holding point for Runway 23, via the airfield's northern taxiway; it is probable that the pilot carried out a power check while awaiting the opportunity to take off. After being advised by the airfield radio operator that there was nothing to affect their departure, the aircraft lined up at the end of the runway and at 1059 hrs the pilot called "rolling".

G-AVRP was seen by various witnesses to continue its takeoff ground roll until it had travelled beyond a public footpath which crossed the runway 584 metres from the start of Runway 23. The aircraft then became airborne and climbed to a height of about 50 ft, maintaining that height as it flew over rising ground towards a wooded copse, 660 metres beyond the upwind end of the runway, in which the tops of some trees reached an elevation of 199 ft amsl. A local pilot estimated that the aircraft's pitch attitude after takeoff was 10-15° nose-up. He also commented that the engine sounded normal.

Just before reaching the copse, which was 150 metres deep, the aircraft was seen to pitch up and clear the tops of the uppermost branches of its trees by about 10 ft. Witnesses at the airfield then saw it disappear from view as it descended behind the trees, with the wings level but the nose down. At about the same time, another witness, who was located 550 metres to the west-south-west of the copse, heard an aircraft taking off from the airfield and, as it came into his view, he saw the aircraft clear the trees by about 20 ft in a nose-down attitude. He thought that it might be attempting to land in the field towards which it was heading. He then heard a "crack" and saw the aircraft descend rapidly. He did not see it strike the ground because his view was blocked by a nearby tree, but he realised that it had crashed and told a nearby householder to call the emergency services while he ran across the field to render assistance.

At approximately 1100 hrs, a member of the public was walking along a path in a thin line of trees that run south from the copse which the aircraft was seen to clear. He recalled hearing the noise of an aircraft engine, which initially sounded normal but then spluttered, as if being "throttled back", and seemed to stop. Two or three seconds later there was a thump. He had not seen the aircraft but concluded that it had crashed in the field to his left and made his way in that direction. Within a few seconds he emerged from the trees and saw an aircraft nose-down in the field with its tail almost vertical, wings level, facing in a northerly-easterly direction. The left side of the fuselage was on fire.

Another member of the public had also arrived on the scene and was standing in front of the right wing next to the aircraft's door. Together they attempted to extricate the heavily built male occupant from what was considered to be the front right seat of the aircraft. He had head injuries and did not respond to their efforts; they were unable to move him more than a few inches before being beaten back by the intensifying fire. During these attempts, one of the two witnesses noticed signs of life in a younger occupant, who was further back on the left side of the cabin and in a seat that had moved into a higher, upright position. This occupant then became silent and the fire suddenly intensified. The right arm of a third person was visible below and between the first two occupants that they had encountered.

These two witnesses retreated 30 to 40 metres and, about a minute after the crash, a private Jet Ranger helicopter arrived from Sandown Airport. On arrival, the crew of the helicopter observed flames on the crashed aircraft's left wing, and other flames rising from the engine cowling up into the cabin. One of the crew disembarked and went over to the two walkers, thinking that they were survivors of the crash. They advised him that there were at least three people in the aircraft. He then attempted to approach G-AVRP but, at a distance of 5 metres, had to shield his face from the intense heat. He could not see the occupants and, as the fire worsened, he observed the tail of the aircraft twist and fall into the cabin. Before re-embarking in the helicopter he called the emergency services.

The emergency services had also been contacted by the aerodrome air/ground radio operator when he had observed smoke emerging from behind the trees which he had just seen the aircraft fly over, before disappearing from view. In addition, the smoke had alerted the aerodrome FFRS, who immediately departed for the scene of the accident.

Between three and five minutes after being alerted, the aerodrome fire vehicle arrived at the accident site and the two fire crew personnel immediately began to fight the fire with a combination of 675 litres of aqueous film forming foam (AFFF), two 9 kg monex powder extinguishers and a 9 kg foam extinguisher. Using all their fire fighting media they extinguished the fire. As their extinguishants ran out, the local fire brigade vehicles arrived and continued to dampen down the aircraft and surrounding area.

Following post-mortems, it was reported that three of the occupants had died as a result of their injuries and that the fourth, the youngest, who had shown some signs of life immediately after the crash, had died as a result of the effects of fire. There was no evidence of any medical condition that could have contributed to the accident.

Accident site details

The aircraft had struck the upper branches of a line of trees approximately 1 km from Sandown Airport and on the extended centreline of Runway 23. It had then crashed, in an inverted attitude, into a wheat field some 60 m beyond the trees. An intense, post-impact fire occurred, which consumed the cabin and fuselage before being extinguished by the Airfield and local Fire Services.

A number of small branches and twigs had been dislodged from the trees, together with a substantial bough of approximately 150 mm in diameter. It was considered that the latter was responsible for causing a large indentation in the left wing leading edge immediately outboard of the main landing gear, which had detached and fallen in the field between the trees and the main wreckage. It is probable that the collision with the tree imparted a significant left yaw, which led to the aircraft becoming inverted before it struck the ground.

The first marks on the ground were two propeller slashes, followed, some 1.3 metres further on, by a shallow impression made by the forward edge of the top of the engine cowling. Windscreen fragments were found close by, together with the propeller. There was an absence of significant damage to the wing tips, with the main force of the ground impact being sustained by the nose/engine. The combination of the ground marks and the disposition of the wreckage indicated that the aircraft had struck the ground with a roll angle of 180° (ie inverted) and with a flight path inclined at approximately 30° to the horizontal. It slid for around 4 metres before coming to rest with the tail, according to witnesses, pointing vertically upwards. As the fire developed, the aircraft settled back into an inverted attitude.

Following an on-site assessment, the wreckage was recovered to AAIB's facility at Farnborough for a detailed examination.

Aircraft history

The aircraft was built in July 1967 and had achieved 9,983 flying hours up to 3 June 2007, the last date for which there was a flight recorded in the aircraft log book. The most recent maintenance was an Annual Check, which was signed for on 10 July 2007, with the same flight hours as the 3 June entry. Prior to this was a 50-Hour Check, on 20 April 2007, with a Star Annual Inspection (ie Certificate of Airworthiness (C of A) renewal) conducted on 3 August 2006.

On 14 July 2007, the aircraft was sold by its two co-owners to the new owner. The log book of the new owner was not recovered, but it is thought that he flew no more than about two familiarisation flights between acquiring the aircraft and the day of the accident. In addition, the log books of the previous co-owners indicated that four flights, totalling 2 hrs 35 mins, were flown since 3 June. The last of these, on 14 July, was likely to have been a familiarisation flight for the new owner. It is thus probable that on the morning of the accident, fewer than 5 hours would have been flown on the aircraft since the Annual Check.

The engine was a Textron Lycoming, factory overhauled unit, sourced from a UK agent in March 1997 and fitted to G-AVRP in May 1997. In its first year of operation, the aircraft flew only 25 hours. Over the next 5 years, it averaged approximately 150 hours per annum, reducing to around 53 hours per annum for the last 4 years. It had achieved in excess of 980 hours at the time of the accident.

In July 1999, at approximately 240 operating hours, the engine was removed and disassembled in order to conduct a shock load inspection, although the log books did not record the reason for this. The work included polishing the main and connecting rod journals, honing the cylinder bores and re-facing and lapping the valves and seats. In addition, a log book entry in January 2002 recorded the repair of some minor propeller damage.

The aircraft documentation did not include any recent refuelling records although there were some old receipts for Avgas. Although the aircraft is likely to have started the day of the accident with full tanks, there was no fuel taken on at Tatenhill; nor was there any record of any recent sale of fuel to the aircraft from that airfield. During the investigation there was some anecdotal evidence that a private supply of Avgas was available, with the possibility of motor gasoline being used on occasions.

Examination of the aircraft

The extensive fire damage to the cockpit area meant that the remains of the instruments yielded little useful information. However, the throttle control was identified, and was found pushed fully forward, ie at the full power position. The flap operating lever, located on the floor between the front seats, was found in its lowest detent, indicating that the flaps were retracted at impact.

The extremities of the aircraft were all accounted for and the flying control operating cables had remained intact. The single cabin entry door, located on the right side of the aircraft, was largely consumed in the fire. However, part of the door frame was recovered, which contained the door latch engagement slot; this was damaged in a manner that suggested that the door had burst open in the impact. The aircraft was not equipped with a baggage door.

Examination of the engine

The engine had been affected by the fire to the extent that the magnetos had been badly damaged and the ignition harness had been destroyed. The carburettor had broken off its mounting on the underside of the engine but had remained attached to the aircraft by its control cables. The carburettor air box had been badly distorted in the impact, but it was possible to establish that the heat control lever was in the COLD position.

Burnt residues within the carburettor float chamber, together with a sample of oil sludge, were analysed in a laboratory. Traces of lead were found in the carburettor residue, indicating that leaded gasoline had been used recently, although it did not necessarily prove that it was being used at the time of the accident. No evidence of lead was found in the oil sludge sample, although this might simply be due to the recent oil change.

The engine itself was subjected to a strip examination at a UK overhaul agent for Textron Lycoming, under the supervision of the AAIB. During this process, it was noted that the camshaft was correctly timed to the crankshaft and that the oil pump, main and big end bearings were all in good condition. The spark plugs were normal in appearance, with a lead nodule being evident on one of them, indicating the recent use of leaded gasoline.

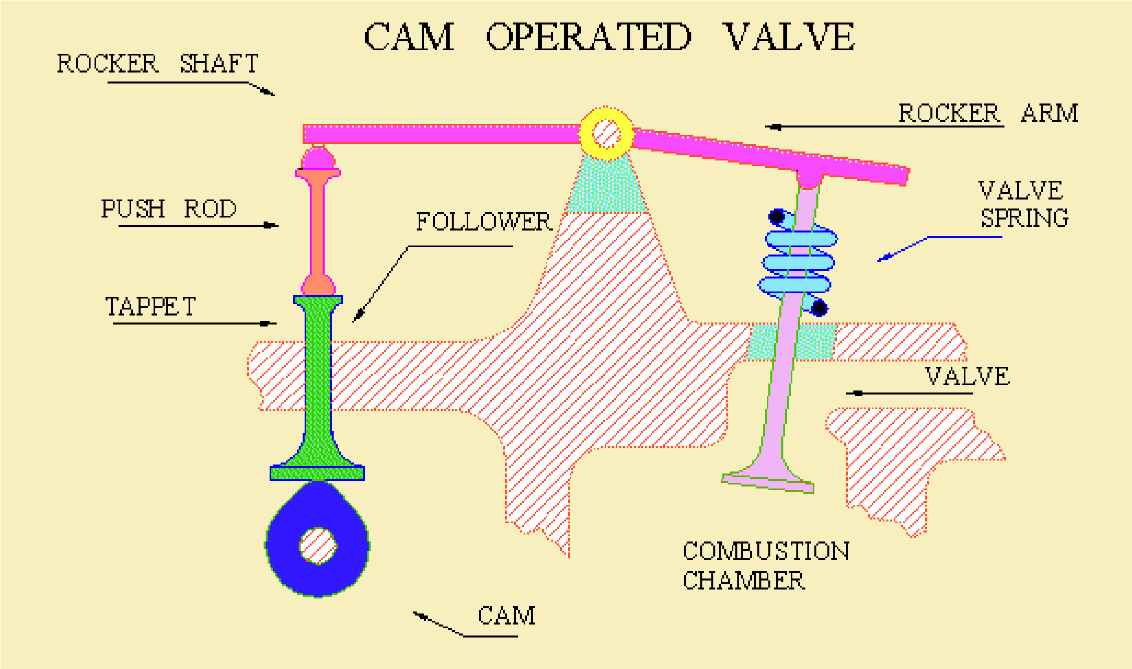
On removing the camshaft it was noted that the surface of one of the cam lobes exhibited evidence of severe spalling[1], with the valve-lifting portion of the profile having been worn down to a significant extent. In addition the surfaces of the cylinder Nos 1 and 2 cam followers had suffered considerable pitting where they had been in contact with the damaged cam lobe.

Photographs of the camshaft, the damaged lobe and the associated cam followers are shown at Figures 1 and 2. Also shown is a sketch indicating the principle of cam/valve operation, although in the subject engine, the cam followers contain hydraulic tappets, which become charged with oil when the engine is running, causing them to expand so that they take up clearances between the various components in the valve operating system. It should be noted that although there is a total of eight valves in the engine, the camshaft has only six lobes because the second and fifth lobes (counting from the front of the engine) each operate the inlet valves of opposing cylinders, Nos 1/2 and 3/4 respectively. Each exhaust valve is operated by a dedicated cam lobe. The effect of the wear was to remove approximately 0.138 in from the cylinder Nos 1/2 inlet valves cam 'peak', which would have resulted in a corresponding loss of inlet valve lift for both cylinders.

The material removed from the cam lobe would have been in the form of finely divided metallic debris, much of which would have fallen into the sump and

Footnote

[1] Process by which flakes of a material are broken off a larger solid body; this can be produced by a variety of mechanisms.

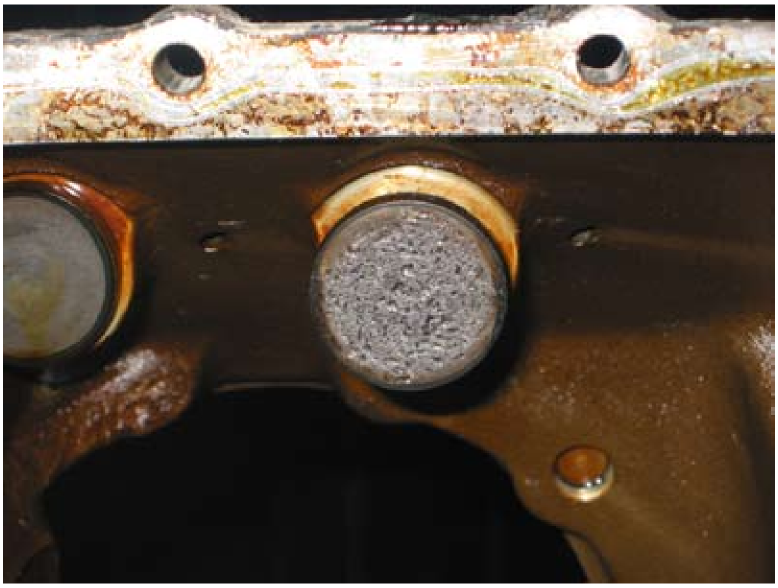


Sketch showing principle of valve operation

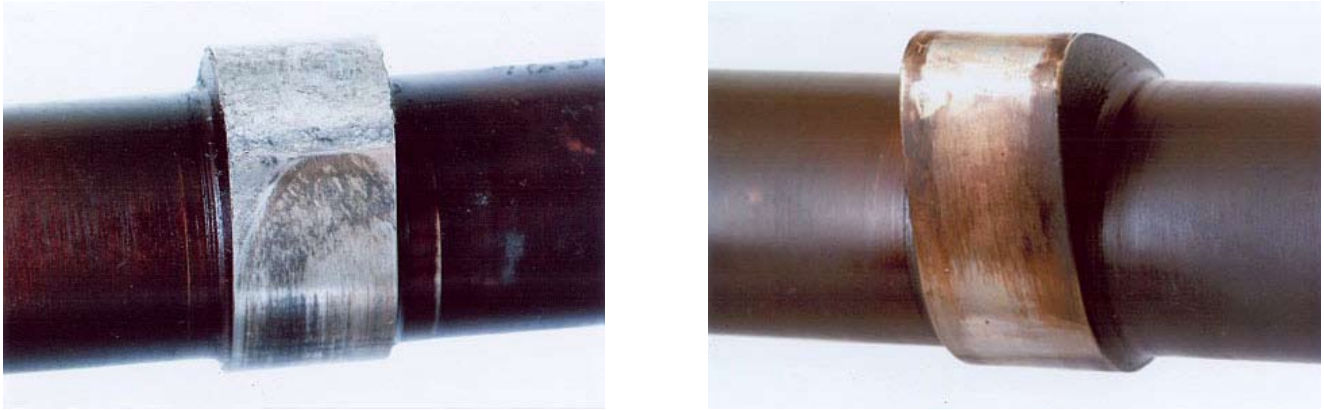
Worn cam lobe, as found during engine strip

Figure 1

Valve operation and camshaft details

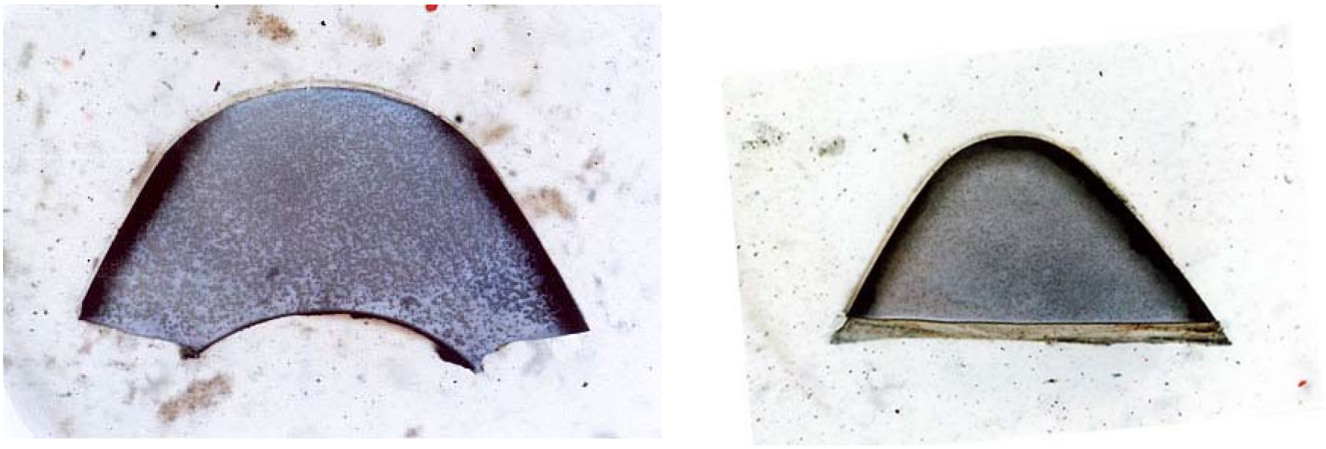


View of spalling on one of the cam followers



Photos: HT Consultants

Comparison of worn and normal cam lobes



Photos: HT Consultants

Section through worn and normal cam lobes. Note hardened layer showing as dark areas

Figure 2

Details of worn cam

subsequently been caught in the filter. The filter element was recovered but had been partly carbonised within its container, due to the effects of the fire. However, after the remains of the element had been crushed, a quantity of magnetic material, which is likely to have originated from the cam lobe, was apparent within the debris mass. The amount of magnetic material appeared small in relation to the missing portion of the cam, which raised the question of its whereabouts. The scavenge filter was clear, although this had a relatively coarse mesh. The sump was not fitted with a magnetic plug. Some metal particles were observed clinging to the surface of the No 1 piston skirt, although the quantity was small. Whilst it is possible that some debris could have been held in suspension in the oil, it was considered that much of the wear could have occurred prior to the Annual Check on 10 July 2007. The oil change carried out at this time ought to have included the process of examining the old filter to look for any metallic debris, thus allowing an opportunity for investigation, should any have been found.

A metallurgical examination of the camshaft included micro hardness tests on the cam lobe wearing surfaces. During manufacture, the camshafts are subjected to a carburising process, in which carbon is diffused into the surface of the material, resulting in a hardened layer. According to the engine manufacturer, the hardness depth should be around 0.030 to 0.045 in. In fact the micro hardness tests revealed that there was no significant reduction in hardness values until approximately 0.050 in below the surface. The amount of wear on the affected cam lobe was considerably more than this: the wear rate would have increased rapidly once the hardened layer had been removed.

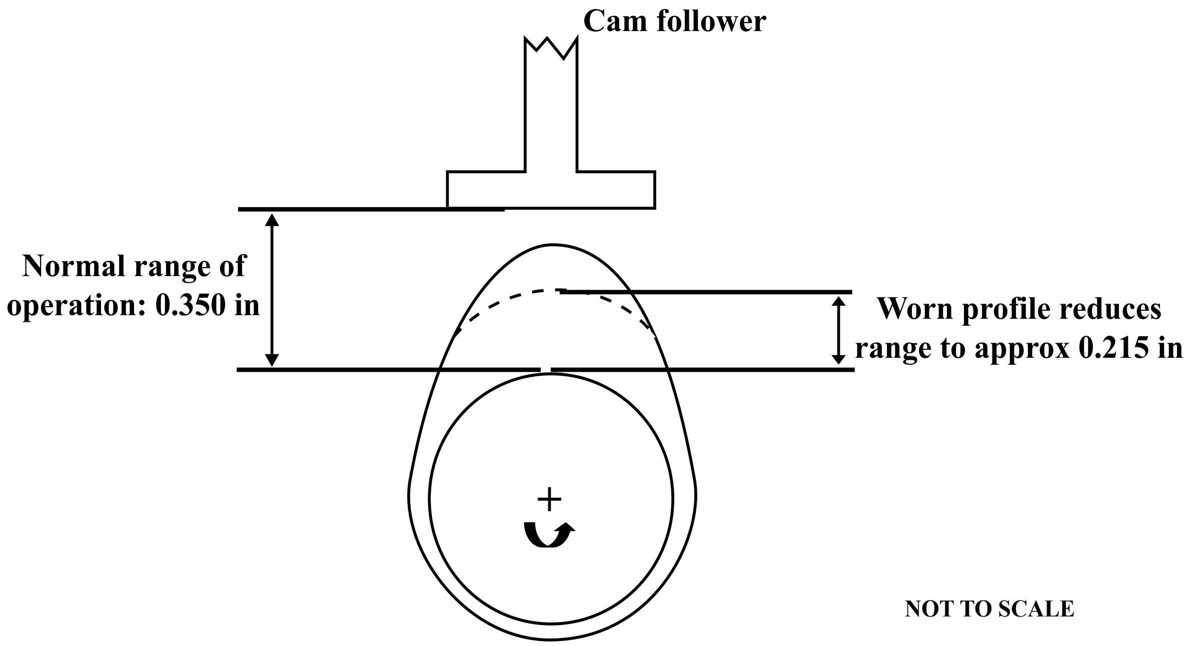
The remainder of the cam lobes appeared in good condition, with little wear having occurred.

Cam wear and its effects

Cam wear is not a new problem and can occur for a number of reasons, such as infrequent engine use and condensation-induced corrosion arising as a result of the aircraft being parked outside in humid conditions. As the camshaft is located at the top of the engine, oil quickly drains away following shutdown. Although an oil film is left behind, condensation can sometimes result in a corrosion pit, which initiates a spalling process between bearing surfaces. When the engine is started from cold, the first few revolutions tend to remove the oil film, thus allowing metal-to-metal contact, until fresh oil is supplied from the pump. The front cam lobes are the most vulnerable as they are located furthest from the oil pump.

A Textron Lycoming Service Instruction, No L180B, issued in November 2001, contains advice on engine preservation for active and stored aircraft. In particular, it recommends a procedure to be followed if it is known that the engine is to remain inactive for 30 or more days. It additionally cautions against pulling the engine through by hand prior to start, as this simply wipes the oil film from cylinder walls, cams and followers, thus extending the period of exposure to which these components are subjected before oil is circulated from the pump.

It is difficult to establish a typical timescale, in terms of engine operating hours, for cam lobes to wear through the case hardened layer, and at which point the wear rate would increase by an unpredictable amount. In addition, the engine manufacturer was unable to provide a figure of how much wear can occur before engine maximum power output is affected. The diagram overleaf illustrates how the cam wear affects valve operation.



The effect of the cam wear in this case was to reduce the cam follower range of movement by approximately 40%. This in turn would reduce the amount by which the inlet valves opened during the induction stroke, thus possibly resulting in a lower volume of fuel/air mixture and ultimately, reduced engine power output.

There is no routine maintenance carried out on the engine that attempts to measure any cam wear, other than an examination of the removed oil filters. Apart from the reduction in maximum power, there would be no other symptoms, such as rough running. Nor would there be any increase in noise, as most, if not all, of the cam wear would be taken up by the expansion of the tappets.

Additional tests

In order to provide additional data concerning cam lobe wear, a UK engine overhaul company conducted a series of engine runs under the supervision of the AAIB. For this they procured a time-expired (ie 2000+ hours) engine of the same model as that fitted to G-AVRP and separately identified a camshaft on which the front lobe was worn almost to the same extent, ie 0.136 in compared with 0.138 in for the accident aircraft. The engine was rebuilt with the worn camshaft installed and run on a test stand, on which the engine was driving a fixed pitch 'club' propeller, specially designed for test purposes. The manifold pressure and rpm were monitored throughout the operating range and several 'slam accelerations' were carried out. The engine operated smoothly throughout, apart from a reluctance to accelerate from a low rpm. Significantly however, the maximum rpm obtained was 2,575, as opposed to 2,700 for an engine in good condition. This equated to a peak power of 134 bhp, compared with the rated value of 150 bhp, ie a loss of around 10%.

The engine was then disassembled and rebuilt once again, this time using a new camshaft. The opportunity was also taken to renew the main and big-end bearings. (Note: this was a decision taken by the engine overhaul company in preparation for eventually releasing the engine as an overhauled unit. As a result, the 'tightness' of the bearings may have absorbed a small amount of power during the subsequent test.) During the next run, it was noted that a higher rpm was achieved for an equivalent manifold pressure throughout the operating range. This translated into a corrected peak power value of 144 bhp. Whilst this figure is still less than the rated value, it should be noted that, camshaft apart, the engine was largely still in its time-expired condition; thus the shortfall would be due to the combined effects of degradation of the cylinder bores, piston rings, cylinder heads and valves. Since the engine from G-AVRP was only half-way through its overhaul life, the equivalent losses from these sources might be expected to be less.

In conclusion, the tests indicated that at least 10 bhp was lost solely as a result of the cam wear, representing 6.7% of the rated maximum power of the engine. It is thus probable that a similar loss may thus have occurred in the engine from G-AVRP, in which the cam wear was marginally more.

Personnel

The pilot had been issued with a UK Private Pilot's Licence (Aeroplanes) (PPL(A)) in November 1998, with a rating that qualified him to fly as pilot in command of microlight aeroplanes (landplanes). In February 2005 he qualified for a Joint Aviation Requirements (JAR) PPL(A) with a class rating for Single Engine Piston (Land) (SEP(Land)) aeroplanes. This rating was revalidated in February 2007.

The pilot's most recent JAA class 2 medical certificate was issued on 7 November 2006, expiring on 7 November 2008.

He had flown into Sandown Airport a number of times before. Prior to the accident, his most recent flight from the airfield was on 17 June 2007 in a Vans RV-7A.

Meteorology

During the investigation an aftercast was obtained from the Met Office. At the time of the accident, the synoptic situation showed a slow moving low pressure area over the Irish Sea; much of southern England was cloud-free due to the advection of dry, continental air from the French coast in a light to moderate southerly flow. There was no significant weather in the vicinity of the accident site, where visibility was between 13 km and 26 km. The estimated surface wind was from 160° at 3 to 7 kt, possibly varying in direction between 110° and 220°; the wind at 500 ft agl was estimated to be from 200° at 12 kt. The temperatures at the surface and at 500 ft were assessed to be 22°C and 20.5°C respectively. The mean sea level pressure was 1009 millibar.

With the presence of the built-up area to the south-east of Sandown Airport, it was considered that the combination of roughness of the airflow over the buildings and higher surface temperatures may have induced variability in the surface wind at the accident site. The aerodrome operator recalled that the surface temperature at the airport was 27°C, which was included in a meteorological observation taken at the time of the accident, and the surface wind was described as light and variable. Subsequently, a record of that observation could not be located. A further, detailed assessment of the temperature at Sandown Airport was carried out and it was estimated that the surface temperature at the aerodrome at 1100 hrs was between 23°C and 25°C. The temperature at 500 ft agl was also revised to between 21°C and 24°C.

Photographs of smoke rising from the crashed aircraft, taken three minutes after the accident had occurred, and another 12 minutes later, appeared to show that the surface wind at the accident site varied during that time between a south-easterly and north-easterly direction.

The impression was of a light wind. The pilot of another Piper PA- 28-140, which took off from Runway 23 at 1030 hrs, reported that the indications from the wind sleeve on the airfield, at that time, were of a surface wind from between 110° and 120° ie a tailwind. The wind sleeve, which is located abeam the threshold of Runway 05 and visible from the Runway 23 threshold, is fully elevated when the wind speed reaches 25 kt. In this instance it was elevated approximately two-thirds.

The CAA conducted a three-yearly assessment of the extent of the meteorological services at Sandown Airport on 15 August 2007; this had been arranged before the accident on 5 August. It was confirmed that the anemometer at the airport, which provided the air/ground radio operator with a digital readout of the wind speed and direction on a Davis Weather Monitor 2 weather station, showed good correlation with other anemometry and the airport's wind sleeve. The temperature sensor on the weather station was also assessed and found to be accurate, within the tolerance limits given in Civil Air Publication (CAP) 746, *Meteorological Observations at Aerodromes*.

CAP 746 also includes the requirement for a meteorological observation in the event of an aircraft accident. It states:

> *'The observer shall provide a full non-routine observation at the time of an aircraft accident on or in the vicinity of the aerodrome. This is to ensure that complete details of the weather at the time of the incident will be available to an official inquiry.'*

The CAA noted that the aerodrome staff were aware of this requirement. It was considered that the aerodrome offered *a comprehensive, quality meteorological service to its users*, providing briefing facilities in the control tower and the restaurant on the airport.

CAP 168, *Licensing of Aerodromes*, provides guidance on the positioning of wind sleeves. It states that they:

> *'should be so positioned on the aerodrome as to be visible from the approaches to all runways and be free from the effects of any disturbances caused by nearby objects. They should be sited so that at least one sleeve is visible from each take-off position .... Preferably between 300 m and 600 m from the runway threshold measured along the runway...'*

Airfield information

Sandown Airport is a licensed aerodrome at an elevation of 55 ft amsl. The Takeoff Distance Available (TODA) on grass Runway 23, as published in the UK Aeronautical Information Publication (UK AIP), is 884 metres. When measured, shortly after the accident, the length of the grass on the runway was less than or equal to the maximum recommended length of 4 inches. The runway has a 1% upslope.

Runway 23 is designated as a code 1 runway for the purpose of determining the freedom from obstacles when landing and taking off. As such, its takeoff obstacle limitation climb surface has a slope of 5%, originating 30 metres beyond the end of the takeoff run and extending out to a distance of 1,600 metres, orientated on the extended centreline. The inner edge of this surface is 60 metres in width and the outer edge is 380 metres wide, with a linear increase in width of the surface between the two edges. See Figure 3.

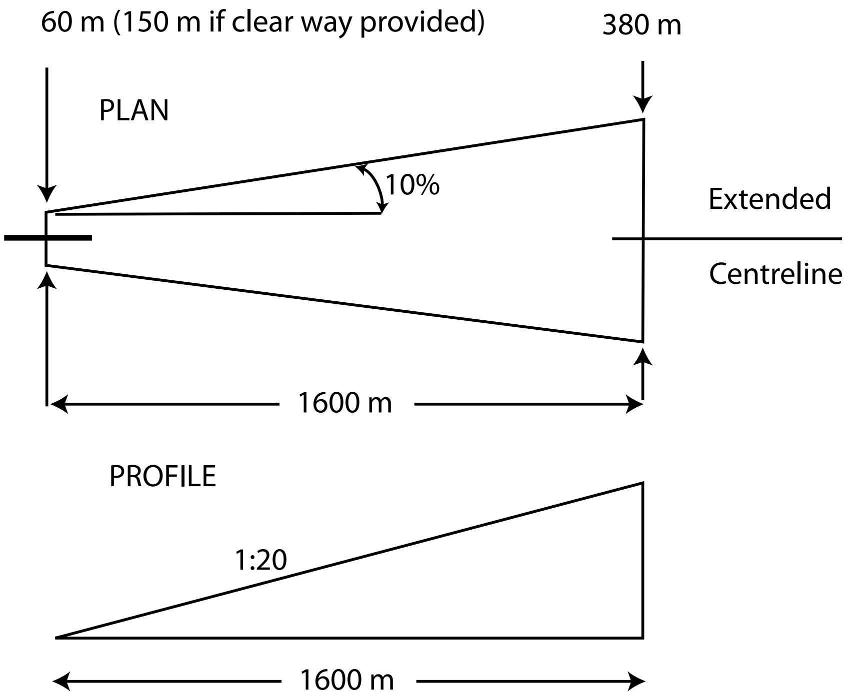


Figure 3

Takeoff climb surface associated with a runway where the code number is 1

Civil Aviation Publication (CAP) 168, entitled *Licensing of Aerodromes*, states:

> *'In ideal circumstances all the surfaces will be free from obstacles but when a surface is infringed, any safety measures required by the CAA will have regard to:*
>
> *a) the nature of the obstacle and its location relative to the surface origin, to the extended centreline of the runway or normal approach and departure paths and to existing obstructions;*
>
> *b) the amount by which the surface is infringed;*
>
> *c) the gradient presented by the obstacle to the surface origin;*
>
> *d) the type of air traffic at the aerodrome;…*
>
> *... Safety measures could be as follows:*
>
> *a) promulgation in the UK AIP of appropriate information;*
>
> *b) marking and/or lighting of the obstacle;*
>
> *c) variation of the runway distances declared as available;*
>
> *d) limitation of the use of the runway to visual approaches only;*
>
> *e) restrictions on the type of traffic.'*

It also states that:

> *'Existing objects above an approach surface, transitional surface, take-off climb surface, inner horizontal surface or conical surface should as far as practicable be removed…'*

An aerodrome survey in May 2006 identified nine trees in the copse, over which the aircraft was seen to climb, that penetrated the takeoff climb surface associated with Runway 23 by between 3.26 metres (10.7 ft) and 7.28 metres (23.9 ft). It is likely that these trees, which were not felled or pruned, grew in the intervening 14 months up to the time of the accident and that they then represented a higher obstacle. At the time of the survey, the trees identified were up to 144 ft above the elevation of the airfield, within 820 metres of the upwind end of Runway 23. The highest of these trees was included in the AIP entry for Sandown, under *Aerodrome Obstacles*.

Since the accident, a permanent Notice to Airmen (NOTAM) has been published for Sandown Airport cautioning pilots against *'rising ground and trees to SW and NE of AD'*. The airport operator has appointed a contractor to control and manage the trees within the various obstacle limitation and safety surfaces at the Airport to maintain a balanced runway and an obstacle (tree) free environment.

Figure 4 shows a photograph taken from half way down the runway, looking south-west.

Aerodrome communications

The airport provides an air/ground communications service (AGCS), as described in CAP 452, *Aeronautical Radio Station Operator's Guide*. The phraseology specific to an AGCS is provided in CAP 413, *Radiotelephony Manual* (Chapter 4). It states:

Figure 4

Photographs of Runway 23 looking south-west

> *'Information provided by an AGCS radio station operator may be used to assist a pilot in making decisions, however, the safe conduct of the flight remains the pilot's responsibility.'*

CAP 413 also includes examples of phraseology for use by an AGCS, see Table 1.

It was normal practice for the airport's air/ground radio operator to provide pilots, in radio equipped aircraft which were preparing to take off or land, with advice on the surface wind, as determined from the wind sleeve. This was given in the form of a general wind direction ie from the left or right, or from the south-east, north-west etc with the speed being judged from the angle of the wind sleeve. Pilots were also advised if there was a tail wind. The digital wind readout was regarded as a secondary source of wind information.

Recorded information

Primary and secondary surveillance radar information from the radar heads located at Clee Hill and Pease Pottage was available for the aircraft's flight prior to the accident flight. Figure 5 shows this track, starting at 0748:23 hrs as G-AVRP climbed away from Tatenhill airfield, to the west, ending at 0939:40 hrs with the aircraft approaching Sandown Airport. No more radar data of G-AVRP was available.

Performance

The pilot's flight plan specified a route to Pontivy which took G-AVRP via the NDB at Cherbourg and overhead Avranches, a total distance of 186 nm. It also indicated that the aircraft would cruise at 105 kt and had an endurance of 2 hours. The majority of the fuel on board was burned off during the fire following the crash, but it was estimated that the aircraft's takeoff weight at Sandown was 2,120 lb. This was based on the minimum fuel that was understood to have been on board, and is below the maximum allowable takeoff weight of 2,150 lb.

For the conditions estimated to have existed at the time, the Takeoff Distance Required (TODR) by G-AVRP was between 771 metres and 789 metres. The associated Takeoff Run Required (TORR) was between 424 metres and 434 metres and the Net Gradient of Climb on the takeoff flight path, between heights of 50 ft and 1,000 ft aal, was between 7.1% and 7.3%. These figures, derived from the Aeroplane Flight Manual (AFM), are net data and include margins for loss of performance due to factors such as small and unavoidable variations from the correct airspeed, and variations from the average airframe drag and engine power. G-AVRP's AFM was not on the aircraft and was recovered from the initial point of departure.

Event	Response
A/C requests taxi information	(Aircraft callsign) runway (designation) left/right hand circuit wind number (degrees) number (knots) QFE/QNH (pressure) millibars.
A/C reports ready to take off	(Aircraft callsign) no reported traffic (or traffic is...) surface wind (number) degrees (number) knots.

Table 1

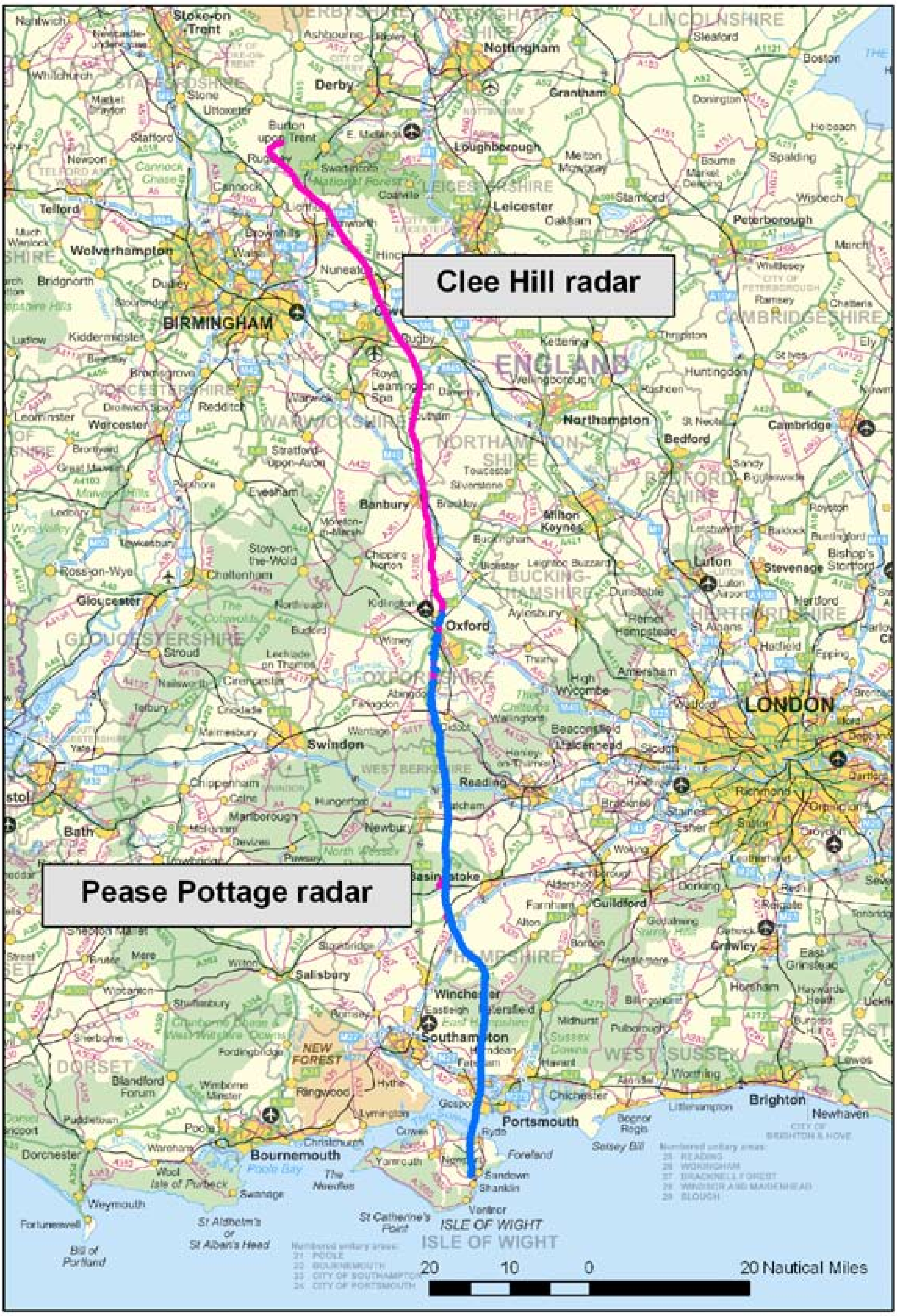


Figure 5

G-AVRP's flight track from Tatenhill to Sandown Airport

If the surface temperature was 27°C, as advised verbally, the TODR and TORR would have been 820 metres and 451 metres respectively, and the Net Gradient of Climb on the takeoff flight path would have been marginally shallower, at 7.0%.

Some specific UK registered PA-28-140's AFMs include CAA Change Sheet No. 3 issue 1 to the FAA approved UK Flight Manual. This specifies corrections which are applicable to certain performance calculations and reflect that aircraft's less capable performance, as noted during an airworthiness flight test. This CAA Change Sheet had not been issued for G-AVRP's AFM.

As an example, for the estimated conditions at the time, and incorporating the CAA Change Sheet corrections, increases the TODR to between 848 and 868 metres and the TORR to between 466 metres and 477 metres. The Net Gradient of Climb on the takeoff flight path reduces to between 4.6% and 4.7%. Similarly, if the surface temperature was 27°C, the TODR and TORR would become 902 metres and 496 metres respectively, and the Net Gradient of Climb on the takeoff flight path would be 4.4%.

The TODR, from rest to a height of 50 ft aal, is based on the following takeoff technique, as advised in the AFM:

> *'Engine: Full throttle*
>
> *Wing flaps: Retracted*
>
> *Lift-off initiated at the take-off safety speed of 74 mph (64 kt).'*

The net gradient of climb between 50 ft aal and 1,000 ft aal is predicated on that speed, configuration and throttle setting being maintained. There is no data in the AFM for takeoff performance with flaps selected.

On the evidence available, the aircraft's centre of gravity was calculated to be at 90.6 inches aft of the datum; within the permitted range, towards the forward limit of 89.55 inches aft of the datum.

The aircraft's power-off stalling speed at a weight of 2,120 lb, with the flaps retracted, was 61 mph (54 kt). With 10° of flap set, the power-off stalling speed, at the same weight, was 52 mph (46 kt). A stall warning light was installed on the instrument panel to provide warning at a uniform 5 to 10 mph speed increment above the stall, in all configurations. During the aircraft's last airworthiness flight test, in July 2003, the aircraft stalled within 1 mph of its scheduled stall speed. During the stall the nose dropped but the wings remained level.

CAA Safety Sense Leaflet 7c, entitled *Aeroplane Performance*, states under the heading *TAKE OFF – POINTS TO NOTE*;

> ***'Decision point**: you should work out the runway point at which you can stop the aeroplane in the event of engine or other malfunctions e.g. low engine rpm, loss of ASI, lack of acceleration or dragging brakes. Do NOT mentally programme yourself in a GO-mode to the exclusion of all else.'*

The aircraft's earlier departure from Tatenhill Airfield, at a cooler time of day, was not observed. Its asphalt Runway 08/26 is 1,190 metres in length, which is also the TORA. The airfield is situated on higher ground than the surrounding countryside and there are no significant obstacles for aircraft taking off.

Air tests

The most recent air tests carried out on the aircraft were in May 2000 and July 2003; these were conducted by the same pilot on both occasions from the same airfield (Tatenhill) and comprised part of the renewal of the Certificate of Airworthiness (C of A). The performance section of the Airworthiness Flight Test Schedule included a timed climb; a comparison of the results is shown below, see Table 2.

Note that for the maximum power check on the ground, the Schedule requires the aircraft to face crosswind unless the wind strength makes this hazardous, in which case the aircraft should be parked into wind. Scheduled rate of climb is determined from the Performance Section of the Flight Manual.

The Flight Test Schedule notes that:

> *'Unless it is impractical to do so, the aircraft should be loaded to maximum take off weight. It is permissible to test at a lower weight if climb data and stall speeds are scheduled with weight.'*

It can be seen from the table that the aircraft was loaded reasonably close to its maximum authorised weight of 2,150 lbs.

After completing the flight test an Engineer's Declaration on the front page of the Schedule is signed, which certifies that the air test results are within the allowable tolerances. If there is a shortfall in the climb rate, the reasons for acceptance must be stated, although a shortfall in excess of a specified maximum value should not be submitted unless discussed with the CAA Flight Department. The maxima in the 2000 and 2003 tests were respectively 80 and 70 ft/min; the difference was due to the 2003 test being completed using a later revision of the Test Schedule. The reason for accepting the shortfall in the 2000 air test was stated as *"Weather conditions"*, with the explanation in the later test being "*A/C in need of paint strip and re-spray"*.

Parameter	**May 2000**	**July 2003**
Max power engine rpm on ground	2350	2290
Mean weight, lb	1974	1966
Mean altitude, ft	2460	2480
Mean OAT, °C	+16	+14
Scheduled rate of climb, ft/min	620	610
Observed rate of climb, ft/min	580	540
Difference from scheduled, ft/min	-40	-70

Table 2

In October 2005 the CAA issued Letter to Owners/ Operators No 2839, which gave advice on changes to the CAA's policy for flight testing resulting from the implementation of European Commission Regulations. Additional information was contained in Airworthiness Notice (AN) No 48, issue 4 of which is dated 29 September 2006. Both publications refer to the European Aviation Safety Agency (EASA) Regulations Part M, which deals with continuing airworthiness, the responsibility for which has passed from the CAA to EASA. Part M, Section B requires a 'Competent Authority' (ie the CAA in the UK) to develop a survey programme to monitor the airworthiness status of aircraft on its register. The procedure is laid down in M.B.303, with details of acceptable means of compliance contained in AMC M.B. 303 (b); 'Aircraft Continuing Airworthiness Monitoring'. This paragraph lists a number of items that sample product surveys of aircraft would include, such as 'In-flight surveys, as deemed necessary by the competent authority'.

Prior to these Regulations the flight testing regime for all aircraft was published in the British Civil Airworthiness Requirements (BCARs), with Section A3-5 dealing with flight testing for renewal of the Certificate of Airworthiness or Permit to Fly.

The EASA Regulations will not be fully in force until 28 September 2008 but the AN anticipates the measures that need to be in place by that date and identifies when a flight test is necessary. A fundamental change arising from these Regulations is that EASA aircraft are no longer subject to the systematic programme of continuing airworthiness flight test (CAFT), previously carried out at the time of C of A renewal, or to an agreed flight test sampling programme, required under the BCARs. No distinction is made between privately operated aircraft and those engaged in Civil Air Transport (CAT). Therefore, no flight test was conducted on G-AVRP at the last C of A renewal in August 2006.

Other accidents and incidents

AAIB Bulletin 1/1997 reported on an accident at Sandown Airport involving a PA-28-140, registration G-OHOG, which descended into the trees 800 metres beyond the end of Runway 23 while taking off. These were the trees over which G-AVRP managed to climb, before descending into the ground. The pilot of G-OHOG had commented that his aircraft had climbed at a shallow angle to clear the trees, but that it encountered disturbed air when it was 30 ft to 40 ft above them. The aircraft then began to sink towards the trees and, realising that a collision would occur, the pilot closed the throttle and raised the nose of the aircraft to reduce the severity of impact.

It was calculated that G-OHOG, with four people on board, had weighed 2,150 lbs, and an aftercast report, from the Met Office, assessed the surface wind as being from 120º at 3 to 7 kt, with the surface temperature at 20°C and the mean sea level pressure 1021 millibar.

Evidence indicated that some flap was selected for the takeoff and that the stall warning light was illuminated on the instrument panel as the aircraft flew past the light aircraft parking area adjacent to the threshold of Runway 05. It also appeared to be illuminated prior to impact with the trees.

Discussion

Performance

The weight of G-AVRP at the time of the accident was estimated to be close to the maximum authorised, which suggests that it must have taken off from Tatenhill earlier that morning overweight. There were no witnesses to this takeoff so no comment can be made as to the length of takeoff run or the subsequent climb performance. However, the 1,190 metres of available asphalt runway and the relatively cool temperature may have served to mask any performance shortfall caused by the excessive weight or lack of engine power.

The aircraft's predicted performance at Sandown Airport, calculated on the basis of the estimated takeoff weight and the conditions that were assessed to have existed at the time, indicated that G-AVRP should have taken off successfully, avoiding all obstacles. The fact that this was not the case could have been because of a number of factors.

The shortfall in the aircraft's climb performance during its last Airworthiness Flight Test, in July 2003, was at the maximum limit and, subsequently, the investigation revealed wear in the engine. The performance capabilities of certain UK registered PA-28-140s have been downgraded, following flight test. When considered necessary, this is applied in the form of a CAA Change Sheet to a particular aircraft's AFM. Such an amendment had not been issued for G-AVRP and, consequently, the performance calculations may have been optimistic.

It is possible that the wind shifted during the takeoff, presenting the aircraft with a tailwind, or that there was an initial tailwind of which the pilot was not aware. The aircraft's estimated takeoff weight, which was based on the minimum fuel that was understood to have been on board, may have been greater, increasing the TODR and reducing the climb performance. Also, it is conceivable that the takeoff technique, in particular the aircraft's speed, differed from that recommended in the AFM, again with an adverse effect. Finally, there is no record of the surface temperature at the airport upon which to base an accurate assessment of the aircraft's performance capability; an increase in temperature reduces the performance of the aircraft.

The length of the aircraft's takeoff ground roll appears to have exceeded the calculated TORR by 163 metres. It also exceeded, by some 85 metres, a TORR that was calculated on the basis of the warmest surface temperature that was recollected and also included the CAA Change Sheet performance corrections which are added to some other PA-28-140s. This indicates that G-AVRP was underperforming even before it lifted off the runway and that there were early signs that the takeoff was unlikely to be successful. Consequently, it would have been appropriate to abort the takeoff at that stage. CAA Safety Sense Leaflet 7c, entitled *Aeroplane Performance*, advises selecting a decision point on the runway at which the aeroplane can be stopped in the event of lack of acceleration during takeoff.

Some trees, notified in the AIP, penetrate Runway 23's takeoff obstacle limitation climb surface, which has a 5% slope. Since the accident, a contractor has been appointed to control and manage the trees to maintain a balanced runway and an obstacle-free environment.

Once airborne, it is likely that the pilot was attempting to use all the energy available in the aircraft to clear the obstructions ahead. Accordingly, the aircraft's nose-up attitude was seen to increase as it cleared the trees approximately 700 metres beyond the end of the runway. In doing so, its speed would have reduced and, realising the aircraft's predicament, the pilot may have decided to land it in the field where it crashed, contacting trees in the process, which caused lose of control. Alternatively, G-AVRP could have lost sufficient speed for it to stall. The aircraft's stall behaviour during its last Flight Test resulted in the nose dropping while the wings stayed level. This reflects the observations of witnesses at the airport when the aircraft disappeared from view.

The pilot requested Runway 05 for his departure, but was advised that Runway 23 was in use because of landing traffic. His decision making would have been assisted by a suitably located wind sleeve within 300 metres to 600 metres of the threshold of Runway 23, as advised in CAP 168, *Licensing of Aerodromes*, in addition to the airport's one wind sleeve, which is located abeam the threshold of Runway 05.

Engine

The engine had sustained considerable damage in the impact and subsequent fire. Consequently it was not possible to test the magnetos or the integrity of the ignition harness. Nor was it established, in the absence of the refuelling history, what type of fuel was being used at the time of the accident, although the presence of a lead nodule on a spark plug, together with evidence of lead in the carburettor residues, indicated the recent use of leaded fuel. The use of motor gasoline can make an engine more susceptible to stopping as a result of vapour lock. However, the engine kept running in this case, which, together with the apparent lack of problems on the two flights to Sandown, suggests that the fuel type was not a factor in the accident.

No major mechanical failure had occurred in the engine, although the cam lobe that operated the inlet valves of cylinders 1 and 2, had suffered a considerable amount of wear. This had resulted in a reduction of approximately 40% of the cam follower range of movement, which in turn would have caused a similar reduction in valve opening. A consequence of this could be that a reduced amount of fuel/air mixture would be drawn into the affected cylinders during the induction stroke, with a corresponding reduction in maximum power output. Indeed, additional tests indicated that, in an engine with a cam lobe worn to a similar degree, at least 10 bhp was lost solely as a result of the cam wear, representing 6.7% of the rated maximum power of the engine. It is thus probable that a similar loss may have occurred in the engine from G-AVRP.

Worn cams are not a new problem, yet there is little or no available data on wear rates or effect on power. A number of AAIB investigations have revealed worn camshafts in accidents where performance issues have not been a concern. Similarly, whilst engine overhaul agents can find worn cams in engines that have been reported by their owners to be down on power, cam wear can be found in engines where there have been no such reports. This suggests that a degree of wear can occur without impacting on engine performance and/or many pilots are simply unaware of performance deterioration because, for example, they seldom operate their aircraft at maximum weights out of limiting airfields.

On aircraft with fixed pitch propellers, such as G-AVRP, confirmation of maximum power is indicated by full throttle static engine rpm on the ground, which would be around 2,450 rpm in this case, although it would vary according to wind speed and direction. However, such a test is not conducted as part of the normal pre-takeoff power checks, with maximum power only being applied at the start of the takeoff roll. By this stage the pilot is involved with the conduct of the takeoff and it would be easy for him to dismiss any observed low rpm as wind effects. Thus, in the absence of a dedicated air test, conducted at high weights, it is probable that the only indication to the pilot of a gradual loss of performance is a perceived reduction in obstacle clearance, during take off from an airfield with which the pilot is familiar.

Air tests

The most recent air tests were carried out in 2000 and 2003, respectively around 600 and 200 operating hours prior to the accident. A comparison of the data indicates a deterioration in the climb performance over the period. The validity of such a comparison might be questionable, but it should be noted that, in this case, both tests were conducted at near-identical weights and temperatures, by the same pilot at the same airfield.

Whilst it is tempting to conclude that the reduction in climb rate could be an indication of the onset of cam wear, it is important to bear in mind that other factors, such as poor panel fit, paint finish, propeller condition, loose exhaust baffles and ignition system performance, could all make a contribution. Also, despite the absence of reliable data on cam wear rates, there is a perception that the wear process progresses comparatively rapidly, especially in the softer substrate material beneath the hardened layer. This being the case, the 2003 air test might be considered as being too long ago for cam wear to be a factor; thus the subsequent performance loss arising from this would be additional to whatever was responsible for the somewhat marginal results.

In fact the 70 ft/min shortfall in the climb rate put the aircraft on the cusp of failing the air test and, as a consequence, its C of A renewal. A failure would have resulted in an investigation into the cause(s) of the shortfall, an opportunity that is no longer available since the CAA ceased the requirement for C of A renewal air tests. It is probable that, for many privately operated aircraft, such tests represented the only occasions on which a professional assessment of performance was made.

The end of C of A renewal air tests coincided with changes in the Regulations in which EASA assumed overall responsibility for continuing airworthiness. News of this was promulgated in the UK by means of a letter to Operators and an Airworthiness Notice. However, in the absence of any logical arguments presented in these documents, the reason for the removal of the air test requirement seems to stem simply from the fact that the administration of continuing airworthiness had changed, as opposed to the results of any safety assessment. An additional feature of the new Regulations is that no distinction is made between privately operated aircraft and those engaged in commercial air transport, despite the different operating regimes of these categories.

The guidance material associated with the Continuing Airworthiness Regulations allows flight tests, or 'in flight surveys' to be conducted 'as deemed necessary by the competent authority'. On the face of it, this seems to allow each EASA member state the freedom to require flight tests, either on an ad hoc or regular basis. However, it is probable that the intent is not to permit the imposition of regular tests, since this would counter the EASA ethos of a common standard across the European region.

Safety Recommendations

This is the second accident of this nature at Sandown Airport, involving the same type of aircraft departing from Runway 23 in light south-easterly winds. The direction of the surface wind is an important factor during takeoffs, particularly when an aircraft's performance may be marginal. In addition to the wind direction and speed being notified over the radio by the air/ground radio operator, good visual indications enhance the information available to departing pilots, especially if their aircraft are not fitted with a radio. Hence, the following Safety Recommendation is made:

Safety Recommendation 2008-050

It is recommended that the Isle of Wight/Sandown Airport aerodrome licence holder installs an additional, suitably located wind sleeve within the appropriate distance from the threshold of Runway 23, in accordance with the advice contained in CAP 168.

Safety action

In May 2008, the Isle of Wight/Sandown Airport aerodrome licence holder installed an additional windsleeve located about 70 metres from the threshold of Runway 23. The windsleeve is clearly visible to the pilot of an aircraft on the threshold of Runway 23.

The lack of a requirement for a periodic flight test, which includes a measure of the aircraft's climb performance at or near its maximum weight, removes a degree of quality assurance upon which aircraft performance calculations can safely be made. For many pilots of privately owned light aircraft, a reduction in the maximum available power might remain undetected so long as operations are confined to relatively light weights at non-limiting airfields. However, the availability of maximum performance becomes increasingly vital at higher weights and shorter runways, as demonstrated by this accident. The issue of a Certificate of Airworthiness is a declaration of confidence in the condition of the aircraft: until 2005 the same certificate conferred a similar degree of confidence that the aircraft would meet its performance criteria. If performance issues are considered in the context of continuing airworthiness, it follows that a periodic confirmation that an aircraft can deliver its scheduled performance should form an integral part of this process. The following Safety Recommendation is therefore directed to EASA:

Safety Recommendation 2008-051

It is recommended that the European Aviation Safety Agency amend that part of the Regulations dealing with Continuing Airworthiness so that aircraft under their jurisdiction will require a periodic performance assessment.

ACCIDENT

Aircraft Type and Registration:	Piper PA-32-301 Saratoga, G-BMDC
No & Type of Engines:	1 Lycoming IO-540-K1G5 piston engine
Year of Manufacture:	1980
Date & Time (UTC):	16 September 2007 at 1609 hrs
Location:	Shotteswell, near Banbury, Oxfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Damaged beyond economic repair
Commander's Licence:	Private Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	Approximately 200 hours (of which 4 were on type) Last 90 days - N/K hours Last 28 days - N/K hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot was attempting to take off from the shorter of two runways at a private airstrip at Shotteswell, near Banbury, having earlier landed on the longer runway. Advice in the airstrip's entry in a general aviation flight guide indicated that a takeoff by that type of aircraft, from that runway and flown by a pilot of his experience was not recommended. During the takeoff the aircraft cleared a hedge at the upwind end of the runway but stalled and struck trees on the far side of a road running alongside the airstrip. The aircraft crashed in the field beyond and the pilot was fatally injured. There was no fire.

Subsequent performance calculations indicated that there was insufficient clear distance on the short runway for the takeoff to be successful.

History of the flight

The pilot had hired the aircraft for the afternoon and had advised the owner/operator (a flying club) that he was planning to fly from Wellsbourne Mountford Aerodrome to the south-east, then to an unspecified destination to pick up a friend. He then intended to fly west along the south coast to overfly a member of his family who lived in the Exeter area, before dropping his friend back at their meeting point and returning to Wellesbourne Mountford. There was also some suggestion that he might land at Turweston en route to the south-east.

The aircraft departed Wellesbourne Mountford at 1107 hrs with full fuel and only the pilot on board. It overflew a private grass airstrip at Shotteswell, 10 nm to the south-east, and continued south, crossing the south coast of England at Seaford and arrived at Dieppe [Saint-Aubin] Airport, France at 1243 hrs. (This was established from data that was subsequently retrieved from GPS equipment which was recovered from the aircraft after the accident.) The pilot carried out two approaches to Dieppe Airport, landing successfully off the second attempt. He did not make any radio calls and, after landing, told ATC that he could receive calls on the radio but was unable to transmit.

The pilot had experienced difficulty with the radio at Wellesbourne Mountford before his departure. He had been able to transmit but did not seem to be receiving incoming calls. The problem was diagnosed as an incorrect switch selection and was resolved before G-BMDC took off. Apart from his initial calls on departure from Wellesbourne Mountford, there was no record of the pilot making any other radio calls southbound or, later, northbound.

The pilot was seen to make some phone calls while he was on the ground at Dieppe, then, without refuelling, G-BMDC took off at 1417 hrs, again with only him on board. He returned across the English Channel and followed much the same track back towards Wellesbourne Mountford. As it approached the airstrip at Shotteswell, the aircraft completed a right-hand circuit and was seen to make a low approach to Runway 33, the longer of its two runways. The aircraft carried out a go-around and completed another circuit before landing. On both approaches it was apparent to observers on the ground that the pilot had to contend with a crosswind from the left. The GPS data indicated that during the touchdown the aircraft veered to the left, possibly off the runway, before returning to the prepared runway surface (see Figure 1). After landing, G-BMDC remained at the end and to the left of Runway 33 for two and a half minutes before backtracking along Runway 33 to the threshold, where

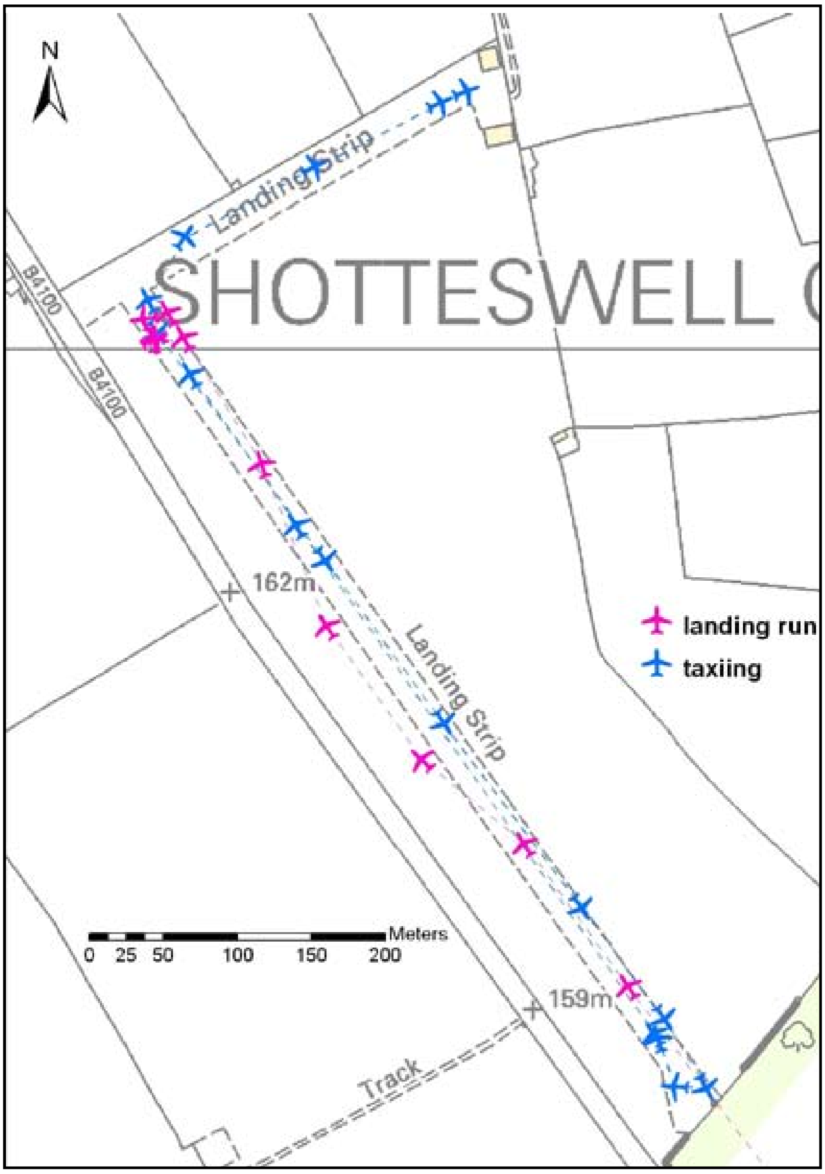


Figure 1

Landing and subsequent taxiing at Shotteswell airstrip prior to accident flight it remained for three and a half minutes. It then taxied back along the runway and down the shorter Runway 25 to its threshold. The aircraft was last recorded at that position, by the GPS unit, at 1608:36 hrs.

Between 1600 hrs and 1700 hrs, two members of a family, who were walking along a footpath in an adjacent field, about 800 metres away, saw a light coloured aircraft trying to take off from Runway 25. Before it had completed the takeoff, the aircraft disappeared from their view behind a hedge although one of these two witnesses did recall seeing the aircraft's wheels leaving the ground. Within a few seconds, the sound of the high revving engine stopped, silence returned and they thought that the pilot had either aborted the takeoff or been successful and flown off into the valley to the west.

At about 1610 hrs a couple were driving south along the B4100, a road which runs parallel to and immediately to the west of the grass airstrip. As they approached the airstrip they were startled by a small white aircraft which rose up sharply from behind a hedge on their left, about 100 metres ahead. It was in a nose-up attitude, banked steeply to the left, possibly as much as 90°, such that they could view the underneath of the fuselage. It flew across the road from left to right, with the roar of its engine clearly audible, appeared to clear the trees on their right and descended into the field beyond. Although he did not see the aircraft strike the ground, the driver immediately stopped the car, got out and ran across the road. Through a hedge, he could see the aircraft on the ground, inverted in the middle of the field.

Whilst he ran towards the aircraft, his wife phoned the emergency services; the call was timed at 1609 hrs. When the driver arrived at the left side of the aircraft he saw the pilot motionless inside the cabin, suspended upside down in his harness. The aircraft's left cabin door was jammed, so the driver ran to the opposite door, which did open, and, after removing the front passenger seat, which was blocking his access, released the pilot from his harness and pulled him half out of the aircraft. The pilot seemed to be unconscious but there were signs of life.

At that point the driver's wife arrived, still in contact with the emergency services on her mobile phone. They provided continuous first aid advice until the first ambulance arrived at 1621 hrs, shortly followed by the other emergency services. Attempts to revive the pilot were unsuccessful and he was pronounced dead at the scene. There was no fire.

Pilot

In August 2004 the pilot began a course of instruction for a Private Pilot's Licence (Helicopters). He did not complete the course and commenced a course for a Private Pilot's Licence (Aeroplanes) PPL(A). In August 2005 he qualified for his PPL(A), with a Single Engine Piston (SEP) (Land) class rating. This rating was revalidated in May 2007 and was valid until July 2009.

One week before the accident he received an instructional flight in G-BMDC, his first flight in that type of aircraft. This check flight, which included general handling and circuits, enabled him to hire the aircraft for private flights from the owner/operator, a local flying club.

For about six months the pilot had been a part-owner of a Piper PA-28R-201T. There was anecdotal evidence that he may have flown into the airstrip at Shotteswell prior to the accident, but no record of such flights could be found. He was also known to have conducted cross-country flights to Belgium, France, the Scilly Isles and Dublin.

The pilot held a Joint Aviation Authorities (JAA) Medical Certificate Class 2 which was issued on 11 April 2007 and expired on 11 April 2008. His total flying hours declared on his medical form on the date of issue were 175 hours. His log book for his fixed wing flying could not be located but it was understood that he had flown approximately 200 hours in total.

Aircraft information

The aircraft was a Piper PA-32-301 Saratoga powered by a 300 hp Lycoming IO-540-K1G5 piston engine driving a three-bladed constant speed McCauley propeller. The aircraft was of conventional design with conventional mechanical flying controls and fixed tricycle landing gear. It was equipped with six seats including the pilot's seat. The aircraft's last annual inspection was in November 2006 and its last 50-hour check was completed on 31 August 2007. At the time of the accident the airframe had accumulated 3,980 hours; the engine had accumulated 598 hours; and the propeller had accumulated 91 hours.

Meteorology

During the investigation an aftercast was obtained from the Met Office. The synoptic situation indicated that a cold front, which was orientated from north-east to south-west, lay to the north-west of Shotteswell and was moving in a south-easterly direction. It was estimated that there was scattered or broken cloud at the accident site with a base at 2,200 ft agl, although it was possible that the cloud base was higher than that, between 2,600 ft and 3,800 ft agl. Visibility was assessed as being greater than 20 km, possibly as much as 60 km, and the surface temperature was estimated to be +18°C.

There was no inclement weather affecting the area, but there was a strong westerly gradient resulting in a surface wind estimated to be from 220° at 15-20 kt, gusting from 25 to 30 kt. The wind at 1,000 ft agl was estimated to be from 260° at 35 kt. It is likely that there was moderate turbulence. The airfield has an elevation of 530 ft amsl and the QNH pressure setting at the time was 1,007 hPa.

At 1609 hrs, a meteorological observation at Wellesbourne Mountford recorded a surface wind from 250° at 15-18 kt and a temperature of 19°C.

Airstrip information

Shotteswell Airfield is a private unlicensed airstrip for which visiting aircraft require no prior permission. Its details, as supplied by the airstrip owner, appear in a number of general aviation flight guides, and the pilot was carrying a copy of an entry for the airstrip from an edition of such a guide, with an effective date of 25 November 2004. This gave details of two grass runways; 15/33 and 09/27. Their lengths were given as 853 metres and 400 metres respectively, and these distances were also listed as the relevant Take-Off Runway Available (TORA) for each runway. Under ***Remarks***, there was a note which stated:

> *'Rwy 09/27 use only when crosswind precludes use of Rwy 15/33... Rwy surface maintenance excellent.'*

And, under an adjacent section headed ***Warnings***, it stated:

> *'Rwy 09/27 only recommended for use by microlights, STOL ACFT & experienced pilots due to parked ACFT & hangars Rwy 27 Thr. Also upslope from Rwy 27 Thr.'*[1]

Footnote

[1] STOL ACFT means aircraft capable of conducting a 'Short Takeoff and Landing'.

The entry for Shotteswell, in the 2007 edition of the flight guide being used by the pilot (effective date 23 November 2006), which was current at the time of the accident, showed two grass runways; 15/33 and 07/25. Their respective lengths were given as 853 metres and 350 metres, with the TORA for Runway 15/33 being 700 metres in each direction. Hence, between November 2004 and November 2006 the orientation and length of Runway 09/27 had been changed and shortened. The entries in the ***Remarks*** and ***Warnings*** sections were the same as in the earlier edition, but with Runway 09/27 now identified as Runway 07/25. The runway length information in the guide was based on the information provided by the owner of the airstrip and was not independently verified. Using owner-provided information is common practice when compiling these guides.

In its introduction, the flight guide used by the pilot stresses, that it:

> *'is a guide only and it is not intended to be taken as an authoritative document.'*

A survey of the airfield immediately after the accident indicated that the useable length of Runway 25 was 302 metres, with a 1.6% upslope; this distance did not include the grass area in front of the hangar which was not considered useable by an aircraft of the size of G-BMDC. Including the grass area in front of the hangar resulted in an approximate 'hedge-to-hedge' distance of 330 metres. At the western end of the runway was a hedge which was approximately 18 to 22 ft tall. Immediately on the other side of that was a single carriageway road, the B4100, on the far side of which stood trees that were approximately 30 to 40 ft in height. See Figures 2 and 3.

During the investigation it was noted that the information given for this airstrip in the 2007 edition of another flight guide relating to private airfields, was also incorrect.

Figure 2

Runway 25 from the threshold

Figure 3

Approximately halfway along Runway 25

The east-west runway was designated 09/27 and given as 853 metres in length. This publication includes the advice that:

> *'it should be used as a guide only and must not be treated as official work, and the editor, publishers, owners and operators cannot be held responsible for any inaccuracies or omissions therein.'*

The inaccuracies in the flight guide being used by the pilot, and the other relating to private airfields, were brought to the attention of the owners of the airstrip and the publishers of the two guides.

The Civil Aviation Authorities (CAA's) General Aviation Safety Sense Leaflet 12d, entitled *Strip Sense,* provides comprehensive guidance on the use of unlicensed aerodromes and private airstrips. Included is the following advice to pilots:

> *'It is important to realise that the CAA criteria for the licensing of an aerodrome, e. g. clear approaches without power or other cables, no trees or obstructions close to the runway and so on, are unlikely to have been applied to the strip….'*
>
> *Tell the operator of the strip what experience you have, which strips you have used recently, and what aeroplane you intend using. He has probably seen pilots with similar aeroplanes flying into and out of the strip and you can benefit from local knowledge….*
>
> *The length of the strip must be accurately established….*
>
> *Consider having a familiarisation flight to and from the strip with a pilot who knows the strip and*

> *is both current on your aeroplane and operations into grass strips….*
>
> *If the strip is shorter than you are used to or has difficult approaches, you should arrange for a flying instructor to appraise your flying skills and revise and improve short field, soft field, general circuit and airmanship skills….*
>
> *Work out an acceleration check point from which you can stop if you haven't reached sufficient speed to make a safe take-off.'*

Procedures

The Pilot's Operating Handbook (POH) for the PA-32-301 specifies the procedures to use during takeoff. For a short field takeoff with obstacle clearance it states:

> *'Lower flaps to 25°, accelerate aircraft to 58 to 66 KIAS, depending on aircraft weight, and ease back on the wheel to rotate. After breaking ground, accelerate to 61 to 71 KIAS, depending on aircraft weight, and climb past obstacle. Continue climb and accelerate to best rate of climb speed 90 KIAS, and slowly retract the flaps.'*

The POH also gives advice on *STALLS*. It states:

> *'The gross weight [3,600 lbs] stalling speed with power off and full flaps is 58 KIAS. With flaps up this speed is increased by 4 KTS. Loss of altitude during stalls can be as great as 500 feet, depending on configuration and power.'*

The POH details airspeeds '*which are significant to the safe operation of the airplane*'. Included is the aircraft's maximum demonstrated crosswind velocity of 17 kt.

The owner/operator of the aircraft stated that they did not permit the operation of the aircraft from grass runways.

Accident site and wreckage examination

The aircraft wreckage was found lying inverted in a field beyond the end of Runway 25. The ground scars and wreckage distribution were consistent with the aircraft having hit the ground with its left wing tip first, in a steep left bank, before impacting on its nose and cartwheeling to the right. Both wing spars failed during the impact sequence. There was evidence that the aircraft's left wing had struck trees that were approximately 30 metres from the end of Runway 25, as depicted in Figure 4. The aircraft's left wing tip strobe light housing was found at the base of these trees which were approximately 30 to 40 ft high.

There were three propeller slash marks in the ground where the nose of the aircraft had hit. All three propeller blades had separated from the hub. One blade was embedded in the ground by the slash marks. Another blade was resting on the ground 24 metres further along the wreckage trail, and the third blade was resting on the ground 95 metres south-east of the aircraft wreckage. All three blades had chordwise scratches consistent with rotation at impact. The distance between the first two propeller slash marks was measured at 25 cm which meant that a linear relationship between ground impact speed and engine rpm could be established. If one assumed that the engine was turning at the normal takeoff rpm of 2,700 then the ground impact speed was approximately 66 kt. If one assumed a low impact speed of 40 kt then the rpm could have been as low as 1,650. However, the extent of damage to the aircraft and injuries to the pilot would suggest a ground speed of greater than 40 kt and closer to 66 kt, so an engine rpm of greater than 1,650 was likely, which would indicate that the engine was producing power.

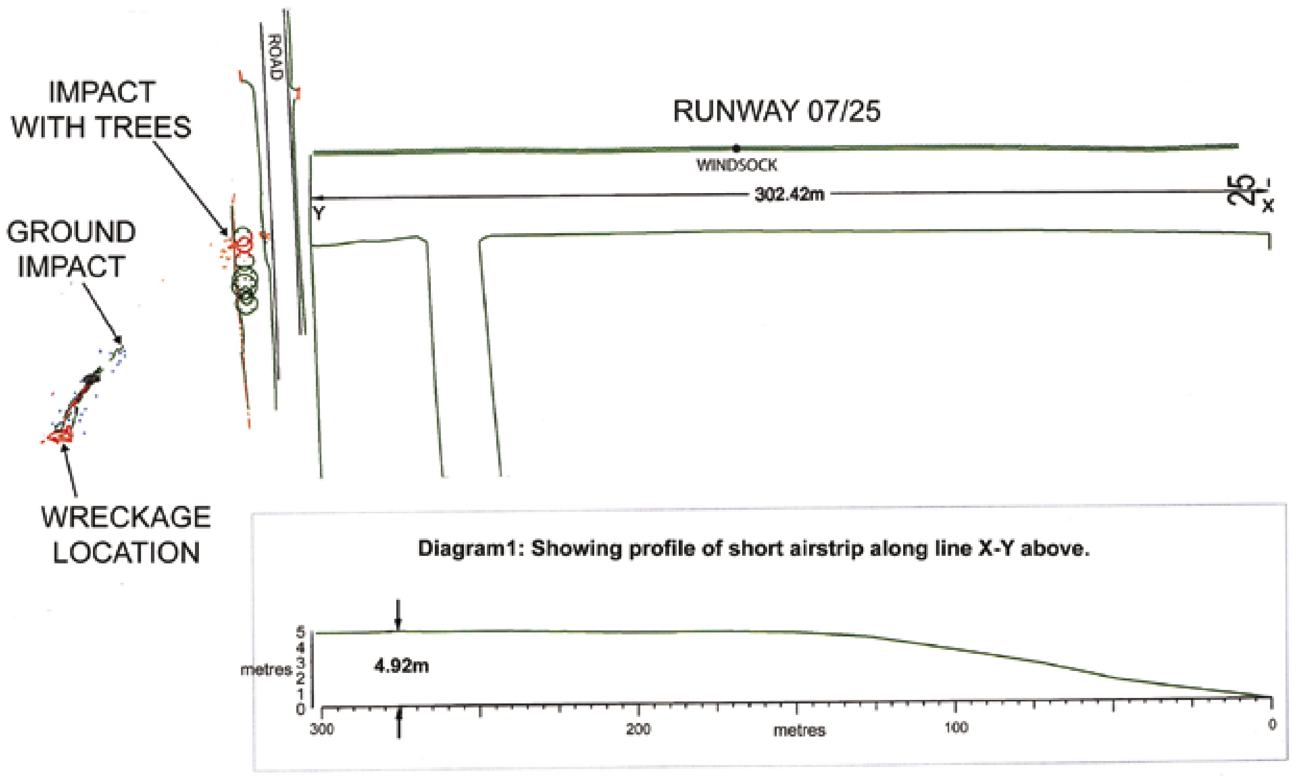


Figure 4

Runway length and profile with relative impact and wreckage locations.
(Note that the x and y axes in the vertical profile have different scales;
the total upslope gradient is 1.6%.)

The fuel tank in the right wing was intact and contained approximately 15 gallons (US) of fuel. The left wing fuel tank had suffered some impact damage and was leaking from the leading edge. The remaining fuel content in the left wing tank was approximately 4.5 gallons (US). The unusable fuel in each tank was 2.4 gallons (US) and the fuel capacity of each tank was 53.4 gallons (US). Fuel samples were drained from both tanks and contained no water or sediment.

The power lever, propeller control lever and mixture control lever were in the full forward position although the impact force on the engine could have disrupted these lever positions. The master and fuel pump switches were in the on position. The magnetos were turned off and the key had been removed. The flap lever selector was in the full down position which corresponded to a flaps up selection. The flap lever selector was latched into this position, although it was possible that the latch had released during the impact sequence. The control linkages to both flaps had failed in overload which rendered the flaps free to pivot on their hinges, and made flap position determination difficult. The right flap was almost undamaged and the left flap had buckled at the inboard edge.

Aircraft weight

The aircraft's basic empty weight (including full oil and unusable fuel) was 2,164 lb. The pilot's weight was 180 lb and there was approximately 10 lb of miscellaneous items in the aircraft. The recovered fuel, totalling 19.5 gallons (US), weighed 117 lb, although some fuel may have leaked out following the impact so this should be taken to represent a minimum fuel weight. The aircraft weight at takeoff was therefore at least 2,471 lb. The aircraft's maximum takeoff weight is 3,600 lb.

Powerplant examination

The engine was taken to an approved overhaul facility for a strip examination. The number two cylinder (front left as viewed from the pilot's seat) had suffered considerable impact damage. The remaining cylinders were in good condition. There was no evidence of any internal heat distress or evidence of a pre-impact failure of a mechanical component. The oil filter was clear of debris and the oil scavenge pump rotated freely. The timing of the magnetos was checked. The left magneto was within specification, but the right magneto was firing 3° early. The engine manufacturer was consulted about this and it was their opinion that this small difference would not have had a significant effect on engine operation or power output. The magnetos were both rig tested and operated normally. The spark plugs were in good condition apart from the two plugs from cylinder number two. One of these contained some debris and the other had a slightly bent electrode – this evidence was not surprising given the impact damage to cylinder number two. The remaining engine and accessory strip examinations did not reveal any evidence of a pre-impact fault that might have affected the engine's operation.

Survivability

The post-mortem examination revealed that the pilot had died of multiple injuries, the most serious of which were a severe head injury and a transaction of his thoracic aorta. The head injury was consistent with his face having struck the instrument panel and would have almost certainly rendered him unconscious. The transected aorta would have resulted in a rapid loss of blood and consequently it was the pathologist's opinion that any medical intervention would have been unlikely to have affected the fatal outcome. The transacted aorta is an injury associated with peak decelerations in excess of 80g.

Despite the crushing damage to the nose of the aircraft and the damage to the roof structure, a survivable space around the left pilot's seat was retained. The pilot's seat was provided with a three-point inertial reel harness and injuries to the pilot's body indicated that it was being used at the time of impact. However, damage to the instrument console indicated that his head probably struck the centre section rather than the instruments immediately in front of him. The lateral forces during the cartwheel may have caused his upper body to slip out of the shoulder harness strap and flex forwards and to the right. It is possible that a secure four-point harness would have prevented this from happening and would have prevented the head injury and also reduced the peak deceleration of the upper body, therefore reducing the g-force on the aorta. However, it is not possible to be certain that a four-point harness would have altered the fatal outcome of the accident.

Performance

The *Performance* section of the POH provides a means of calculating the Takeoff Ground Roll and the Takeoff Distance Required (TODR), to a height of 50 feet, for a '*Normal Procedure Takeoff*, a *Maximum Effort Takeoff – Flaps 0°*, and a *Maximum Effort Takeoff – Flaps 25°'*. All three techniques require an engine speed of 2,700 rpm and full throttle before brake release. Thereafter, the lift off and 50 foot barrier speeds are given as follows:

Normal Procedure Takeoff – Lift off speed 80 KIAS. Barrier speed 80 KIAS.

Maximum Effort Takeoff – Flaps 0°: Lift off speed 68 KIAS. Barrier speed 74 KIAS.

Maximum Effort Takeoff – Flaps 25°: Lift off speed 65 KIAS. Barrier speed 70 KIAS.

The POH advises pilots that:

> *'The performance charts are unfactored and do not make any allowance for varying degrees of pilot proficiency or mechanical deterioration of the aircraft… Effects of conditions not considered on the charts must be evaluated by the pilot, such as the effect of soft or grass runway surface on takeoff…'*

The CAA's General Aviation Safety Sense Leaflet 7c, entitled Aeroplane Performance, provides guidance on performance calculations. Under the heading USE OF PERFORMANCE DATA it states:

> *'a) Many light aeroplanes are…. certificated with UNFACTORED data, being the performance achieved by the manufacturer using a new aeroplane and engine(s) in ideal conditions flown by a highly experienced pilot.'*

> *To ensure a high level of safety on UK Public Transport flights, there is a legal requirement to apply specified safety factors to un-factored data (the result is called Net Performance Data). It is strongly recommended that those same factors be used for private flights in order to take account of:*
>
> - *Your lack of practice*
> - *Incorrect speeds/techniques*
> - *Aeroplane and engine wear and tear*
> - *Less than favourable conditions ……*
>
> ***SAFETY FACTORS***
>
> *a)* ***Take-off***
>
> *It is strongly recommended that the appropriate Public Transport factor, or one corresponding to that requirement, should be applied for all flights. For take-off this factor is x 1.33 and applies to all single engined aeroplanes…'*

The Leaflet contains a table, (Table 1) which gives pilots of aeroplanes, for which there is only unfactored data, guidance on the factors to use in certain conditions. A reminder is given that:

> *'where several factors are relevant, they must be* ***multiplied****. The resulting Take-Off Distance Required to a height of 50 feet, (TODR), can become surprisingly high.'*

CONDITION	*INCREASE IN TAKE -OFF DISTANCE TO HEIGHT 50 FEET*	*FACTOR*
Dry grass - Up to 20 cm (8 in) (on firm soil)*	*20%*	*1.20*
*A 2% slope**	*Uphill 10%*	*1.10*
*Notes: 1. * Effect on Ground Run/ Roll will be greater.*		
NOW USE ADDITIONAL SAFETY FACTORS *(if data is unfactored)*		***1.33***

Table 1

Using the *Maximum Effort Takeoff* charts in the POH, the aircraft's weight of 2,471 lb and the meteorological conditions from the aftercast[2], the following takeoff performance figures were determined for a paved level runway, a grass level runway, a grass runway with a 1.6% upslope, and a grass runway with a 1.6% upslope including the 1.33 safety factor, (Table 2)

Although a 50 foot obstacle height is normally used for takeoff performance planning purposes, in this case the aircraft only needed to clear a hedge at the end of the runway which was approximately 18 to 22 feet high. Therefore, for the purposes of this accident investigation, it was considered useful to calculate the approximate takeoff distance to an obstacle height of 20 feet. The trees that were approximately 30 to 40 feet high were to the south of the runway centreline and would not have posed an obstacle if a straight track had been maintained.

The POH did not provide a method for calculating takeoff distance required to a height of 20 feet, so the geometric method depicted in Figure 5 was used.

The estimated takeoff distances to a height of 20 feet are shown below, together with the 1.2 factor for grass, the 1.08 factor (for the 1.6% upslope), and the 1.33 safety factor, (Table 3).

Analysis

The pilot appears to have had some difficulty during his approach to Runway 33 at Shotteswell Airstrip, veering to the left during the landing. This was probably due to the crosswind from the left, which was gusting beyond the maximum demonstrated for the aircraft. The wind direction also meant that Runway 33 was in the lee of a tall hedge on its left, which would have disrupted the airflow at ground level. The strength of the crosswind

Takeoff Performance	Paved, Level Rwy	Grass, Level Rwy (x 1.2)	Grass, 1.6% up-slope (x 1.08)	Plus Safety Factor (x1.33)
Ground Roll, Flaps Up	213 m	256 m	276 m	367 m
Distance to 50 ft, Flaps Up	335 m	402 m	434 m	577 m
Ground Roll, Flaps 25	183 m	220 m	237 m	315 m
Distance to 50 ft, Flaps 25	244 m	293 m	316 m	421 m

Table 2

Estimated Takeoff Performance	Paved, Level Rwy	Grass, Level Rwy (x 1.2)	Grass, 1.6% up-slope (x 1.08)	Plus Safety Factor (x1.33)
Distance to 20 ft, Flaps Up	262 m	314 m	340 m	452 m
Distance to 20 ft, Flaps 25	207 m	248 m	268 m	357 m

Table 3

Footnote

2 13 kt headwind component using Runway 25; temperature of 18°C; pressure altitude of 710 feet.

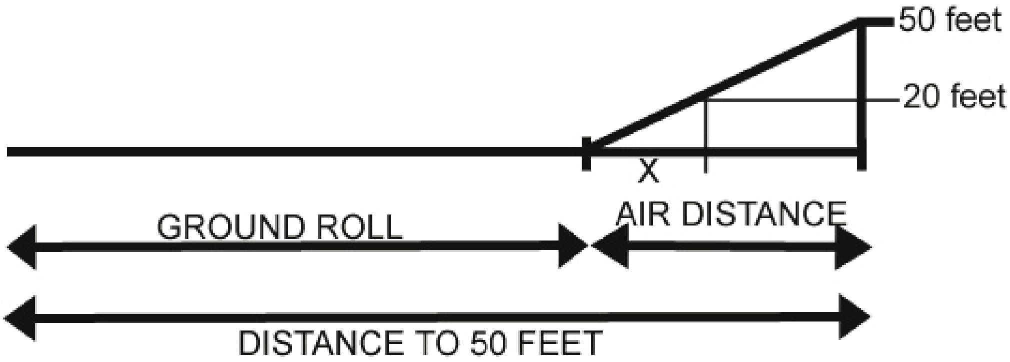


Figure 5

Method used to estimate the takeoff distance to a height of 20 feet[3]

and associated turbulence may have influenced his decision to depart from Runway 25.

The calculated takeoff distance from Runway 25 to a height of 20 feet was 340 metres (flaps up), before applying the 1.33 safety factor. This was 38 metres greater than the 302 metres of runway length available. With the 1.33 safety factor the distance required rose to 452 metres. Had the pilot used flaps 25 then the achievable takeoff distance to a height of 20 feet was 268 metres, before applying the 1.33 safety factor. This was 34 metres less than the runway length available. However, this figure makes no allowance for imperfect pilot technique, aircraft and engine wear, or less than favourable conditions. Therefore, applying the 1.33 safety factor provides a more realistic takeoff performance figure of 357 metres to a height of 20 feet with flaps 25. This was 55 metres more than the runway length available, which indicates that a successful takeoff from this runway was unlikely, even with flaps 25 set. This was, however, less than the 400 metres quoted in the pilot's out-of-date chart from the flight guide that he had used. This excessive figure for the runway length may not have been obvious to the pilot and may have contributed to his decision to depart from the shorter runway. However, the guide's incorrect designation of Runway 25 as Runway 09/27 should have been evident to the pilot from the aircraft's flight instruments when he was lined up for takeoff.

Having lifted off, it appears that the aircraft cleared the hedge at the upwind end of the runway but, in doing so, stalled. The left wing dropped as G-BMDC flew across the road and it struck the trees on the far side, before descending into the field beyond. The left wing tip struck the ground first and the aircraft cartwheeled. During the impact the pilot sustained injuries which, despite prompt attempts by a member of the public and the emergency services, proved fatal.

Footnote

[3] AIR DISTANCE = (DISTANCE TO 50 FEET) – (GROUND ROLL).
X = 20 * (AIR DISTANCE) / 50. The takeoff distance to 20 feet is equal to (GROUND ROLL) + X.

The engineering evidence was consistent with the aircraft having struck trees in a left wing low attitude following a low speed loss of control, resulting in the left wing hitting the ground in a steep left bank and the aircraft cartwheeling to the right. The flap position at impact could not be conclusively ascertained. No evidence of a powerplant fault was found that would explain a loss of performance.

The recommendation in the flight guide entry for the airstrip at Shotteswell warned against an inexperienced pilot and an aircraft of that type from using the east-west runway. Although the pilot had experience of a number of cross country flights in other SEP (Land) aircraft, this was his first solo flight in a PA-32. Landing at an airstrip of that size, in crosswinds gusting beyond the maximum demonstrated for the aircraft, would have represented a considerable challenge for the pilot. Moreover, the aircraft operator did not permit the operation of the aircraft from grass runways. Why the pilot chose to land at this airstrip during his return flight from Dieppe is not known.

CAA General Aviation Safety Sense Leaflets 7c and 12d, entitled *Aeroplane Performance* and *Strip Sense*, respectively, give comprehensive guidance for flying operations from private airstrips.

ACCIDENT

Aircraft Type and Registration:	Socata TB9 Tampico, G-BHOZ
No & Type of Engines:	1 Lycoming O-320-D2A piston engine
Year of Manufacture:	1980
Date & Time (UTC):	13 July 2008 at 0955 hrs
Location:	Shobdon Airfield, Herefordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to right wing skin panel
Commander's Licence:	Private Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	229 hours (of which 55 were on type) Last 90 days - 7 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

As the aircraft taxied along the tarmac Taxiway B parallel to Runway 09, the pilot missed his intended right turn onto the parallel grass Taxiway B. The pilot candidly admits that this was due to a loss of concentration. Distracted by the missed turn, the pilot then failed to see and avoid a plastic safety barrier which had been installed around a hole in the taxiway. The right wingtip of the aircraft struck the barrier, resulting in minor damage to the wing leading edge.

ACCIDENT

Aircraft Type and Registration:	Aeromot AMT-200 Super Ximango, G-BWNY
No & Type of Engines:	1 Rotax 912-A2 piston engine
Year of Manufacture:	1996
Date & Time (UTC):	25 June 2008 at 1000 hrs
Location:	RAF Syerston, Nottinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Propeller blades damaged and possible engine shock-loading
Commander's Licence:	Private Pilot's Licence
Commander's Age:	40 years
Commander's Flying Experience:	1,624 hours (of which 40 were on type) Last 90 days - 15 hours Last 28 days - 10 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

In an effort to avoid rapidly approaching inclement weather, the pilot joined the circuit on the down wind leg but failed to extend the landing gear. In combining the 'circuit joining' checks with the 'down wind leg' checks he omitted the landing gear check and landed with the gear retracted.

History of the flight

The pilot was an experienced motor glider pilot with over 40 hours on type and was conducting a local flight in the vicinity of the airfield. As the flight progressed he noted the rapid approach of a heavy rain shower and became concerned that this would separate him from the airfield. The pilot elected to cut the flight short and returned to the airfield, joining the circuit for the grass Runway 25 on the down wind leg, but omitted to extend the landing gear. He then combined the 'circuit joining' checks with the 'down wind leg' checks and in doing so missed the landing gear check, which would normally have been part of his down wind leg routine. As the pilot extended the airbrakes prior to landing, the configuration warning buzzer sounded to signal that the gear had not been extended. However, the pilot was wearing a noise-attenuating headset and did not hear the warning. He continued the approach and landed with the gear retracted, resulting in damage to the aircraft's propeller blades.

Discussion

In cutting short the flight, joining the circuit on the down wind leg and combining the ‘circuit joining’ checks with the ‘down wind leg’ checks, the pilot deviated from his anticipated approach and landing and thus had a higher than normal workload. This is a typical scenario in which human factors issues, such as missed tasks and checks, can become prevalent. The use of a noise-attenuating headset, which reduced or removed the ability of the pilot to hear the configuration warning buzzer, was also a contributory factor. The manufacturer provides a caution in the owner’s guide, to advise pilots to ensure that aircraft warning alarms can still be heard when using the headset. The pilot in this accident has elected to modify the aircraft, so that the configuration warning buzzer is now transmitted through the intercom.

ACCIDENT

Aircraft Type and Registration:	CFM-Metal Fax Shadow Series BD, G-MTTH
No & Type of Engines:	1 Rotax 447 piston engine
Year of Manufacture:	1988
Date & Time (UTC):	20 May 2008 at 1915 hrs
Location:	Bucknall Airfield, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Tail boom distorted
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	380 hours (of which 100 were on type) Last 90 days - 30 hours Last 28 days - 28 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft made what the pilot considered to be a "correct approach" to the grass Runway 09 at Bucknall Airfield. He described the visibility as good and estimated that the wind was easterly at 8 kt. Shortly before touchdown the aircraft dropped unexpectedly to the ground from a height of approximately 10 ft, resulting in a heavy landing which distorted the tail boom.

The pilot considered that the unexpected descent was caused by disturbance of the air as it passed over a clump of trees near the start of the runway. The circumstances are similar to those reported in AAIB Bulletins 9/2004 and 6/2000 in which aircraft of related type, G-BRZZ and G-BUVX respectively, suffered comparable damage.

BULLETIN CORRECTION

AAIB File:	**EW/G2008/05/25**
Aircraft Type and Registration:	Piper PA-22-160 Tri-Pacer, G-ARDT
Date & Time (UTC):	18 May 2008 at 1230 hrs
Location:	Northside, 5 miles SW of Aberdeen
Information Source:	Aircraft Accident Report Form

AAIB Bulletin No 8/2008, page 111 refers

In describing the landing strip at Northside, the AAIB report on the accident stated that:

> 'The centre and southern portions of the strip sloped upwards towards the south at an angle of about 25° to the horizontal.'

It should have stated that the centre and southern portions of the strip sloped upwards towards the south at an angle of about **6°** to the horizontal.

BULLETIN CORRECTION

AAIB File:	**EW/C2008/04/06**
Aircraft Type and Registration:	Turbolet Let L 410 UVP-E, OK-RDA
Date & Time (UTC):	28 April 2008 at 1003 hrs
Location:	En route from Belfast City to Ronaldsway, Isle of Man
Information Source:	Aircraft Accident Report Form

AAIB Bulletin No 9/2008, page 10 refers

Under the paragraph 'Securing of baggage door', the first sentence incorrectly stated that the report was from the Hungarian aircraft accident investigation authorities instead of the Czech.

The sentence should therefore read:

> 'A report from the **Czech** aircraft accident investigation authorities…'

FORMAL AIRCRAFT ACCIDENT REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

2007

4/2007 Airbus A340-642, G-VATL
en-route from Hong Kong to London Heathrow
on 8 February 2005.

Published September 2007.

5/2007 Airbus A321-231, G-MEDG
during an approach to Khartoum Airport, Sudan
on 11 March 2005.

Published December 2007.

6/2007 Airbus A320-211, JY-JAR
at Leeds Bradford Airport
on 18 May 2005.

Published December 2007.

7/2007 Airbus A310-304, F-OJHI
on approach to Birmingham International Airport
on 23 February 2006.

Published December 2007.

2008

1/2008 Bombardier CL600-2B16 Challenger 604, VP-BJM
8 nm west of Midhurst VOR, West Sussex
on 11 November 2005

Published January 2008.

2/2008 Airbus A319-131, G-EUOB
during the climb after departure from London Heathrow Airport
on 22 October 2005

Published January 2008.

3/2008 British Aerospace Jetstream 3202, G-BUVC
at Wick Aerodrome, Caithness, Scotland
on 3 October 2006.

Published February 2008.

4/2008 Airbus A320-214, G-BXKD
at Runway 09, Bristol Airport
on 15 November 2006.

Published February 2008.

5/2008 Boeing 737-300, OO-TND
at Nottingham East Midlands Airport
on 15 June 2006.

Published April 2008.

6/2008 Hawker Siddeley HS 748 Series 2A, G-BVOV
at Guernsey Airport, Channel Islands
on 8 March 2006.

Published August 2008.

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