ACCIDENT

Aircraft Type and Registration:	P&M Aviation Ltd Flight Design CTSW, G-VINH
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2006
Date & Time (UTC):	12 August 2009 at 1550 hrs
Location:	Caird Park Golf Course, Dundee
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	136 hours (of which most were on type)[1] Last 90 days - 20 hours Last 28 days - 13 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot made a forced landing in a tree after the engine stopped near Dundee. The investigation identified flight planning as a contributory factor. One Safety Recommendation is made.

History of the flight

The pilot planned to fly from Barrow (Walney Island) Airfield to Kinloss, a distance of 212 nm. During a pre-flight check, he judged that the left and right tanks contained 25 litres and 15 litres of fuel, respectively. He calculated a maximum flying time of 3 hr 20 mins based on a fuel consumption of 12 litres per hour, which he had assessed as the "long-term average" for this aircraft. In his planning he considered Dundee Airport as an alternate.

The aircraft began taxiing at 1346 hrs and took off at 1352 hrs, climbing initially to an altitude of between 1,600 ft and 2,000 ft. At 1425 hrs the aircraft commenced a further climb to 7,500 ft. This took 10 minutes and the pilot used "80% power". At 1435 hrs the aircraft made a further climb to 8,700 ft. During this climb the aircraft entered Class A airspace at FL85 over Eskdalemuir, exiting into Class D airspace as it crossed into the Scottish TMA approximately 10 nm further north (see Figure 1).

Footnote

[1] The pilot was not able to reconstruct a complete record of his flying experience

Figure 1

The aircraft's GPS track

At 1440 hrs the pilot contacted the Scottish Area Control Centre (SACC), advising his intended route and his wish to climb to 9,000 ft to remain clear of cloud. The controller cleared the aircraft on track to Kinloss and asked the pilot to advise her before making any "big turns" because the aircraft was in the "TMA environment" and potentially in conflict with aircraft under her control bound for Edinburgh.

As the aircraft approached the lateral limits of the Edinburgh Control Area (CTA)[2] from the south, the pilot requested and was cleared to make a further climb to 10,000 ft in order to remain clear of cloud. Five minutes later the pilot reported 'CLOUD AHEAD THE BASE LOOKS QUITE HIGH COULD I HAVE PERMISSION TO DESCEND 5,000 FT SAME HEADING'. Initially, SACC cleared the aircraft to FL70, due to traffic in the CTA, and instructed the pilot to contact Edinburgh Radar. The pilot read back the correct frequency but had not made contact with Edinburgh ATC before the aircraft entered the CTA. It exited the CTA northbound at an altitude of approximately 4,500 ft and continued to descend to 2,000 ft.

Later, as the aircraft crossed the Firth of Tay, having climbed again to a height of approximately 4,500 ft, the pilot noted that the right wing fuel tank was empty and that only 10 litres remained in the left tank. Judging that he had insufficient fuel to continue the flight he turned the aircraft south towards Dundee Airport, where he was instructed to join for Runway 27 via the reporting point at Broughty Castle. He stated that at that point there was at least 5 litres of fuel remaining in the left tank. At 1548 hrs the pilot advised Dundee ATC that the aircraft had run out of fuel.

Footnote

2 The Edinburgh CTA is a column of airspace 40 nm in diameter centred on Edinburgh Airport and extending from the surface to an altitude of 6,000 ft. It lies within the Scottish TMA and is classified as Class D airspace.

The aircraft was now heading south-east over fields on the northern edge of Dundee, approximately 2 nm northeast of the airport. The pilot judged that he would be unable to land clear of the built up area on his present track and turned north in an attempt to find more open ground. He reported that initially the most favourable landing area appeared to be nearby playing fields but, noticing that these were occupied by children, he turned towards an adjacent golf course. However, the fairways also appeared congested, so the pilot decided to land in a tree. The impact resulted in substantial damage to the aircraft, which remained in the tree.

The pilot, who sustained minor injuries, was removed from the aircraft with the assistance of the emergency services and taken to hospital.

Flight in controlled airspace

The pilot held a National Private Pilot's Licence which does not permit flight under instrument flight rules and therefore does not permit flight in Class A airspace. There is no record of the pilot holding a valid flight radio telephony operator's licence at the time of the flight.

Flight in Class D airspace requires a clearance either via radio telephony or by prior arrangement. The commander of an aircraft flying in an aerodrome traffic zone is required to obtain permission to do so from the associated ATC unit and to maintain a continuous watch for instructions (though not necessarily by radio[3]). The Edinburgh ATC unit reported entry of the aircraft into the CTA without clearance as an infringement.

Footnote

3 Rule 45 of the rules of the air, Schedule 1 Section 7 of Civil Aviation Publication (CAP) 393 – *'The Air Navigation Order'* refers.

Recorded information

An AvMap EKP-IV GPS unit and a Bräuniger Alpha multi-function display (MFD) were recovered from the crash site; both contained recorded data for the accident flight.

AvMap EKP-IV GPS

The GPS unit had a complete log of the accident flight starting at 1346:03 hrs at Walney Airfield, Barrow-on-Furness, and ending at 1548:31 hrs at the Caird Park golf course, Dundee. The recorded track included altitude information and is presented at Figure 1. The highest altitude the aircraft reached was 9,935 ft amsl, at 1504:24 hrs, when it was approximately 15 nm south of Edinburgh.

Altitude and groundspeed, averaged between consecutive points, are plotted in Figure 2. This shows a descent from 9,935 ft to 1,663 ft amsl, as the aircraft crossed the A91 north of Glenrothes, before it climbed again.

The final descent was at a rate of approximately 900 ft/min, reducing to 600 ft/min as the aircraft flew a descending turn, clockwise, through 270° (see Figure 3) The aircraft continued descending at about this rate until the final recorded GPS position, which placed the aircraft at 340 ft amsl (110 ft agl), close to the accident site.

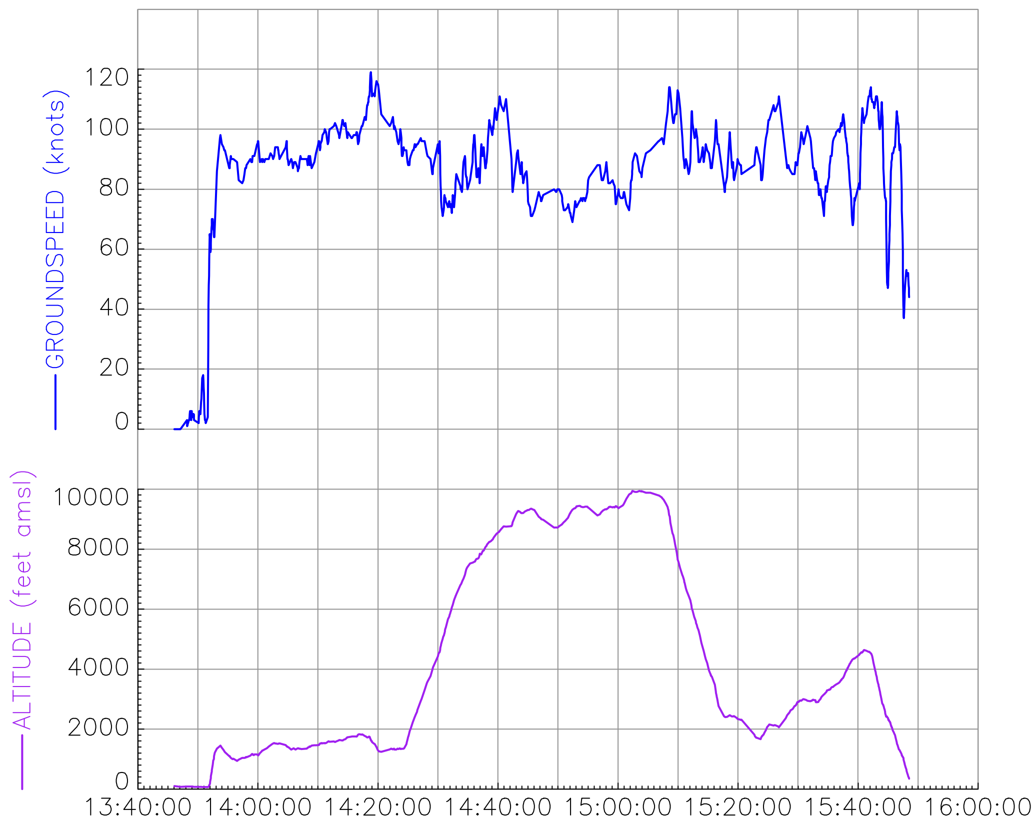


Figure 2

The aircraft's altitude and groundspeed

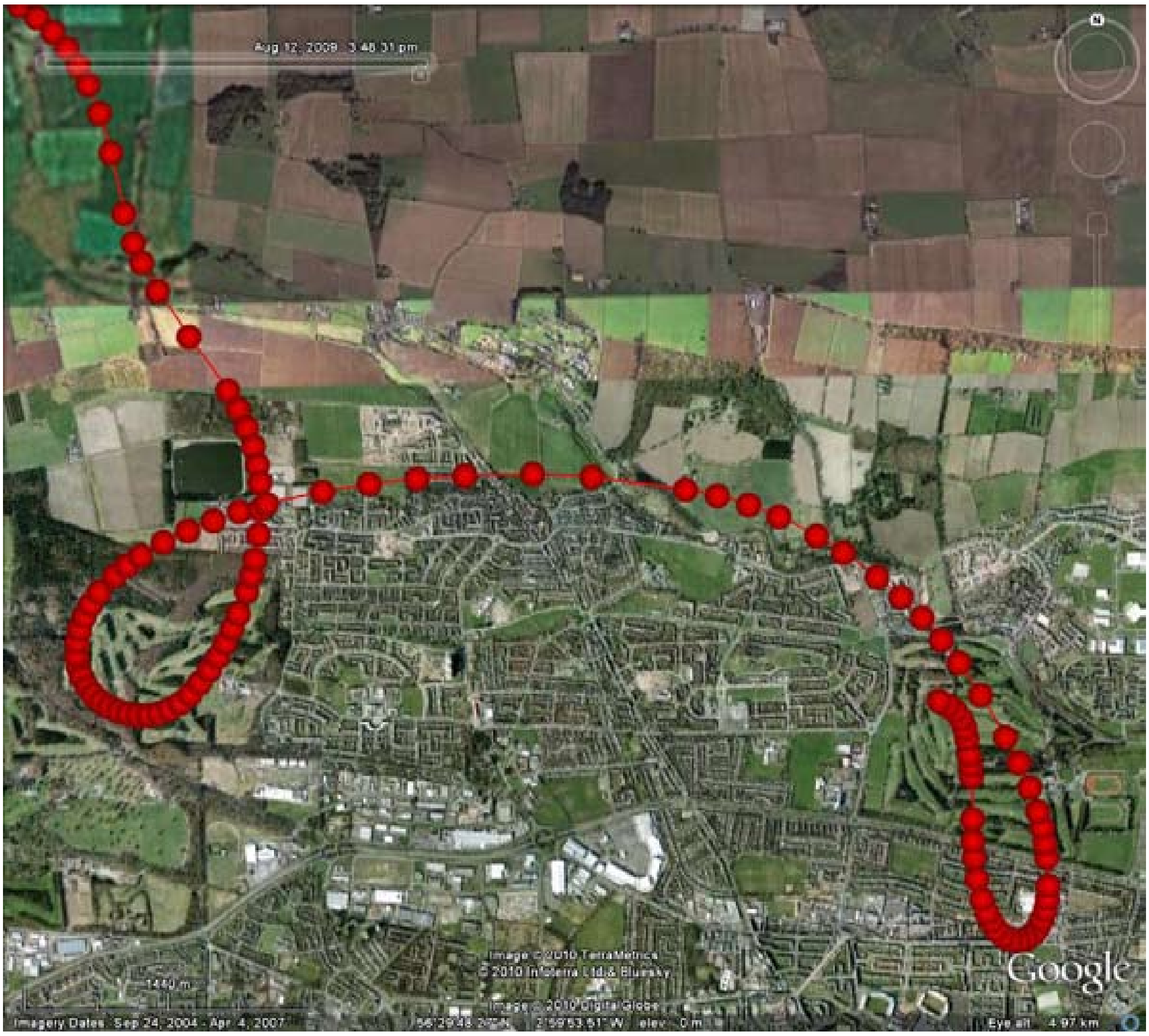


Figure 3

Image of the aircraft's GPS track just prior to the accident

Bräuniger Alpha MFD

This unit consisted of a multi-function display instrument pod with a memory module that recorded a number of engine parameters for the accident flight and the preceding 23 flights. The unit did not provide a continuous record for the duration of each flight but recorded maximum values, which highlighted any exceedences. In general, these were of little value, as no calibration data or limits were provided. However, it was apparent from the downloaded data that the maximum altitude achieved during the accident flight was 10,013 ft (at 1013mb), the maximum indicated airspeed was 120 kts, the takeoff (at the point where 50 km/hr was exceeded) was at 1350 hrs, with flight time and engine running time being 1hr 57 mins and 2 hrs 4 mins, respectively. There were two exhaust gas temperature records, EGT 1 and EGT 2, with recorded maxima of 113°C and 804°C. In addition, there were two cylinder head temperatures, CHT 1 and CHT 2 which were reported as "not measured". Reference to the engine manufacturer's Installation Manual revealed that the nominal EGT is 800°C, with a maximum of 850°C (880°C at take off power). Maximum CHT is specified as 135°C.

The disparate values of EGT1 and EGT2, together with the absence of any CHT record, suggested that there may have been a wiring fault associated with the instrument pod and memory module. The numerical values indicated that a representative CHT value (113°C) may have been recorded into the EGT1 data location. The EGT2 value of 804°C compared favourably with the specified maximum of 850°C.

Flight planning

The pilot stated that during flight planning he assumed an average fuel consumption of 12 litres per hour, based on records of previous flights. In its own literature, the aircraft manufacturer states that fuel consumption of the 912 ULS engine in this installation is 18.5 litres per hour at 75% cruise power and 25 litres per hour at maximum continuous power (5,500 rpm). The same document states that the cruise speed at 75% power is 112 kt.

The manufacturer indicated that lower fuel consumption can be achieved at lower power settings, which will result in lower cruise speeds. The *'Performance & engine data'* section of the CTSW Operators Manual states that cruising fuel consumption ranges from 10 to 14 litres per hour. It concludes with the warning:

> *'Fuel consumption figures are guide figures only. Always fly with a minimum of 1 hours reserve fuel.'*

Kinloss is 212 nm from Barrow on a bearing of 357°(M).

Meteorological information

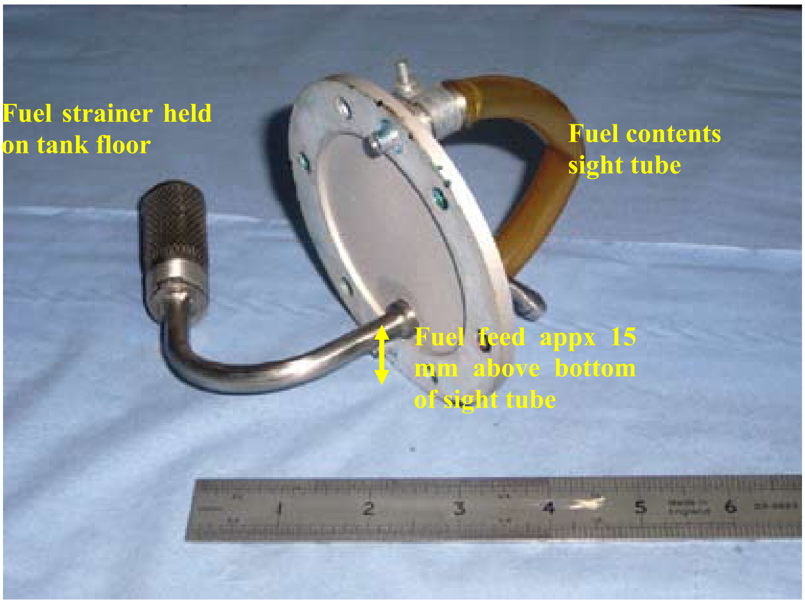
Forecasts available to the pilot for flight planning purposes indicated average winds along the route of 25 kt from 280°(T) at 2,000 ft, increasing to 35 kt from 300°(T) at 10,000 ft. This suggests an average headwind component of approximately 11 kt on the direct track between Barrow and Kinloss.

Aircraft and fuel system description

Type approval for this aircraft in the United Kingdom was obtained by P&M Aviation, who submitted the design to the UK CAA against British Civil Aircraft Requirements (BCARs) Section 'S', although parts of the Joint Airworthiness Requirements - Very Light Aircraft (JAR-VLA) were also used. Certification in other countries was achieved using various design codes. P&M are responsible for modifications on aircraft with UK Permits to Fly, with Flight Design retaining overall control of the design. The relevant BCAR for unusable fuel is specified in paragraph S959 as follows:

> *'The unusable fuel quantity for each tank must be established as not less than that quantity at which the first evidence of malfunctioning occurs under the most adverse fuel feed conditions occurring during take-off, climb, approach and landing involving that tank. It shall not be greater than 5% of the tank's capacity.'*

The CTSW is a high-wing aircraft equipped with integral wing tanks, with the fuel stored in the volume ahead of the main spar. Each 65 litre capacity tank extends from the wing root to approximately mid span. A circular plug in each root rib incorporates a fuel contents sight tube and the fuel off-take tube (see photographs at Figure 4). The latter comprises an inlet strainer assembly attached to a short length of rigid tube that serves to hold the inlet strainer close to the fuel tank floor at the aft inboard corner. The wings have a 1.5° dihedral angle, which, in balanced flight, would assist in keeping the fuel towards the inboard ends of the tanks. Each tank contains a single baffle located approximately 0.45 m from the wing root; its purpose is to limit the span-wise fuel surge that occurs



Fuel off-take tube

View of left tank fuel contents sight tube and gauge

Figure 4

Views of fuel tank off-take, fuel contents sight tube and gauge

as a result of aircraft motion. The baffle is essentially an internal rib, but with a series of small holes drilled close to the tank floor, which, in conjunction with narrow slots around the edges, allow the passage of fuel. The outlets of the left and right tanks are joined together in the fuselage, immediately upstream of a simple ON/OFF fuel selector. Thus, an ON selection will result in fuel being drawn simultaneously from both tanks. Although the high-wing configuration provides a gravity feed system, the aircraft is additionally equipped with an engine driven fuel pump.

There is no sump or depression in the tank that would tend to keep the end of the fuel off-take tube immersed in fuel; neither is there a weir, nor a flap valve within the baffle, that would assist in maintaining a quantity of fuel within the inboard section of the tank.

The CTSW was developed from the CT2K, which has an identical fuel system, although UK registered aircraft were originally required by the CAA to have the fuel selectable from either the left or right tank only, not both. In July 2007, following a number of engine failure incidents, the manufacturer issued Service Bulletin (SB) CT125, which incorporated Modification No M186. This was mandated by the CAA. The SB modified the fuel system so that the left and right tanks were interconnected and fuel was fed from both tanks simultaneously, in the same manner as foreign registered CT2Ks and the CTSW. Information in the SB noted that:

> *'after the modification, the fuel should feed reasonably evenly from both tanks. Imbalance in flight can be corrected by flying with a little sideslip for a while.'*

Additional guidance material included the caution that:

> *'The aircraft should be parked wings reasonably level, otherwise the fuel will cross feed to the low tank and may be lost through the tank vent.'*

The latest development of the CT family is the CTSL, of which there are none currently on the UK register. The manufacturer stated that although the fuel system is essentially the same as for earlier variants, the fuel tank baffles incorporate flap valves.

Examination of the aircraft

Agents acting for the insurance company that recovered the aircraft reported that the right fuel tank was intact but empty, with "several pints" pouring out of the left tank during the recovery. The pilot subsequently supplied photographs of the site that were taken several days after the accident; these showed characteristic staining of the vegetation on and around the tree in which the aircraft had come to rest. It was impossible to assess the quantity of fuel required to cause the observed staining; however, it was considered to be broadly consistent with the pilot's observation of approximately 5 litres in the left tank shortly before the engine lost power.

The aircraft wreckage was taken to the AAIB's facility at Farnborough for examination. The fuel lines were found free from obstructions and there was no evidence of pre-impact engine component failure. An internal inspection of the cylinders revealed them to be in good condition, with no evidence of lubrication failure. A small quantity of fuel, approximately 1 cc, was found in the float chamber of one of the detached carburettors. This was analysed and found to conform to the specification of motor gasoline containing 4% ethanol.

In view of the circumstances of the accident, while focussing on the fuel system, the investigation paid particular attention to the tank installation. A simple test was conducted on one of the tanks.

Fuel tank tests

The right wing of the aircraft, which had remained relatively intact following the accident, was placed on trestles at an approximate zero angle of incidence and 1° dihedral. Having ensured that the tank was completely empty, water was then introduced, one litre at a time. After 5 litres had been added, a few drops were seen to emerge from the fuel feed tube, with the water level just visible at the bottom of the sight tube. A sustained flow could be achieved only when the wing tip was raised to an angle of around 8°, at which point the water level was almost halfway up the sight tube. The late onset of flow was attributed to the fact that, with reference to Figure 4, the fuel feed tube is positioned approximately 15 mm above the sight tube lower fixture, meaning that the fuel had a small gradient to climb from the inlet strainer assembly in the bottom of the tank. Once a siphon was established, flow could be maintained at lower dihedral angles and continued to the point at which the inlet strainer in the tank became uncovered. At this point slightly more than 0.5 litre remained in the tank.

Similar tests conducted by the aircraft manufacturer indicated that, with the aircraft on level ground at zero angle of incidence (cruise attitude), fuel feed continued until 0.5 litres remained in the tank, which represented the unusable fuel. This equated to 0.7% of the tank volume of 65 litres, compared with the 'not more than 5% of the tank volume' requirement in BCAR S959. However, when the test was repeated with the aircraft at a 1º nose-down attitude with a 2º adverse sideslip, the unusable fuel was found to be 3.6 litres, although it should be noted that S959 does not cover continuous sideslip.

The manufacturer also described an airborne test in which an aircraft was flown until the engine became starved of fuel, before gliding to a landing. Measurement of the remaining fuel showed that the unusable quantity was very small. Additional tests were conducted, with the aircraft on the ground, in which the engine was run from a small quantity of fuel in one tank, the aircraft tilted so that the fuel off-take was uncovered, following which the engine stopped. After tilting the aircraft back to a level attitude, it was possible to restart the engine; this showed that the engine driven pump was effective in assisting to restore the siphon. The manufacture now requires a production test in which the restart time must be less than 60 seconds.

Discussion

Operational issues

Flight planning

The pilot estimated that the aircraft's maximum endurance without reserves was 3 hours 20 minutes, based on his assessment of average fuel consumption. The corresponding estimate based on the aircraft manufacturer's literature was 2 hours 9 mins. The flight time from Barrow to Kinloss would have been 1 hour 53 mins in still air, at the manufacturer's stated cruise speed of 112 kt, or 2 hours 6 mins allowing for the forecast headwind component of approximately 11 kt. The average ground speed was in fact approximately 90 kt, at which the flight to Kinloss would have taken 2 hours 21 mins.

The accident flight time of 1 hour and 57 mins was preceded by 6 minutes of ground running and included at least 10 minutes in the climb. There is no record of the actual power setting used during each phase of the flight. On previous flights, during which the aircraft cruised at or below 3,000 ft, the peak recorded engine speed was approximately 4,800 rpm, which corresponds to 75% cruise power, whereas on the accident flight the peak recorded engine speed was 5,180 rpm. This suggests that power settings greater than 75% were used on this flight. Also, the pilot stated that the climb to 7,000 ft was conducted at "80% power". It follows that actual average fuel consumption was greater than cruise consumption because the extra fuel used during the climb would not be entirely offset by any reduction in power during the subsequent descents. The average fuel consumption assumed by the pilot was insufficient to account for operational realities.

Safety Sense Leaflet 1 – *'Good airmanship guide'*, published by the CAA, provides guidance on flight planning. It states, in part:

'Always plan to land by the time the tank(s) are down to the greater of ¼ tank or 45 minutes cruise flight, but don't rely solely on gauge(s) which may be unreliable. Remember, headwinds may be stronger than forecast and frequent use of carb heat will reduce range.'

And,

'Don't assume you can achieve the Handbook/Manual fuel consumption. As a rule of thumb, due to service and wear, expect to use 20% more fuel than the "book" figures.'

Flight in controlled airspace

Infringement of controlled airspace and flight within the Edinburgh ATZ without permission did not directly affect the outcome.

Engineering issues

The pilot reported that, shortly before the engine lost power, he had observed zero fuel indication in the right tank and approximately 5 litres in the left. It is apparent from Figure 4 that the 5 litres represents a low value, and it is noteworthy that it is written in red on the adjacent fuel contents scale. In addition, the location of the sight tube relative to the scale would be prone to parallax error. However, any such error is likely to be insignificant compared with the inherent inaccuracy arising from the tank geometry, the width to length ratio of which could give rise to considerable span-wise movement of fuel in response to lateral accelerations. Thus an accurate reading, or at least one with the least amount of error, would only be achieved with the aircraft in a level attitude and in balanced flight in smooth conditions.

In a fuel system such as this, where the fuel tanks are interconnected, there will be a tendency for fuel to transfer from one tank to another in the event that the aircraft is flown out of balance, ie in a condition of sideslip. This could be exacerbated by any difference in the fuel feed rates between the two tanks. In such a situation, the pilot is advised by the manufacturer to correct any imbalance by flying with an amount of sideslip for a period.

As the fuel quantity reduces, any sideslip in excess of the 1.5° dihedral would result in significant outboard migration of fuel in the lower wing, although this would be compensated by inboard fuel movement in the opposite wing. There could come a point, if this state continued, where the fuel off-take in one tank would be uncovered, thus breaking the siphon, although fuel feed to the engine should be maintained from the opposite side. A situation could thus arise whereby the fuel flow in one tank would be interrupted, with an attendant possibility of air being drawn into the system. A similar situation could result from a nose-down aircraft attitude, since this would cause the fuel to move forward, away from the fuel off-take.

Conclusions

The reported circumstances of the accident indicate that the engine became starved of fuel. The nature of the tank design is not conducive to accurate gauging, with any sustained sideslip or nose-down attitude effectively generating quantities of unusable fuel in excess of the 0.5 litres stated by the aircraft manufacturer. In fact the manufacturer's own tests, conducted with the aircraft on the ground, indicated a significant increase in the unusable fuel quantity when the aircraft attitude changed from the straight and level. The manufacturer additionally noted that it was possible to restart the engine following temporary fuel starvation; however, this might not be a practical procedure for pilots in the course of a normal flight and, moreover, would not comply with BCAR S959, which refers to the **first** evidence of malfunctioning. The BCAR allows up to 5% of the tank volume to be unusable, which equates to 3.25 litres. This would seem to represent a more realistic figure in actual flying conditions, despite the manufacturer having conducted flight tests in which lower quantities were demonstrated.

On this flight, the headwind and vertical profile resulted in it taking longer than planned. Nevertheless, during the latter stages the pilot was convinced, from the indication of left fuel tank contents, that he was not about to run out of fuel.

Safety Recommendation 2010-045

It is recommended that Flight Design GmbH, together with P&M Aviation, revise their assessment of the unusable fuel in the CTSW aircraft.

Additional safety action

Following this accident, P&M Aviation declared their intention to publish a Service Letter which will explain the effects of aircraft attitude and turbulence on fuel feed at low fuel levels. In addition, it will point out that the minimum quantity that the fuel sight gauge will indicate is 3 litres. Finally, a placard will be required to be fitted to the aircraft advising the pilot that he or she must ensure that at least 1 cm of fuel is visible on both fuel contents sight gauges at all times.