# Piper PA-34-220T, G-OMAR

| | | |
|---|---|---|
| **AAIB Bulletin No: 9/2001** | **Ref: EW/G2001/4/1** | **Category: 1.1** |

| | |
|---|---|
| **Aircraft Type and Registration:** | Piper PA-34-220T, G-OMAR |
| **No & Type of Engines:** | 2 Continental TSIO-360-KB piston engines |
| **Year of Manufacture:** | 1982 |
| **Date & Time (UTC):** | 2 April 2001 at 1355 hrs |
| **Location:** | Shoreham by Sea, West Sussex |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 - Passengers - None |
| **Injuries:** | Crew 1 minor - Passengers - None |
| **Nature of Damage:** | Aircraft destroyed |
| **Commander's Licence:** | Private Pilots Licence |
| **Commanders Age** | 52 years |
| **Commander's Flying Experience:** | 287 of which- |
| | Last 90 days- |
| | Last 28 days 1 hour 35 minutes |
| **Information Source:** | AAIB Field Investigation |

## Flight planning

The pilot planned a return flight from Shoreham, West Sussex to Sheffield City Airport, Yorkshire, departing from Shoreham at 1000 hrs and returning at about 1500 hrs after 2 to 3 hours on the ground in Sheffield. The route was planned from Shoreham via Woodley non-directional beacon and Netherthorpe airfield to Sheffield and returning from Sheffield direct to Woodley and thence to Shoreham. The outbound leg was planned at 2,000 feet and the return leg at 3,500 feet.

The forecast weather for the route was fine. A weak cold front located in the Irish Sea was forecast to move eastwards during the day, but conditions at Shoreham and Sheffield were expected to remain fine until late afternoon. The wind at the selected cruise levels was generally south to south westerly at 20 to 35 kt with the stronger winds to the north.

The pilot arrived at Shoreham in good time and the Chief Pilot of the aircraft operating company authorised the flight. To avoid the requirement to uplift fuel at Sheffield, the pilot planned to carry sufficient fuel for the return flight. The pilot completed the technical log and indicated that he planned to uplift 30 US gallons of fuel (15 US gallons in each wing tank) giving a total fuel on board of 60 US gallons. After completing his walk around check, which included a check of the fuel drains, the pilot started the aircraft and taxied to the refuelling pumps. The refueller recalled that the pilot initially mentioned that he needed '15 gallons' but that he quickly realised that the fuel pumps delivered in litres, and he used his circular slide rule to calculate the required quantity in litres. Having completed the calculation, the pilot asked the refueller to put 45 litres (12 US gallons) of fuel in each wing. After refuelling the pilot noted that the fuel gauges indicated 'full' on the left and 'three quarters full' on the right.

**History of the flight**

The flight to Sheffield was uneventful with an airborne time of 1 hour 2 minutes and a block time (start of taxi at Shoreham to end of taxi at destination) of 1 hour and 5 minutes. On departure from Sheffield the pilot completed a further walk-round check and again checked the fuel drains. The flight departed from Sheffield on the return journey at 1242 hrs, after about 2hrs and 40 minutes on the ground.

On the return flight, Shoreham ATC cleared the aircraft for an overhead join at 2,000 feet for Runway 21. As the aircraft passed through the Shoreham overhead, the pilot began a shallow left turn and started to carry out the Pre-Landing checks. As he did so he noted that the fuel gauges indicated 'half full' for the left wing tanks and a 'quarter full' for the right tanks. As part of the checks, the pilot advanced the propeller control levers toward the FULLY FINE position, and immediately the aircraft yawed and rolled rapidly to the left and the pilot noticed that the left engine manifold pressure had reduced to 15 inches. The pilot instinctively returned the left propeller control lever to the cruise position and the left engine seemed to recover power. The pilot informed Shoreham ATC of the problem with the left engine and was cleared for a wide left-hand circuit for Runway 21.

Shortly thereafter the pilot placed both propeller control levers back in the FULLY FINE position and almost immediately the left engine failed completely. The pilot attempted to restart the left engine using the normal electric starter but nothing happened and, during the course of the restart attempt, the right engine also failed.

As the aircraft began a glide descent the pilot made a further attempt to restart the left engine with the left engine fuel lever to CROSSFEED but again without success. The pilot informed ATC of the total loss of power and was cleared to land on grass Runway 25 which was the nearest runway. By this stage the aircraft had descended to about 900 feet with both propellers windmilling and the landing gear and flap retracted. The pilot returned the fuel selector controls to NORMAL and attempted a further restart on the right engine but still without success. In the limited time available the pilot was unable to refer to the emergency checklist during the restart attempts and he cannot recall whether he selected the AUX fuel pump to HI in accordance with the checklist.

Now at about 400 feet and pointing directly at the airfield, the pilot realised that he would be unable to glide to the runway and he began looking for a suitable place to land. Noticing a narrow strip of grass between a railway line and the end of several rows of houses the pilot aimed for this area and lowered the landing gear. As he approached the grass area the pilot flared the aircraft but the left wing struck the roof of a house and the right wing and tailplane struck an adjacent tree. The roof collapsed absorbing much of the aircraft's forward speed and the aircraft yawed left and slid into the rear garden of the house largely intact. The pilot suffered head injuries but was able to exit the aircraft unassisted. He later returned to the cockpit to switch off the aircraft electrical systems.

Both the pilot and a firemen who reached the scene a matter of minutes after the impact, recalled seeing fuel seeping from damage to the right wing, but none of the eyewitnesses were able to recall seeing or smelling fuel in the area of the severely damaged left wing.

The elapsed time from the pilot reporting problems with the left engine to ground impact was about 1 minute 15 seconds and the pilot reported that both engines had suffered power loss about 35 seconds after reporting the initial problem with the left engine. The total flight time from Sheffield was one hour and 11 minutes.

**On-site and subsequent examination**

Having struck the house roof the aircraft yawed left through some 40° before coming to rest in the back garden of the house. A roof timber had penetrated the nose of the aircraft, coming to rest inside the cabin against the right seat. The left wing, outboard of the engine, was almost detached. The right wing was still attached, but the inboard section of the right wing fuel tank had been ruptured by an impact with a low concrete wall. There was little evidence of fuel at the site; some fuel had drained from the right wing down the wall, destroying a small amount of vegetation beneath. There was no evidence of fuel from the left wing.

There was evidence that the propeller blades were rotating at impact, although the lack of damage to the blades indicated a low speed. The blades were in a fine pitch position and had not been feathered. The flaps were retracted, and the landing gear selector in the cockpit was in the DOWN position. The main landing gear was down and locked, the nose landing gear was still in transit.

A small amount of fuel was obtained from the fuel drains located at the base of the fuel filter on each engine on site. Subsequent disassembly of the fuel filters yielded approximately a further 0.25 litres of fuel which represented their capacity. Examination of both the engines, which could still be rotated, revealed no mechanical failures.

**Fuel System**

Fuel is stored in this type of aircraft in two wing tanks. Each wing tank has an inboard and outboard tank and this particular aircraft had an additional 'bladder' fuel cell fitted between the two main tanks. Each wing tank is filled via a single refuelling point located on the top of the outboard tank and fuel is fed by gravity from the outboard tanks to the inboard tanks and thence to the engines. The total fuel capacity is 128 US gallons, with 5 US gallons unusable.

There are three fuel drains on each wing, one at the bottom of the outboard tank, one at the bottom of the inboard tank, and one located on a pipe at the base of the fuel filter. There are two additional fuel drains located at the fuel selector controls beneath the fuselage. The interconnecting pipes between the outboard and inboard tanks are not flush with the bottom of the tank and unusable fuel tends to pool at the bottom tanks below the fuel outlets. The design is such that it is possible to obtain a fuel sample by operating the fuel drains when only unusable fuel is present.

Fuel is fed from the inboard tank to the selector valve, and each engine can be supplied from its 'own' fuel tank (NORMAL), or from the opposite wing tank (CROSSFEED). Selection of the fuel supply is made via the controls located between the two pilot seats, both were found in the OFF position after the accident. Subsequent enquiries revealed that the selectors were originally found in the ON position and had been positioned to OFF by the emergency services. The left engine fuel selector valve was found selected to the left tank; damage to the left wing would have meant that an OFF selection after impact would not have moved the position of the valve itself. The right engine selector valve was found in the OFF position.

From the selector valve fuel is fed via the fuel filter to a fuel metering unit. Fuel enters the filter via the inlet fuel line at the top, filling the filter bowl, is drawn through screens and is taken out again through the top of the unit. It is therefore possible for the bowl itself to be full of fuel, but no fuel being supplied to the engine if no fuel supply is present. No debris was found in the filter bowl.

Each engine has an engine-driven fuel pump (EDP) and an electrically powered auxiliary pump downstream of the fuel filter which supplies fuel in the case of EDP failure and also for in-flight starting and vapour suppression. The AUX fuel pumps have three selections, LO, HI and OFF. In the case of an EDP failure, HI AUX fuel pressure should be selected, LO is used on the ground or inflight for vapour suppression as necessary. This aircraft was equipped with a separate primer system as part of the engine fuel system. Primer button switches are used for normal engine starting and select HI auxiliary fuel pump operation regardless of other switch settings. They are spring loaded to OFF. The Aircraft Flight Manual (AFM) states that if an attempt is made to restart a failed engine before the propeller has been feathered, the AUX fuel pump should be placed to the HI position. If power is not immediately restored the AUX pump should be turned to OFF.

**Maintenance details**

The aircraft had been flown to a maintenance facility at Redhill on 26 March 2001 where a '50 hour' check was carried out. This was the second such check on this aircraft since remanufactured engines had been fitted. Work was also carried out to adjust the engine fuel injection system in order to correct differences in the throttle/propeller lever positions between the two engines. A number of engine runs were performed. The aircraft had flown approximately four hours since this maintenance activity and prior to the accident flight.

**Fuel planning**

The evening before the flight the pilot had carried out his navigation planning using a computer based navigation planning aid. The computer was programmed to assume zero wind for the route and a cruising true airspeed (TAS) of 154 kt with a fuel consumption of 25.5 US gallons per hour (GPH). The computer printout of the plan, which the pilot took with him on the flight, showed a total flight time for the return trip of 2 hrs and 2 minutes and a fuel burn of 52 gallons.

The pilot later stated that he did not rely on his computer programme for fuel calculations but used a 'rule of thumb' rate of fuel consumption of 20 US GPH which had been given to him by instructors during his type conversion training. He was also aware that G-OMAR was occasionally used for charter flights and that in order to avoid potential weight problems the aircraft operator had an unwritten policy that the aircraft should not be returned with very high residual fuel loads.

Accordingly, the pilot calculated he would need 40 US gallons for the 2 hour flight plus 10 US gallons reserve giving a total requirement of 50 US gallons. The pilot further stated that he was in the habit of converting the US gallon figure to Imperial gallons to provide an extra safety margin. Thus for this flight he planned to have 50 Imperial (60 US gallons) on board for the flight.

**Fuel uplift**

The aircraft technical log indicates that 30 US gallons remained on board after the previous flight, but the pilot states that he based his uplift calculation on 30 Imperial gallons (36 US gallons) remaining. To achieve his planned total fuel of 50 Imperial gallons (60 US gallons) the pilot calculated that he needed to load a further 20 Imperial gallons (24 US gallons); he therefore requested the refueller to load 45 litres (12 USG) in each wing tank. The pilot was unable to explain why he had indicated in the aircraft technical log that he would uplift a total of 30 USG.

**Fuel on board prior to take-off**

The investigation tried to establish the amount of fuel on board prior to take-off.

In common with similar systems fitted to other light aircraft, the fuel gauges in the Seneca III provide a general indication of fuel on board but cannot be relied upon for fine tolerance readings. Other pilots who had flown the aircraft recently stated that G-OMAR's fuel guages were 'reasonably accurate' and provided an accurate indication of the trend in fuel consumption. The fuel gauge indications noted by the pilot could not therefore be relied upon as an accurate indication of actual fuel on board.

Each wing has significant dihedral and a single fuel filler cap for each wing is located in the outboard tank. When the aircraft is parked with wings level it is just possible for a person of average height standing on the ground to see into the outboard tank with the filler cap removed. However, with an evenly balanced fuel load of 50% or less the fuel is carried only in the two inboard tanks and there is therefore no fuel to be seen in the outboard tank. Thus with low fuel loads it is not possible visually to check the fuel in tanks. Similarly, since the single filler caps are located only in the outboard wing tanks, it is not possible to use a dipstick to check fuel quantity at fuel states less than about 50%.

The aircraft technical log has a record of arrival fuel, fuel uplift and fuel on board for each flight. Departure fuel is calculated by adding any fuel uplift to the previous arrival fuel figure. Arrival fuel is calculated by estimating the rate of fuel consumption on the flight and multiplying rate of fuel consumption by flight time and deducting the result from the departure fuel figure. The fuel gauge readings are used to provide a gross error check of the calculation.

The aircraft had last been filled with fuel two weeks before the accident flight and a total of fourteen flights had been made prior to the aircraft's departure from Shoreham on 2 April 2001. The investigation therefore attempted to reconcile fuel uplift receipts with flying hours flown to determine fuel remaining before the flight. Unfortunately a number of factors mitigated against this. During the '50 hour check', a week before the accident flight, extensive engine ground running had been carried out. The amount of fuel used during the ground runs could only be estimated. In addition there had been two errors in entering fuel uplift quantities which in total resulted in 10 USG less fuel on board than indicated by the technical log. However, this error was more than compensated for by an uplift of 26.5 USG that had been omitted. In addition the estimated fuel consumption used by different pilots operating the aircraft on apparently similar flight profiles varied significantly. Lastly the heater on the aircraft uses fuel only from the left wing tank at a rate of roughly one USG per hour. The heater had been used for about two hours on the flights immediately prior to the accident flight. It was therefore not possible to determine accurately the amount of fuel on board prior to the flight by reconciliation.

**Additional information**

The pilot carried a hand held Global Positioning System (GPS) and the aircraft had been tracked on radar throughout the outbound and return flight. By combining the recorded data from these two sources and applying the actual winds provided by the Meteorological Office in an aftercast, it was possible to calculate the TAS being flown and, from the AFM, the engine power being used.

The data showed that an average cruise TAS of 154 kt was used throughout the flight which would require a 65% power setting and result in a fuel consumption of 23.3 USG per hour. The performance equates to the 'Economy Cruise' settings provided in the AFM. The total fuel used on the two flights calculated from this data is 55.5 USG.

The aircraft operating company in its CAA approved checklist recommends a cruise setting of 30-32 inches of MAP, and a propeller RPM of 2,200 with a cruise speed of roughly 140 kt IAS. Fuel consumption figures are not provided in the company checklist, but the AFM indicates that these settings are roughly equivalent to 55% power, which would result in fuel consumption of 18.7 USG per hour. PA 34 qualified pilots of the operating company questioned during the investigation were all aware that the unwritten, but generally widely used consumption figure of 20 USG per hour was applicable to the 55% power settings.

The performance information provided in the AFM is based on a new aircraft at maximum take-off weight, and fuel consumption figures assume that the fuel mixture in the cruise is leaned such that the EGT is 25° C below the amber range. The manufacturer advises that the variation of fuel consumption with aircraft weight is small, but the effects of ageing engines and the airframe condition could increase consumption significantly. General Aviation Safety Sense Leaflet 1C 'Good Airmanship Guide', published by the CAA, recommends that the AFM fuel consumption figures should be increased by 20% to allow for in-service wear. Actual fuel consumption, in comparison with the AFM figure, depends on the mixture leaning technique used by the pilot, aircraft weight, engine and airframe condition and the actual taxy distance compared to the AFM allowance.

The Flying Order Book (FOB) for the aircraft operating company requires pilots to take account of the fuel burn for the entire route plus five per cent and carry additional fuel to allow a diversion to a nominated alternate from overhead destination plus a further 45 minutes reserve. A fuel plan calculated in accordance with the AFM and the FOB and using Lydd as an alternate for the return flight shows a total fuel required for the return flight of 73 USG. Safety Sense Leaflet 1C 'Good Airmanship Guide' recommends that pilots should 'plan to land by the time the tanks(s) are down to the greater of 1/4 tank or 45 minutes, but do not rely solely on the gauges which may be unreliable'. The Safety Sense leaflet's fuel planning advice applied to the pilot's calculated fuel burn would have given a total fuel required of 71 USG.

**Analysis**

It is highly unusual for twin-engine aircraft with independent fuel and ignition systems to suffer near simultaneous double engine failure for mechanical reasons. This, combined with a lack of evidence of significant quantities of fuel at the crash site and the absence of post impact fire, pointed at an early stage to lack of fuel at the engines. The subsequent engineering investigation was unable to discover any malfunction with the aircraft's engines, fuel or ignition systems, and this analysis will therefore concentrate on addressing the fuel issues.

FUEL PLANNING.

The pilot based his fuel plan on a 'rule of thumb' provided to him during his type-conversion training. In common with many such 'rules' nothing was written formally, but the 'rule' was based on cruising at about 140kt IAS with 2,200 RPM and 30 to 32 inches of MAP giving fuel consumption of about 20 USG per hour. However, the pilot planned to fly at 154 kt TAS which the AFM indicates requires 23.3 USG per hour. Analysis of GPS and radar data indicates that the flight took a total of 2 hrs and 13 minutes and 55.5 USG would have been burned compared to the 2 hrs flying time and 40 USG fuel consumption calculated by the pilot.

The pilot calculated his reserve fuel by adding 10 USG to the fuel burn and by adding a further safety factor by converting the final figure into Imperial gallons. He thus planned to carry a total of 60 USG compared to the 73 USG that would have been required if the flight had been planned in accordance with the AFM and the FOB.

The pilot's fuel plan gave him less fuel than either the FOB or CAA recommend, but the AFM allowance for start, taxy and take-off can be quite generous depending on the length of taxy routes. With 60 USG on board there could have been just sufficient fuel for the flight without normal reserves provided that performance had been close to AFM figures.

FUEL ON BOARD

The pilot's habit of converting USG to Imperial gallons to provide an added safety margin was of no benefit when he confused the unit quantities used in the technical log and mistakenly based his uplift calculation on 30 Imperial gallons (36 USG) remaining in the aircraft. As a result only 24 USG was uplifted which gave a total on board of 54 USG compared to the 60 USG that had been planned.

The investigation was unable to determine precisely the amount of fuel remaining on the aircraft prior to refuelling. However, given the actual flight times and performance used during the flights to and from Sheffield and thus the likely actual fuel consumption, it appears that the fuel on board prior to refuelling was at or very close to the 30 USG shown in the aircraft technical log. However, the number of errors in the fuel section of the technical log combined with the difficulty in determining the exact amount of fuel on board by any other means gives cause for concern especially since the aircraft is occasionally used for public transport operations.

**Conclusion**

The fuel on board prior to departure from Shoreham was at least 54 US gallons. The actual fuel burned during the flight was approximately 55 USG. It is therefore possible, but perhaps unlikely, that both aircraft wing tanks emptied within a few seconds of each other. It seems more likely that the fuel remaining on board when the aircraft arrived overhead Shoreham was very low with perhaps slightly more in the right tank than the left.

The deceleration as a result of the pilot selecting FULLY FINE propeller pitch during the Pre-Landing checks is likely to have caused what little fuel remained to move fore and aft within the left inboard tank thereby uncovering the fuel line from the wing tank to the engine. Air entering the fuel line for the left engine would have caused the engine to falter and then fail. The unexpected engine failure caused the aircraft to yaw to the left which would have caused the little fuel remaining in the right inboard tank to move outboard and again uncover the fuel line from tank to engine causing the right engine to fail.

The pilot left the propeller control levers in the FULLY FINE position with the result that the propellers continued to rotate at a speed relative to the forward speed of the aircraft. At 90 kt the windmill RPM would have been above the maximum for starter motor engagement and the pilot's attempts to restart with the electric starter motor would have had no effect. However, with the propellers windmilling and the fuel and electrics remaining ON, the basic requirements for an engine restart remained almost all the way to impact. If sufficient time and fuel had been available, it is possible that the mechanical fuel pump would have been sufficient to achieve an engine restart. However, if the AUX pump had not been selected to HI it is unlikely that the mechanical fuel pump alone would have had sufficient time to re-establish fuel to the engine, and the engines would therefore have failed to restart.

## Safety recommendation

### Recommendation 2001-67

The difficulties of establishing the exact amount of fuel on board on this and other similar types presents a flight safety hazard to both private and public transport category operations. The investigation of this accident revealed significant discrepancies in the recording of fuel states for some of the previous fourteen flights. It is therefore recommended that the CAA should ensure that operators of twin engine light aircraft (all types similar to the PA 34) in the Transport Category (Passenger) have an effective back up procedure, in addition to the aircraft fuel gauges, by which the fuel remaining in tanks after flight may be established and recorded.