ACCIDENT

Aircraft Type and Registration:	Piper PA-38-112 Tomahawk, G-RVRF
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1978
Date & Time (UTC):	29 July 2011 at 1123 hrs
Location:	Newlands Avenue, Eccles, Greater Manchester
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passengers - 1 (Serious)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	426 hours (of which 302 were on type) Last 90 days - 3 hours Last 28 days - 1 hour
Information Source:	AAIB Field Investigation

Synopsis

The aircraft suffered an engine stoppage on takeoff at approximately 200 ft, stalled, rolled more than 60° to the left, crashed into houses and caught fire. Both occupants survived the impact and fire but the pilot succumbed to his injuries later in hospital. The most likely cause of the engine stoppage was stiffness of the fuel selector valve causing it to be in an intermediate position, reducing fuel flow to a level too low to sustain continuous engine operation.

History of the flight

The aircraft was on a local flight and had been privately hired from a flying training school. The pilot was expecting a friend to accompany him on the flight but, when the friend did not arrive, the pilot offered the vacant seat to the passenger. Witnesses who saw the pilot before he went to the aircraft describe him as appearing well, alert and in good spirits.

The pre-flight inspection, start-up and taxi were uneventful. The passenger stated that the pilot had carried out the power checks, including a check of the carburettor heat system, and the engine had behaved normally. He also recalled that the pilot operated the fuel selector prior to takeoff as part of the normal pre-flight procedure but he was unsure when this was done. The flying order book for the flying training school states that the pilot should select the tank containing the least fuel for engine start and the fullest tank before the power check. The aircraft took off at

1119 hrs from Runway 09R. The aircraft was within the CG limits and near to the maximum takeoff weight. The pilot was trained to use the PA-38 'short field, obstacle clearance' takeoff technique at Barton, which involved using one stage of flap, rotating the aircraft at 53 KIAS and flying the initial climb at 61 KIAS until 300 ft aal then accelerating and retracting the flaps. Immediately prior to the engine stoppage, the passenger noticed that the pilot operated a control to the left of the control column with his left hand. Although he was unsure which control the pilot operated, the cockpit layout suggests that it is likely to have been a heater or ventilation control.

At an estimated 200 ft aal, the engine suffered a rapid and significant power loss. The pilot transmitted a MAYDAY call stating that he had an engine failure. The passenger stated that the engine behaved as if the throttle had been closed suddenly. One witness, who was standing on the airfield at Barton, stated that he saw a quantity of blue or black smoke around the forward fuselage area just before the aircraft rolled to the left. He indicated that this was a brief event and that there was no smoke or fire visible during the aircraft's descent. Several witnesses stated that the aircraft's nose remained in the climb attitude until the aircraft rolled to the left to more than 60° of bank. Two witnesses stated that the aircraft appeared to slow noticeably before the wing dropped. The aircraft's nose then dropped and the aircraft entered a steep descent, turning to the left, before it struck two houses and came to rest between them. Two witnesses, who observed the latter stages of the descent, described the aircraft's bank and nose-down pitch attitudes reducing just before impact. The aircraft suffered substantial damage on impact and there was a sustained post-crash fire. Both occupants survived the crash and fire but the pilot succumbed to his injuries later in hospital.

Personnel information

The pilot had held a PPL(A) since 1988 and had flown 426 hours. Before gaining his PPL he had flown 460 launches in gliders. Six weeks before the accident he had flown two flights with an instructor during which he had practised circuits, practice forced landing and emergencies, including engine failures after takeoff (EFATO). The instructor stated that, during these flights, the pilot had demonstrated a safe and conscientious approach to his flying and had carried out the various exercises successfully.

Aircraft information

The PA-38 Tomahawk is a single-engine, two-seat aircraft. It has a low wing with integral fuel tanks and a distinctive 'T-tail' style horizontal stabiliser. It has a side-by-side seating arrangement and 'bubble' canopy, with doors on each side of the fuselage. The FAA granted a type certificate to the design in 1977 and the aircraft was in production until 1982.

Following a fatal accident in 1981, the National Transportation Safety Board (NTSB) issued a safety recommendation to fit additional flow strips to the leading edge of the wing. A modification to add these strips to the wings, to improve the stall characteristics, was introduced in FAA Airworthiness Directive 83-14-08 in 1983. Following investigations into further fatal PA-38 accidents in America and Sweden, the NTSB noted that, where stall/spin was a factor, this aircraft had a higher rate of fatal accidents than other similar aircraft and issued a safety recommendation in 1994 to carry out flight testing to determine if the aircraft's stall characteristics met certification requirements. No modifications relating to the stall/spin characteristics have been made since that time.

Fuel selector

The aircraft fuel selector is a large, red, plastic, pointed handle in the centre of the instrument panel. The OFF position is with the handle pointing to the bottom left quadrant. The handle must be rotated clockwise to the top left quadrant to select the left fuel tank. It can then be rotated clockwise to the top right quadrant to select the right fuel tank. To return to the OFF position, the handle is rotated anti-clockwise. To ensure the fuel selector is not selected OFF inadvertently, a small pawl must be pushed against spring pressure to allow the rear of the handle to pass (see Figure 1).

A long steel shaft connects the bottom of the handle to the stem of the brass selector valve, which is located on the aircraft floor, at the bottom of the cockpit side of the engine firewall. The valve has three pipes attached in an inverted 'T' shape, one either side from each fuel tank and one which passes through the firewall to deliver fuel to the engine. The stem of the valve is attached to a plastic plug with two holes in it, which rotates within the body of the valve. When the valve is in the OFF position the plug blanks off the engine delivery pipe. When the plug is rotated to select the left tank, the holes line up with the pipe from the left tank and the engine delivery pipe to allow the fuel to flow. Similarly when rotated again to select the right tank, the holes line up with the engine delivery pipe and the pipe from the right fuel tank. The top of the plug has four recesses aligned in a cross shape. Above this is a spring-loaded, non-rotating washer with a ridge across its diameter. In each of the defined positions of the valve, the ridge in the washer slots into the recesses on the plug, providing a positive detent to give tactile feedback that the holes in the plug are correctly orientated with the feed and exit pipes (see Figure 2).

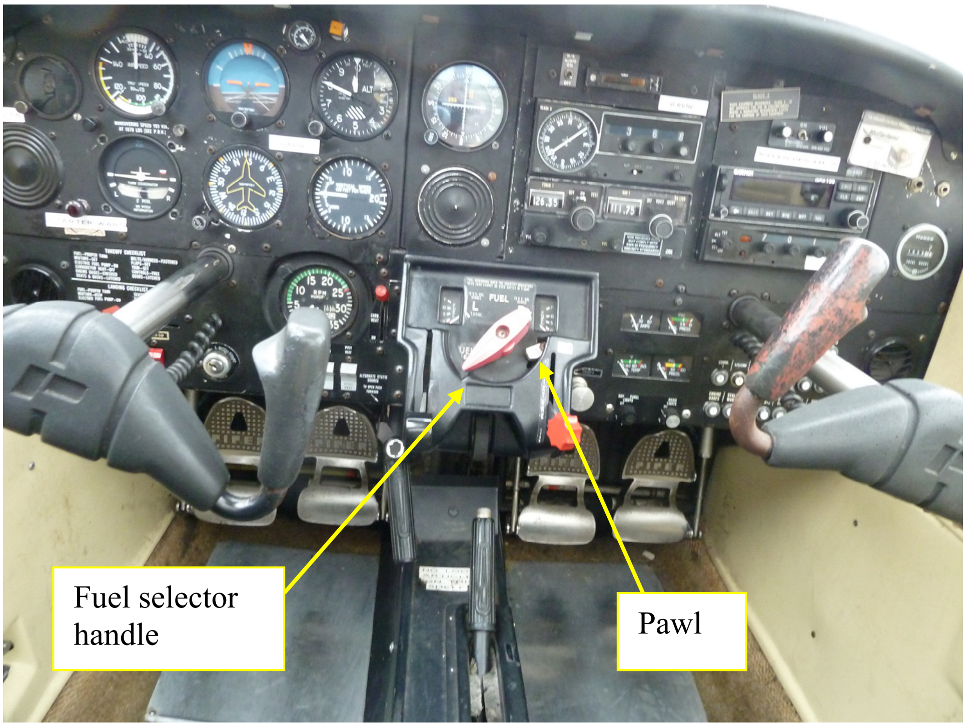

Figure 1

Fuel selector handle in the OFF position

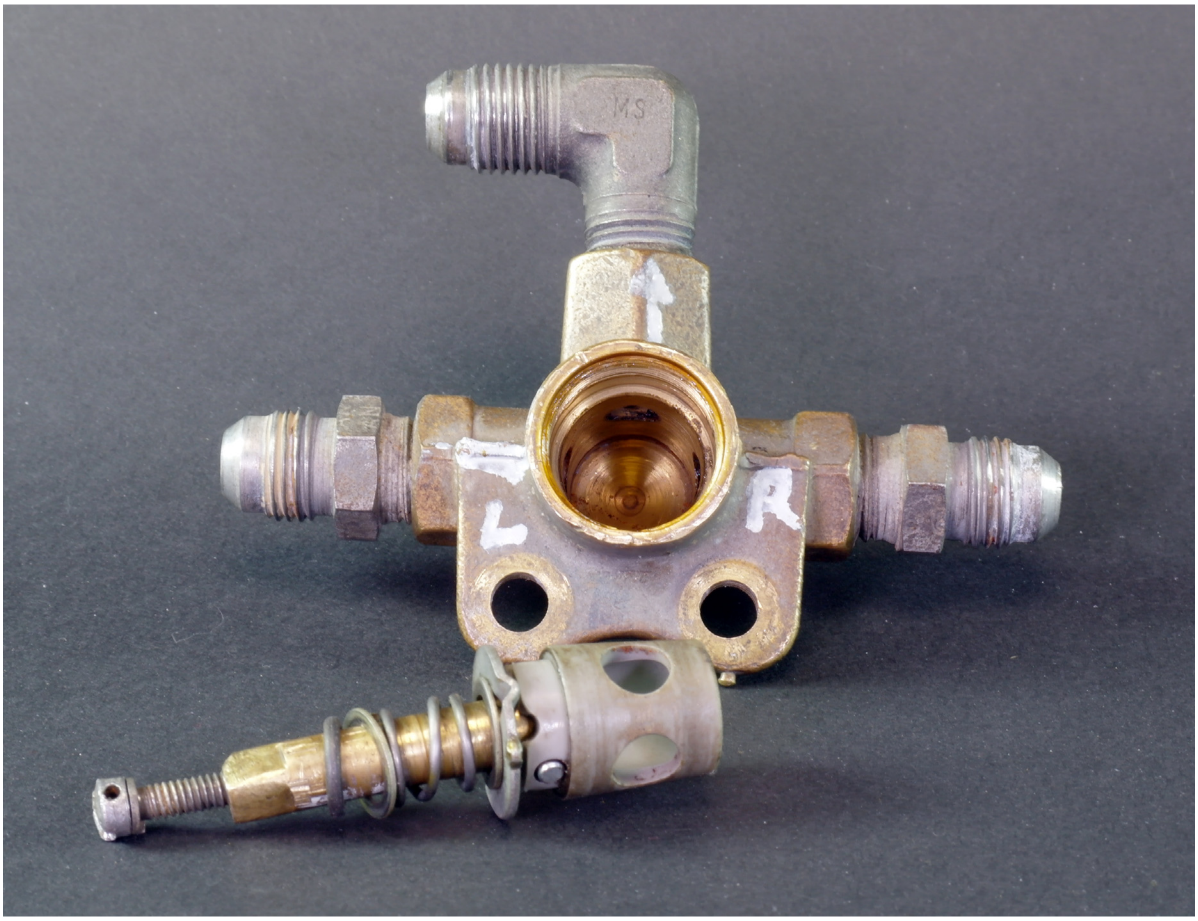

Figure 2
Fuel selector valve (valve cap removed)

Meteorology

The weather conditions at the time of the accident were a surface wind of 070° at 8 kt, visibility greater than 10 km, cloud scattered at 3,000 ft, temperature 16°C, dew point 11°C and QNH of 1025 hPa. These conditions could have produced a moderate risk of carburettor icing[1].

Airport information

Manchester/Barton City Airport is located 5 nm west of Manchester. The airport has four grass runways: the longest (09R/27L) is 621 m in length. Local orders state that practice EFATOs are not permitted on climbout from Runways 09L, 09R and 14. An aerial view of the airfield, the crash site and surrounding area is shown in Figure 3. The open grass area to the southeast of the crash site and to the west of the motorway was, at the time of the accident, a building site with a large stadium in the advanced stages of construction. The area to the north of the housing estate on which the aircraft crashed is a cemetery.

Recorded information

The aircraft taking off from Runway 09 at Barton was captured on a CCTV video system that also recorded sound. The video only captured a small section of the flight and did not include the point at which the engine

Footnote

[1] Civil Aviation Authority - SafetySense Leaflet 14.

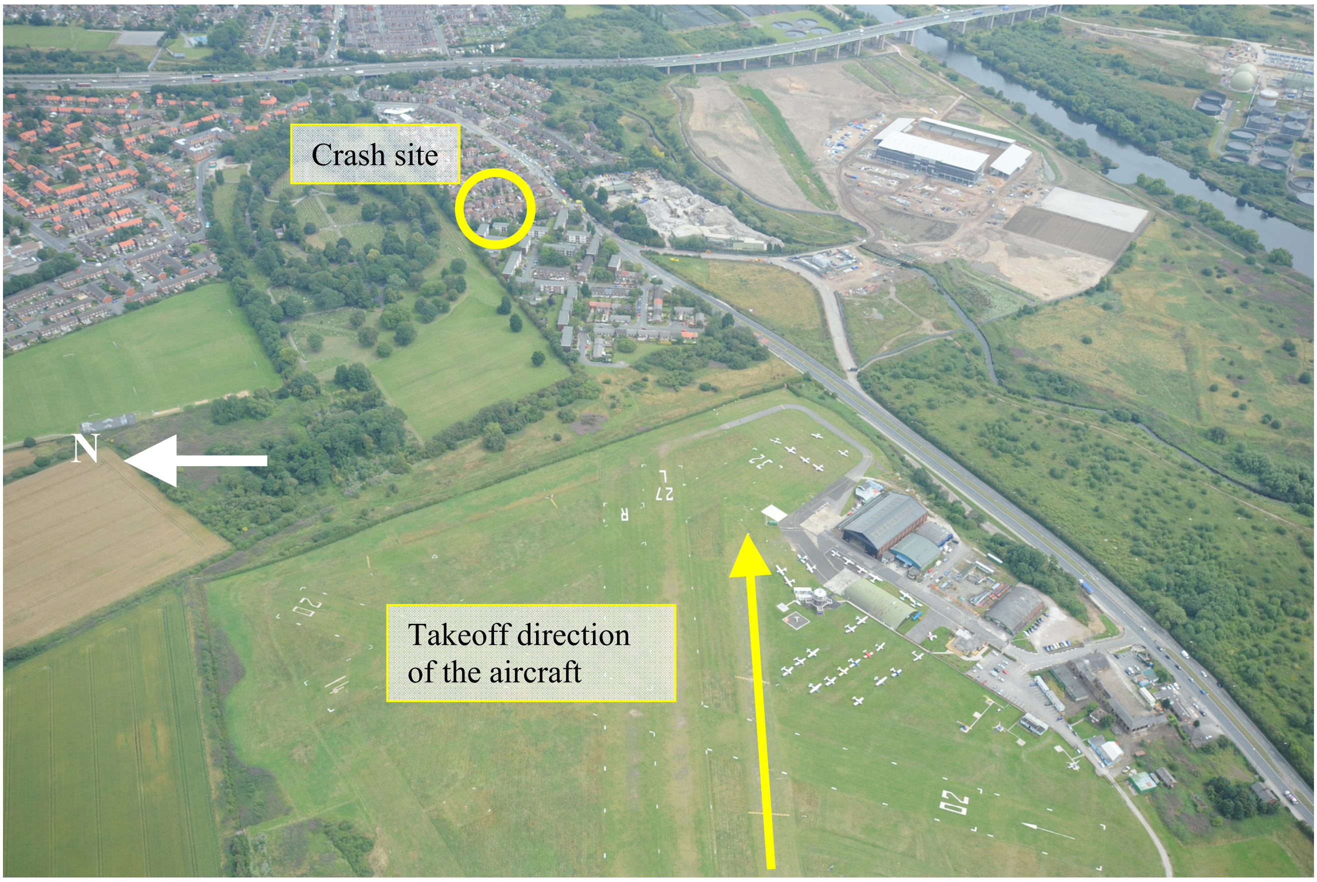

Figure 3
Manchester/Barton Airport

lost power or the start of the takeoff. However, the audio recording captured the sound of the aircraft outside the camera's field of view. Through analysis of this recorded audio, the time between the engine being set to takeoff power and the point at which the engine rpm suddenly reduced was 36 ± 1 seconds.

Accident site

The aircraft came to rest in a driveway between two adjacent houses. The house to the right, when viewed from the back, had a single storey extension to the rear. The roof of this extension had a large number of missing roof tiles and the upper floor window of the house was damaged. The left main landing gear leg and wheel assembly of the aircraft was lodged in the boundary fence to the right of this property. The house to the left of the driveway had a two-storey extension in a mirror image position to the house on the right. The sidewall of this extension, facing the driveway, had a large hole at upper floor level through to the interior of the house. The adjacent wall and roof section also exhibited severe structural damage (see Figure 4). Both houses had suffered significant heat damage from the fire in the immediate area around the aircraft wreckage.

The aircraft had come to rest where a wooden boundary fence between the two houses had been. The T-tail section was suspended inverted and twisted over an intact fence panel. The main fuselage had separated from the tail section and was lying on its right side, pointing along the driveway, to the left of where the fence line had been. The right wing had almost completely separated from the fuselage and was lying diagonally across the width of the driveway with the wingtip against the wall of the house on the right. A six-inch high concrete gravel board in the fence had punctured the integral fuel tank in the wing. The left wing had been almost entirely consumed by fire having detached from the fuselage at the wing root; what remained was lying on the right side of the driveway in front of the right wing. The cockpit structure had been significantly disrupted during the impact and also by the fire and rescue services to enable extraction of the aircraft occupants. Large areas of the fuselage, cockpit and engine bay had suffered significant fire damage during the post-impact fire, but most of the structure was still present. The starter ring and propeller hub had been damaged in the impact, as had one of the two propeller blades, which had curled significantly at the tip. The other blade was relatively undamaged.

Detailed wreckage examination

Initial inspection of the wreckage on-site showed that the throttle was approximately two-thirds open and the mixture lever was in the FULL RICH position. The carburettor heat lever was in the OFF position and the flap lever position confirmed that first stage flaps had been selected. The fuel selector was in the OFF position, as was the magneto key switch. The primer pump was found unlocked and slightly extended from its stowed position. The officers who attended from the fire and rescue services confirmed that they had not intentionally changed any switch or lever positions during the extraction of the aircraft occupants or to make the aircraft safe.

The aircraft was recovered from the accident site for detailed examination. The engine was removed from

Figure 4

Accident site

the fuselage, stripped, and inspected. No evidence was found of pre-impact mechanical failure in the engine or the accessories. The spark plugs were removed and examined; several of the electrode gaps were larger than the maintenance manual limit and there was evidence of what may have been lead fouling, with two of the plugs found to have debris bridging the gap between the electrodes.

The area around the filter bowl and fuel filter had been significantly fire-damaged. There was no fuel remaining anywhere on the aircraft, so no sample could be taken. The fuel system piping that remained post-fire was inspected and no blockages were found, neither were any anomalies with the carburettor identified. As the air intake on the carburettor had been crushed during the impact and then significantly damaged in the fire, it was not possible to confirm its condition or the selected position and serviceability of the carburettor heat system pre-impact.

The fuel selector handle was found in the OFF position but the ridged washer above the valve plug was not located in the detent for the OFF position on the plug. The valve plug was exceptionally stiff and difficult to rotate and the edges of the recessed detents on the top of the plug were also noticeably worn. The dried lubricant on the valve plug contained small particles of the valve body material released by wear between the plug and the valve. The top of the valve stem, which located in a keyway recess on the end of the connecting rod, was also heavily worn, as was the recess into which it fitted. This allowed a degree of rotational movement of the rod without moving the valve, even with the retaining screw tightened and wire-locked. As the valve and fuel selector handle were not rigidly connected, it was possible for a variation to exist between the actual valve position and the position selected by the handle. No evidence was found to indicate that the valve had been damaged or degraded in the crash or subsequent fire.

Maintenance

The engine had reached the manufacturer's maximum overhaul life of 2,400 hrs on the flight prior to the accident. *CAP 747, Generic Requirement No 24* issued by the CAA, permits up to a 20% life extension for engines operated in accordance with their approved Light Aircraft Maintenance Programme (LAMP), as this engine had been. The engine had last been inspected on 14 July 2011, 10 hrs prior to the accident, during a routine 50 hr maintenance check. The aircraft was certified to continue in service with this engine during the 14 July maintenance check, although the life extension had not been annotated in the engine logbook.

The Technical Logbook for the aircraft recorded two defect entries identifying that the engine had been *'rough running'* with the right magneto selected. Maintenance records showed the defects were cleared at the most recent 50 hr check by servicing the spark plugs and replacing one plug that was damaged.

In 1982, the aircraft manufacturer issued Service Letter 944 to address a problem where fuel selector valves had become difficult to rotate, damaging the valve and preventing switching between fuel tanks. The Service Letter introduced a repetitive 400 hr valve disassembly, inspection and lubrication task. The logbook for the accident aircraft identified that this task was last carried out on 25 July 2010, 109 hours prior to the accident. The lubricant specified by the Service Letter has an operating temperature range of -30°C to +230°C.

Medical and pathological information

The post-mortem identified that the pilot had an undiagnosed pre-existing medical condition. This condition can cause incapacitation.

Fire

Eyewitnesses recalled seeing a single "puff" of black smoke from the engine before the aircraft descended, followed by an initial flash of flames as the aircraft impacted with the house. However, a key witness, who was one of the first on the scene after the aircraft came to rest, reported seeing a pool of fluid spreading from beneath the aircraft and then igniting. The fire then engulfed the wreckage. Attempts were made by the first responders to try to protect the aircraft occupants from the fire using water from garden hoses and containers, but the effect was limited due to the extent of the fire. The fire also impinged on the houses either side of the aircraft, causing significant heat damage. However, the timely intervention of the fire and rescue services prevented the fire from spreading.

Survival aspects

With the exception of burns, both occupants of the aircraft had sustained only minor injuries. Had there not been a post-crash fire it is likely that the accident would have been survivable for both occupants.

Investigation test flight

A test flight was carried out to determine the likely flight path of the aircraft following an EFATO. The aircraft tested was aerodynamically similar to the accident aircraft and was of similar weight and CG. The test flight was conducted at 3,500 ft.

During the test flight, the pilot flew the aircraft in the short field takeoff configuration (full power, one stage of flap and 61 KIAS) and an EFATO was simulated by rapidly closing the throttle to idle. The pitch attitude was held constant. As soon as the pilot closed the throttle the aircraft decelerated rapidly. Within 3 seconds, the aircraft stalled. At the point of the stall there was no significant pitch down but the aircraft rolled to 60° left bank. After it rolled, the nose dropped below the horizon and the aircraft entered a descent during which it lost 350 ft. The rapid deceleration to the stall meant that there was no timely stall warning. This test was repeated. This time the aircraft rolled 90° to the left and lost 400 ft in the subsequent descent. During this descent, the pilot observed a rate of descent of 2,000 ft per minute, which was full-scale deflection on the instrument. On both occasions the aircraft stalled at 49±1 KIAS which is consistent with the data in the Pilots Operating Handbook (POH). The POH states that:

> *'Loss of altitude during stalls can be as great as 320 feet, depending on configuration and power.'*

The test was conducted 3,000 ft higher than the altitude at which the accident occurred. The additional height would result in the engine producing less power than during a climb out from Barton and this would result in the test aircraft exhibiting a shallower climb angle and a slower deceleration to the stall. The test was unable to assess the effect of a complete engine stoppage safely but had this occurred, the time to aircraft stall would have been further reduced. Therefore, the 3 second interval experienced on the test flight between engine throttle back and stall probably represents the maximum interval that would have been experienced during the accident flight.

Engineering tests

A number of tests were carried out to determine the significance of the physical evidence found during investigation of the wreckage.

Primer pump test

An equivalent aircraft to the accident aircraft was ground run at takeoff power with the primer pump in various positions from unlocked but stowed, through to fully extended and then with the pump being operated. Although the effect on engine performance of the additional fuel was detrimental, the effect was only momentary and it was not sufficient to cause a rich cut[2].

Ignition system test

The ignition system from the accident engine, comprising both magnetos, both High Tension (HT) lead assemblies and the sparkplugs, was transposed to a serviceable donor engine. The engine was then installed on a calibrated engine test rig. Initially the engine would not start but this was traced to the condition of the HT lead assemblies, which had been damaged in the post-impact fire. When the damaged leads were replaced with new ones, engine performance was normal, despite the visual appearance of the spark plugs.

Fuel starvation test

This test was also conducted on an equivalent aircraft to the accident aircraft, although at a lower outside air temperature than on the day of the accident. The engine was run at full power, then the fuel selector was moved to the OFF position and the time taken for the engine to stop was recorded. The test was repeated a number of times and the process was repeated on a second representative aircraft. Although some variation was seen between aircraft and between tests on the same aircraft, the results were consistently in the region of 25 to 30 seconds.

Fuel selector valve test

Following an initial inspection of the valve, connecting rod and handle, they were replaced in the aircraft and a test was carried out to assess the actual valve plug position against fuel selector handle position. The test identified that the detent position could not be confirmed when turning the selector handle. The results of the test showed that the holes in the valve plug did not align with the feed and exit pipes of the valve, despite the fuel selector handle visually indicating the correct position.

Previous event

On 12 July 2000, a PA-38-112 registered and operated in the USA, lost engine power and hit the ground whilst conducting a practice go-around at Selma Airport in California. The occupants were not injured and there was no fire. The instructor reported that the fuel tank in use had been changed just after rotation on the final go-around. The NTSB investigation confirmed that the engine was not operating at impact. They later identified that although the instructor had selected the fuel selector handle to the OFF position prior to evacuating the aircraft, the fuel selector valve could not be moved, and the valve plug openings were found to be positioned between the left and right port openings. The connecting rod was confirmed to be slipping within its connection in the handle, allowing movement of the handle without movement of the valve.

Footnote

[2] Engine stoppage due to the mixture of air and fuel vapour containing too much fuel to support combustion.

Analysis

Operational aspects

The pilot's pre-flight preparation appears to have been normal with all appropriate pre-flight checks carried out. The takeoff and initial climb also appear to have been normal until the aircraft reached an estimated height of 200 ft. At this point the engine suffered a rapid and significant power loss. In the event of a power loss during initial climb out from an airfield, a priority action for a pilot is to lower the nose of the aircraft to prevent it stalling. On this occasion, the pilot does not appear to have lowered the nose after the power loss and the aircraft continued in a climbing attitude and decelerated until it stalled with the aircraft rolling to the left.

The suddenness of the engine stopping meant that the pilot may not have been mentally prepared to carry out the actions required during an EFATO and, although he transmitted an emergency call, he appears to have omitted to lower the nose before the aircraft stalled. The investigation test flight showed that, when using an initial climb speed of 61 KIAS for a 'short field, obstacle clearance' takeoff, a maximum of 3 seconds were available for the pilot to react to an engine stoppage before the aircraft stalled.

The pilot's pre-existing medical condition could have caused incapacitation. However, this is highly unlikely to have been the case as he had adjusted a heater or ventilation control immediately prior to the engine stoppage, transmitted a MAYDAY call immediately after the engine stopped and spoken to the passenger during the descent.

On the investigation test flight a height loss of 350 ft was experienced when the testing pilot was expecting to carry out the recovery manoeuvre. The estimated height of the accident aircraft when it stalled was 200 ft and therefore it is highly unlikely that the pilot could have recovered the aircraft from the descent in the height available. The flight path experienced during the investigation test flight was consistent with the observed flight path of the accident aircraft.

Technical investigation

Accident sequence

During the final moments of the flight, it is likely the aircraft's right wing contacted the extension roof of the first house, which pivoted the aircraft around such that the underside of the aircraft impacted the sidewall of the neighbouring house. The left wing, main gear leg and nosewheel detached during the collision. The aircraft then dropped towards the ground striking the boundary fence, almost completely detaching the right wing, which folded underneath the fuselage. The aircraft came to rest lying on its right side, with the left wing lying over the top and with the tail section hung over the fence panel to the rear. The propeller was not rotating at impact, and had stopped in an approximately vertical position. The lower blade damage was most likely to have occurred as it struck the wall, which also caused damage to the propeller hub and starter ring. The upper blade remained relatively undamaged.

No evidence was found to corroborate the witness report of smoke from the aircraft in-flight. This smoke may have been caused by an attempt to restart the engine by the pilot, although the passenger did not recall the pilot taking any recovery actions after the engine stopped. It is likely that the flames seen by the witnesses following the initial impact were caused by the ignition and flashover of an amount of atomised fuel released by the disruption of the left wing fuel tank during the aircraft's impact with the house. However, the pooling fluid and subsequent sustained fire were most likely due to continued release of the remaining fuel from the left wing tank and, more significantly, leakage of the entire contents of the right wing fuel tank from the hole caused by the impact with the concrete gravel board. Multiple ignition sources were present including hot engine components and the aircraft's damaged electrical system.

Causal factors of the engine stoppage

The account of the passenger and the findings from the investigation support a fuel supply problem as being the most likely cause of the engine stoppage. Analysis of the audio track recovered from the CCTV recording of the accident flight, identified that the engine stopped approximately 36 seconds after it was set to full power at the start of the takeoff roll. The fuel starvation tests showed that the engine would run at high power for a period just less than this on the fuel remaining between the fuel selector valve and the engine.

Based on the passenger's statement, the pilot changed the fuel tank in use while the aircraft was on the ground. Had the pilot inadvertently selected the OFF position on the fuel selector valve then this would have resulted in the engine stopping approximately 30 seconds later. However, given that the recorded data indicates a period at high engine power of greater than 30 seconds and that the spring-loaded pawl preventing inadvertent rotation of the handle to the OFF position was found to be fully serviceable, this scenario is considered unlikely. In addition, although the handle was found in the OFF position post-accident, the magneto key switch was also switched OFF. Selecting these items off is part of the standard emergency actions for an EFATO. As such, these selections were more likely to have been a deliberate action taken by the pilot either just prior to or immediately after impact, or by another unidentified individual attempting to make the aircraft safe immediately after the event.

The balance of evidence from the findings relating to the stiffness of the valve, the relative movement between the valve and the selector handle and the results of the tests carried out, support a more likely cause. When the pilot changed tanks prior to takeoff, he may have turned the handle sufficiently for a correct selection to appear to have been made. However, the stiffness of the valve and the free movement between it and the connecting rod, may have resulted in the plug within the valve not rotating sufficiently to line up the holes with the fuel tank and engine supply pipes fully. The pilot might not have been aware of this as he may not have been able to feel the detent and there was no other means of determining the actual valve position. This would have reduced the supply of fuel to the engine sufficiently that the mixture eventually became too lean to support combustion and the engine stopped. This would also account for the discrepancy between the time identified on the CCTV footage for the engine to stop and the time to engine stop identified during the fuel starvation tests. Although the possibility of some degradation of the valve lubricant due to heat from the post-impact fire can not be ruled out, the lubricant was designed to tolerate temperatures up to 230°C and the valve did not exhibit evidence of impact damage, sooting or heat damage. There was also evidence of progressive wear in the body of the valve. The extent of the wear to the valve stem and the connecting rod also indicate that the valve may have become stiff on a number of previous occasions, despite the repetitive lubrication task being performed. Although the problems relating to lubrication of the valve identified by the NTSB investigation of the accident at Selma Airport had reached a more advanced stage on that aircraft, the basic findings matched those of this investigation, providing further evidence to support this as a potential cause.

Although considered unlikely based on the evidence that was available, a number of other possible causes for the engine stoppage could not be eliminated from the investigation, due to the destruction of evidence by the post-impact fire. These included:

- Carburettor icing
- Fuel contamination or water in the fuel tanks
- Blockage of the fuel system in a section that was destroyed by the post-impact fire.

Conclusion

Although other potential causes for the engine stoppage could not be eliminated from the investigation, the most likely cause, based on the available evidence, was that stiffness of the fuel selector valve and wear on the rod connecting it to the selector handle may have resulted in the valve being in an intermediate position during the takeoff. This would have reduced the fuel flow to a level too low to sustain continuous engine operation. The suddenness of the engine stopping and the limited time available to react to it probably resulted in the pilot omitting to lower the nose before the aircraft stalled. Once the aircraft stalled, it is highly unlikely that he could have recovered the aircraft in the height available.