ACCIDENT

Aircraft Type and Registration:	PA 31 Navajo, N80HF
No & Type of Engines:	2 Lycoming TIO-540-A2C piston engines
Year of Manufacture:	1971
Date & Time (UTC):	25 July 2010 at 1521 hrs
Location:	North Weald Aerodrome, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 4
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to propeller tips and severe damage to fuselage skin and frames
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	2,920 hours (of which 4 were on type) Last 90 days - 55 hours Last 28 days - 27 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was nearing its destination when both engines lost power as a result of fuel exhaustion. No fuel leak was found and it is considered that a combination of factors led to a higher fuel consumption than had been planned by the pilot.

History of the flight

The pilot arrived at Antwerp Airport at about 1300 hrs with the four passengers who had accompanied him on a one hour flight from North Weald the previous day. After completing the necessary customs and administrative requirements, he conducted a pre-flight check of the aircraft. This did not reveal any faults.

The pilot started the aircraft's engines at 1405 hrs and took off at 1415 hrs for the return flight to North Weald. The aircraft climbed, initially, to FL50 before descending to an altitude of 4,000 ft amsl for the transit across the English Channel. The aircraft then descended further, as it continued towards North Weald, reaching 2,500 ft amsl approximately 10 nm south-west of the airfield. The pilot contacted North Weald Radio and descended to 1,500 ft amsl.

The pilot stated that, with the aircraft at a range of about 5 nm from the airfield and the landing runway (Runway 20) in sight, he heard what he described as a "surging" noise. He looked at the engine instruments

and saw that the right propeller rpm and right engine manifold pressure indications were fluctuating. He quickly switched both the electric fuel pumps to ON and set both engine mixtures to FULL RICH. The indications kept fluctuating, so the pilot switched the right fuel selector to the outboard tank. The engine stabilised for a few seconds but then cut out. The pilot increased power on the left engine and feathered the right propeller before making a PAN call to North Weald, requesting a priority landing.

Shortly after the PAN call was made, the left engine began making a similar "surging" noise and the left propeller rpm and engine manifold pressure indications began fluctuating. The pilot kept the left inboard fuel tank selected and, after several seconds, the left engine ran down. The pilot feathered the left propeller, trimmed the aircraft for a glide speed of 120 kt and continued towards the runway. At this point the aircraft was at a range of between 1.5 and 2 nm from the airfield and at an altitude of about 1,000 ft amsl.

When the pilot considered that the aircraft would reach the runway, he tried lowering the landing gear using the normal gear lever but, as he expected, nothing happened. He stated that he did not try lowering the gear manually as he wanted to concentrate on flying the aircraft and reaching the airfield. The pilot decided to land on the asphalt surface of the runway, rather than the grass area alongside, and deliberately left the flaps up in order to achieve a level attitude for the touchdown. He positioned the aircraft over Runway 20 at a height of approximately 10 ft and a speed of about 90 kt, and set the mixture on both engines to FUEL CUT OFF. He then maintained the aircraft in a level attitude, allowing the speed to decrease and the aircraft to descend on to the runway surface. The aircraft decelerated rapidly and stopped in the middle of the 1,920 m long paved surface.

No one was injured, and the pilot and passengers were able to disembark, unaided, using the rear cabin door. The time that the aircraft touched down was recorded by the airfield as 1521 hrs.

Weather

The weather for both flights was good and there was no requirement to use the de-icing boots or pitot heat. The aircraft did not encounter any rain, either en route or overnight whilst parked. The pilot stated that he experienced about a 10 kt tailwind on his flight to Antwerp and about a 10kt headwind on the return flight.

Aircraft examination

Following the accident the aircraft was raised on jacks, the landing gear was extended and the aircraft was moved to a parking area to facilitate further examination. The fuselage belly exhibited extensive skin and fuselage frame damage, consistent with a landing on a hard runway with the landing gear retracted. Both propellers were in the feathered position and exhibited blade tip damage with no evidence of rotation during impact.

The fuel selectors were positioned to draw fuel from the left inboard fuel tank and the right outboard fuel tank. Both firewall emergency shutoff valves were open and the cross-feed valve was closed. The fuel tanks were individually drained in order to establish accurately the fuel remaining onboard the aircraft - see Table 1.

The aircraft fuel gauges registered empty for the left inboard fuel tank and ⅜ full for the left outboard fuel tank. The right wing gauge appeared to be inoperative as it did not move when the aircraft master switch was turned on, remaining in a position well below the E (empty) marking.

Fuel tank	Left wing, outboard	Left wing, inboard	Right wing, inboard	Right wing, outboard
Fuel recovered (USG)	4.8	0.1	0.9	0.1

Table 1

Fuel drained from the aircraft following the accident

No external evidence of fuel leakage was found on the aircraft skin or on the runway. The wing mounted fuel filters were dismantled and no contamination was observed on the filter screen elements.

The Hobbs meter reading when the aircraft was inspected after the accident was 1177.6. Paperwork provided by the pilot indicated that the Hobbs meter reading prior to the flight from North Weald was 1175.1. The Hobbs meter recorded engine running time on the right engine, regardless of the engine power set. The readings indicated that the right engine had run for a total of 2.5 hours since the aircraft was last refuelled. This was consistent with the combined flight times of 2.1 hours and 0.4 hours of ground running. The pilot reported that there had been no significant delay between starting and stopping both engines at the beginning and end of each flight. Therefore, the left engine had run for a similar length of time as the right engine.

Fuel onboard

The pilot refuelled the aircraft prior to its departure from North Weald. He had no means of determining the amount of fuel onboard, since there was no means of dipping the tanks and he believed that the gauges were not accurate[1]. Also, there was no aircraft technical log or other documented fuel record available to him. Therefore, the pilot considered that the only way he could be sure of the quantity of fuel onboard was to refuel the tanks until they were full. The pilot reported that, after refuelling, the fuel gauges indicated that each inboard tank was only between ⅔ and ¾ full, despite both he and the bowser operator confirming that the inboard tanks had been filled completely. The refuelling docket recorded 273 litres (72 USG) being delivered and fuel checks conducted by the pilot and the bowser operator did not reveal any fuel quality issues.

Although the pilot did not visually check the outboard fuel tanks, he stated that the fuel gauges indicated that both tanks were empty. He also stated that there were no indications of any fuel leaks during his external checks.

Prior to its departure from Antwerp the aircraft's fuel gauges indicated that each inboard fuel tank was approximately ⅓ to ½ full.

It was normal practice for pilots operating the aircraft to pay directly for fuel uplifted, with no procedure in place to receive compensation for fuel uplifted but not used.

Footnote

[1] The pilot stated that both fuel gauges appeared to be serviceable prior to each flight.

Engine management

The pilot stated that in the cruise on each of the two flights he had adjusted the mixture on both engines to achieve a peak EGT before then enriching each engine slightly. He reported setting 30 inches of manifold pressure and the propellers at 2,400 rpm, consistent with a power setting of approximately 70%, as determined from the Aircraft Flight Manual. He stated that this gave him an indicated fuel flow on each engine of 16-17 USG per hour, which is also consistent with a power setting of approximately 70%, as specified in the Aircraft Flight Manual.

The pilot reported achieving a cruise speed of about 170 kt, confirmed by radar recordings, which the Aircraft Flight Manual equates to a power setting of approximately 75%.

Documentation

The pilot completed a weight and balance chart for each flight. For the flight from North Weald he recorded the fuel on board as 670 lbs (112 USG). For the return flight from Antwerp he recorded 420 lbs (70 USG).

For his fuel calculations, the pilot relied on an Information Manual produced by the aircraft's manufacturer. This gave total cruise fuel consumption figures of 35.6 USG per hour at 75% power and 27.8 USG per hour at 65% power. The Information Manual also stated a climb power total fuel consumption figure of 56 USG per hour, with 39.5 inches of manifold pressure set and the propellers at 2,400 rpm. These fuel consumption figures assume that the engines are 'leaned' in accordance with the operating instructions contained in the Flight Manual. For cruising conditions, these instructions require the mixture to be leaned to peak EGT followed by further leaning of the mixture until a drop of at least 25°F EGT is observed.

No other fuel consumption figures were provided in either the Information Manual or the approved Flight Manual. However, both of these documents stated that:

> *'Performance for a specific airplane may vary from published figures depending on the equipment installed, the condition of engines, airplane and equipment, atmospheric conditions and piloting technique.'*

The Flight Manual contained no information regarding fuel consumption when the engines are running at idle. However, subsequent inquiries with the engine manufacturer indicate that this figure is approximately 1.5 USG per engine per hour.

The pilot's navigation log showed a planned flight time from North Weald to Antwerp of one hour, equivalent to a fuel consumption of 35.6 USG at 75% power. However, his weight and balance charts indicated that he calculated a fuel consumption for the first flight of 42 USG, taking into account additional fuel consumption for taxiing and higher power settings whilst climbing.

The return navigation log again showed a planned flight time of one hour. The planned fuel consumption was the same as for the outbound leg, giving a total fuel consumption for the two flights of 71.2 USG, at 75% power, or 84 USG using the pilot's figures, in which the additional factors for taxiing and climbing were included. The inboard fuel tanks held a total of 108 USG useable fuel, giving, for the greater rate of consumption, 24 USG of reserve fuel (equivalent to approximately 40 minutes flight time) for holding and diverting.

Pilots operating the aircraft were requested by the owner to complete a 'Flight Record Sheet' and to return this to him following each flight. This document recorded departure and destination aerodromes, flight times, oil consumed and technical defects. On receipt of a completed Flight Record Sheet the owner updated the airframe, engine and propeller logbooks. The Flight Record Sheet was then discarded. Copies of completed Flight Record Sheets were not kept in the aircraft and therefore no information relating to fuel consumption or technical defects from previous flights was available to pilots operating the aircraft.

CAA Safety Sense Leaflet 1e - *Good Airmanship*

Section 13 of this leaflet provides the following guidance on fuel planning:

> *'13 FUEL PLANNING*
>
> *a) Always plan to land by the time the tanks 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.*
>
> *b) Understand the operation and limitations of the fuel system, gauges, pumps, mixture control, unusable fuel etc. and remember to lean the mixture if it is permitted.*
>
> *c) 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.'*

Aircraft information

The Piper PA-31-310 Navajo is powered by two Textron Lycoming TIO-540-A2C piston engines, each rated at 310 hp. There are two pilot seats and cabin seating for five passengers. The airframe has retractable landing gear and electrically-driven trailing edge flaps. The flight controls are conventional and manually operated.

Aircraft fuel system

Fuel is stored in four flexible fuel cells (tanks), two in each wing. A diagram of the fuel system is shown in Figure 1. The two inboard tanks each have a capacity of 56 USG, of which 54 USG is useable. The outboard tanks each hold 40 USG, of which 39 USG is useable. Each fuel tank has a drain valve and a filler cap. The capacity of the inboard fuel tanks was checked after the accident and found to conform to the stated capacity.

The fuel system consists of two independent systems that allow each engine to be fed by its own fuel supply. During normal operation each engine should be supplied with fuel from its respective fuel system. However, fuel can be cross-fed, when necessary, via a cross-feed valve to feed both engines from one set of fuel tanks.

Fuel is drawn from each tank, through a screen located in the tank outlet fitting and on to the fuel tank selector valve. From the fuel tank selector valve it passes through the fuel filter, the electrically driven fuel pump and the firewall emergency shutoff valve to the engine-driven pump.

The fuel valves are operated through controls located on a panel between the pilots' seats. Included on this panel are the controls for the fuel tank selector valves,

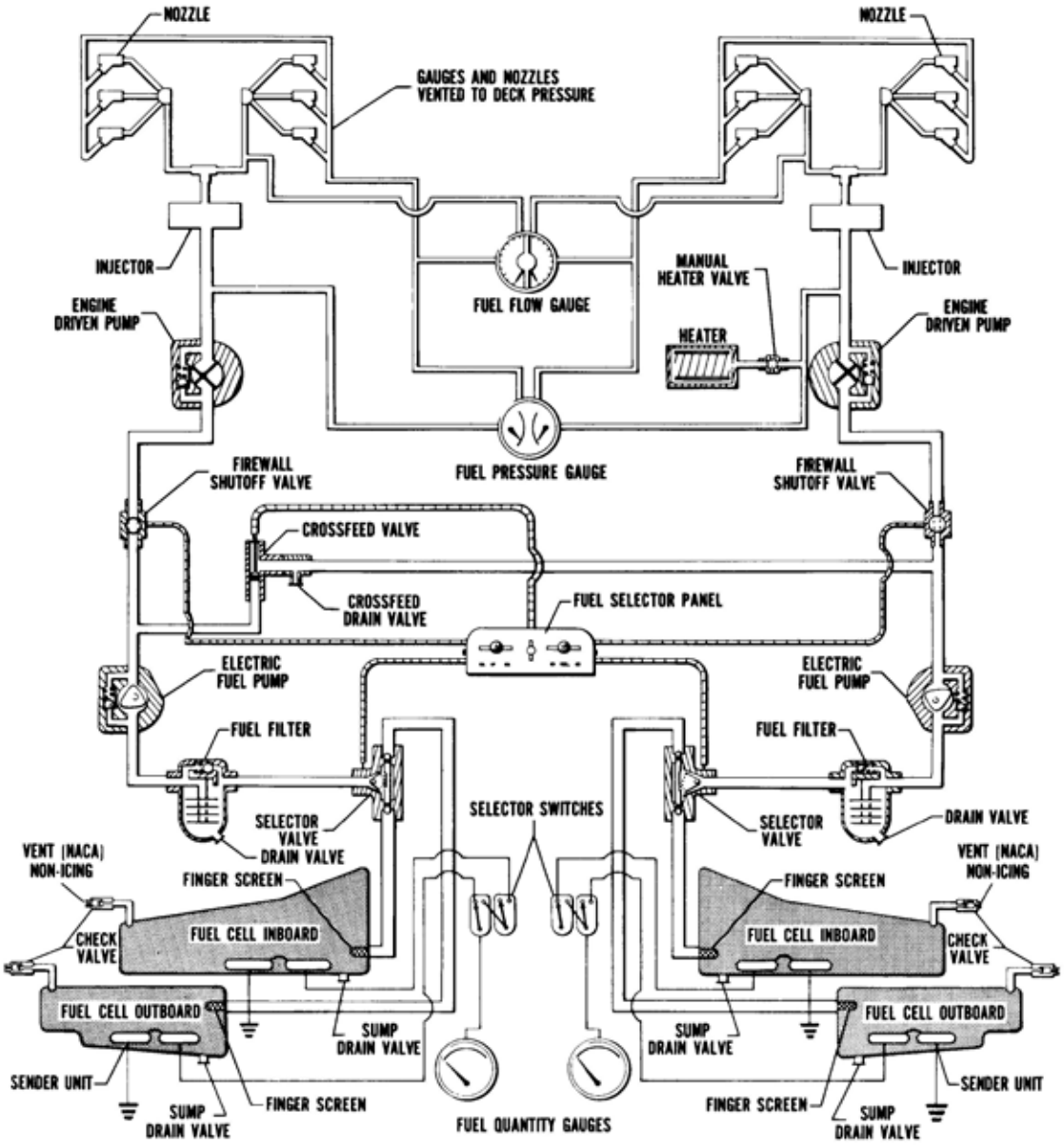

Figure 1

PA-31-310 Fuel System Schematic

the firewall shutoff valves and the cross-feed valve. Fuel boost pump controls are located on the right side of the overhead panel next to the fuel gauges.

The outboard fuel tanks should only be used in level flight. Takeoff, climb, descent and landing should be carried out using fuel from the inboard fuel tanks.

Fuel gauging

Two fuel gauges are mounted on the cockpit overhead panel, one each for the left and right fuel tanks respectively. Each gauge has markings for E (empty), ¼, ½, ¾ and F (full). The gauges indicate the contents of the respective inboard or outboard tank, depending on which is in use.

Aircraft maintenance

An annual inspection had been performed on 3 November 2009, by an FAA approved aircraft maintenance technician, when the aircraft had flown 2,850.9 hours. No fuel system-related defects had been reported to the maintenance technician since this annual inspection and, at the time of the accident, the aircraft had flown 2,866.5 hours.

Analysis

The pilot based his fuel calculations on the information available to him. He believed that the aircraft would consume 42 USG on each of the two flights, in still air, and that the fuel tanks contained 108 USG of usable fuel. This would have left a figure of about 24 USG unaccounted for, equivalent to about 40 minutes flight time. Under the prevailing conditions this should still have proved adequate. However, the aircraft ran out of fuel after a combined flight time, since refuelling, of about 2 hours 6 minutes. In the absence of any known fuel leaks it must therefore be considered that either the aircraft had less fuel on board than was thought or that the fuel consumption rate was higher than calculated.

Fuel on board

Both the pilot and refueller stated independently that both main tanks had been filled completely, which, as confirmed by testing, would have given about 112 USG fuel in the inboard fuel tanks.

The arrangement put in place by the owners of the aircraft did not allow members of the club to be compensated for fuel that they had uplifted and paid for, but not used. Therefore, it would be in a pilot's interest to uplift only the amount of fuel required, although there is no evidence of this having occurred in this case.

Whilst the exact fuel load could not be determined, the refuelling receipt indicates that at least 72 USG was onboard.

As with many light aircraft of an older design, the fuel gauges appeared to be of little benefit to the pilot in accurately monitoring the amount of fuel onboard. In addition, it is unclear at what point the right wing gauge became inoperative. Without the ability to dip the tanks, filling the tanks completely was the only method available to the pilot to be sure of the amount of fuel being carried.

Fuel consumption

Information provided by the aircraft manufacturer on fuel consumption in the Flight Manual was limited to three power settings; 65% and 75% rated power, and climb power. The fuel consumption figures stated assume that the engines are leaned in accordance with the operating instructions contained in the Flight Manual. The pilot's stated engine-leaning technique of leaning to peak EGT followed by enriching each engine slightly would have caused the fuel consumption to be greater than the Flight Manual figures, but to what extent is unknown.

Fuel consumption can also be affected by:

> *'the equipment installed, the condition of engines, airplane and equipment, atmospheric conditions and piloting technique'*

as stated in the aircraft Flight Manual. Whilst the investigation did not extend to estimating the performance degradation due to the aircraft's age (39 years) and the condition of its engines, it is likely that the fuel consumption figures for the aircraft were in excess of the Flight Manual figures.

The CAA suggested figure of 20% would have allowed for such degradation, but was not applied. Whilst this would have increased the planned fuel consumption rate at 75% power from 35.6 USG/hr to 42.7 USG/hr the stated fuel flow indicated during the flight was consistent with the actual planned figure used.

Summary

It was not possible to determine a single cause for the fuel exhaustion. It is considered that it resulted from a combination of factors which increased fuel consumption in excess of the Flight Manual figures. The possibility that the aircraft departed without the assumed fuel quantity of 112 USG onboard could not be discounted.