ACCIDENT

Aircraft Type and Registration:	Cessna T303 Crusader, G-PTWB
No & Type of Engines:	2 Continental Motors Corp TSIO-520-AE piston engines
Year of Manufacture:	1984
Date & Time (UTC):	5 August 2006 at 1810 hrs
Location:	Denham Green, Buckinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 5
Injuries:	Crew - 1 (Serious) Passengers - 5 (Serious)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	1,717 hours (of which 662 hours were on type) Last 90 days - 37 hours Last 28 days - 5 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was completing a day VFR flight from Durham Tees Valley Airport to Denham Airfield. As the pilot turned on to the final approach for Runway 06, the right engine ran down. The pilot attempted to increase power on the left engine but it did not appear to respond. The airspeed decayed and the right wing dropped. The aircraft descended into a wooded area short of the runway, seriously injuring all those on board.

The investigation identified that fuel starvation of both engines was the cause of the accident. One Safety Recommendation is made.

History of the flight

The pilot and five passengers were flying from Denham Airfield on a return day VFR flight to Durham Tees Valley Airport. The purpose of the flight was for all those on board to attend a football match in Newcastle. Having met his passengers at Denham, the pilot carried out the normal daily checks and taxied the aircraft to the refuelling pumps. He checked the fuel gauges and recalled that they indicated approximately 26 to 30 US Gallons (USG) per side. Using the aircraft's Information Manual (referred to in this report for clarity as the Pilot's Operating Handbook or POH), a conversion factor of 1 USG = 6 lbs was used; by this means it was calculated that each wing tank contained 156 to 180 lbs of fuel. With the assistance of one of the passengers reading the fuel delivery meter, he uplifted 70 litres of fuel into each wing tank (one litre of Avgas 100LL of typical density weighs 1.58 lb). This would have taken the total fuel on board the aircraft to between 533 and 581 lbs. After boarding the aircraft, the pilot and passengers secured themselves in their seats and both engines started normally.

The weather for the flight was good with a scattered cloud base between 3,500 ft and 5,000 ft, visibility in excess of 10 km and light winds. The aircraft was taxied to Runway 06, where the power checks were carried out with both engines responding normally. The aircraft departed at 1215 hrs and following a stepped climb, levelled at FL065. During the flight the pilot set the power to 23 inches of Manifold Air Pressure (MAP) with 2,300 rpm and leaned the mixture accordingly. The flight was uneventful and the aircraft landed at Durham Tees Valley Airport at 1332 hrs and taxied without delay to the parking area.

On arrival, the pilot checked the fuel quantity remaining which he recalled as approximately 30 USG per side or 360 lbs total. He noted that there was a slight imbalance between the left and right tanks but he could not recall which tank gauge indicated the lower quantity. From this he calculated that there was sufficient fuel for the return flight with approximately one hour's flying in reserve. The handling agent asked the pilot if he required fuel and the pilot declined.

Having attended the football match, the pilot and his passengers returned to Durham Tees Valley Airport and boarded the aircraft for the flight back to Denham. The pilot carried out his usual pre-flight inspection of the aircraft and once again checked the fuel gauges, confirming sufficient fuel was available for the return flight. The engines started normally and the aircraft was taxied to the holding point for Runway 23. The pre-takeoff and power checks were completed and the aircraft departed at 1656 hrs climbing to a cruising level of FL055. The power was again set at 23 inches MAP with 2,300 rpm and the mixture leaned.

The descent was initiated some 25 minutes prior to the intended landing. It was almost a continuous descent apart from levelling briefly on three occasions. At some point in the latter stages of the flight, the passenger occupying the front right seat noted some instrument indications and the pilot's actions. He saw two rectangular gauges, adjacent to each other with the indicating needles on one gauge just above a red marking and the other in the red marking. He also saw the pilot turn rotary selectors and pull a red 'T' shaped toggle lever out at the base of the inter-seat console.

The pilot, who suffered serious head injuries during the accident, had very poor recollection of some aspects of the flight, particularly just prior to the impact. He could remember operating the fuel crossfeed and thought he may have retarded one of the throttles to idle in order to conserve fuel. He could not recall the fuel quantity indications. He lowered the landing gear, set 10º of flap and turned the aircraft left on to the final approach at approximately 90 kt Indicated Air Speed (IAS). At some point in the left turn the right engine ran down and he advanced what he thought were both throttles, but the left engine did not respond. The passengers described the aircraft rolling to the right and the right engine running down followed by what appears to have been the intermittent sound of the stall warning.

Witnesses on Denham Airfield saw the aircraft execute the left turn on to the final approach at what they described as a slightly steeper than normal bank angle of between 30º and 40º. They could not hear the sound of the engines due to the ambient noise around them. The aircraft rolled to wings level but then continued to roll to its right pausing briefly at a bank angle of approximately 30º before the right wing and nose appeared to drop and the aircraft disappeared behind some trees.

Recorded information

The aircraft was not fitted with a Flight Data or Cockpit Voice recorder, and was not required to be so equipped. National Air Traffic Services, the provider of en-route air traffic control services throughout the UK, provided recorded radar data for both the outbound flight to Teesside and the return flight to Denham. This data included both altitude and position.

From the recorded radar data, the ground track of the aircraft and the vertical profile of the outbound and return flights were established. The ground track distance for the outbound flight was 196 nm and the return ground distance flown was 184 nm. This was a total increase of 24 nm over the planned distance of 178 nm. The flight profiles were plotted and used to estimate the outbound and return flight fuel consumption.

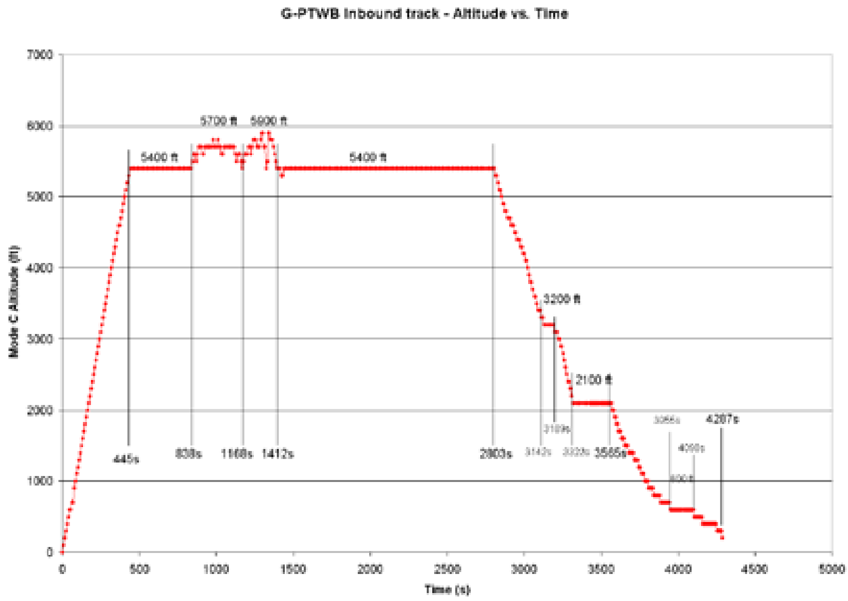


Figure 1

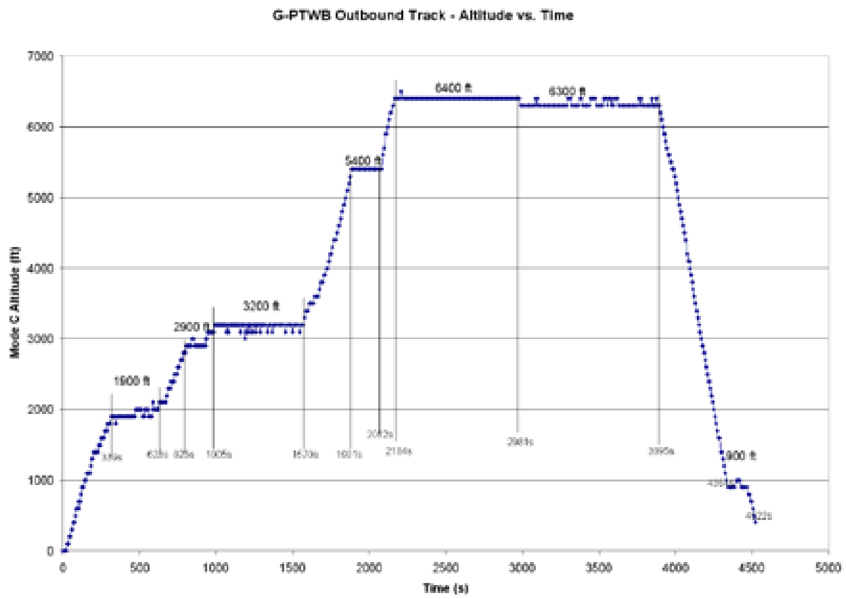


Figure 2

Survivability

The pilot and passengers were all secured in their seats by restraint harnesses. The pilot and front seat passenger had lap and diagonal, upper body restraints. The rear cabin passengers had lap restraints only. The aircraft had passed through the trees before striking the ground in a level attitude with virtually no forward speed. All those on board suffered serious injuries and were incapacitated, experienced different levels of consciousness and were unable to exit the wreckage. The rear cabin door on the left side had burst open during the impact. There was no fire.

The accident was witnessed and reported by a member of the public using his mobile telephone. He was promptly on the scene and provided detailed information to the police control room operator. The call was logged at 1810 hrs. The police initiated their Major Incident procedure and the first police officer was on the scene at 1817 hrs. The Denham Airfield staff, who had also seen the accident, immediately deployed the Airfield Rescue and Fire Fighting Service. Following some difficulty in locating the scene, they supported the police and paramedics in rendering assistance to the injured. The county Fire and Ambulance Services arrived and, following stabilisation and treatment by paramedics, the first casualty was extracted at 1858 hrs, departing for hospital at 1905 hrs. The last casualty was removed by ambulance from the scene at 1951 hrs and all the casualties were taken to hospital.

Training

On 4 August 2006, the day before the accident, the pilot completed his Licence Proficiency Check (LPC) and Instrument Meteorological Conditions (IMC) revalidation test. The person conducting the LPC was an experienced instructor/examiner who had carried out the pilot's initial conversion on to the type and periodical flight checks since he acquired the aircraft. The flight test comprised of simulated instrument flying, visual circuits and upper air work with both engines operating and single engine asymmetric handling. The pilot demonstrated a satisfactory level of flying and passed the LPC.

For the LPC, the aircraft departed Denham at 1206 hrs and landed back there at 1340 hrs giving a total flight time of 1 hour and 34 minutes. The start and taxi to and from the runway was estimated to take approximately 10 minutes. Prior to the flight the aircraft was refuelled to the half full indication on both fuel gauges giving a total fuel of 465 lbs. No weight and balance calculations were recorded but the examiner recalled that following the flight both fuel tank gauges indicated slightly more than one quarter full, which would have been at least 19.3 USG (116 lbs) per side, or 232 lbs total. Fuel used during the training flight would have been 233 lbs, giving a fuel consumption rate of 148 lbs per hour including start and taxi.

Following the flight check, both candidate and examiner seated themselves in the rear of the cabin. The examiner asked the pilot to explain how he would carry out the engine fire drill and the fuel crossfeed drill. The examiner stressed the need not to trust to memory for crossfeed procedures because, in his experience fuel crossfeed labelling was frequently ambiguous. The pilot correctly covered the memory items of the fire drill but stated that he would consult the aircraft checklist for the fuel crossfeed operation. Neither pilot nor examiner could find the crossfeed drill in the checklist and therefore consulted the fuel system description in the aircraft's POH.

From the fuel system diagram and the system description text, they concluded that to crossfeed fuel from the left tank to the right engine, two actions were required. The right engine rotary fuel selector should be turned to the CROSSFEED (yellow sector) position and the crossfeed emergency shutoff control should be pulled out to open the crossfeed fuel line. The use of the crossfeed emergency shutoff control is not clearly explained in the fuel system description. Immediately above the red coloured crossfeed emergency shutoff control, written in white letters on a black background, is the following instruction:

> *'PULL-EMER FUEL X-FEED SHUT OFF'*

In the 'Emergency Procedures' section of the POH, the 'Engine Fire in Flight' and 'Landing Gear Malfunction' procedures clearly state the purpose and operation of the crossfeed emergency shutoff control. For example, in the 'Engine Fire in Flight' non-memory items and in three of the landing gear abnormal procedures, the following action is required:

> *'Emergency Crossfeed Shutoff - - PULL TO CLOSE'*

The examiner and candidate read the text above the shutoff control but did not link the 'Fire Drill' non-memory action shown above. They had no reason to consult the landing gear malfunction procedures when discussing the crossfeed issue and therefore placed an incorrect interpretation on the information contained in the fuel system diagram.

An additional limitation was relevant when using the fuel system crossfeed controls. The crossfeed fuel line pickup in the tank was above the lowest point of the tank. In order to prevent the pilot attempting to crossfeed when the fuel level was lower than the pickup, a minimum fuel level and phase of flight was imposed. This was stated in the fuel system description as follows:

> *'If single-tank operation is being used when fuel levels are low, the fuel quantity in the tank in use should not be allowed to drop below 60 pounds prior to re-establishing normal single-engine per tank operation; this will avoid the possibility of dual engine stoppage due to fuel starvation.'*

A note was also included to emphasise the phase of flight when crossfeeding fuel should not be used:

> *'The fuel selector valve handles must be turned to the NORMAL FLIGHT, L. TANK, T.O./LDG (green sector)position for the left engine and the NORMAL FLIGHT, R. TANK, T.O./LDG (green sector) position for the right engine for takeoff, landing and all normal operations. Crossfeeding is limited to level flight only.'*

The information available to the pilot contained in the aircraft's POH regarding crossfeeding can be summarised as:

1. Only crossfeed during level flight and not during takeoff and landing.
2. Ensure that crossfeeding is stopped before the fuel quantity in the tank being used drops below 60 pounds (10 US gals).
3. The crossfeed emergency shutoff control is pulled to close the valves, not open them, and is not operated when crossfeeding.

Weather

An aftercast provided by the Met Office gave the synoptic situation at 1200 hrs on the 5 August 2006. It showed a ridge of high pressure extending across the British Isles from the south-west with a weak warm front lying north to south across the country. A light north to north-west wind covered the route. By 1800 hrs there was little change in the general conditions and the weather was good for the flight to and from Durham Tees Valley.

There was a possibility of slight rain from a strato-cumulus cloud layer mainly near the Teesside area but the weather was mainly dry throughout the route. The visibility was 20 to 30 km with a Mean Sea Level pressure of 1020 hPa.

In the Denham area at 1200 hrs, the cloud was mainly shallow cumulus base 3,500 to 4,000 ft with small amounts of strato-cumulus and cirrus above. The strato-cumulus layer increased to full cover around the East Midlands/Lincolnshire area, base 4,000 to 6,000 ft. For the return journey, extensive strato-cumulus covered the route from Teesside to the Cranfield area with the base around 3,500 to 5,000 ft. From Cranfield southwards it appears to have improved, with just small amounts of cumulus.

The table below sets out the actual winds for the altitudes given which were recorded from the Nottingham radiosonde ascent for midday on 5 August 2006. It is also a good guide to the winds later in the afternoon for the return journey and throughout the route. (Table 1)

Height AGL	Wind speed and direction
2,000 ft	300º/05 kt
5,000 ft	330º/05-10 kt
10,000 ft	020º/20-25 kt

Table 1

Fuel planning

Article 52 (e), '*Pre-flight action by commander of aircraft*' of the Air Navigation Order (ANO) places the following requirement on the commander:

'In the case of a flying machine or airship, that sufficient fuel, oil and engine coolant (if required) are carried for the intended flight, and a safe margin has been allowed for contingencies.'

The CAA produces Safety Sense Leaflets covering many aspects of aviation. Safety Sense Leaflet number 1e '*Good Airmanship*' contains a section on fuel planning and offers the following advice to private pilots:

'Fuel planning

- *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.*
- *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.*
- *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.'*

From his evidence to the investigation, the power settings generally used by the pilot of G-PTWB in the cruise were 23 inches Manifold Air Pressure (MAP) and 2,300 propeller rpm on both engines. From the performance section of the POH, this equates to approximately 67% power or 143.5 lbs per hour cruise fuel consumption (2.4 lbs per minute). The POH states that a normal rate climb at 5,150 lbs All Up Weight (AUW) to 8,000 ft takes approximately 10 minutes and uses about 33 lbs of fuel (3.3 lbs per minute). Descent from 8,000 ft takes 10 minutes and the fuel required is given as 21 lbs, giving a consumption of 2.1 lbs per minute. Applying these consumption rates to the vertical profile of the radar data indicated that the fuel used on the first sector was 220 lbs and on the return sector was 186 lbs. To this must be added 25 lbs for the start, taxi and takeoff at Denham and Durham Tees Valley, giving an additional total of 50 lbs. Based on this calculation, the total fuel consumption for the 'round trip' flight was approximately 456 lbs.

From previous experience the pilot had derived a planning figure of 100 litres per hour. This was based on 80 litres per hour (126 lbs) consumption, with an additional 20 litres (32 lbs) for contingency or the equivalent of a total 158 lbs per hour. From his experience this provided adequate fuel for the flight he undertook with a reserve which, if not required, would still be available on landing. If payload permitted he would also take additional fuel depending on the weather or nature of the flight being carried out. He had not previously experienced any difficulties with a shortage of fuel.

The pilot used a planning airspeed of 160 kt which, given the light winds at his cruising level, he used as a groundspeed for calculating the time to cover the 178 nm track distance from Denham to Teesside. This gave a flight time of 66 minutes at the 158 lbs per hour rate, requiring 174 lbs for the flight up and 174 lbs for the return flight. To this he added 25 lbs for each sector for start, taxi and climb and one hour reserve giving a total fuel required of 556 lbs.

The POH contains comprehensive tables, graphs and examples covering fuel consumption for all phases of flight in order for a pilot to establish the fuel required for a specific flight. In the introduction to the Performance section, the following statement is made:

'It should be noted that the performance information presented in the range and endurance profile charts allows 45 minutes reserve fuel at the specified cruise power. Fuel flow data for cruise is based on the recommended lean mixture setting. Some indeterminate variables such as mixture leaning technique, fuel metering characteristics, engine and propeller condition and air turbulence may account for variations of 10% or more in range and endurance. Therefore, it is important to utilise all available information to estimate the fuel required for the particular flight.'

In the performance section, specific 'Fuel and Time Required' graphs were provided for 50%, 60% and 70% power. The graphs permit the pilot to calculate the fuel required for a specific distance, wind conditions, altitude and power setting. This includes the fuel used for engine start, taxi, takeoff, normal climb, descent and 45 minutes reserve. By entering the 50% power graph with a distance of 178 nm and nil wind, a fuel required of 265 lbs is obtained. By adding the 10% contingency from the note above, a fuel required of 291.5 lbs is obtained.

The manufacturers were provided with time versus altitude data for the flights and asked to calculate the fuel used during the round trip including ground taxiing. They concluded that, based on the Cruise Performance chart, with a flight time in radar contact of 2 hours and 27 minutes the aircraft used 377 lbs of fuel. Adding 25 lbs of fuel for start, taxi and climb at Denham and Teesside gave a total consumption of 427 lbs for the round trip flight.

If the Fuel and Time Required chart was used and the 45 minute reserve of 104 lbs subtracted the figure increased to 455 lbs. The difference was accounted for by the Fuel and Time Required chart including an allowance for start, taxi, climb and descent, whilst the cruise chart does not.

The AAIB calculation was based on the minute/lb burn rates set out above with 25 lb start, taxi and takeoff allowance at Denham and Teesside, and produced a figure of 444 lbs based on the performance at a maximum AUW of 5,150 lbs.

From the different methods of calculating the POH fuel consumption, the 'round trip' fuel consumption was estimated at between 427 lbs and 456 lbs.

Weight and balance

No written record of the weight and balance calculations carried out by the pilot was available to the investigation. The weights of the pilot and passengers are their actual weights at the time of the accident, subsequently provided to the investigation. The calculation set out below is based on the examiner's recollection of the fuel remaining on board the aircraft following the training flight, that is, approximately ¼ full. The addition of 70 litres per side on the morning of the accident has been added to that amount. (Table 2)

Using the pilot's recollection of the tanks being between 26 and 30 USG per side before refuelling at Denham, for the lower figure an additional 80 lbs should be added to the total fuel weight. At 30 USG per side, an additional 128 lbs should be added to the 453 lbs shown in Table 2.

The Maximum permitted TakeOff Weight (MTOW) for the aircraft was 5,150 lbs. The aircraft CG envelope at 3,300 lb was from the forward limit at 146.5 in to the aft limit of 157.2 in aft of the CG datum. The forward limit is constant to 3,800 lb and then reduces in a linear fashion to 151.2 in at the MTOW of 5,150 lb. The aft CG limit remains constant at 157.2 in up to the MTOW.

Item	Weight (lbs)	Arm (in)	Moment
Aircraft basic weight	3,696		559,083
Pilot	191	138	26,358
Front passenger	112	138	15,456
Middle seat passengers (2)	476	178	84,728
Rear seat passengers (2)	353	216	76,248
Cargo	25	250	6,250
Fuel	453		73,000
Departure Denham	**5,306**	**158.5**	**841,123**
Flight fuel burn	*220		
Landing Teesside	**5,086**	**158.37**	**805,489**
Flight fuel burn	*186		
At impact	**4,900**	**158.4**	**776,223**

*AAIB calculated leg consumption, no inclusion of 25 lbs for taxi and takeoff.

Table 2

From the weights provided and the estimate of fuel carried and consumed, the aircraft was operated initially 156 lb above the MTOW during the departure from Denham. This would increase to 284 lbs if the higher fuel quantity was carried. The CG was calculated initially at 158.5 in aft of the CG datum reducing to 158.4 in aft of the datum as fuel was consumed. This was beyond the aft CG limit for the aircraft throughout the flight.

When loading the aircraft, the pilot had placed the heavier passengers and baggage at the rear. By re-seating the heavier passengers at the front and lighter passengers at the rear, as well as placing the baggage in the forward baggage hold, the CG could have been brought forward of the aft limit. The aircraft could also have been operated within the MTOW of 5,150 lbs, if fuel for the outbound flight only had been carried, as set out below, although it would have been necessary to refuel for the return flight. (Table 3)

Medical

After the accident, the pilot was admitted to hospital and a sample of his blood was taken for hospital purposes. During the course of the day, the pilot had been seen to consume alcoholic beverage and analysis of the blood by the hospital indicated the presence of alcohol. The amount detected was not considered to be a major contributory factor in the accident but the exact effect on the pilot's performance could not be established.

Performance

The aircraft was observed by ground witnesses in a left turn with an angle of bank of 30º to 40º before rolling through the wings level attitude to approximately 30º right bank. At this point the right wing dropped. The stall speeds with 10º of flap set with an aft CG and the angle of bank flown are reproduced below, showing both indicated and calibrated airspeeds (KIAS and KCAS). (Table 4)

Item	Weight (lbs)	Arm (in)	Moment
Basic weight	3,696		559,083
Pilot	191	138	26,358
Front passenger	245	138	33,810
Middle passengers	418	178	74,404
Rear passengers	280	216	60,480
Forward baggage bay	25	82	2,050
Fuel	295*		48,800
Weight and CG at Takeoff	**5,150**	**156.31**	804,985
Weight and CG at Landing	**4,950**	**155.72**	

* The fuel required of 295 lbs would have been sufficient to operate the aircraft on the sector to Durham Tees Valley with 45 minutes reserves and 10% contingency, using 50% power settings.

Table 3

Angle of Bank	0°	0°	30°	30°	45°	45°	60°	60°
Weight (lb)	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS
5150	57	62	61	67	68	74	81	88
4650	53	59	57	63	63	70	75	83

Table 4

A note states that:

> *'Altitude loss during an engine inoperative stall recovery may be 300 feet with a pitch below the horizon of 30°.'*

As an indication of the aircraft's performance with one engine inoperative at 4,800 lbs at sea level, the rate of climb at 97 kt (V_y) with the failed engine propeller feathered, landing gear and flap retracted and maximum power set on the operating engine is 270 ft per min. The following decrements must be subtracted from that rate of climb to calculate the aircraft climb/descent performance. (Table 5)

Configuration	**Decrement**
Landing gear extended	-350 ft/min
Flaps extended 10º	-50 ft/min
Flaps extended fully	-450 ft/min
Inoperative propeller windmilling	-250 ft/min

Table 5

With landing gear lowered, flap set to 10° and the right propeller windmilling, a net rate of descent of 380 ft/min would result. If power was not available from the left engine, the drag from both propellers windmilling and the aircraft configuration would have resulted in a rapid loss of airspeed had a positive nose-down attitude not been adopted.

Significant Aircraft Features

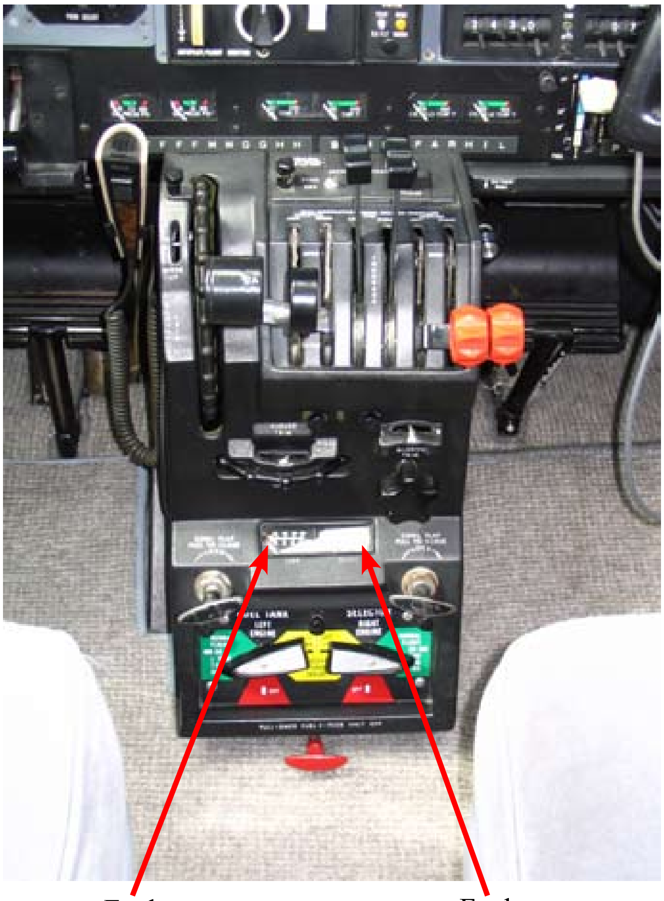
The aircraft type is equipped with two integral fuel tanks. These are positioned in the outer wings and are formed by the upper and lower skins and the front and rear wing spars. They are bounded at their inboard ends by closure ribs, approximately co-incident with the outboard sides of the engine nacelles, and extend outboard from there to stations close to the wing tips. The fillers are at the outboard ends of the tanks and since the wing has significant dihedral, the tanks can contain a large proportion of their capacity before any fuel can be seen via the filler orifices.

The fuel pick-up points are positioned at the forward and aft ends of manifolds sited at the extreme inboard ends of each tank. Each pick up point is positioned close to the plane of the lower wing skin and is closed by an individual float valve. Thus, when fuel is present at the pick-up point, the valve admits it to the manifold, but when it is absent, closure of the valve prevents air from flowing into the manifold. The POH states that each tank has a maximum capacity of 77.5 USG, whilst the total unusable fuel is quoted as 2.0 USG.

The fuel system supplies the engines via fuel selector valves positioned in the wings, just inboard of the tanks. These are controlled, via sliding cables within conduits, by means of handles mounted on a console between the two front seats, just above the cabin floor. The relevant tank contents gauges are to be found above the fuel selector handles. Each of these is annotated with white markings on a black background at 10, 30, 50, and 70 USG levels. These numerical indications are positioned below a horizontal white line. Above the line, fuel quantities are annotations in lbs. Those graduations indicated are at the 100, 200, 300 and 400 lbs levels. The section which appears to fall between the empty and 10 USG graduations on each gauge is coloured yellow and white, whilst a narrow red line graduation is positioned approximately at the empty position.

Each selector can be turned to the 'OFF', 'ON' or 'CROSSFEED' position. With the selector set to the 'ON' position, the relevant engine is supplied by the tank on the same side of the aircraft. When the 'CROSSFEED' setting is selected, the engine on the same side as that selector receives fuel from the tank on the other side of the aircraft, via crossfeed pipes which pass beneath the cabin. To prevent leakage of fuel, should one or both crossfeed pipes become damaged, crossfeed shutoff valves are provided. These are fitted close to the tanks. They ensure that only the fuel volume within the pipes, and no fuel from either tank, can be lost through any crossfeed pipe leakage once the shutoff valves are moved to the 'OFF' position. Both shutoff valves are operated via cables within conduits from a singe T-handle below the fuel selector valve console. If the handle is pulled when both fuel selectors are in the 'ON' position, engine operation is not affected. If, however, it is pulled when a fuel selector is set to 'CROSSFEED', the supply to the engine on the side of the selector with that setting will be interrupted and the engine will not continue to operate. The cross-feed shut off valve control handle is painted red, signifying its emergency control status.

The crossfeed pipes have open pick-up points positioned on the inboard closure ribs of the fuel tanks, significantly



Fuel gauge   Fuel gauge

Figure 3

Fuel system controls and gauges

above the plane of the lower wing skins. Air can thus be drawn into the crossfeed system and thereby interrupt the fuel supply to the engine selected to crossfeed, if the fuel in the tank in question is below the level of the orifice of the crossfeed pick-up.

The fuel divider units on the engines each incorporate a spring-loaded valve. This shuts off the fuel supply to the injectors positively when the fuel pressure to the relevant divider drops below a threshold. Loss of fuel supply to an engine fuel/air control unit thus results in closure of the valve and engine stoppage. A volume of fuel, however, remains in the engine fuel system upstream of the flow divider, following such engine fuel starvation.

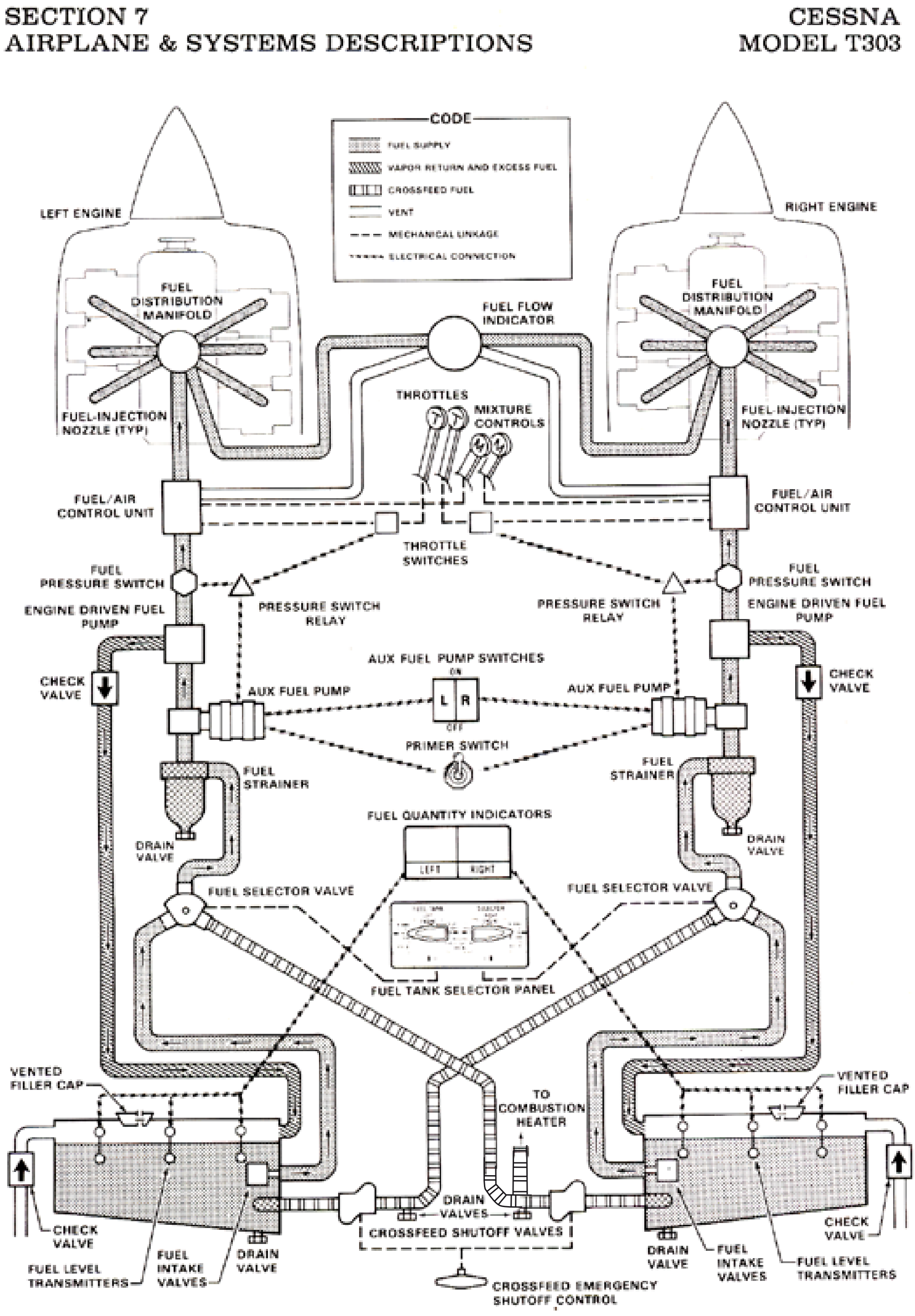


Figure 4

Fuel system diagram

The accident site

The aircraft came to rest in a wings-level attitude on an upward sloping surface in dense woodland, at a point having no significant ground vegetation. The slope formed the upper part of a railway embankment. Examination of the damaged trees revealed that the aircraft had struck and demolished one, but had inflicted little damage to adjacent trees. It had come to rest while moving laterally to the right, as indicated by the vertical trunk of a small tree which had penetrated the wing tip and travelled inboard for approximately ½ metre. A substantial branch had passed vertically between the elevator and the horizontal stabilizer. Both engine nacelles were deformed into a pronounced 'hogging' (ie down at the extremities) shape. Extensive damage had been inflicted to the nose of the aircraft forward of the windscreen although no significant longitudinal compression damage was evident. The fuselage was reduced in depth and the tail unit, complete with fuselage tailcone, was separated from the aft end of the fuselage. The seatback of one of the rear row of forward facing seats had collapsed backwards.

Both propellers were in the normal operating range and the lower two blades of both were embedded in soft soil. Neither propeller exhibited any evidence of rotation at impact. A number of tree boughs were found to have been chopped in an orientation approximately perpendicular to the branch axes. It was known, however, that sawing equipment had been used to cut away timber to gain access to the forward end of the cabin during rescue operations. This created significant quantities of cut timber of similar appearance to tree boughs having suffered blade strikes from fast rotating propellers.

The aircraft had the landing gear extended and one stage of flap (10º) was set.

On entering the aircraft cabin it could be seen that the right fuel selector was in the crossfeed position whilst the left selector was in the normal tank to engine position. The crossfeed shutoff control was in the shutoff position.

After initial examination, the aircraft was dragged approximately four metres forward on to level ground, using strops attached to the main landing gears, in order to ensure there was no danger of it sliding down the embankment and descending through trees on to the adjacent railway track. It was subsequently noted that the interior of the right tank at its inboard end could be seen through a hole in the upper wing surface. No fuel was present. The lower surfaces of the tank appeared to be undamaged so it was postulated that the tank may have been empty at impact. When a quantity of water was poured into the tank filler, however, a rupture was identified where the lower edge of the rear spar had deformed close to the inboard end of the tank. A hole deliberately created in the top skin of the left tank revealed that it was also empty and introduction of water revealed a correspondingly positioned rupture to that identified in the right tank. Samples of the water introduced into the tanks were then recovered in a transparent beaker and examined. Only a scarcely detectable layer of hydrocarbon appeared to be present on the surface of the water from each tank.

It was reported that rescue of the occupants initially required access to both sides of the aircraft from the rear, involving rescuers passing behind the points of tank rupture. With the aircraft on a steep slope this required personnel to pass below the points from which any fuel present would have drained immediately after the impact. None of the personnel on the scene immediately after the impact reported seeing or smelling any fuel or noticing any dampness of the otherwise very dry soil. The absence of surface vegetation precluded the examination for discolouration which often reveals the presence of Avgas residue.

Detailed examination

The aircraft was cut into a number of sections for removal from the woods before being transported to the AAIB headquarters where a detailed examination was carried out. Prior to separation of structural elements, all piping requiring cutting was crushed flat using special equipment, thus sealing the ends against loss of fuel or ingress of other substances. The crushed areas were then cut at mid length, preserving, as far as possible, the sealing effect of the crushing on both sides of the cut.

During subsequent examination, the settings of the two fuel selector valves and the crossfeed shutoff valves were established by determining the presence or absence of flow resulting from application of air pressure to various fuel lines following cutting away of the crushed sections. It was thereby established that all four valves were set to the same position as their cockpit selectors indicated. Both crossfeed pipes were found to contain fuel.

The powerplants were removed from the firewalls and examined in the presence of the AAIB and a specialist provided by the engine manufacturer. All the engine fuel system components were rig tested in accordance with their manufacturer's specifications. All were found to contain varying amounts of fuel and to function correctly, with the exception of one variable fuel valve mounted co-axially with its throttle butterfly. This valve exhibited a small volume leak. Examination of the local area revealed no evidence of discolouration from pre-accident leakage in this area, however. Examination of the seals on the shaft in the region of the leakage did not reveal any excessive wear, deterioration or damage. The possibility that slight bending of the shaft had occurred during the impact resulting in reduced performance of the seal could not be ruled out.

Strip examination of both engine carcases revealed no evidence of pre-crash failure.

Discussion

From the evidence at the accident site, it could be deduced that the aircraft had struck the top of a tree in an approximately erect attitude with very little forward speed but significant vertical speed. The restriction of major damage to one tree in a wood of closely spaced trees all of similar height was a particularly positive indication of this. It was further concluded that the presence of the tree had reduced the final descent rate. The ground impact force on the main landing gear appeared, however, to have been sufficient to produce the deformation of the nacelles and contributed to the flattening of the cabin. Some backward motion during the impact sequence was evident from the backward collapse of one of the seatbacks. Damage inflicted to the right wing tip and to the elevator / horizontal stabiliser junction was indicative of, respectively, lateral and vertical motion through the trees, whilst absence of wing leading edge damage confirmed an absence of significant forward motion.

The impact with, and subsequent destruction of, the one tree had left no positive evidence as to the pitch and roll attitude at initial contact. The lack of leading edge impact damage and the failure of the aircraft to impact nose-down between trees tended to confirm the view that tree-top impact occurred in an attitude not grossly different from that of normal flight. It indicated significant downward rather than forward motion.

The propellers exhibited no evidence of rotation, although the soft ground and lack of forward speed constitute conditions which frequently leave no evidence even when significant power is known to have been produced at impact.

There are two possible reasons for the absence of fuel visible through holes in the upper skins at the inboard ends of both tanks:

(1) The tanks were empty at the time of the accident, or

(2) At the time of the impact the remaining tank contents all drained through the ruptured rear spar joints at the inboard ends of the tanks.

The latter event is a possibility since the aircraft initially came to rest on a slope in a nose-up attitude causing the ruptures to be positioned close to the lowest points in the tanks. The wreckage was only subsequently dragged to a level surface where much of the examination took place. It is surprising, however, that a small residue of fuel from the extreme low point of the tanks did not remain when the tanks were examined.

Although some fuel was found in components of the engine-mounted fuel systems and pipe-work, one component was damaged by the impact and had allowed some leakage to take place. It was thus not possible to compare usefully quantities of fuel in the two engine systems. It should be noted that the flow divider unit incorporates a spring-loaded shutoff valve so that when air enters the engine system leading to a loss of delivery pressure, the valve will shut off. This causes power loss even though a significant volume of fuel remains in the components and pipe-work. The presence of fuel in these areas, therefore, does not necessarily indicate that fuel was still being supplied from either tank at the time of the impact.

The use of a cable and conduit system for controlling the fuel tank selector and crossfeed shutoff valves makes it unlikely that either the valves or their controls moved from their immediate pre-impact positions. This is despite the considerable impact distortion of the fuselage relative to the wing structure.

The settings of the valves, as determined from tests using air pressure, confirm that the left fuel valve was in the normal position, the right valve was in the crossfeed position and both crossfeed shutoff valves were in the closed position. These all corresponded with their cockpit selections as found during the site examination and this is presumed to have been the situation at the time of ground impact.

The signs of a lack of forward motion through the trees, the relatively intact, although severely damaged state of the aircraft and the survival of the occupants indicate relatively low energy at the time the aircraft struck the trees. These factors are consistent with both a low forward speed and low height at the time control was lost. Although the engine power at impact could not be determined, it appears that the impact was consistent with a stall rather than the consequences an asymmetric power induced control loss during the approach.

No failure or defect within the aircraft or its propulsion system was identified.

Fuel starvation was probably the main causal factor of the accident, although fuel exhaustion could not be ruled out. The lack of a record of the aircraft fuel state prior to the departure from Denham or Durham Tees Valley meant accurate departure fuel quantities could not be established. There were two different recollections of the fuel quantity remaining onboard the aircraft after the training carried out on the day before the accident. The examiner recalled slightly more than ¼ full or 19.5 USG per side and the pilot thought there was 26-30 USG per side. With the addition of 140 litres of fuel prior to departure from Denham the quantity onboard was between 453 lbs by the examiner's recollection, and up to 581 lbs from the pilot's.

No precise quantity of fuel consumed on the 'round trip' flight could be established but using fuel consumption data from the POH, between 427 lbs and 455 lbs was considered a reasonable estimate.

The two gauges, one alongside the other, which were observed by the front right seat passenger, were probably the fuel gauges. The needle on one gauge was just above the red and the other was in the red. Whilst he could not remember exactly at what point he saw them, from his description it was just prior to the approach to Denham. The red line indicates the tank is almost empty and therefore suggests that the fuel in the tank with the needle in the red was about to run out. The other tank contained a small amount of fuel. The pilot also recalled seeing an imbalance but could not recall the indications.

These indications were consistent with the pilot reducing power on the engine on the side with the tank with the lowest fuel contents, and attempting to crossfeed from the other tank, which had slightly more fuel remaining. From the position of the crossfeed selector and valve, the right tank was the tank which contained least fuel, and was nearly empty. Opening the crossfeed, however, would not draw fuel from the left tank as the level was below its crossfeed fuel pick-up. If sufficient fuel had been available to crossfeed, the effect of pulling the crossfeed emergency shutoff would have been to prevent the right engine drawing fuel from the left tank. However, this was not relevant at such a low fuel state since crossfeeding was not possible. The right engine therefore ran down and with the propeller not feathered the aircraft would have yawed to the right.

The information contained in the POH (Information Manual) and the crossfeed labelling was not clearly understood by either the pilot or the LPC examiner, and so the following Safety Recommendation is made:

Safety Recommendation 2007-086

The Federal Aviation Administration should review the Cessna T303 Crusader Information Manual and Checklists to ensure that clear and unambiguous information is provided for the operation of the fuel crossfeed system.

If the left tank fuel was also exhausted, then the left engine would also have run down. If, however, useable fuel remained in the left tank, it is possible that in the 30º- 40º left bank, with the aircraft yawing to the right, the fuel migrated towards the left wing tip and uncovered or partially uncovered the normal fuel pick-up. Again, the left engine would suffer a reduction in power, or stop.

With the left engine not responding and the right engine propeller not feathered, airspeed would have decayed rapidly from the 90 kt approach speed. The stall speed is given as 60 to 65 KCAS depending on the angle of bank. If the nose was not lowered positively the aircraft would stall and possibly drop a wing. This was the behaviour described by the witnesses on the ground.

There was no evidence of fuel on the ground, and none was reported escaping by those first on the scene. Although a small spillage might not have been obvious, larger amounts should have been evident from smell and visible leaks. From this, it is probable that the fuel on board on departure from Denham was closer to the lower estimate of 453 lbs than the higher estimate of 581 lbs.

The pilot had not carried out a full weight and balance calculation to determine the AUW and balance of the aircraft. Had he done so the limited amount of fuel that could be carried and the CG position outside the permitted envelope should have been apparent. With the weight of the aircraft, the pilot, passengers and baggage, only 297 lb of fuel could be carried in order to remain below the 5,150 lbs MTOW. By re-arranging the passenger seating and baggage, the CG could have been moved forward to within the permitted envelope.

With only 297 lbs of fuel available, the aircraft could have operated the Denham/Durham Tees Valley sector with 45 minutes reserves and 10% contingency at 50% power. This would not have met the Safety Sense leaflet recommendation of 20%. Refuelling at Durham Tees Valley would have been necessary for the return flight.

Conclusions

The pilot was properly licensed and qualified to conduct the flight. The aircraft was fully serviceable and the weather was suitable for the flight and was not a factor in the accident.

From the evidence provided, the loading of the aircraft was such that it was operated initially above the MTOW of 5,150 lbs and throughout the flight the aircraft was operated outside the aft CG limit of 157.2 inches aft of datum.

With the payload being carried, the aircraft was not capable of safely completing the 'round trip' flight and remaining within the permitted weight and balance envelope without refuelling at Durham Tees Valley. Insufficient fuel was carried for adequate reserves and contingency fuel to complete the flight.

The pilot had consumed alcoholic beverage during the day but the effect on his decision making and aircraft handling ability is not known.

During the approach, the fuel crossfeed was used, which was not permitted. The selection of crossfeed from the left tank to the right engine was probably the cause of the right engine running down. This was due to insufficient fuel contents being available to allow fuel to be drawn from the left tank by the crossfeed pick-up. Pulling the crossfeed emergency shutoff control therefore did not contribute to the accident.

The accident was caused by fuel starvation of both engines with the right engine ceasing to produce power and the left engine operating at reduced power or stopping. Control was then lost when the airspeed decayed and the aircraft stalled, dropping the right wing.