Accidents Investigation Branch

Department of Transport

Report on the accident to Vickers Varsity T1 G-BDFT at Marchington, Nr Uttoxeter, Staffordshire on 19 August 1984

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Department of Transport
Accidents Investigation Branch
Royal Aircraft Establishment
Farnborough
Hants GU14 6TD

30 July 1986

The Rt Honourable John Moore
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr M M Charles, an Inspector of Accidents, on the circumstances of the accident to Vickers Varsity T1 G–BDFT, which occurred at Marchington Nr Uttoxeter, Staffordshire, on 19 August 1984.

I have the honour to be
Sir
Your obedient Servant

G C Wilkinson
Chief Inspector of Accidents

Contents

Accidents Investigation Branch

Aircraft Accident Report No. 2/86
(EW/C883)

Operator:		Leicester Aircraft Preservation Group
Aircraft:	*Type:*	Vickers Varsity T1
	Nationality:	British
	Registration:	G–BDFT (WJ 897)
Place of Accident:		Marchington, Nr Uttoxeter, Staffordshire
		Latitude: 52° 52′ N
		Longitude: 001° 46.5′ W
Date and time:		19 August 1984 at 1008 hrs
		All times in this report are GMT

Synopsis

The accident was notified to the Accidents Investigation Branch at 1132 hours on the 19 August 1984 and the investigation began on the same day.

The aircraft, which was being operated by a preservation group, was to have taken part in a flying display that afternoon at Liverpool (Speke) Airport. During the transit flight from East Midlands Airport to Liverpool in the morning the aircraft joined in formation, at 3000 feet, with a Cessna 180 which had been pre-arranged to take aerial photographs of the Varsity. After approximately thirty minutes of flight, and while in formation with the Cessna, the Varsity pilot reported that he had some engine problems. The aircraft lost height steadily and the left engine was seen to stop, but to start rotating again seconds later. Shortly afterwards, at a height of approximately 400 feet, witnesses saw the undercarriage lower and the aircraft roll suddenly to the left and hit the ground inverted in a steep nose down attitude, immediately bursting into flames. Eleven of the fourteen occupants were killed.

The report concludes that the aircraft suffered a progressive loss of power on both engines and stalled at low altitude while attempting to make a forced landing.

1. Factual Information

1.1 History of the flight

The Varsity aircraft was a twin engined training aircraft used by the Royal Air Force until 1974 when it was sold into private ownership. It was currently owned and operated by an aircraft preservation group who maintained the aircraft to its service specification. For this reason it carried the military designation "WJ 897" on the fuselage and wings although it was registered as G–BDFT. The aircraft had been granted a Permit to Fly and was restricted to display and demonstration flying and the practising for such displays. It was the usual practice for the society to attend air displays and for the organisers of the display to pay the society. This was the principal source of revenue for the maintenance and operation of the aircraft.

Thirteen members of the society had boarded the aircraft earlier that morning at RAF Syerston in Nottinghamshire, where the aircraft was hangared, for the short flight to East Midlands Airport. This flight was uneventful and, after landing, the aircraft was refuelled with 436 imperial gallons (imp gals) of aviation gasoline (Avgas 100 LL) increasing the total fuel on board to 510 imp gals.

It was intended to fly to Liverpool (Speke) Airport to take part in an air display that afternoon. The editor of an aviation magazine joined the passengers at East Midlands Airport for this flight and he had arranged that aerial photographs of the Varsity would be taken during the flight to Liverpool. A professional photographer was on board a Cessna 180 aircraft that had been prepared for the photography by the removal of the passenger door and this aircraft was to rendezvous with the Varsity at 3000 feet above mean sea level (amsl) in the area of Blithfield Reservoir some 20 miles to the west of East Midlands Airport. The removal of the passenger door imposed an airspeed limit of 105 knots (kt) on the Cessna so this aircraft took off ahead of the Varsity to proceed to the rendezvous area.

The Varsity engines were normally started using a ground electrical supply consisting of two commercial vehicle batteries mounted on a small trolley which would be stowed on the aircraft after the engines had been started. On this occasion, the left engine was reluctant to start and after it initially fired, it faltered and stopped, emitting smoke from the exhaust. For fear of exhausting the batteries with repeated attempts to start, the right engine was started first. The left engine was then motored over before another start attempt was made, this time successfully. The passengers on the Varsity were told that the left engine had been over primed on the first attempt to start.

It could not be established whether a power check was carried out before take-off at 0932 hrs but, later, the survivors commented that there was nothing unusual about the take-off although in the opinion of one of them, the climb had been slower than he expected. The approach controller at East Midlands Airport provided bearing and range information to the Varsity pilot to help him locate the Cessna 180 and, at 0947 hrs, both aircraft changed to a discrete radio frequency.

The Varsity was then flown in formation on the right hand side of the Cessna in a series of wide orbits of the Blithfield Reservoir. During this time, both the photographer and the pilot of the Cessna, together with many ground witnesses, commented that the left engine of the Varsity was seen to emit occasional puffs of smoke accompanied by loud bangs which several witnesses likened to the sound of a shotgun being fired. When the photographer requested that the Varsity climb slightly above the Cessna and lower its undercarriage, the Varsity pilot reported that he was having trouble with the right engine. The Cessna pilot replied that it looked to him as if the problem was in fact with the left engine, as he could see puffs of smoke as if the engine were running too rich. When the Varsity pilot replied that it might be engine icing, the Cessna pilot noted that his intake temperature was indicating in the range where there was no risk of intake icing on his engine. The undercarriage of the Varsity was lowered briefly before being retracted again with the pilot's comment that he "could not accept the drag and might have to abort the photography".

The passengers on the Varsity were also aware of the backfiring and could see the intake pressure relief panel on top of the left engine cowling lifting and emitting a flash of flame when the engine backfired. They described this as happening every 30 seconds or so at first but later becoming more frequent and they were told by an engineer member of the group that it was because a spark plug was oiling-up during the slow speed flying and that it would be all right when the throttles were opened. However, towards the end of the photographic flying, the right engine started to backfire as well.

At 1005 hrs, the Varsity pilot called East Midlands Airport on the approach frequency requesting a direct return to the airport because he had some engine problems and might have to declare an emergency. In reply the approach controller passed the Varsity a course to steer to East Midlands and asked whether the Varsity could maintain height. The pilot answered that "at the present we are able to but it's with some difficulty".

The Cessna pilot remained in visual contact with the Varsity which was flying towards East Midlands although steadily losing height and, at 1007.20 hrs, he informed the controller that the (left) engine of the Varsity had stopped. Thirty seconds later the Varsity co-pilot radioed "we're going to have to put it down in the nearest field, we're down to 400 feet and losing power on both engines so we are going into the . . . .". Ten seconds later, the Cessna pilot reported that the Varsity had crashed and was on fire. Several ground witnesses reported that while the left engine was stopped the right engine was still backfiring and that just before the accident the left engine was then seen to start to rotate again although some witnesses described it as "hesitating" or "not developing power". The undercarriage of the Varsity was then lowered and, at a very low height, the left wing was then seen to drop and the aircraft rolled over, the nose dropped and it crashed inverted. Just before impact the left mainplane severed 11,000 volt electricity supply wires.

The accident site was on the southern edge of a disused military camp, a part of which had been converted into a gliding site with a short runway orientated east-west. As the aircraft broke-up on impact, the rear part of the fuselage together with the empenage fell into a drainage ditch some 10 feet deep. The three survivors were seated in rearward facing seats in this part of the fuselage. Two were able to escape from the fuselage but the third was hampered by a broken leg and received severe burns when a wire fence prevented him from leaving the accident area.

Members of the gliding club were quickly on the scene and although the fire extinguishers that they brought were of no use against the fire in the main wreckage, they were able to cover the injured passenger with a fire blanket and extinguish brushwood and grass fire around him. The two pilots and nine passengers died either of injuries received in the impact or of asphyxia.

The fire service and police had been alerted by telephone calls from members of the public and were at the site 16 minutes after the accident occurred. The fire was extinguished by water hoses.

1.2 Injuries to persons

Injuries	Crew	Passengers	Other
Fatal	2	9	–
Serious	–	3	–
Minor/None	–	–	–

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

The wires of an 11,000 volt overhead electricity supply were severed.

1.5 Personnel information

1.5.1 *Pilot:* Male, aged 56 years

Licence: Commercial Pilot's Licence

Medical examination: Class 1, renewed 1 August 1984, valid for 12 months.

The pilot was under periodic review by the Consultant Cardiologist to the Civil Aviation Authority (CAA). Following an examination, which included an exercise ECG, on 1 August 1984, the cardiologist concluded that the pilot remained fit for a Class 1 medical certificate.

Certificate of Test: 20 February 1984, Cessna 404 aircraft, valid for 13 months in respect of private flights.

Flying experience: Total hours: 7760

Total hours on type: 63

A Certificate of Exemption had been issued to the pilot by the CAA and was valid until 30 June 1985. This certificate exempted the pilot from the provisions of Articles 18 and 19 and also Schedule 9 of the Air Navigation Order 1980 to the extent necessary to enable him to fly as pilot-in-command of Varsity G–BDFT notwithstanding that his licence did not contain an aircraft rating, Certificate of Test or Certificate of Experience for this aircraft. This exemption was granted subject to the following conditions:

(a) no flight should be made other than for the purpose of flight testing, giving displays of flying, or practising for such displays or for the purpose of flying the aircraft to or from the place where the display is to be given;

(b) no flight should be made for the purpose of public transport;

(c) no person should be carried on any flight other than a person carried in accordance with any condition of the Permit to Fly.

1.5.2	*Co-pilot:*	Male, aged 49 years
	Licence:	Private Pilot's Licence, Landplanes Groups A and B.
	Medical examination:	Class 3, renewed 5 March 1984, valid until 31 March 1985.
	Certificate of experience:	Groups A and B aeroplanes, valid until 29 August 1985.
	Flying experience:	Total hours: 793
		Total hours on type: 21.

A Certificate of Exemption had been issued by the CAA, valid until 30 June 1985. This Certificate exempted the pilot from the provisions of Articles 18 and 19 and also Schedule 9 of the Air Navigation Order 1980 to the extent necessary to enable him to fly as co-pilot of Varsity G–BDFT. This exemption contained the same conditions as that issued to the pilot.

1.6 Aircraft Information

1.6.1 General

Manufacturer:	Vickers Armstrong Aircraft Ltd
Type:	Varsity T1.
Year of manufacture:	1952
Constructor's Serial No:	620
Engines:	2
Engine type:	Bristol Hercules 264 radial piston engine
Permit to fly:	Issued 17 August 1984, valid for twelve months.

Certificate of inspection:	17 August 1984, valid for 7 days or 5 hours flying time.
Maximum take-off weight:	36,000 lb
Maximum landing weight:	36,000 lb
Total airframe hours:	6682 hours

1.6.2 *Description of aircraft*

The Vickers Varsity was a twin piston-engined aircraft designed as a multi-role training aircraft for the Royal Air Force. This particular aircraft was built in 1952 and used for training until it was sold to a private owner in 1975. The Leicester Aircraft Preservation Group became associated with the aircraft from that time and in 1982 ownership was transferred to them with the two pilots, as principal shareholders, acting as trustees for the group.

1.6.3 *Engine description and operation*

The Hercules 264 is a 14 cylinder, sleeve valve, supercharged radial engine. The supercharger is a single stage, two speed centrifugal type with a single turbine entry which mounts a Hobson–RAE B1/BH 13/1 injection carburettor, and directs the mixture into a guide vane rotor at the eye of the impeller. The two speeds are denoted "M" and "S" gears, and are selectable from the cockpit via a clutch. The higher speed is "S" and is used to maintain boost at high altitudes. Dual ignition is provided by two Rotax N14/B1 polar induction type magnetos.

The injection carburettor is used in conjunction with a Plessey TM5 Mk 7BH engine driven fuel metering pump. The operation of the carburettor is based on the principle that the air flow through the engine is proportional to engine speed, boost pressure, exhaust back pressure and charge temperatures. The carburettor is therefore designed to meter fuel for any combination of these four factors and thus ensure a correct air/fuel ratio for any engine running requirements. The fuel pressure within the injection carburettor is regulated by the engine driven pump. The metered fuel is discharged on the engine side of the throttle valves via two spray nozzles.

Engine hours since last overhaul:

Left	716
Right	619

Date of last overhaul:

Left	17.7.69
Right	24.11.70

Date of installation in G–BDFT:

Left	16.8.71
Right	1.6.71

The left engine underwent a repair in February 1971 during which the injection carburettor was changed. It was normal practice only to change carburettors and engine-driven fuel pumps as matched pairs. Although there is no record of the serial number of the pump installed on the engine at that time, the serial number of the new injection carburettor identified it as the unit found on the engine at the time of the accident, and it therefore appears almost certain that the engine driven pump installed at the time of the accident was fitted in February 1971. Information received from the engine manufacturer indicates that the fuel pump and injection carburettor lives were double the engine life. The pump diaphragm shelf life was up to 10 years, subject to a satisfactory inspection after 7 years.

1.6.4 *Aircraft accommodation*

A total of 14 seats was fitted to G–BDFT. Behind the two pilots' seats was a radio operator's station with 2 aft-facing seats and, on the port side of the fuselage, a sideways-facing, collapsible instructor's seat. Two further collapsible seats were fitted to the seat rails of the radio operators' seat and were forward-facing so that one was positioned behind the co-pilot's (right) seat and the other behind the central control pedestal. Both of these seats consisted of a cushioned base but with no back support other than the tubular metal frame forming the back of the radio operator's seat. A lap strap was provided for each seat but there was no upper torso restraint. Further aft in the fuselage, immediately behind the main spar, was a single, aft-facing seat for the navigator instructor from where he could monitor 2 trainees in aft-facing seats at the navigation station.

There were additionally, 4 aft-facing seats fitted between the navigation station and the main entry door. In military service these would have been used by students awaiting instruction at the training stations. These last 4 seats were not fitted to the aircraft at the time that it entered civil operation but were added at a later date. The CAA have no record of an application for approval to fit these additional seats.

Air Publication (AP) 101B, published by the then Air Ministry, was a maintenance manual, a copy of which was in the possession of the aircraft operator. Section 1, chapter 2 of this manual described the controls and equipment at the various crew stations. Reference was made to the sideways facing seat at the radio station as "not to be occupied when the aircraft is landing" and to the seats behind the pilots and attached to the radio operators' seat rails as "must not be used as a crash position". It is understood that this would have precluded their use for take-off or landing in RAF service.

1.6.5 *The Permit to Fly*

No Certification of Airworthiness had been issued for the aircraft but the CAA had issued a Permit to Fly enabling the aircraft to be operated within the United Kingdom for the purposes of demonstration and exhibition, subject to certain conditions. Condition 10 stated: "The aircraft shall not be flown for the purpose of public transport or aerial work, except aerial work which consists of flights for the purpose of public exhibition or demonstration, including practice flights, test flights, and positioning flights associated with such demonstration".

A space on the Permit allowed the CAA to specify the "Maximum number of seats authorised to be fitted (including crew)". This space had been left blank on this Permit and also on previous Permits relating to the aircraft. There is only one other Varsity flying on the British civil register. The Permit to Fly for this aircraft limits the total number of authorised seats to eleven. This other aircraft is equipped with eleven fixed seats and one collapsible "jump" seat.

After inspection by the CAA on 17 May 1984 the permit was revalidated for a two month period for the specific purpose of conducting a test flight. On 24 June 1984, during this 2 month period, the aircraft was flown from Syerston to Bruntingthorpe to take part in an air display. Eight passengers were carried on these flights and the flight test schedule was completed while the aircraft was on route to and from Bruntingthorpe.

The aircraft was inspected by a CAA surveyor on 17 August 1984 following which the Permit to Fly was renewed until 16 May 1985. During this examination, the surveyor noted that the maximum number of seats had been omitted from the Permit and intended to advise the CAA issuing office on the next working day, 20 August.

1.6.6 *The Weight Schedule*

A Weight Schedule had been prepared for the aircraft when it first entered civil ownership in 1975 and a copy of this Schedule was held by the CAA. The information on this Schedule was based upon an RAF Weighing Report of 1972 and corrections were made for the removal, prior to the sale, of certain RAF equipment.

Part C (Disposable Load) of the Schedule detailed 4 rows of passenger seats in addition to those of the 2 pilots. By examination of the lever arms of these seat rows about the aircraft datum, it was established that the seats referred to as Row 1 were the two collapsible seats fitted behind the pilot's seats; Row 2 comprised the seats at the radio station together with the sideways facing collapsible seat; Row 3 was the single seat for the navigation instructor and Row 4 referred to the 2 navigation trainees' seats. No reference was made to the 4 additional seats fitted between the navigation station and the main door as these were installed at a later date. No later Weight Schedule that included these seats could be traced.

1.6.7 *Weight and centre of gravity*

Maximum permitted take-off weight		36000 lb	
Maximum permitted landing weight		36000 lb	
Centre of gravity limits:	Forward	29.6 feet	aft of datum
	Aft	30.8 feet	aft of datum

In calculating the weight and centre of gravity of the aircraft, the following assumptions were made:

(1) The weight of each person on board was 172 lb (78 kg)

(2) The weight of items intended for sale at the Liverpool Airshow, together with a trestle table was 150 lb and they were stowed just forward of the mainspar.

(3) The weight of the ground starting batteries and the trolley was 150 lb and they were stowed just aft of the main door.

(4) The aircraft had been refuelled to a total of 510 imp gal and this fuel was equally disposed in the 6 tanks.

(5) 82 gals of fuel was consumed from the start of take-off to the time of impact.

At the start of the take-off run at East Midlands Airport, the aircraft weight was 36,528 lb and the centre of gravity was 30.05 feet aft of the datum. At the time of the impact with the ground, the aircraft weight was 35,938 lb and the centre of gravity was 30.045 feet aft of the datum, assuming that the fuel had been used equally from all tanks.

1.6.8 Air Publication 4331A Pilot's Notes

The following extracts are from the first edition copy of the Pilot's Notes which was held by the Leicester Aircraft Preservation Group.

> "57. Testing the engines and services
>
> (i) While warming up to 120°C cylinder head temperature, and 15°C oil temperature, open the cross-feed cock and switch on a booster pump, on one side only, for a period of 10 seconds. This will carry away any slight accumulation of water in the pipe."
>
> "Final checks for take-off.
>
> . . .
>
> Fuel — Contents: Checked
> Booster pumps: ON
> Master cocks: ON
> Cross-feed cock: Shut"

1.6.9 Maintenance history

Whilst in RAF service, the aircraft was maintained in accordance with a schedule laid down in AP101B–3201–5A. The schedule essentially consisted of the following checks:

Primary	every 100 flying hours
Minor	every 400 flying hours
Minor Star	every 800 flying hours
Major	every 2000 flying hours or 5 years.

Typically the aircraft flew in excess of 400 hours annually whilst in RAF service. However, since the aircraft came on the civil register, it had achieved only some 63 flying hours up until the day of the accident. The log book records show that a total of six primary inspections were carried out between 14 April 1976 and 11 August 1983. In addition, out of phase maintenance tasks were performed at various times, and all the work details were recorded on work sheets. A Major Service became due in January 1977 but the owners applied to the CAA for deferment due to the low utilisation. This was granted as were all subsequent applications.

All engine maintenance tended to be routine, with little work arising as a result of defects. An exception was a rough running magneto (right hand unit on the right engine) in June 1981, which, on examination was found to contain evidence of damp in the distributor. There was no record of any work done on the fuel metering pump or injection carburettor, and neither does any scheduled requirement exist in the APs. When in RAF service, the engines had an overhaul life of 1400 hours, with pumps and injectors being overhauled at every second engine overhaul.

The aircraft was seldom flown during the winter months and when not being flown, the aircraft was housed in a hangar at Syerston. Although the engines were not inhibited at these times, it is understood that they were periodically turned over on the starter motor, the plugs having first been removed.

Engines which are not run for extended periods are normally required to be inhibited to guard against corrosion. Engine ancillaries, which in the case of the Hercules, includes the injection carburettors, also have to be protected. The following is an extract from Engine Technical Bulletin No C 7, Issue 11, dated May 1961, entitled "Inhibiting Hobson Injection Carburettors".

1. It is extremely important to give protection to the diaphragms of these carburretors during periods of idleness, for deterioration is most likely to take place when the chambers are empty, partly full of fuel or full of stale fuel. Adopt the inhibiting technique given below.

2. If the engine is expected to be idle for a period of not more than four weeks it is essential that the carburettor is completely filled with fuel. To ensure this, run the engine at least once a week. If the engine cannot be run, prime the carburettor in the following manner:

    (1) Make sure that the cut off lever is in the CUT-OFF position

    (2) Set the throttle lever at take-off boost to give maximum metering valve port opening.

    (3) Turn on the fuel and switch on the relevant tank pump. Check that the low pressure warning device (if fitted) indicates satisfactory pressure.

    (4) Move the throttle lever through its range once or twice to fill the accelerator diaphragm chamber.

    (5) After one minute, turn off the fuel then switch off the tank pump.

    (6) Move the throttle lever to the closed position, the lever must remain in this position during any period of idleless.

3. If at the end of four weeks the engine still cannot be run, drain the stale fuel through the plug hole in the fuel inlet adaptor, or alternatively set the throttle lever at take-off boost and remove the pipe from the impeller tip connection. Refill the plug or pipe then reprime the carburettor as detailed above.

4. When it is known that an engine is to be out of service for more than four weeks, run the engine on unleaded fuel and storage oil (see Bulletin No A36) then inhibit the carburettor with anti-freezing lubricating oil ....".

1.7 Meteorological Information

The Meteorological Office produced the following aftercast for the area and time of the flight.

Synoptic situation: Slow moving anticyclone over Germany and the North Sea, with a light southerly airflow over the British Isles.

The characteristics of the air mass were as follows:

Height	Wind	Air Temp (°C)	Dew Point (°C)	Humidity
Surface	Southerly 5 kt	+21 to +23	+15	60–70%
1000 feet	Southerly 5 kt	+19	+13	68%
2000 feet	Southerly 10 kt	+17	+11	68%
3000 feet	200° 10 kt	+15	+09	67%

Cloud: No low cloud, 1/8–3/8 cirrus above 25000 feet.

Surface visibility: 6–10 km.

Weather: Hazy

0°C Isotherm: 12000 feet.

Icing/turbulence: Nil.

The accident occurred in daylight.

1.8 Aids to Navigation

Not relevant.

1.9 Communications

The aircraft was in communication with the Aerodrome and Approach Controllers at East Midlands Airport from the time of take-off until 0945 hrs and again from 1005 hrs, when the pilot announced that he wished to return to East Midlands, until the time of the accident 3 minutes later. Recordings and transcripts were made of these communications.

During the period from 0945 until 1005 hrs the aircraft and the Cessna were operating on a discrete frequency which was not tape recorded.

1.10 Aerodrome information

Not relevant.

1.11 Flight recorders

Recorders were neither fitted nor required to be fitted.

1.12 Wreckage and impact information

1.12.1 On site examination

The aircraft had crashed into level ground on the southern boundary of a disused military camp located 1 mile east of the village of Marchington, near Uttoxeter, Staffordshire. The first point of impact was beneath an electrical power line running in an east-west direction some 26 feet above the ground; all three conductors were severed. The wreckage was contained in a relatively small area, with the furthest flung fragments being some 250 feet from the initial impact point, from which the aircraft had broken up along a track of approximately 040°M. The first wreckage item was the left propeller, this having partially embedded itself in a concrete slab. The left and right hand sides of the wreckage trail were bounded respectively by the right and left outer wing sections; the aircraft centre section and tail had come to rest in an upright position with the rear fuselage lying in a ditch.

It was apparent from the disposition of the impact marks made by the left wing tip, the engines and the nose that the aircraft had struck the ground, left wing tip first, in an inverted attitude. The right wing and engine had severed the branches of some mature trees and the line of broken off stumps indicated that the dive angle was approximately 45°. It was clear that following the detachment of the engines and outer wing sections, the remainder of the aircraft somersaulted, thereby coming to rest in an upright attitude, with the fin undamaged. During the post impact fire, the fin subsequently collapsed on to the left hand tailplane.

The left engine and outer mainplanes were the only parts of the aircraft to remain unaffected by the fire. The centre section wings, nacelles and mid/forward fuselage had been rendered down to ash and it is considered that the fuel on board contributed to the intensity of the fire. A general view of the accident site is presented at Appendix A.

Examination of the left hand propeller revealed little chordwise scoring or leading edge damage on the blades; this led to the conclusion that there was little rotational energy at impact, and consequently the engine was developing little if any power. In contrast, the right hand propeller had cut through the central trunks of two substantial trees, and had suffered some blade leading edge damage as a result of this and subsequent contact with the ground. Some of the timber cuts were approximately 1 foot in diameter and it was therefore concluded that the right hand engine was developing at least a degree of power. On site examination of the engines was confined to extracting some of the spark plugs. Those from the right hand engine were a normal slate grey in appearance, whereas those from the left hand unit were covered with a black, sooty deposit and some were still wet with fuel. It was considered that the state of the plugs from the left engine was indicative of an over-rich condition.

Most of the nose and flight deck had been destroyed by the ground impact and subsequent fire; among the few instruments that survived were an airspeed indicator (ASI) which had stuck at a reading of 100 kt; an altimeter with a subscale reading of 1024 mb; an engine oil temperature gauge indicating approximately 100°C, and an engine rpm indicator (subsequently identified as the right engine gauge) indicating approximately 1400 rpm. The throttle pedestal had been badly disrupted and burned; thus no information was available on the pre-impact settings of the engine controls.

The only fuel that was obtained from the wreckage was a small quantity – approximately 2 ml – from the injection carburettor that had become detached from the left engine. This was sent for analysis at the Materials Quality Assurance Directorate (MQAD) at Harefield, along with samples taken from the bowser from which the aircraft had refuelled at East Midlands Airport.

A photograph taken from the accompanying Cessna aircraft showed the Varsity in a steep nose down, left wing dropped attitude a second or so before ground impact. (From this position it was evident that the aircraft must have continued to roll to the left in order to comply with the assessed ground impact parameters.) The photograph showed the undercarriage to be extended, although it was not possible to discern the flap position. Examination of the wreckage showed them to be in the retracted position although the linkages were still free to move. The two hydraulic flap actuators in the wings were also in the flaps retracted position and it was concluded that this was the likely pre-impact position. Had they been extended and then pushed into the retracted position due to ground impact, it was considered that the linkages would have broken rather than back drive the actuators to the flaps up position.

Following the on-site examination, the wreckage was recovered to the AIB facility at Farnborough, Hampshire for a detailed examination.

1.12.2 Detailed examination of wreckage

1.12.2.1 Fuel system

Very little of the fuel tanks and associated pipework had survived the fire. Among the components that had survived were the collector boxes in the nacelles, the flowmeters, the boost pumps and the fuel filter bowls. Although severely fire affected, no blockages or restrictions were observed. Ash deposits in the fuel filter bowls were analysed to establish whether any tank material had accumulated there, thus causing a blockage. The results failed to show any evidence of organic material and it was therefore concluded that the debris was ash that had been drawn along the attaching pipework during the ground fire.

The fuel flowmeters were examined in detail, as a jammed mechanism would have prevented fuel from reaching the engine had they been switched on. A spring loaded solenoid valve automatically switches the units to bypass when electrical power is removed, which of course was how they were found. No defect was found that could have resulted in a jammed mechanism. The boost pump impellers and shrouds were examined for evidence of rotation which would have shown them to be switched on at impact. The results were inconclusive however, as impact forces had not been severe enough to leave any witness marks.

The crossfeed cock is located in the rear, inboard section of the left wing. All that remained was the valve actuating rod and the solidified molten remains of a knurled nut that had attached to the valve body and through which the rod passed. The position of the rod with respect to the nut, and hence valve body, was shown by a bright area of the rod that had been shielded from the effects of the fire. This revealed that the valve rod had been at its "valve open" limit of its range of movement. Whilst there remains a possibility that movement occurred at impact, it is considered that its Arens control linkage (ie Bowden cable type) would have sustained the impact with less likelihood of moving the valve than, say, a push-pull rod type of linkage.

1.12.2.2 Fuel and oil samples

In addition to the small quantity of fuel taken from the injection carburettor of the left engine of G–BDFT, MQAD also analysed samples taken from the fuel bowser at East Midlands Airport. These consisted of samples from the tank, vehicle filtration, delivery hose, and the daily sample from 18 August 1984, ie the day preceding the accident. All the samples complied with the AVGAS 100LL specification, although the sample from the delivery hose contained a small quantity of water. The documentation relating to the daily fuel storage checks for the days preceding and including the day of the accident showed no departure from the normal appearance, described as "blue, clear and bright". Contact was made with the operators of a Cessna aircraft that refuelled from the same vehicle after G–BDFT and they reported that they had experienced no fuel related problems.

Oil samples were taken from the propeller hub assemblies (propeller control and lubrication being effected by engine oil) and analysed by Dowty Rotol as part of the propeller strip examination. The results showed the oil to comply with the correct specification, although a high lead content was noted.

1.12.2.3 Engines, engine ancillaries and propellers

The engines, engine ancillaries, propellers and propeller control units were examined in detail. Both engines had suffered severe impact damage to their front faces but no evidence was found in either engine of pre-impact mechanical failure.

The right propeller control unit was badly fire damaged but showed no evidence of pre-impact failure and the left unit performed satisfactorily under rig testing. Impact damage to the propeller blade root attachments and bearings showed that the left propeller was turning only very slowly whereas the right propeller was turning at significantly higher speed. This was in agreement with the previously noted damage to the propeller blades themselves and with the 1400 rpm indication on the right engine instrument. Both propellers were found to have been operating at blade angles of between 20° and 23° (measured at 0.7 blade radius). The amount of engine power required to sustain a given propeller rpm at this angle is a function of true airspeed (TAS). Information from the propeller manufacturer indicated that at 80 kt (the approximate stalling speed of the aircraft under these conditions) a small power contribution would have been required from the engine to sustain 1400 rpm.

The magnetos showed evidence of considerable impact and fire damage. Three out of the four units produced satisfactory sparking during rig tests after simple rectification of obvious impact damage and contamination had been carried out. The fourth unit was so severely heat damaged that its shaft had seized; its coil nevertheless produced a correct spark output for 30 seconds at maximum capacity test. All terminal boards produced correct continuity and flash test results on all terminals in undamaged areas. The high tension (HT) harness of the left engine was subjected to an insulation check which proved satisfactory, however, a dusty deposit was observed in the adaptor plugs. The harness of the right engine had suffered fire damage which had destroyed the insulation. Following an incident to the Duxford Varsity, G–BEDV (see Section 1.17.1) the magnetos of G–BDFT were re-examined for evidence of HT tracking. A small burn mark was visible in the poleshoes tunnel of one of the left engine magnetos. The right engine magnetos had suffered considerable fire damage which could probably have obliterated any evidence of tracking.

Detailed examination of the injection carburettors showed that both had suffered impact damage and, in addition, the right hand unit was extensively fire damaged. No evidence was found in either unit of pre-impact malfunction.

The engine driven pumps of both engines had been broken from their mountings during the impact. Although damaged, no abnormalities were found in the right pump and the relief valve and its associated diaphragm were intact and capable of correct operation. The left pump had suffered generally similar mechanical damage in the impact but the diaphragm controlling the relief valve had deteriorated with local swelling in the rubber material over an area surrounding a split. This diaphragm was protected by its housing, which was still intact, and it was clear that the split existed before ground impact. The major effect of a split in this diaphragm is to produce a progressive enrichment of the fuel/air mixture as boost is reduced at a constant engine rpm. (See paragraph 1.16.3.)

1.13 Medical and pathological information

A full post mortem examination including histology and toxicology was carried out on each of the eleven victims and, in addition, urine drug screening was carried out on the two pilots. Seven of the victims died from multiple injuries, one from a fractured skull and three were asphyxiated. No pre-existing medical condition was revealed by these examinations that might have a bearing on the accident.

1.14 Fire

There was an intense post-impact fire which destroyed most of the aircraft except for the outer mainplanes and part of the empennage. Units of the Staffordshire Fire Brigade were at the scene sixteen minutes after the accident. A total of four hose pipes was deployed using water from the the water tenders initially and then from an adjacent static water tank.

1.15 Survival

At the time of the impact with the ground, the aircraft was inverted with a steep nose-down attitude. The two pilots and the two passengers seated immediately behind them were the only occupants in forward facing seats and they were the only occupants to suffer severe head injuries. One passenger was using a sideways facing collapsible seat, all the others were using rear facing seats. The three survivors were occupying rearward facing seats on the centre line of the fuselage behind the main spar. This section of the fuselage fortuitously fell in a drainage culvert and so escaped the initial fireball from the burning fuel.

1.16 Tests and Research

1.16.1 Flight test on Varsity WL679

A flight test was conducted using a Varsity from the Royal Aircraft Establishment, Farnborough to explore the low speed flying envelope and to establish the amount of power available to G–BDFT during the last minutes of the flight. The aircraft was flown at 105-110 kt at a range of rpm settings and the engine parameters noted after the conditions had stabilised. No abnormalities were noted and the engines showed no signs of distress.

The right engine was then "failed" and allowed to windmill. The left engine power was increased to 2400 rpm at 33 inches of boost to maintain 105-110 kt in level flight. The windmilling right propeller continued to rotate at 2000 rpm but the cylinder head temperature cooled to 100°C in approximately 15 seconds.

A descent was then initiated with the right engine still windmilling and the power on the left engine adjusted to establish an average rate of descent of 1000 ft/min. The right engine continued to windmill at 2000 rpm, the left engine was initially set to 2400 rpm and 22 inches of boost. The boost was steadily reduced to 16 inches to maintain the speed and rate of descent. At this low boost setting the left propeller control unit was on the limit of its control range and the rpm decreased to 2350.

1.16.2 Fuel starvation test

The Varsity from the Royal Aircraft Establishment was used to study the effect of running both engines from a single fuel tank until the tank was empty. The aircraft was fuelled with approximately 85 imperial gallons in each of five fuel tanks and a measured quantity of 15 gallons in the left forward outer tank. The engines were ground run with the inner tank boost pumps switched on so that fuel would be used initially from these tanks. These boost pumps were then switched off and the pump for the left forward outer tank switched on and the cross feed opened. The engine power was increased to 2200 rpm at 30 inches of boost and the contents of all the fuel tanks were noted at regular intervals. The contents of the left forward outer tank decreased progressively for the first eight minutes while the contents of the other tanks remained constant. At this time the fuel in the left forward outer tank had been used and thereafter the contents of all the other tanks began to decrease slowly. Under these conditions the engines could be run to full power without showing signs of distress at any power setting and it was clear that fuel was being drawn from other tanks after the left forward outer tank was empty.

1.16.3 Tests on the engine driven fuel pump

Fuel was supplied to the injection carburettor by an engine driven fuel pump which was fitted with a relief valve. The relief valve was controlled by a spring and also a diaphragm, one side of which was affected by fuel pressure. The air chamber on the other side of the diaphragm was vented by way of a flexible pipe leading to the supercharger entry casing. Technical information from the engine manufacturer indicated that this was primarily a fire precaution measure to ensure that, in the event of a diaphragm failure, the fuel from the pump relief valve would not flow freely into the engine bay. The vent incorporated a restrictor to prevent excessive quantities of fuel passing into the entry casing in such a contingency. The combination of engine driven pump and injection carburettor was designed to maintain the correct fuel/air ratio for normal engine operation.

Active development of the system ceased over 30 years ago and it was not possible to obtain certain details of the way it operated. It was noted that the diaphragm vent pipe was connected to the intake system between the throttle butterflies and the supercharger impeller. It was clear that under a large range of engine operating conditions (particularly at low boost/high rpm combinations) the air side of the diaphragm would be subjected to pressure below ambient. Engine ground runs were carried out on the Varsity at RAE Farnborough, (fitted with simple instrumentation) which gave an indication of the pressure drop experienced in the vent pipe and confirmed that the greatest drop in pressure occurred at low boost/high rpm settings.

In order to determine the effect of a rupture in the diaphragm, rig tests were carried out on a serviceable pump of the same type as that fitted to the left engine of the accident aircraft. Fitted with an intact diaphragm, the pump output pressure and flow rate were measured for various values of pump rpm and air pressure acting on the diaphragm. As air pressure was reduced at a constant pump rpm it was observed that both the output pressure and flow rate also reduced. The tests were repeated with the intact diaphragm replaced by one which had been deliberately perforated to match the defective item in the left engine unit. It was found that variations in air pressure acting on the diaphragm now had no effect on either the pump output pressure or flow rate. It was therefore evident that the reduction in pump output pressure and flow rate, which was normally produced by low engine boost settings, was not occurring when the diaphragm was ruptured. It was concluded that, with a ruptured diaphragm, the engine could be expected to have operated with a near correct fuel/air mixture when at high boost settings, but to have become progressively over-rich as boost was reduced.

1.17 Other information

1.17.1 Other instances of engine failure on Varsity aircraft

The only other known engine failure on G–BDFT occurred on 20 September 1981, which was only 10 flying hours before the accident flight. All power was lost on the left engine and the aircraft made an emergency landing at Leicester East. After landing the engine was restarted and ran without any apparent problem. The crew concluded that the failure had been the result of induction icing and no further investigation was carried out.

The only other civil registered Varsity, G–BEDV, based at Duxford, experienced rough running on both engines whilst on a cross channel flight on 25 September 1981. The aircraft diverted into Southend, following which the engines ran normally, and no fault was found despite extensive investigation. In April 1985 the same aircraft suffered a major power loss on both engines after an extended test flight and the final approach was flown with only partial power on the left engine and virtually no power from the right engine. When the boost lever was pulled back during the landing phase the left engine produced a surge of power which required prompt use of rudder to maintain directional control. The following day, the engines started without difficulty, and met the power check requirements.

On a subsequent test flight, the right engine began to run roughly when high power was demanded, (ie at economical cruising boost levels and above), but ran normally following a cooling off period on the ground. The crew concluded that the problems stemmed from a time related heat soak fault in the magnetos, and advised AIB.

The magnetos from the left engine were tested under AIB supervision, and no problems were found. However, the endurance testing was carried out at room temperature and thus did not simulate the sort of temperatures experienced in an engine bay. Subsequent examination of the magnetos revealed that the coil from the inner unit had a hole of approximately 1/8 inch x ¼ inch burned through the curved surface of the cylindrical capsule. Elsewhere there was a small stained area that indicated intense heat had been present. The coil from the outer magneto displayed a small surface blemish in the same position as the hole on the inner magneto coil. It is considered that this may have been a manifestation of an impending burn-through. Examination of the left engine magnetos revealed some evidence of tracking on the inside of the cover plates; furthermore, a degree of erosion, which could have been indicative of tracking, was visible where the end plates joined with the cylinders of the coil capsules. The varnish had flaked off in this area, and this could have allowed the ingress of moisture over a period of time.

The RAF was also approached for information on in-service engine malfunctions. The Maintenance Analysis and Computing Establishment at RAF Swanton Morley supplied computer print-outs of incidents occurring between 1971 and 1977, which covered the period between when computerised records began, and the phasing out of the Varsity from RAF service. The list cannot therefore be assumed to be exhaustive. The computer listing included "Engine Flame-out" and "Engine Mis-firing" incidents, and there were a large number of these due to a variety of causes. Typical problems included spark plugs, oil contamination in the injection carburettor and magneto faults. A total of six fuel pump failures was recorded, and there were a number of "no fault found" entries. The computer abstract contained no detail as to the nature of the component faults or failures. Pre-computerised records were rather sparse, although one copy of a card index system record of an incident was obtained. This concerned an occurrence in 1969 where a Varsity experienced an engine vibration after take-off and subsequently landed after one circuit. The narrative mentions only that the fuel metering pump was subsequently found to be defective.

A more recent computer record included an incident that occurred in August 1977, when a total power loss was experienced on one engine. Microfilm record of the same incident was also in existence, and the narrative detailed how all power was lost on the left engine during a test flight following the replacement of the left engine. The aircraft was successfully recovered on one engine but once on the ground, the defective engine ran satisfactorily. Despite an extensive investigation, no fault was found and it was concluded that a transient fault in either the fuel pump or the injector had caused the problem.

The engine manufacturers (now Rolls Royce) were also approached for information, and they supplied details of a defect investigation arising as a result of an incident to a Varsity in May 1966. The aircraft had suffered an engine cut whilst in straight and level flight at 6000 feet and, although the engine recovered, it cut again some 20 seconds later, and was subsequently throttled back and ran for a further 25 minutes until the aircraft landed. On the ground, the fault could not be reproduced. Subsequent investigation revealed the presence of a black carbon dust in the adaptor plug that connected the HT harness with the distributor boards. Although this seemed to have no effect, it was found that the presence of moisture (simulated by holding the plugs over a steam source) induced electrical tracking, with a corona discharge effect.

1.17.2 Radar recordings

The digital recording from the radar station at Clee Hill near Birmingham was examined. This indicated that the Cessna, G–BETG had taken off shortly before the Varsity and had flown in the area of Blithfield Reservoir at 3000 feet altitude until it was joined in formation by the Varsity. The two aircraft then flew close together for 20 minutes. During this time the altitude reporting facility on the Cessna's transponder became inaccurate and suddenly indicated that the aircraft was flying at 7600 feet so the pilot was asked to switch off the altitude reporting facility to avoid confusion with other radar returns.

After the announcement by the Varsity at 1005 hrs that he wished to return to East Midlands Airport, the radar recording showed that the aircraft flew in a generally north-easterly direction from Blithfield Reservoir to Marchington.

1.18 New investigation techniques

None.

2. Analysis

2.1 General

It was apparent that, while the Varsity was being flown in close formation with the Cessna at 3000 feet altitude and at a speed of around 105 kt, it suffered a progressive loss of power. Indicative of this was the Varsity commander's reluctance to lower the undercarriage when requested by the photographer and the fact that, having lowered it, it was retracted almost immediately with the comment that "he could not accept the drag". Under these ambient conditions the normal performance of the aircraft is such that height can be maintained with the undercarriage lowered even with one engine feathered.

It was also reported that at the time that the commander retracted his undercarriage, he expressed concern over the right engine and considered that icing was a possible reason. However, the surviving passengers in the Varsity and the pilot and photographer in the Cessna have stated that the left engine was backfiring and that puffs of smoke were seen from the exhaust and flames from the intake pressure relief panel on top of the engine.

The aircraft's position at this time, in the vicinity of Blithfield Reservoir, was within 7 miles of a private airfield at Tattenhill that was known to the commander. A disused airfield at Hixton was only 3 miles to the west and there were numerous generally large, flat fields in the area, many of which might have been suitable for a successful forced landing. That the commander ignored these possibilities and decided to return to East Midlands Airport some 22 miles away suggests that he considered that there was sufficient power available.

When the Varsity commander informed the approach controller at East Midlands Airport that he had an engine problem he also stated that "he could maintain height although with some difficulty". Nevertheless, over the next three minutes, the aircraft lost nearly 3000 feet of altitude until the co-pilot announced that they were at 400 feet and had lost, or were losing, power on both engines and would have to land. The aircraft crashed inverted soon afterwards just south of a disused military camp, part of which was used as a gliding site.

2.2 The Engine Failures

The failure of the left engine was attributed to a split diaphragm in the fuel metering pump. Tests showed that the fuel/air mixture became progressively over-rich as the boost was reduced; this accords with the engine settings that would have been used when the aircraft was flying in formation with the Cessna. It is possible that the reluctance of the left engine to start at East Midlands Airport was indicative of a split in the diaphragm but, equally, this could have been due to overpriming. Furthermore, low boost settings would have been used during the previous approach and landing at East Midlands and no engine difficulties were encountered then. This leads to the conclusion that the diaphragm split occurred later on, or perhaps attained a critical dimension if it was already split. It therefore follows that there came a stage where the engine could not be accelerated out of the over rich regime, and suffered a rich cut instead. The condition of the plugs and piston crowns provided additional evidence of over-rich running.

The cause of the power loss from the right hand engine was not established; however, evidence from the propeller indicated that at least a degree of power was being developed at impact. It was possible to establish that there had been no mechanical failure, and, although the injection carburettor was badly damaged in the impact, no evidence of failure was found. Whilst maladjustment of the injector could result in rough running, it is considered improbable that such a large power loss could occur for this reason over such a short period of time. Witness reports of back-firing on the right hand engine suggest that neither the injector cut-off (ICO) nor magneto switches were inadvertently operated, as this would have resulted in a windmilling propeller with no ignition occurring in the engine.

The possibility of water contamination of the fuel was considered, due to the trace of water in the delivery hose sample. However, all the remaining samples including the one from the left engine injector were clear. Also, no problems were reported by the operators of aircraft subsequently refuelling from the same bowser as G–BDFT. An engine the size of a Hercules would require a considerable quantity of water contamination in order to stop it, and in view of this, one would expect to find evidence of water elsewhere. Furthermore, unless it is presumed that any water was deposited only in the right wing tanks, then the diaphragm failure in the left engine fuel pump is reduced to an unexplainable coincidence.

The only part of the right engine whose condition could not be adequately assessed was the ignition system; which had been severely fire affected. The ignition troubles experienced by the Duxford Varsity subsequent to the G–BDFT accident have illustrated the type of insidious faults that may occur in 20-30 year old components. In this case it was shown that heat soak from the engine could cause a partial ignition coil breakdown, with resultant tracking in the magnetos and consequent erratic engine running. Although not positively established, the breakdown is likely to be due to the effects of moisture ingress in the coils. It was apparent that in the early stages of breakdown very little evidence of tracking existed, this usually being confined to small burn marks in the poleshoes tunnel, or what appeared to be a slight stain on the surface of the coil capsule. No hint of breakdown was evident during endurance tests on the bench, although the tests were conducted at ambient, as opposed to engine bay temperatures.

In the case of G–BDFT, a small burn mark in one of the left engine magnetos indicated HT tracking had occurred at some time. It is thus possible that ignition problems were superimposed on the over-rich condition caused by the fuel pump diaphragm failure. Generally however, HT tracking could be expected to occur at the higher boost settings, due to the higher gas pressure in the cylinders encouraging the HT to find an easier path to earth. The right engine magnetos had been badly fire affected and it is considered that this may have obliterated any evidence of tracking. The coils had also suffered fire damage, although there were no obvious signs of sparking.

Examination of historical evidence showed that the Varsity fleet suffered engine failures from a variety of causes throughout its service career, and that there were a number of "no fault found" cases. Fuel pumps, injection carburettors and magnetos were cited a number of times as the reason for failure, although generally, the records were not specific as to which component part was to blame. Nowhere in this data, nor in any of the Aeronautical Publications relating to the aircraft, was it clear that a fuel pump diaphragm failure could result in engine failure, although a diaphragm failure was catered for in that a balance pipe was fitted between the pump and the entry casing downstream from the injector to prevent fuel leaking into the engine bay.

Further historical evidence from the engine manufacturers indicated that ignition problems could result from HT tracking due to a build up of carbon dust in the adaptor plugs. Although a dusty deposit was observed in the plugs from the left engine of G–BDFT, (the ones from the right engine having been burnt), it was not possible to be conclusive as to whether any tracking had occurred.

A failure of the left engine of G–BDFT in September 1981, only 10 flying hours before the accident, was attributed to induction icing. Such a phenomenon is unlikely in an engine of this configuration and it is possible to speculate, in the light of subsequent occurrences on the Duxford Varsity, that this was a manifestation of an ignition breakdown.

In summary therefore, G–BDFT had experienced a power loss on both engines. The left engine failure was precipitated by a fuel pump diaphragm failure. The cause of the right engine failure could not be established, but it is possible that there was an ignition failure due to ignition coil breakdown when higher boost was demanded. If this is accepted then it will be realised that a common element linking these two apparently unrelated failures is age related deterioration of different components; the diaphragm in the case of the left engine, and the magneto coils in the right.

2.3 The feathering of the left engine

It was observed that the left propeller was feathered at a point late on in the descent and that shortly afterwards it was seen to rotate again, although witnesses doubted whether it was developing power. This was in agreement with the impact information that while the right engine was developing some power, the left engine was producing virtually none. It is only possible to speculate as to why the left engine was stopped and almost immediately an attempt made to re-start it.

It is a known feature of super-charged piston engines with variable pitch propellers that an engine failure may not readily be detected by reference to the engine instruments. The propeller control unit will sense the initial reduction in rpm resulting from a power loss and adjust the blade angle to maintain the selected rpm. The propeller will now drive the engine and super-charger so that manifold boost is still indicated and the automatic boost control unit will maintain this at the required setting. In the absence of abnormal rpm or boost pressure indications the rudder required to maintain balanced flight will immediately permit identification of the failed engine and in the longer term a drop in cylinder head temperature and perhaps oil temperature will provide confirmation. In the event of a partial loss of power (rather than total failure) the indications of which engine is malfunctioning are less obvious.

It seems probable that, at the power settings used for the formation flying, the left engine began to suffer from the over-rich mixture due to the split diaphragm. When the undercarriage was lowered, more power was required to overcome the increased drag and the throttles were advanced. The over-rich condition of the left engine prevented it from providing more power and the throttles were therefore advanced further until the right engine had reached a boost setting at which an ignition problem may have occurred. With neither engine producing the required power the aircraft now began to lose height. During the descent the pilots may have concluded that the left engine had failed and that the drag of the windmilling propeller was unacceptable, without at the same time realising that only partial power was available from the right engine. The stopping of the left engine would have removed what little power it was contributing and thus made the situation even more critical. Having then realised this the pilots may have attempted, in desperation, to re-start the engine while the aircraft was at low height, in an attempt to reach the open area of the gliding site. Whatever the actual reason there can be little doubt that the combined effect of the additional drag caused by the lowering of the undercarriage and the unfeathering of the left propeller was sufficient to precipitate a stall and rapidly roll the aircraft inverted.

2.4 Other operational factors

Four other operational factors were examined to determine if they contributed to the accident.

2.4.1 Operation of the engine air intake system

The reports from the survivors have each described the mis-firing of the left engine as being accompanied by the lifting of the intake pressure relief panel on the top of the engine and the emission of flames. This relief panel was incorporated to protect the air filter from damage during a mis-fire and will operate only if the air intake system is selected to "filtered air". The recommended procedure was to take off with the air intake selected to "filtered air" and on reaching a height of 1000 feet to re-select "normal air" unless the aircraft was operated in areas of atmospheric dust and sand. It is unlikely that the hazy atmosphere that day would have been sufficient to justify the "filtered air" selection and it is possible that the selection to "normal air" was omitted.

The effect of leaving the intake selected to "filtered air" would be to raise the temperature of the inlet air by about 12°C above the ambient air temperature and to cause a slight loss of power available above the full throttle height of 2800 feet. This would not cause a power loss at the low power settings being used initially during the formation flying or restrict the maximum power available when the aircraft was subsequently flying at lower altitude.

2.4.2 Engine intake icing

During the formation flying when the Varsity commander expressed his concern over the lack of power and considered that he had a problem with his right engine he believed the problem to be one of engine icing.

The condition of temperature and humidity at this height, 15°C and 67%, would generally be considered as conducive to engine intake icing. However, the Hercules engines of the Varsity aircraft were super-charged and used the Hobson injection carburettor. This system was not prone to engine icing because of its configuration. Furthermore, since it is believed that the air intakes were in the "filtered air" position and this typically caused a rise of 12°C over ambient in the air intakes, the possibility of icing was further reduced. It was also noted that the pilot of the Cessna 180 aircraft, which was equipped with a conventional carburettor and which was more prone to intake icing, reported that he had no indication of icing during that flight. It is considered unlikely therefore that engine icing was a contributory factor to the loss of engine power experienced by the Varsity.

The Varsity commander's concern over intake icing is perhaps surprising in that in his activities as a professional pilot, he was familiar with flying aircraft with fuel injected engines and which in general, like the Varsity, are not prone to intake icing. However, it is known that in September 1981 only 10 aircraft flying hours earlier, the commander had landed the aircraft at Leicester East with only one engine operating following an in-flight failure of the left engine. It is understood that after the landing the engine was run satisfactorily and as no fault was ever found the reason for the failure was ascribed to icing. It might be that recollection of that previous occasion persuaded the commander that the left engine was suffering from icing again.

2.4.3 *The cross-feed cock*

It was noticed during the wreckage examination that the cross-feed cock was in the open position. Immediately prior to starting the engines, photographs had been taken of the flight deck and these showed that, at that time, the cock was closed. It must therefore be inferred that the cock had been opened subsequently and there were three occasions during this flight when it might have been reasonable to open the cock:

(1) Prior to the engine power check

The Pilot's Notes for the aircraft required the cross-feed cock to be opened during the warm up period for the engines prior to the power check. A single boost pump was then switched on for 10-15 seconds. The purpose of this check was two-fold; it proved the functioning of the cock and the fuel low pressure lights and it also purged the cross-feed fuel line of any water accumulation. The cock should then have been selected shut and the pump switched off; both these items should then have been re-checked during the pre-take-off checks.

The starting difficulties with the left engine had delayed the departure so that the crew were late for their rendezvous with the Cessna and it was noticed that they took-off without clearance to do so from ATC. This suggests that the take-off was rushed and in these circumstances it is possible that the pre-take-off fuel check might have been ommitted, and the flight commenced with the cross-feed cock open and one boost pump on. The significance of this would be that one tank would have supplied all of the fuel to both engines until it became exhausted, and a coincidental factor was that the fuel consumed during the flight almost equated to the contents of each tank prior to engine start.

There was a lack of documentary evidence as to whether in these circumstances the boost pumps would start to inject air into the fuel and cause the engines to misfire. Ground tests conducted on the Varsity at the Royal Aircraft Establishment showed that the engines would in fact continue to run satisfactorily up to full power by drawing fuel from the other tanks.

(2) After engine malfunction

It is conceivable that if an engine started to malfunction, and no obvious cause could be found, then the crew might suspect the quality of the fuel and attempt to change the fuel supply. This could be achieved by selective use of the boost pumps and/or by opening the cross-feed cock.

(3) After engine shut down

After an engine has failed or has been deliberately feathered, it would be normal practice to open the cross-feed cock and to use the boost pumps so that the fuel for the remaining engine is drawn equally from both sides of the aircraft to prevent a lateral imbalance developing.

It cannot be stated which of these reasons might account for the cross-feed cock being found in the open position. The first is unlikely to have had any adverse effect upon the performance of the engines, nor should the second or third unless there had been any accumulation of water in the cross-feed line when the opening of the cock could have allowed the water to affect the engines for a relatively short period.

2.4.4 *Aircraft weight*

Calculations show that the aircraft was overweight on the take-off from East Midlands Airport by 528 lb. It is understood that within the preservation group the commander had assumed the responsibility for the aircraft weight and centre of gravity calculations. The only weight certificate that could be traced was prepared in 1975 when the aircraft left RAF service and before the extra seats were fitted in the rear of the fuselage. It is not known whether the commander had accounted for this change in the aircraft configuration nor is it known whether he actually calculated the weight and centre of gravity for this flight.

However, since the aircraft had taken-off and climbed to height without incident and the weight had been reduced by fuel burn-off to below the maximum permissible all-up-weight by the time that the aircraft engine started to malfunction, the excess weight was not considered to be a contributory factor to the accident.

2.5 The seating capacity

The two collapsible seats fitted to the seat rails of the radio operators' seats consisted of upholstered bases but there was no support for the occupant's back other than the tubular metal frame that formed the back of the radio operator's seat, nor was there any upper torso restraint fitted. These seats are unsatisfactory as they would provide no support for the occupants in anything other than normal flight and could even be the source of serious injury in an emergency situation. In RAF service, they had been designated "not to be used as a crash position". The sideways facing seat by the radio station similarly failed to provide sufficient restraint in an emergency situation and had been designated "not to be occupied during landing" by the RAF. These three seats were part of the aircraft's equipment at the time that it was sold by the RAF.

The civilian aircraft maintenance organisation that had prepared the Weight Certificate when the aircraft was placed on the UK register had included these three seats on the certificate thus implying that they were usable during take-off and landing. The failure of the CAA to place any limitation on the number of persons on board the aircraft compounded the situation. The owners of the aircraft would have wished to give as many of their members as possible an opportunity to fly and these seats were regularly used, especially as they were the only seats from which the pilots could be observed.

On the only other Varsity flying on the UK civil register, the number of persons on board is limited by the conditions of the Permit to Fly. This number equals the number of fixed seats but there is nothing to prevent the operator using the collapsible seats during take-off and landing. It is considered that the use of seats during take-off and landing which do not provide sufficient protection should be prohibited by the conditions of the Permit to Fly.

2.6 Maintenance History

The maintenance records indicated the aircraft had received regular maintenance based on the schedule used in RAF service. The CAA had agreed to deferment of major servicing tasks due to the low number of flying hours the aircraft had achieved since coming onto the civil register. In fact only 63 hours had been flown in the last nine years, compared to typical annual utilisations of 400 to 500 hours whilst in Service use.

The CAA had made no requirements regarding engine overhauls: both engines had approximately half their 1400 hour RAF overhaul lives remaining. In RAF use, engine overhauls could occur approximately every 3 years, although in fact no calendar limit was stipulated. As the injection carburettors, together with their associated fuel pumps, were overhauled every alternate engine life, the various diaphragms would have been examined every 6 years or so. Premature engine removals and in-service defects would probably have tended to reduce this period. The fuel pump diaphragms on G–BDFT had probably not been examined for 13-14 years, and whilst the recommended inhibiting procedures were not followed whilst the aircraft was in private hands, the engines were at least motored over regularly, and were in otherwise good condition mechanically. It is not possible to assess whether diaphragm deterioration would have been delayed by correct inhibiting procedures. However, such components cannot be expected to last indefinitely, although their condition may be influenced by the environment in which the aircraft (or component) is stored.

This accident has focussed attention on the difficulties faced by the CAA in satisfying themselves as to the airworthiness of an ex military aircraft for which there is no continuing product support, and of which they themselves may have little knowledge. Clearly, they have to attempt to strike a balance between excessive maintenance demands that would be beyond the resources of private groups such as the LAPG, and a loose adherence to a military maintenance schedule that was conceived with a high aircraft utilisation in mind. Whilst no one could have predicted the twin engine power loss that befell G–BDFT, with the benefit of hindsight it might have been prudent to have called for a periodic inspection of the various diaphragms in the fuel injection system.

A considerable number of vintage aircraft types survive and are successfully maintained and flown. The Varsity is perhaps different from many in that its size exposes a larger number of people – the volunteer passengers – to risk in the event of a mishap. Such aircraft are maintained by teams of skilled tradespeople during Service life and it is doubtful whether any amount of diligence and enthusiasm on behalf of the members of private groups could keep such aircraft flying without an increasing risk of failure due to age related deterioration.

3. Conclusions

(a) Findings

(i) The pilot and co-pilot held valid licences and both had been issued, by the CAA, with exemptions from the provisions of Articles 18 and 19 of, and Schedule 9 to, the Air Navigation Order 1980 to enable them to fly G–BDFT.

(ii) Both pilots held valid medical certificates and there was no evidence of medical factors which might have contributed to the accident.

(iii) The aircraft suffered a progressive loss of power on both engines while flying at low airspeed in formation with another aircraft at an altitude of 3000 feet.

(iv) The loss of power on the left engine resulted from an excessively rich fuel/air mixture caused by a split diaphragm within the engine driven fuel pump.

(v) The age of the diaphragm could not be established but it had almost certainly been on the engine since 1971.

(vi) It was not possible to determine the cause of the loss of power on the right engine but it possibly resulted from ignition failure due to ignition coil breakdown at high engine boost settings.

(vii) The aircraft was unable to maintain height and, during the attempted forced landing at a gliding site, it stalled and crashed inverted.

(viii) Eleven of the occupants were killed and the three survivors were sitting in aft facing seats in the rear of the fuselage.

(ix) The aircraft's Permit to Fly had been renewed two days before the accident for a period of nine months.

(x) The Permit to Fly did not specify the maximum number of seats authorised to be fitted to the aircraft.

(xi) Three of the passenger seats in use did not provide adequate protection to the occupants.

(b) Cause

The accident was caused by a loss of control when the aircraft stalled at low altitude while the pilot was attempting a forced landing following a progressive loss of power on both engines.

Safety Recommendations

It is recommended that:

4.1 When an aircraft is to be operated on a Permit to Fly, the Permit should specify the maximum number of seats authorised to be fitted to the aircraft.

4.2 The Permit to Fly should specify those seats which are unsuitable for use during take-off and landing or as an emergency position.

4.3 The maintenance procedures for historic aircraft should take into account age related deterioration of components in addition to the effects of flying time.

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