ACCIDENT

Aircraft Type and Registration:	BAC 167 Strikemaster Mk 80, G-UPPI
No & Type of Engines:	1 Rolls-Royce Viper 535 turbojet engine
Year of Manufacture:	1969
Date & Time (UTC):	26 April 2009 at 1543 hrs
Location:	Witheridge, near Tiverton, Devon
Type of Flight:	Private (Training)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 1 (Serious) 1 (Minor) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	34
Commander's Flying Experience:	4,610 hours (of which 48 hours were on type) Last 90 days - 75 hours Last 28 days - 14 hours
Information Source:	AAIB Field Investigation

Synopsis

An instructor was carrying out a training flight with his student. This was the second flight of the day and as part of the sortie the aircraft was rolled inverted for approximately five seconds, which was within the permitted negative g time limitation. Shortly after the aircraft had been rolled back to the normal wings level attitude, the engine flamed out and, despite two attempts, it failed to relight. A forced landing was carried out into a field, during which the aircraft struck a substantial earth bank at the upwind end, sustaining severe damage. The instructor suffered a serious back injury and the student received a minor injury. There was no fire.

Background

The instructor was an experienced, serving military fast jet pilot who had conducted training and display flying on the Jet Provost aircraft, of which the Strikemaster is a variant. On 25 April 2009, he ferried a Strikemaster from RAF Church Fenton to Exeter Airport, arriving at 1355 hrs. He was due to conduct initial training for the co-owner of G-UPPI, another Strikemaster, who was new to the type. The afternoon was spent carrying out ground training, which included touch drills from the Flight Reference Cards (FRCs), discussion of the aircraft systems and some of the emergency procedures. The instructor's final task that afternoon was to prepare a brief for a three-aircraft formation sortie the following morning. Meanwhile, the student observed a ground run on G-UPPI.

The next day, the instructor carried out the formation brief before he and his student went out to their aircraft. The instructor demonstrated the pre-flight inspection to the student and noted that there was no emergency battery fitted to the aircraft. He checked if the battery was required for the flight and was informed that it was not. On this flight, he occupied the left seat, as the pilot flying, allowing his student to gain a better understanding of the aircraft by observing his actions from the right seat. The engine was started normally using a ground electrical power supply and the formation sortie was completed without incident. On the completion of the sortie, an after-flight inspection was carried out and the engine oil level was noted as full.

History of the flight

The instructor briefed his student that the second flight that day would involve general handling, throughout the aircraft's speed range, and a demonstration of some aerobatic manoeuvres, including inverted flight. The student would occupy the left seat and the commander the right. After completing the briefing, the pilots of the other two aircraft requested a short formation sortie before they departed for their home airfields. Based on the earlier briefing, the instructor agreed to this, with his aircraft occupying the number three position in the formation.

He carried out the pre-flight inspection, again noting that the emergency battery was not fitted, and joined his student in the cockpit. The engine was started using the aircraft's internal batteries and the start cycle was noticeably slower and hotter than normal. The normal operation of the igniters was clearly audible but the acceleration from 15% to 30% engine rpm (ERPM) was particularly slow. When the ERPM indicated about 18%, the Jet Pipe Temperature (JPT) rapidly increased through 500°C and the pilot prepared to close the HP cock. The rate of increase slowed and the JPT peaked at 610°C before dropping back within the normal temperature range. Despite the start being slower and hotter than normal it remained within permitted limits.

The After Start and Taxi checks were completed, which included confirming that the DC voltages were indicating in the green sector, and the aircraft was taxied as the number three aircraft for a formation departure from Runway 08. The 'After Line-Up' and 'After Takeoff' checks both included checking the Standard Warning Panel (SWP) for any illuminated captions. No captions or warnings were visible. The takeoff was carried out using 95% ERPM and the close formation element of the sortie was complete after approximately five minutes. For the next 40 minutes, the instructional part of the sortie was flown as briefed, using the large gaps in the weather over north Devon. Regular cruise checks were carried out and the wing tip fuel transfer was isolated at the appropriate time. Throughout the sortie, all the aircraft systems operated normally and no SWP captions or other warning lights illuminated. The voltage of the main busbar was normal and the GEN warning light did not illuminate, indicating that the generator was producing a voltage of at least 26 volts, enough to charge the batteries.

The weather was not suitable for aerobatics and a recovery back to Exeter Airport was initiated. The aircraft was decelerated to 140 kt at 2,400 ft on the Exeter QFE which, given their location, was approximately 2,000 ft agl. A clear horizon became visible, so the instructor took control to carry out the inverted flight check. He accelerated the aircraft to 200 kt, checked that his student's straps were secure and carried out the appropriate airmanship checks for the manoeuvre. The fuel remaining was 1,200 lbs; it was equally balanced and the tip tanks were isolated. The instructor selected

90% ERPM, pitched the nose up slightly and rolled the aircraft to the left adopting an inverted, wings level attitude, which he pointed out to his student whilst noting a small rate of descent. The aircraft was rolled to the left after approximately five seconds adopting the normal upright, wings level attitude. The time spent inverted was within the aircraft limits established for the engine lubrication and fuel systems.

The aircraft had been level for only a couple of seconds when the instructor noticed a change in engine note and the aircraft slowing down, accompanied by the nose pitching gently down. He checked the ERPM, which showed the engine slowly winding down through 50% ERPM. He informed the student that the engine had flamed out and initiated a 2g turn to the right in order to ensure a positive fuel supply. The throttle was closed and the relight button on the High Pressure (HP) fuel cock was pressed, to restart the engine. After about two seconds of pressing the relight button, the electrical systems failed. After some 30 seconds the engine had not restarted and the instructor released the relight button. The electrical systems recovered but when he tried to transmit a distress call the electrics faded again.

Without a successful relight, the instructor selected a large, open grass field which had its longest dimension approximately into the light south-easterly wind. He set up a forced landing pattern to the right and, with the aircraft trimmed for 130 kt, flew a constant sight line, angle approach while he attempted a cold restart from memory, without success. Once again the electrical systems failed and the instructor concentrated on executing the forced landing. Prior to the flight he had decided to eject only in the event of a loss of control or if a safe forced landing was not possible and had briefed his student to that effect. He selected mid-flap followed by full-flap, with the landing gear remaining up, and re-trimmed for an airspeed of 110 kt. The aircraft passed over some trees at the downwind end of the field with the IAS reduced to 100 kt and touched down positively. The aircraft did not appear to slow down on the wet grass surface as much as the instructor had expected and headed towards what appeared to be a substantial hedge at the end of the field. He had to shout to his student to brace, due to failure of the aircraft intercommunication system, and helped him to place his hands on the instrument coaming in a brace position. This resulted in the instructor not being properly braced when the aircraft impacted what turned out to be an earth bank, with a hedge on top. The aircraft struck the bank at approximately 50 kt and came to a rapid stop. The lack of bracing contributed to the instructor's back injury.

The instructor saw debris fly up and heard the rush of what he believed was fuel flowing. There was a significant pain in his back and he was concerned that the ejection seats may have been dislodged and might fire. He switched the Low Pressure (LP) and HP fuel cocks OFF, turned the battery OFF and checked for any signs of fire, of which there were none. Both crew made their seats safe, using the ejection seat pins, but realised they could not open the canopy manually. The instructor pulled the canopy emergency jettison handle and the canopy was blown up and backwards, allowing the pilots to exit the cockpit. They moved upwind of the wreckage and walked to a nearby farmhouse to summon assistance. The emergency services arrived shortly afterwards and both pilots returned to Exeter Airport. Later that afternoon, the instructor became increasingly aware of the pain in his back and attended the casualty department at the local hospital.

Recorded data

The aircraft was not, and was not required to be, equipped with any type of data recorder. Two GPS receivers were

fitted; one was of a type that does not record a GPS track and the other relied on an internal battery to maintain the memory used to store a GPS track. However, the age of the internal battery had exceeded its recommended replacement period by 50% and did not have sufficient voltage to maintain the memory. A track was recorded by Burrington radar but it was limited to primary radar returns and did not record altitude information. It only covered part of the flight and no recorded data was obtained that was of benefit to the investigation.

Accident site

It was established that the aircraft had cleared an 8 m high line of trees before touching down in a level attitude, with the wheels retracted and flaps extended, 132 m into a field which was approximately 380 m in length. The aircraft skipped six times before it collided with an earth bank, approximately 2 m high, 3 m deep and covered with a mature hawthorn hedge, which was at the far boundary of the field. The field was the largest open space in the area and at the time of the accident the grass surface was damp and relatively slippery.

The tail skid had made an indentation in the last few ground marks, indicating that the aircraft struck the bank in a slightly nose high attitude. The aircraft's nose was extensively damaged, its back had broken aft of the cockpit area and the left wing had separated from the fuselage. Both wings had been extensively damaged and fuel had leaked into the local water course. The canopy was found lying upside down on top of the right wing. The ejection seat safety pins had been fitted to the seat-pan and face-blind firing handles on both seats but the guillotine sear, drogue gun and canopy jettison sear safety pins were still located in the storage panel in the cockpit.

Detailed examination of the aircraft

General

Whilst the wings and the structure forward and aft of the cockpit area were extensively damaged, there was little damage to the cockpit area. Both ejection seats were undamaged and one of the two cartridges in the canopy jettison system had operated – it is normal for only one of the cartridges to operate. The inertia (crash) switch, the fire extinguisher and its cockpit indicator had all operated. All the fuses in the DC electrical system were checked and found to be intact.

Batteries

The Strikemaster is designed to operate with a main and an emergency battery, with the latter providing power to essential services, such as the engine starting control and engine relight. The accident aircraft was fitted with two main batteries, connected in parallel, but an emergency battery had not been fitted. The main batteries were both 24 volt, twin cell, lead acid batteries that had last passed a capacity check[1] on 31 January 2009. Three days after the accident the open circuit voltage of the batteries was checked. A drop test, which is an indication of the battery's ability to provide a high load, was also carried out. One of the batteries failed the drop test and had an output voltage of 21 volts. On the second battery one of the two cells failed the drop test and the battery had an output voltage of 20.5 volts. The battery manufacturer advised the AAIB that, based on these test results, both batteries would have had approximately 30% of their capacity remaining and neither battery would be able to support a high electrical load.

Footnote

[1] Check carried out in accordance with Hawker Energy Products Manual 2602-0018 rev 2.

When an electrical load is applied across a battery it starts to discharge and the voltage drops. Once the load is removed the reaction of the acid on the battery plates causes a partial recovery of the voltage and the battery's capacity to provide electrical power. Most electrical equipment is voltage-sensitive and will cease to function when the voltage drops below a critical level.

The owners and the organisation who maintained the aircraft believed that an emergency battery was not required as the aircraft was only cleared for VMC operations. The CAA have since reviewed the records for Strikemaster aircraft and advised that the emergency battery is considered part of the approved configuration. They are unaware of any documentation authorising the removal of this emergency battery from the aircraft.

Aircraft fuel system

Each wing contains three flexible fuel tanks, one integral fuel tank and a tip tank feeding into a common collector tank situated in the centre fuselage. The fuel system is pressurised by air from the engine compressor which allows fuel to be transferred from the wing tanks to the collector tank, where an electrically driven low pressure fuel pump transfers fuel to the engine. During inverted flight, valves in the wing and collector tanks isolate the fuel system and fuel is provided to the engine by a fuel recouperator, which contains 2 gallons of fuel and is also pressurised by air from the engine compressor. The flight manual states that the duration of negative g is limited by the fuel recouperator, which for heights between 0 and 10,000 ft is 12 seconds.

The examination could find no evidence of a restriction in any of the fuel feed pipes and clean fuel was found in the collector tank, recouperator and the feed pipes to the engine. The electrical fuel pump and the inverted flight valves in the collector tank all operated normally. The flexible lining in the recouperator was found to be intact and there appeared to be no pre-impact damage to any of the fuel system pressurisation pipes.

Engine

The engine compressor and turbine rotated freely and there did not appear to be any damage to the compressor or turbine blades, nor had any debris been ingested into the engine. There was also no pre-impact damage to the engine controls. Fuel was found in all the fuel pipes and the fuel filter was found to be free of any debris.

An examination of the engine was carried out by the engine manufacturer who noted that there was a light dusting of carbon in the combustion chamber. This normally occurs when fuel is suddenly turned off whilst the engine is running at a relatively high power setting. It was also noted that whilst there was fuel in the main burner primer pipes, there was no fuel in the main burner feed pipes. All the fuel component drive shafts were intact and the gearbox turned freely. The blow-off valve, pressure ratio switch, barometric flow control unit, air/fuel ratio control unit and the high pressure fuel pump were all stripped and found to be serviceable, with no evidence of any debris that might have caused a fuel restriction.

Aircraft information

The aircraft was delivered to the Royal Saudi Air Force in 1969, where it remained in service until 1997. In May 2002, it was issued with a Permit to Fly in the UK and flown until 2004, when it was taken to South Africa. The wings were removed from the aircraft and it was shipped back, in a container, to the UK in July 2008. The aircraft next flew in December 2008 on a flight test which was required for the issue of a new Permit to Fly. During the flight test the aircraft was flown inverted for 12 seconds. The aircraft was next flown on the day of the accident.

Previous occurrence

The South African CAA reported that an in-flight electrical failure was considered to be a contributory factor to an accident which occurred on 28 October 2006, when the aircraft landed with its landing gear retracted. The report stated that the aircraft was started on main batteries and that during the flight a fuse blew causing the generator to go off-line. Following the accident both main batteries were found to be completely discharged: these batteries are believed to be the same batteries that were fitted to the aircraft during this accident flight.

Procedures and limitations

The FRCs provided information and the pilot actions in the event of engine flameout. These are shown in Figure 1.

The procedure for jettisoning the canopy states:

> ***'In Flight***
> *Fly the aircraft between 125-300 kts with the flaps up (320 kts extreme necessity only). Squeeze the jettison handle and pull firmly upwards.*
>
> ***On the Ground***
> *If possible, jettison whilst the aircraft is above 20 kts.*
>
> ***NOTE:*** *If the aircraft is stationary with the nose-wheel collapsed and any tailwind, there may be a danger of the canopy falling back into the cockpit.'*

Negative g limitation

The following limitation for negative g is set out in the Pilot's Notes:

> ***'Negative g***
> *Negative g conditions will cause the oil pressure to fall, usually to zero. Zero oil pressure is permitted for no longer than 30 seconds then normal g must be restored. Check that oil pressure builds up within 5 seconds of restoring positive g.'*

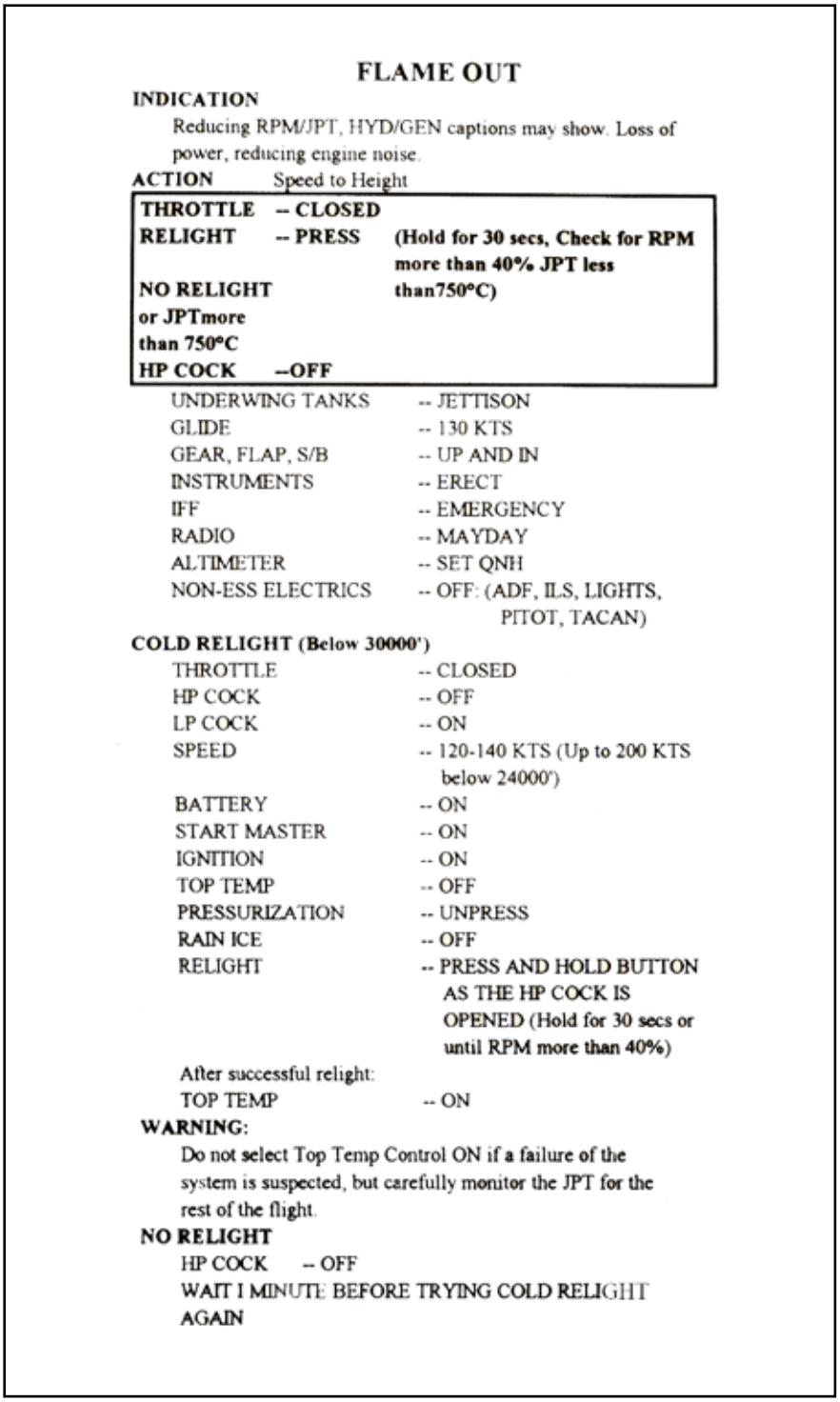
Analysis

The instructor had fully briefed his student on the sortie to be flown, including his decision to eject only in the event of a loss of control or if a safe forced landing was not possible. He was properly licensed and qualified to conduct the flight.

During the pre-flight inspection the instructor noticed that the emergency battery was not fitted to the aircraft. The inverted, negative g manoeuvre was of a short duration and less than the 30 second limitation for engine oil pressure and the 12 second below 10,000 ft for the fuel system limitation. Despite this, shortly after returning to normal flight the engine flamed out. Whilst the actions taken by the instructor during his two attempts to restart the engine were in accordance with the FRCs, the failure of the aircraft electrical system prevented the instructor transmitting a distress call and also prevented the use of the aircraft intercom.

The forced landing was made in the largest level field available, with the aircraft flaps fully lowered and the landing gear retracted. Despite the aircraft touching down at the earliest point in the field after clearing the trees, there was insufficient distance remaining for it to stop on the wet grass before it collided with the earth bank.

The light dusting of carbon in the combustion chamber, lack of fuel in the main burner fuel feed line and the



FLAME OUT

INDICATION

Reducing RPM/JPT, HYD/GEN captions may show. Loss of power, reducing engine noise.

ACTION Speed to Height

THROTTLE	**-- CLOSED**	
RELIGHT	**-- PRESS**	**(Hold for 30 secs, Check for RPM more than 40% JPT less than750°C)**
NO RELIGHT or JPTmore than 750°C		
HP COCK	**--OFF**	

UNDERWING TANKS	-- JETTISON
GLIDE	-- 130 KTS
GEAR, FLAP, S/B	-- UP AND IN
INSTRUMENTS	-- ERECT
IFF	-- EMERGENCY
RADIO	-- MAYDAY
ALTIMETER	-- SET QNH
NON-ESS ELECTRICS	-- OFF: (ADF, ILS, LIGHTS, PITOT, TACAN)

COLD RELIGHT (Below 30000')

THROTTLE	-- CLOSED
HP COCK	-- OFF
LP COCK	-- ON
SPEED	-- 120-140 KTS (Up to 200 KTS below 24000')
BATTERY	-- ON
START MASTER	-- ON
IGNITION	-- ON
TOP TEMP	-- OFF
PRESSURIZATION	-- UNPRESS
RAIN ICE	-- OFF
RELIGHT	-- PRESS AND HOLD BUTTON AS THE HP COCK IS OPENED (Hold for 30 secs or until RPM more than 40%)

After successful relight:

TOP TEMP	-- ON

WARNING:

Do not select Top Temp Control ON if a failure of the system is suspected, but carefully monitor the JPT for the rest of the flight.

NO RELIGHT

HP COCK -- OFF

WAIT I MINUTE BEFORE TRYING COLD RELIGHT AGAIN

Figure 1

absence of debris in the compressor were all consistent with the engine having stopped in flight as a result of fuel starvation. Despite an extensive examination of the aircraft and engine fuel system, it was not possible to determine why the fuel interruption had occurred. The engine manufacturer informed the AAIB that, since the introduction of this engine variant, there had been a small number of unexplained engine flame outs where the engine had subsequently been restarted in flight. On this occasion, the accompanying electrical failure meant that the pilot was unable to achieve a relight of the engine.

It would appear that, following the engine failure, there was sufficient power in the battery to operate the intercom; however, once the instructor operated the relight button the battery voltage seems to have dropped below the critical level required to operate the radios and the engine relight system. His account of the electrical system recovering is consistent with a partial recovery of the battery voltage. The operation of the fire extinguisher and the cockpit indicator indicates that the inertia (crash) switches had operated and that there had been sufficient power remaining in the main batteries, to operate these systems, when the aircraft landed.

Whilst the batteries had previously passed a capacity check, following the accident they were found to be in a discharged state. Although the pilot commented that the engine took a long time to start, and it was 30 seconds before the engine was self sustaining, the aircraft then flew for approximately 45 minutes during which the generator should have been charging the batteries.

From the accident in South Africa, it is apparent that the batteries on this aircraft, one of which was 15 years old, appeared to take some time to recover their charge following an engine start and it is possible that they were reaching the end of their working life. It is also possible that there was an electrical short circuit on the aircraft which slowly drained the batteries. However, due to the disruption of the electrical system it was not possible to identify such a fault.

Conclusion

The cause of the engine run-down was not established but the loss of electrical power from the two main batteries and absence of an emergency battery meant that the engine could not be restarted. The aircraft was designed to be operated with an emergency battery and haad it been installed, it would have allowed the pilot the opportunity to attempt a relight of the engine.

The CAA subsequently investigated the UK fleet of Strikemaster aircraft and concluded that all the remaining aircraft of this type currently on the UK register had an emergency or third battery fitted, in accordance with the approved configuration.