Hawker Hunter F 4, G-HHUN

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Aircraft Type and Registration:	Hawker Hunter F 4, G-HHUN
No & Type of Engines:	1 Rolls-Royce Avon Mk 122 turbojet engine
Year of Manufacture:	1955
Date & Time (UTC)	5 June 1998 at 1417 hrs
Location:	Dunsfold Airfield, Surrey
Type of Flight:	Private (Display practice)
Persons on Board:	Crew - 1 - Passengers - None
Injuries:	Crew - Fatal - Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence with Display Authorisation for the Hawker Hunter
Commander's Age:	42 years
Commander's Flying Experience:	Approximately 10,100 hours (of which 8 hours were on type)
	Last 90 days - 57 hours
	Last 28 days - 17 hours
Information Source:	AAIB Field Investigation

History of the flight

Four historic aircraft based at Bournemouth Airport, Dorset, were to fly from their home base to Dunsfold Airfield to a position for flying displays which were to be held at Biggin Hill and Dunsfold on the following day. The aircraft, a Meteor (G-LOSM), Vampire (G-HELV), Hawker Hunter T7 (G-VETA) and a single seat Hawker Hunter F4 (G-HHUN) had planned to transit in formation. However before departure G-HHUN had experienced a problem with an exhaust gas temperature (EGT) gauge and so the other three aircraft departed initially and G-HHUN followed some 20 minutes later, taking off at 1141 hrs.

After landing, G-HHUN was refueled with 730 litres of AVTUR for its forthcoming practice display at Biggin Hill. The pilots of the Vampire and Meteor left their aircraft at Dunsfold and returned to Bournemouth as passengers in a light aircraft.

The two Hunter pilots, with the pilot of the two-seater Hunter T7 as the formation leader, planned to carry out a 'pair display' practice at Biggin Hill for the Air Show on the following day. After lunch and a briefing for the afternoon's flights the pair prepared for departure from Dunsfold, but this was delayed for about 5 minutes by some minor problem with G-HHUN after engine start-up.

The two aircraft departed Dunsfold at 1348 hrs and set course for Biggin Hill, climbing to 1,500 feet and heading for the visual reference point (VRP) at Dorking. At 1353 hrs, the formation was instructed by the Dunsfold radar controller to contact Biggin Hill. Four minutes later, however, the formation re-contacted the Dunsfold controller to advise: "The weather is unfit at Biggin we're returning to you". The Dunsfold controller re-identified the formation at Dorking and cleared them to turn towards Dunsfold and to join for a right-hand visual circuit for Runway 07.

At 1400 hrs, the formation leader asked Dunsfold if the pair could carry out a display practice "not below 500 feet". Whilst the controller sought clearance for the display practice, he cleared the formation to descend to 1,300 feet on the Dunsfold QFE. The formation leader replied "ROGER AND THAT WILL BE OUR MAXIMUM (DISPLAY) HEIGHT IF WE STAY WITHIN THE AIRFIELD".

Clearance for the display was duly granted up to a height of 2,500 feet and the pair then flew their complete display sequence. They then decided to repeat the practice display. The weather at 1420 hrs was surface wind 080°/10 kt, visibility greater than 10 km with broken cloud at 2,000 feet, temperature 17°C, dewpoint 12°C and with a QFE of 1005 mb and a QNH of 1008 mb.

The final stages of the display sequence involved opposition rolls, to be followed by G-HHUN turning right through 45° away from the 'crowd-line' to set up for a 'gear and flaps' low speed pass. The other Hunter would meanwhile position on a right-hand circuit so that both aircraft could then perform another pass together in front of the crowd-line, with G-HHUN at low speed and G-VETA at high speed. This was to be the last manoeuvre before both aircraft joined up for a 'run and break' manoeuvre, prior to landing.

As G-VETA reached the end of his downwind leg on his right-hand circuit, the pilot looked to his right to acquire G-HHUN. However, since he could not see the other Hunter he transmitted "PUT YOUR SMOKE ON I'VE LOST YOU". Almost immediately the pilot of G-HHUN transmitted "MAYDAY MAYDAY MAYDAY ENGINE FAILURE HEADING FOR THE FIELD". However ATC did not reply to this transmission, and the Mayday was re-transmitted. The pilot of G-VETA then transmitted "...THE FIELD'S ALL YOURS YOU GO FOR IT". ATC then replied "....YOU'RE CLEARED TO LAND". The pilot of G-VETA then transmitted "KEEP PRESSING THE RE-LIGHT BUTTON GO FOR THE MA---" (intending to complete the transmission with the words "MANUAL FUEL").

At this stage G-HHUN was at some 500 to 700 feet agl and a flame, estimated at some 10 feet in length, was seen emanating from the aircraft's jet pipe by several ground witnesses. A second flame was observed emanating from the side of the fuselage forward of the tailplane, at the base of the leading edge of the fin. The aircraft turned left towards Runway 25 and appeared to barely clear trees on the south-eastern boundary of the airfield before it passed over the perimeter track, at a height of some 20 feet agl and with approximately 10 degrees of left bank. The aircraft then struck the disused runway short of Runway 25 with its left drop tank, whilst at an angle of 40 degrees to the runway heading, before landing heavily on its main landing gear. It then bounced back into the air and rolled left to a bank angle of some 65° before striking the ground a second time with its left wing tip, leaving a long ground mark in the grass approaching the runway. It then pitched downwards and yawed left onto its nose, impacting the runway surface before sliding laterally on its belly, at one stage backwards, across the runway and grass beyond. It finally came to rest in an upright attitude on the northern side of Runway 25. The diagram at Figure 1 shows the estimated track of the aircraft, the point of first ground impact and the final position of the aircraft on the airfield. This impact sequence was described by some witnesses as 'something like a cartwheel'. The pilot, who had been released from his safety harness during the impact sequence, suffered fatal injuries. The emergency services, which had been on standby because of the practice display, arrived on the scene almost immediately at 1417 hrs.

Relevant pilot's notes extracts

'Engine flame-out and relighting

If a flame-out occurs in flight a relight may be attempted immediately, while the RPM are decreasing, by pressing the relight button with the HP cock open and the throttle at its set position. A successful relight will be indicated by the RPM stabilising and then commencing to rise.

Relights are obtained more easily at lower altitudes and with lower airspeeds. Every precaution should be taken to ensure success at the first attempt due to the loads on the battery. If the engine and its fuel system are serviceable and the drill is followed correctly, a relight should occur at the first attempt.

If below 20,000 feet, set the HP pump isolation switch to ISOLATE before relighting and leave it at ISOLATE after relighting has been accomplished.

Action in the event of a fire

If the engine fire warning light comes on, the throttle should be closed immediately. Should the light remain on after throttling back, a fire is indicated (as opposed to a hot gas leak). Switch OFF the HP cock, LP cock and Booster-pumps and quickly reduce speed to a practicable minimum. Then press the extinguisher pushbutton. Should the light remain on and the fire persist, the aircraft should be abandoned.

Forced landing procedure

If a forced landing on an airfield is being made attempt to arrive overhead at approximately 7,000 feet or above. Plan a Manual approach and aim to be downwind opposite the threshold at 210 kt at a minimum of 4,000 feet agl depending on the prevailing conditions. Maintain 175 kt on the final approach and aim to cross the threshold at 150 kt. In Manual the pull force to round out from a glide approach is large. Experience suggests that it is preferable to lower the landing gear when making a forced landing on an airfield or in open country. In the down position it absorbs much if not all of the initial impact. If the speed is too low a wing drop is likely to occur, and if the speed is too high the aircraft is prone to bounce, the initial impact having a damaging effect on the cockpit. With the landing gear down, the rate of descent is high, and it increases rapidly as speed is reduced below 180 kt.

Fuel system

The aircraft is fitted with twin HP pumps that share a common housing. A servo control system limits the total pump output and a governor limits over-speeding of the engine. Control of the fuel flow is affected by the throttle to meter fuel to the burners; a barometric pressure control (BPC), to vary the pump output in relation to intake pressure; and an acceleration control unit (ACU) to prevent an excess supply of fuel to the engine during periods of engine acceleration. Both the BPC and the ACU are connected to the servo control system.

The isolating valve is intended as a means of restoring power in flight in the event of failure of the HP pumps servo system causing a sudden loss of power. The valve is controlled by an ENGINE FUEL PUMPS NORMAL/ISOLATED switch, also known as HIGH PRESSURE PUMP ISOLATION SWITCH (HPPIS). When the switch is set to ISOLATE, one HP pump is cut off from the servo system which continues to control only the other HP pump. The isolated pump moves to full stroke and is controlled only by its over-speed governor.'

On-site examination

The aircraft had been sprayed with foam almost immediately after coming to rest. This had minimised the affects of the ground fire and therefore assisted the determination of the extent of the fire in the air. During the brief period of the in-flight fire, the rear fuselage below the base of the fin leading edge had burned away around most of its circumference, and the rear fuselage had then broken away during the second ground impact. It was determined from photographs taken of the aircraft in flight just before the impact and from the condition of the tailplane flying controls afterwards that although they had been functional at the first ground impact, they would not have survived the affects of the fire for many more seconds in the air.

The nose of the aircraft had been massively disrupted during the second ground impact, which had caused the cockpit canopy to be released and the ejection seat to displace relative to the cockpit structure. This seat displacement had caused the drogue parachute to fire and the pilot to be released from the seat. The left wing and both flaps had received some damage from contact with the ground during the second impact sequence, and the landing gear and drop tanks were severely damaged. Light debris from the rear fuselage was found some distance back under the flight path. Subsequently some debris, including a fragment of jet pipe covered in aluminium 'spatter', was found outside the airfield boundary. Major debris from the nose and underwing tanks was found scattered across Runway 25.

An initial inspection of the engine on-site found evidence of pre-impact damage to the blades of both turbine stages, together with disruption of the tailcone aft of the turbines where it appeared that turbine blade material had been uncontained. The associated holed casing had allowed the combustion flame to penetrate the rear fuselage. No obvious compressor damage was apparent and the compressor and intake area was clean. The Low Pressure (LP) and High Pressure (HP) fuel cocks were found selected to 'Open'. The throttle lever was found positioned around 40% open, but could be easily moved. The filament of the fire warning lamp was found to be extensively elongated, indicating that it had been illuminated and had 'stretched' under deceleration forces at the time of impact. The EGT gauge was badly damaged and the pointer had been broken off and was not recovered, however the face of the instrument showed some paint smearing and scuff marks which were considered to have been caused by contact with the back of the pointer. These marks indicated that the pointer had been at about full scale deflection on impact.

Subsequent to on-site examination, the wreckage was transported to the AAIB at Farnborough for further detailed investigation.

Aircraft information

History

The aircraft was a civil registered Hawker Hunter F4 and carried the manufacturer's serial number HABL - 003020. It was fitted with a Rolls-Royce Avon-122 turbojet engine, serial number 7409. Before the Royal Air Force had disposed of the aircraft, it had carried the military designation XE 677.

XE 677 was first delivered to the RAF 5 Maintenance Unit (MU) from Hawker Aircraft Limited at Dunsfold on 11 July 1955. It had served in the RAF until it was retired on 7 July 1958, at 752.40 airframe hours, when it was positioned at RAF Kemble. In 1961 it was re-purchased by Hawker Aircraft for development work and transported by road to Dunsfold. However it was not in fact used for the intended development programme, but was subsequently donated to Loughborough Technical College for instructional use. While at Loughborough it had been kept under cover and had therefore remained in excellent condition. In 1989 it was declared surplus to college requirements and was then purchased by the operator. The operator registered the aircraft on the UK Civil Register as G-HHUN.

Maintenance History

The maintenance records and Technical Log for G-HHUN were examined. The Permit to Fly had been renewed on 5 September 1996. On 8 June 1997, a flight was diverted due to engine vibration and as a result of this engine, serial No 7409, was subsequently removed and engine serial No 7619 was fitted. The engine which had been removed was inspected and then fitted with new combustion chambers as a precautionary measure.

On 29 October 1997 engine serial No 7619, which had been on loan, was removed and engine serial No 7409 was re-fitted (this was the engine installed at the time of the subsequent accident). Post installation ground runs and an airtest were satisfactorily completed, but the cause of the previous vibration was never identified. During these ground runs, the opening and closing of the compressor bleed valves was checked against the associated schedule and found to be satisfactory. No adjustment of the Bleed Valve Control Unit (BVCU) was required.

Later, on 5 June 1998, the Technical log recorded a pilot report of high EGT on engine start. The corrective action recorded was the interchanging of filaments on the voltage compensator. The subsequent ground run was satisfactory. This suggested that the high EGT indication was an instrumentation fault rather than an engine problem.

'Gundip' system

To obtain the required Permit-to-Fly from the UK Civil Aviation Authority, all armament-related systems had to be removed from the airframe. In particular, the Gun Firing Fuel and Air Dip (Gun Dip) system wiring looms and Line Replaceable Units were removed up to the engine break zone.

The Gun Dip System was introduced to reduce fuel and airflow when the guns were fired in order to prevent related engine surging. The RAF had disconnected the airframe side of the Gun Dip System on many of their Hunters under Mod 1321, but following an accident to Hunter T7 (No XL597) in May 1980, concerns were raised about spurious electrical inputs to the engine fuel system from the residual wiring on the airframe. As a result, the Hunter Design and Engineering

Authority had instructed that the Gun Dip system wiring on the airframe side should also be removed. However this instruction was made after XE 677 (G-HHUN) had been retired from RAF service.

Smoke system

G-HHUN had also been modified with the fitment of a smoke system. Diesel fuel, stored in the left underwing tank, was pumped when required through an ON/OFF valve in the pylon to a spray orifice which protruded into the jet efflux at the rear of the jet pipe. The smoke system was armed by a standard toggle master switch located on the left side of the cockpit, and activated by a pushbutton on the control column. When the button was depressed, an electrical actuator opened the ON/OFF valve, the pump was energised and a warning lamp illuminated in the cockpit. The diesel fuel was pumped through the left wing and then through an elastomeric, steel braided, fire resistant hose routed underneath the engine in the rear fuselage. Although the elastomeric material had deteriorated in the fire, there was no evidence of pre-impact damage to the steel braid, or of pre-existing deterioration of the hose.

The smoke master switch was found in the 'ON' position after the accident. The smoke valve actuator in the pylon was found in the extended position, with the valve arm at the position marked CLOSED. The installation drawings confirmed that this was the 'SMOKE OFF' position. Examination of the 'SMOKE ON' indicator lamp found that the filament had suffered a brittle fracture, however the bulb holder and glass envelope had been broken, subjecting the filament to direct mechanical impact. It was considered that the condition of the filament indicated that the 'SMOKE ON' lamp had not been illuminated at impact.

Detailed examination of the engine and jet pipe

After the engine had been removed from the fuselage at the AAIB, Farnborough, and transported to Rolls Royce Aero Engines Limited at East Kilbride, a strip inspection was carried out. This confirmed the nature of the damage to the turbines. The combustion chambers, compressor stages and Variable Inlet Guide Vane (VIGV) systems were examined, but no reason for the turbine failure was found. The oil had been examined at Farnborough and found to be satisfactory; the associated high and low pressure oil filter screens were checked and found to be clear.

Examination of the internal components, including the bearings and seals, confirmed that the turbines had been subjected to gross overfuelling which had caused progressive loss of HP and LP turbine blade material, followed by blade release and associated thermal damage to the tail cone. Metallurgical examination of the tailcone material confirmed that it had suffered thermal distress due to overheating. This had occurred as a result of contact with the uncontrolled combustion flame envelope. There was no evidence of seal rub, shaft rub, bearing damage or lubrication failure and the engine had not experienced severe vibration. Forward of the turbine damage, the engine was in a normal condition. The degree of turbine damage was such that it could not be explained in terms of the overfuelling effects of compressor stall or compressor damage, of which there was no evidence. The Top Temperature Control (an automatic EGT limiter on the fuel control unit), bleed valves, Bleed Valve Control Unit (BVCU) and Variable Inlet Guide Vane (VIGV) system were found to function correctly, however it was noted that the BVCU setting was slightly outside the normal range.

A split was found in the BVCU 'P7' (ie HP compressor stage 7 air) pressure delivery pipe. This pipe was constructed with a rubber inner hose, reinforced with surrounding steel braid and a rubber outer sheath. Pressure drop tests showed that the split could cause the bleed valves to open slightly late, but the effect was considered by the engine manufacturer to be to be too small to be relevant.

A fault tree analysis of the fuel system components, prepared by the fuel system manufacturer, identified several possible causes of uncommanded overfuelling. Of these, the most probable causes were considered to be a failed pressure diaphragm in the Barometric Control Unit, a blocked servo fuel pressure line, or a fuel pump servo piston ring failure. All of these potential causes were subsequently eliminated by inspection, or rig test. A similar fault tree analysis for underfuelling was produced. Inspection and testing again failed to identify any condition which could have caused either under or over fuelling. All of the fuel system components performed satisfactorily during associated rig tests.

During strip examination of the fuel system components some staining of the pump chambers was noted and attributed to the long term presence of residual fuel, probably caused by prolonged aircraft storage. Slight deterioration of a diaphragm was also noted, but none of these defects were thought to have affected operation of the fuel system.

High pressure pump isolation switch (HPPIS)

The HPPIS was located on the left hand side panel in the cockpit, some 6 inches below the smoke master switch. Both switches were conventional toggle switches, but the HPPIS was guarded and had two positions, 'NORMAL' and 'ISOLATE'. As previously referred to in the Pilot's Notes extracts, when the HPPIS is selected to ISOLATE, one of the two fuel pumps is isolated from the servo control system and its piston swashplate (which controls the stroke of the fuel pistons) deflects to maximum displacement, providing significantly more fuel flow than the maximum required by the engine. With the throttle open, this selection could deliver sufficient fuel to destroy the turbines very quickly, perhaps in about one second. However, the HPPIS was found in the NORMAL position, and functioned correctly. There was no sign of impact damage on the switch, despite the fact that its mounting panel had been torn from the cockpit during the ground impact.

The HPPIS warning lamp was examined and found to be undamaged and serviceable. Its filament had not stretched or fractured, suggesting that the filament had not been 'hot' (ie illuminated) at impact. The starter lamp was examined for comparison; this was also found to be undamaged and showed no evidence of incandescence or brittle fracture. Wiring from the HPPIS to the lamp and to cable loom C3 (which was cut at the engine break during wreckage recovery) was tested and was found satisfactory, with correct earthing and satisfactory electrical continuity. The ground side wiring from the engine (also cut at the engine break) was checked back to ground via two associated connectors and was found to be correctly earthed, with satisfactory electrical continuity. With regard to the electrical supply to the HPPIS, if this had failed the switch could not have operated.

Bleed valve control unit (BVCU)

Although all bleed valves had operated satisfactorily during testing, as previously mentioned the setting of the BVCU was found to be slightly outwith the normal range.

The BVCU operated by balancing air pressures from the 7th and 12th HP compressor stages across a diaphragm. When the differential pressure reached predetermined values, the BVCU operated to open or close the bleed valves. If the BVCU operated incorrectly, the compressor stages could stall, causing the engine to surge or stagnate. The operating points of the BVCU were controlled by two needle valves which were adjusted to provide an exact pressure drop as the air flowed through the unit. These air passages were small, and where the needles operated the size of the airway was critical.

Since the setting of the BVCU was somewhat outside the usual range, this implied that the compressor had been operating outside the normally expected parameters. Since there were no unusual features apparent within the LP or HP compressors, the BVCU was tested again. During this test, slightly different operating points were observed. As a result, a further rig check was carried out with the intention of checking that the BVCU could be correctly adjusted. During that check, interaction between the BVCU and the rig was such that it was not possible to obtain any meaningful measurements. However, the associated test rig had not been used for some years and there was a lack of current experience in its use. It was therefore decided to fit a chart recorder to the rig to facilitate the task. In order to accomplish this, two pressure transducers were fitted which required disturbance of the rig connections.

Subsequent tests showed that the BVCU behaved in a generally controllable manner, but some difficulty was found in adjusting the unit. It was found that when the unit adjusters were moved and then returned to their original positions, the setting of the BVCU had altered. Since there appeared no satisfactory explanation for the behaviour of the rig/BVCU combination during the four tests, it was decided to conduct a strip inspection of the BVCU.

When the BVCU was stripped, some hardening of internal seals was noted. A small piece of sealant was found in one of the smaller passages. It was concluded by the manufacturer that this must have been introduced when the unit had last been overhauled, which had been before the aircraft was retired from RAF service. The sealant appeared dirty and degraded, and there was some contamination of the airway with dirt or fine debris. The piece of sealant was found trapped in a position where it should not have caused a problem however had any part of it broken away, the liberated debris would have passed through both needle valves and any temporary obstruction of either valve would have caused the BVCU to operate incorrectly.

Electrical supply

Generator warning lamps Nos 1 and 2 were examined and showed considerable stretching of their filaments, indicating that they had probably been ON at impact, ie that both generators had ceased to supply power. The associated results also assisted confirmation of the status of the other warning lamps.

Safety and survival

The aircraft was fitted with a Martin Baker Aircraft (MBA) Mk 2HA ejection seat capable of providing a safe ejection at ground level with a forward speed of 90 kt or more. The system had two separate and distinct manual actions which the pilot had to perform in order to eject safely. Firstly, the pilot had to jettison the cockpit canopy and secondly he had to initiate ejection by pulling the seat-pan firing handle (SPFH), or face screen handle. Alternatively, if the canopy jettison system failed to operate, the pilot could eject through the canopy since the ejection seat was fitted with canopy breakers.

Canopy jettison

Cockpit canopy jettison was achieved by pulling the canopy jettison handle, connected by a cable to the 'sear' of the canopy jettison cartridge, and located on the left side of the cockpit. Although the canopy jettison sear was found to have been pulled from the firing pin, it was considered highly unlikely that the pilot had initiated jettison of the canopy.

It was considered that as the cockpit had deformed during the ground impact the canopy had started to break away from the airframe. The cable linking the canopy jettison handle to the sear of the canopy jettison initiation cartridge may have become snagged and entangled in the cockpit wreckage. The ensuing tension in the cable may have wrenched the sear from its firing pin and as a consequence the canopy jacks had been released, assisting the removal of the canopy frame from the aircraft.

The canopy perspex had shattered and canopy frame had been broken into two large fragments during the impact sequence. The fragments were found on opposite edges of the runway. This disruption was much more extensive than would have occurred if the canopy had been jettisoned by the pilot before ground impact. Had this been the case the canopy would have departed the aircraft in one piece and although it would have subsequently broken on impact with the ground, the canopy sections would have been found in close proximity as opposed to being strewn on opposite sides of the runway.

Ejector seat movement

The cockpit floor had deformed and had been forced upwards as a result of the aircraft's nose impacting the runway. This upwards displacement and disruption had thrust the ejection seat upwards by some 15 to 20 cm. The upward movement of the seat had forced the top latch bolt upwards through the circumferential locking collar on the breech assembly, and had also caused the sears attached to the seat's static lines to be withdrawn from the barostatic time release unit (BTRU) and the drogue gun firing cartridge. After a time delay of approximately 0.5 second, the drogue gun would have fired and pulled the '22 inch' and '5 foot' drogues from the drogue parachute container on the ejection seat. However the drogue parachutes would have immediately collapsed, since there was no airflow to keep them inflated, and both became entangled in the cockpit wreckage as the aircraft continued across the runway. After the BTRU had been initiated and the timer mechanism had run through to completion 1.25 seconds later, the scissor shackle would have opened and released the restraint harness lugs of the quick release fitting (QRF). The restraint harness QRF is linked to the BTRU via a cable release mechanism which is activated at man/seat separation to release the pilot. At this point the pilot would no longer have been restrained in the ejection seat, although he would still have been attached to his parachute harness.

As the aircraft had bounced and cartwheeled across the runway, the unrestrained pilot had probably been thrown out of the right side of the cockpit wreckage and then dragged by the main parachute canopy withdrawal line which had failed to release from the ejection seat headbox. During this process the parachute ripcord pins had pulled out, and the main parachute canopy and rigging lines had been pulled from the parachute packing case. The pilot's personal survival pack (PSP) had also torn open and the liferaft released from its container.

Ejection initiation handles

On the Mk 2HA ejection seat, the face screen and seat pan initiation handles are connected by cables to the sear of the ejection gun primary initiation cartridge. These cables are routed across the ejection seat headbox and over the top of the main beam assembly to connect with the sear of the primary initiation cartridge. During the ground impact and the resulting cockpit deformation, the upward movement of the seat had pulled the ends of the cable assemblies upwards which had partially withdrawn the sear out of the firing pin. However the continued upward movement had pulled the cables' attachment rings off the sear and thus the firing pin was left in the half-cocked position. Witness marks and 'kinks' were found on both cables at the point where the cables pass over the ejection gun main beam assembly. These marks were considered consistent with cable contact with the main beam assembly as the ejection seat had moved upwards as a result of the cockpit floor deformation. The overstressing and separation of the cable attachment rings from the partially withdrawn sear of the firing pin in the primary initiation cartridge had prevented the ejection seat gun from firing, leaving the seat within the cockpit.

Previous accidents and incidents

During this investigation the AAIB became aware of two previous RAF Hunter accidents where surviving crews had reported that they had used the HPPIS to overcome power fluctuations, and as a result the engines had been subjected to overfuelling:

In May 1980 an RAF two seat Hunter T7 experienced a power reduction, and a hot relight was attempted. As this was being completed by one pilot, the other pilot had retarded the throttle slightly and operated the HPPIS as the first pilot ceased pressing the relight button. The engine speed increased to 6,000 RPM, but the EGT exceeded full scale deflection and the engine began to vibrate. The instructor took control and advanced the throttle slightly, whereupon there was a slight increase in engine speed, followed by a 'muffled bang' and the engine speed then decreased rapidly. Both pilots then ejected safely, but the aircraft was destroyed in the ground impact and post crash fire**.** The power reduction was attributed to an unidentified failure in the fuel system.

In December 1981, another RAF Hunter T7 experienced an engine malfunction while preparing to land. At about 1000 feet agl and after selecting flap, gear down and airbrake in, and as the airspeed decreased through 250 kt, the instructor advanced the throttle slightly. Both pilots then noticed a slight 'rumbling sound' and that the indicated engine speed was lower than expected for the throttle setting. The instructor moved the throttle further forward, but the engine did not respond. He then operated the HPPIS and the engine speed increased as expected before reducing to low RPM. At about that time, witnesses on the ground saw a plume of flame from the aircraft's jetpipe. Both pilots then ejected safely. Subsequent examination of the wreckage found that the engine turbines had experienced severe in-flight overheat damage. A fault was later found in the BVCU diaphragm which had caused the compressor to stall as the throttle was opened. It was subsequently established that the HPPIS had been operated while the throttle had been set to a position corresponding to about 7,000 RPM.

In addition to these accidents, records kept on a computerised database between 1980 and 1992 showed 22 cases involving the Avon Mk 122 engine where engine speed had dropped and subsequent engineering investigation had not established a clear cause. Anecdotal evidence indicated that Avon Mk 122 engines had suffered from unexplained power reductions from time to time during RAF service, but in most cases the aircraft had returned safely and the subsequent RAF engineering investigations, including related engine ground runs, had failed to identify associated causes or to reproduce the symptoms.

Conclusions

Post accident examination of the escape system showed it to have been well maintained and in full working order prior to the impact. There was no evidence to suggest that the ejection sequence would not have worked through to completion had the pilot initiated ejection in time. The evidence indicated that the pilot had not attempted to eject before impact. After the nose of the aircraft had struck the ground, the evidence from the ejection system indicated that the cables to the seat gun had separated from the sear of the primary initiating cartridge, denying the option to eject.

Examination of the engine, particularly of the turbine, showed that it had suffered an uncontained failure of HP and LP turbine blades as a result of excessive turbine temperatures induced by gross overfuelling. All possible system malfunctions capable of generating such marked overfuelling were considered by the engine manufacturer, drawing on some 50 years of Avon engine experience in RAF Hunter operation.

It was concluded, after elimination of all other possible causes of overfuelling, that the most probable reason for the engine turbine failure was that the pilot may have operated the HPPIS (switch) momentarily to the ISOLATE position, before closing the throttle, and then returned it to the NORMAL position (as found after the accident). When operated in this way the HPPIS would have been capable of providing the required degree of overfuelling to destroy the engine turbine blades within a few seconds. Such selection of the HPPIS, without full closure of the throttle beforehand, had caused similar turbine failures in two previous cases on Hunter aircraft during RAF operation, with experienced pilots. In both cases, however, the decision to select the HPPIS to ISOLATE had been preceded by an engine malfunction. It was therefore considered that the pilot in this accident may have experienced some initial engine malfunction which had led him to select the HPPIS.

An exhaustive search for a cause of any such malfunction was made. The engine components, lubrication system and the fuel system units were examined and tested where applicable, but no evidence of any malfunction was found. Consideration was also given to the possibility of a lower than expected fuel state having caused an intermittent fuel supply to the engine, but there was no evidence to support this. Consideration was also given to a surge or stagnation of the engine due to incorrect handling at low speed and high angle of attack, since the 100 series Avon was not as robust as later engines in this regard, but again there was no direct evidence to support or refute this. It was also considered, in view of the findings associated with the BVCU, that a transient problem within the airflow control system may have occurred.

Malfunction of a BVCU could cause compressor airflow stagnation or surge. Airflow control problems could have caused the incident on 8 June 1997 with G-HHUN where combustion rumble was heard, but for which no cause was subsequently identified. The behaviour of the BVCU during the various rig tests at the engine manufacturer and its subsequent, reasonably correct operation, could be explained by temporary obstruction effects of internal debris (associated with the piece of sealant found during strip inspection) which may have subsequently cleared due to airflow purging. Some of the unexplained power reduction incidents in RAF operation of the Avon Mk 122 engine might also have been caused by such temporary blockages within BVCUs. Subsequent ground runs or adjustment could have cleared such blockages, resulting in normal operation and leaving the engineers involved unable to reproduce or identify the problem. Over-use of sealant during overhaul of such BVCUs was apparently a known problem when Hunter aircraft with Avon Mk 122 engines had been in RAF service.

During the examination of the fuel and air systems, staining of the fuel pumps was noted and also minor deterioration of the diaphragm. The split in the P7 pipe and the deformation of seals in the

BVCU were probably due to age-related material deterioration. It was not determined whether the sealant debris within the BVCU was influenced by age. In RAF service these components had lives in terms of flying hours which would represent extremely long periods of calendar time in current, much reduced, civilian utilisation.

As previously noted, the HPPIS was found in the NORMAL position after the accident. The switch was of the guarded type, and there was no evidence of any impact damage which could have moved the switch into its position as found. It follows that if the pilot had selected this switch to ISOLATE in response to BVCU induced compressor problems, he must then have had some reason to return it to NORMAL. It is also possible that he may have been operated the HPPIS inadvertently, or in error during an intended selection of the smoke master switch; only momentary selection of the HPPIS with the throttle unclosed would have been required to destroy the engine turbine. Although the pilot was apparently not aware of the fire at the time of his MAYDAY transmissions, the post accident condition of the EGT gauge and fire warning lamp suggested that he should then have received associated warnings before impact. Such warnings could have caused the pilot to reselect the HPPIS to the NORMAL position if he had intentionally selected ISOLATE, especially if the fire warning was observed just after he had initially operated the switch.

The pilot's lack of experience on type may have not given him sufficient knowledge of the fuel system to appreciate that operation of the HPPIS switch with the throttle not closed would lead to massive overfuelling and a turbine burnout. He was aware of its existence but may have had a limited appreciation of its function, since the entry in the Pilot's Notes on the use of the HPPIS did not warn of the dangers of its operation. The pilot of the other Hunter, G-VETA, in his truncated transmission to remind the pilot of G-HHUN to use the "manual" fuel switch, would only have started to transmit such a message if he knew that would have understood his advice.

Having had an engine malfunction followed by engine failure and fire the pilot could have decided to abandon the aircraft. The ejection seat was serviceable and capable of providing a low level escape from the aircraft. The pilot however appeared to have elected to attempt an emergency landing on the airfield. It is considered that he may have decided on this course of action for the following reasons:

1 The airfield was close and the pilot may not have appreciated the amount of manoeuvre energy required to achieve a successful forced landing on the active runway from his position following the power loss.

2 He may have possibly been influenced by the other pilot's RT transmission to attempt a forced landing, although it was the former's decision as the commander of the affected aircraft.

3 The pilot was a test pilot and may have believed that, with his experience in dealing with aircraft on the edge of their performance envelope, he could achieve a successful emergency landing.

4 The pilot was not from a military background and he therefore would not have been trained in an ejection seat environment where strict rules were applied as to when to eject when confronted with a critical in-flight situation.

1. The pilot was in command of a prestige historic jet aircraft which had been painstakingly restored and he may thus have felt that he should endeavour to recover the aircraft onto the runway.

Rolls Royce response to earlier draft copy of this Bulletin

Within its written response of the 20 August to an earlier Draft copy of this Bulletin, the engine manufacturer clarified some technical aspects and included the following response to the extracts from the Hunter F4 Pilot's Notes reproduced under 'Relevant Pilot's Notes extracts' in this Bulletin. The Rolls Royce response stated:

> 'The texts quoted in the AAIB Draft Bulletin are taken, we understand, from the Pilot's Notes available to the pilot of G-HHUN. They differ substantially from those for Hunter T7 aircraft which were amended by (the) RAF following earlier cases of turbine burn-out resulting from incorrect use of the 'ISOLATE' system and now contain adequate warnings, eg:

- In Flight Reference Cards AP 101B-1302 & 3-14, Card 14 Engine Failures: "Warning: If the HP pump isolating switch is set to ISOLATE when the throttle is in any position other than closed, over-fuelling is likely to cause surge and overheating and may lead to engine failure." (Note: with the throttle closed, the engine will operate at idle.)
- In Aircrew Manual AP 101B-1302 & 3-15: Part 1 Description and Management of Systems, Chap. 2 Engine, para 9 HP Pump Isolating Valve and Warning Light: "WARNING: to avoid overfuelling, the throttle must be closed before selecting ISOLATE."

> These amendments, introduced in 1984, were not read across to Pilot's Notes for aircraft Marks already obsolete such as the F.4.'

and:

> 'The quoted immediate relight procedure, " ...pressing the relight button with...throttle at its set position," and " If below 20,000 feet, set the HP pump isolation switch to ISOLATE before relighting and leave it at ISOLATE after relighting has been accomplished", would in our opinion result in a severe overtemperature of the turbine.'

In this response of the 20 August to the Draft Bulletin and associated Safety Recommendations (see later), Rolls Royce also stated:

> 'In conclusion, we will be glad to co-operate with CAA in addressing Safety Recommendations Nos 99-26 and 99-27.'

Safety recommendations

As a result of the findings arising from this investigation, the following Safety Recommendations have been made to the CAA and Rolls Royce plc:

Recommendation No 99-26

In view of the potential for rapid uncontained turbine failure on Avon turbojet engines and associated fire following incorrect emergency operation of the HP (fuel) pump isolation switch (HPPIS), which has been demonstrated previously by experienced military pilots in RAF operation of Hawker Hunter aircraft, it is recommended that the CAA in conjunction with Rolls Royce re-evaluate the safety benefit of the emergency use, by civilian pilots, of the HPPIS system on such aircraft which have been placed on the Civil Register.

Recommendation No 99-27

In view of the marked reduction in flying utilisation of ex- RAF Hawker Hunter jet aircraft which have been aquired for civilian use and the related greatly increased calendar time between scheduled overhaul of the fuel and air system components on their Avon turbojet engines it is recommended that the CAA, in conjunction with Rolls Royce, consider the introduction of appropriate calendar time overhaul periods for such engine systems, the serviceable condition of which can be calendar time dependent due to component material 'ageing' affects.

Recommendation No 99-28

In view of the increasing number of ex-RAF high performance jet aircraft on the Civil Register which are equipped with ejection seats, it is recommended that the CAA consider publishing appropriate operational guidance information on the correct and timely use of such ejection seat systems during emergency situations for pilots who fly such aircraft and whose previous flying training and experience has been on aircraft not so equipped.