# AIRCRAFT ACCIDENT REPORT 3/2015

Air Accidents Investigation Branch

# Report on the accident to Eurocopter (Deutschland) EC135 T2+, G-SPAO Glasgow City Centre, Scotland on 29 November 2013

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This investigation has been conducted in accordance with
*Annex 13 to the ICAO Convention on International Civil Aviation*,
*EU Regulation No 996/2010* and
*The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996*.

The sole objective of the investigation of an accident or incident under these Regulations is the prevention of future accidents and incidents. It is not the purpose of such an investigation to apportion blame or liability.

Accordingly, it is inappropriate that AAIB reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

Published 23 October 2015

**Printed in the United Kingdom for the Air Accidents Investigation Branch**

**Department for Transport**
**Air Accidents Investigation Branch**
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October 2015

***The Right Honourable Patrick McLoughlin***
***Secretary of State for Transport***

Dear Secretary of State

I have the honour to submit the report on the circumstances of the accident to Eurocopter (Deutschland) EC135 T2+, registration G-SPAO, in Glasgow City Centre, Scotland on 29 November 2013.

Yours sincerely

**Keith Conradi**
Chief Inspector of Air Accidents

# Contents

**Appendices**

## GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

| | |
|---|---|
| °C | Celsius |
| AAIB | Air Accidents Investigation Branch |
| AIR | Airborne Image Recorder |
| AMM | Aircraft Maintenance Manual |
| amsl | above mean sea level |
| ANO | Air Navigation Order |
| ARIS | anti-resonance rotor isolation system |
| ASB | Alert Service Bulletin |
| ASU | Air Support Unit |
| ATC | Air Traffic Control |
| BEA | Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile |
| BFU | Bundesstelle für Flugunfalluntersuchung |
| C of A | Certificate of Airworthiness |
| C of G | centre of gravity |
| CAA | Civil Aviation Authority |
| CAD | Caution and Advisory Display |
| CAP | Civil Aviation Publication |
| CAVOK | Ceiling And Visibility OK (for VFR flight) |
| CCTV | closed circuit television |
| CDS | Cockpit Display System |
| CPDS | Central Panel Display System |
| CS | Certification Standard |
| CVR | Cockpit Voice Recorder |
| DD | Deferred Defect |
| DFDR | Digital Flight Data Recorder |
| EASA | European Aviation Safety Agency |
| EMM | Engine Maintenance Manual |
| EMS | Emergency Medical Services |
| EOL | Engine Off Landing |
| EU | European Union |
| FADECs | Full-Authority-Digital-Engine-Controls |
| FCDMs | Flight Control Display Modules |
| FCL | Flight Crew Licensing |
| FDR | Flight Data Recorder |
| FLI | First Limit Indicator |
| FLIR | Forward Looking Infra-red |
| FLM | Flight Manual |
| FRF | Final Reserve Fuel |
| FSO | front seat observer |
| ft | feet |
| ft/min | feet per minute |
| g | acceleration due to Earth's gravity |
| GCH | Glasgow City Heliport |
| GIA | Glasgow International Airport |
| GPS | Global Positioning System |
| HEMS | Helicopter Emergency Medical Services |
| HP | high pressure |
| hPa | hectopascal (equivalent unit to mb) |
| hrs | hours (clock time as in 1200 hrs) |
| ICAO | International Civil Aviation Organisation |
| IF | instrument flying |
| IFR | Instrument Flight Rules |
| ILS | Instrument Landing System |
| IMC | Instrument Meteorological Conditions |
| IN | Information Notice |
| JAR | Joint Aviation Requirements |
| kg | kilogram(s) |
| kg/hr | kilogram per hour |
| KIAS | knots indicated airspeed |
| km | kilometre(s) |
| kt | knot(s) |
| lb | pound(s) |
| LP | low pressure |
| LPC | Licence Proficiency Check |
| m | metre(s) |
| MCP | Maximum Continuous Power |
| min | minutes |
| MLA | Minimum Land on Allowance |
| mm | millimetre(s) |
| NAOC | National Air Operators Certificate |
| ND | Navigation Display |
| nm | nautical mile(s) |
| $N_r$ | Main rotor rotation speed |
| NTSB | National Transportation Safety Board |
| NVGs | Night Vision Goggles |
| NVIS | Night Vision Imaging System |
| NVM | non-volatile memory |
| OAT | outside air temperature |
| OEI | one engine inoperative |
| OPC | Operator Proficiency Check |
| ORS | Official Record Series |
| PAOC | Police Air Operators Certificate |
| PAOM | Police Air Operations Manual |
| PFD | Primary Flight Display |
| QNH | altimeter pressure setting to indicate elevation amsl |

## GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT cont

| | |
|---|---|
| RADALT | radio altimeter |
| RAF | Royal Air Force |
| RIPS | Recorder Independent Power Supplies |
| RMT | Rule Making Task |
| rpm/RPM | revolutions per minute |
| RRPM | Rotor RPM |
| RSJ | rigid steel joist |
| RSO | rear seat observer |
| SAS | stability augmentation system |
| SB | Service Bulletin |
| SDS | System Description Section |
| TAS | true airspeed |
| TOT | turbine outlet temperature |
| TRQ | torque |
| TRTO | Type Rating Training Organization |
| UK | United Kingdom |
| UTC | Co-ordinated Universal Time (GMT) |
| VEMD | Vehicle and Engine Monitoring Display |
| VHF | Very High Frequency |
| VMC | Visual Meteorological Conditions |
| $V_{NE}$ | never exceed airspeed |
| VOR | VHF Omnidirectional Radio Range |
| WFOV | Wide Field Of View |
| WU | Warning Unit |

## Air Accidents Investigation Branch

## Aircraft Accident Report No: 3/2015 (EW/C2013/11/04)

| | |
|---|---|
| **Registered Owner and Operator**: | Bond Air Services Limited |
| **Aircraft Type**: | Eurocopter (Deutschland)[1] EC135 T2+ |
| **Nationality**: | British |
| **Registration:** | G-SPAO |
| **Place of Accident**: | Glasgow City Centre, Scotland |
| **Date and Time**: | 29 November 2013 at 2222 hrs<br>All times in this report are UTC |

## Introduction

The Air Accidents Investigation Branch (AAIB) was notified at 2259 hrs on 29 November 2013 that a helicopter had crashed through the roof of The Clutha Vaults Bar, in the centre of the city of Glasgow. A team of AAIB Inspectors and support staff arrived in Glasgow at 0915 hrs the following morning to commence an investigation.

In accordance with established international arrangements, the Bundesstelle für Flugunfalluntersuchung (BFU) of Germany, representing the State of Design and Manufacture of the helicopter, the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) of France, representing the State of Design and Manufacture of the engines, and the National Transportation Safety Board (NTSB) of the USA, representing the State of Design and Manufacture of the Full-Authority-Digital-Engine-Controls (FADECs) on the engines, appointed Accredited Representatives to participate in the investigation. They were supported by advisors from the helicopter manufacturer, the BEA and the engine manufacturer. The European Aviation Safety Agency (EASA), the UK Civil Aviation Authority (CAA) and the helicopter operator also assisted the AAIB.

The investigation was conducted under the provisions of *Regulation EU 996/2010* and the UK *Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996*.

[1] Eurocopter (Deutschland) became Airbus Helicopters (Deutschland) in January 2014.

 

## Summary

The helicopter departed Glasgow City Heliport (GCH) at 2044 hrs on 29 November 2013, in support of Police Scotland operations. On board were the pilot and two Police Observers. After their initial task, south of Glasgow City Centre, they completed four more tasks; one in Dalkeith, Midlothian, and three others to the east of Glasgow, before routing back towards the heliport. When the helicopter was about 2.7 nm from GCH, the right engine flamed out. Shortly afterwards, the left engine also flamed out. An autorotation[2], flare recovery and landing were not achieved and the helicopter descended at a high rate onto the roof of the Clutha Vaults Bar, which collapsed. The three occupants in the helicopter and seven people in the bar were fatally injured. Eleven others in the bar were seriously injured.

Fuel in the helicopter's main fuel tank is pumped by two transfer pumps into a supply tank, which is divided into two cells. Each cell of the supply tank feeds its respective engine. During subsequent examination of the helicopter, 76 kg of fuel was recovered from the main fuel tank. However, the supply tank was found to have been empty at the time of impact. It was deduced from wreckage examination and testing that both fuel transfer pumps in the main tank had been selected OFF for a sustained period before the accident, leaving the fuel in the main tank, unusable. The LOW FUEL 1 and LOW FUEL 2 warning captions, and their associated audio attention-getters, had been triggered and acknowledged, after which, the flight had continued beyond the 10-minute period specified in the *Pilot's Checklist Emergency and Malfunction Procedures*.

The helicopter was not required to have, and was not fitted with, flight recorders. However, data and recordings were recovered from non-volatile memory (NVM) in systems on board the helicopter, and radar, radio, police equipment and CCTV recordings were also examined.

During the investigation, the EC135's fuel sensing, gauging and indication system, and the Caution Advisory Display and Warning Unit were thoroughly examined. This included tests resulting from an incident involving another EC135 T2+.

Despite extensive analysis of the limited evidence available, it was not possible to determine why both fuel transfer pumps in the main tank remained OFF during the latter part of the flight, why the helicopter did not land within the time specified following activation of the low fuel warnings and why a MAYDAY call was not received from the pilot. Also, it was not possible to establish why a more successful autorotation and landing was not achieved, albeit in particularly demanding circumstances.

[2] Autorotation in a helicopter is a condition of descending flight where, following the failure of all engines, the rotor blades are driven solely by aerodynamic forces resulting from the airflow up through the rotor.

The investigation identified the following causal factors:

1. 73 kg of usable fuel in the main tank became unusable as a result of the fuel transfer pumps being switched OFF for unknown reasons.

2. It was calculated that the helicopter did not land within the 10-minute period specified in the *Pilot's Checklist Emergency and Malfunction Procedures*, following continuous activation of the LOW FUEL warnings, for unknown reasons.

3. Both engines flamed out sequentially while the helicopter was airborne, as a result of fuel starvation, due to depletion of the supply tank contents.

4. A successful autorotation and landing was not achieved, for unknown reasons.

The investigation identified the following contributory factors:

1. Incorrect management of the fuel system allows useable fuel to remain in the main tank while the contents in the supply tank become depleted.

2. The RADALT and steerable landing light were unpowered after the second engine flamed out, leading to a loss of height information and reduced visual cues.

3. Both engines flamed out when the helicopter was flying over a built-up area.

Seven Safety Recommendations have been made.

# 1 Factual Information

## 1.1 History of the flight

### 1.1.1 Background

On 29 November 2013 the helicopter was operated by the day-shift pilot and refuelled three times, twice at Inverness and again after its return to Glasgow City Heliport[1] (GCH). The day-shift pilot did not experience any abnormal indications or defects with the helicopter and, on handover to the pilot on the night-shift, he informed him that there were 400 kg of fuel on board.

### 1.1.2 The flight

(The following description of events was created from an amalgamation of recorded data and other evidence. Figure 1 shows the helicopter's track, from its point of departure to the location of the accident.)

After receiving clearance from ATC to operate in the Glasgow Control Zone, the helicopter departed GCH at 2044 hrs. This was the crew's first task of the night-shift, in support of Police Scotland operations. On board were one pilot and two Police Observers, each of whom was in possession of a set of Night Vision Goggles (NVGs). Initially, the helicopter tracked towards the Oatlands district of Glasgow, about 2 nm south-east of GCH. This was a 'non-routine'[2] task, to assist in the search for a person believed to have been struck by a train. At 2046 hrs, the front seat observer made a routine transmission to the Police Scotland control room, using an Airwave radio[3], informing them that the helicopter was "EN ROUTE TO INGLEFIELD STREET"; this was acknowledged. Three minutes later, the control room contacted the helicopter with a general enquiry. This was responded to by the front seat observer. The helicopter remained in the Oatlands district, at an altitude of approximately 800 ft amsl, for about 33 minutes. During this period the crew were in communication with police officers on the ground, via Airwave. When no-one was found, all the resources involved, including the helicopter, were stood down by a Police Sergeant who was in attendance on the ground.

At 2121 hrs, the pilot advised ATC that they were "COMPLETE SOUTH SIDE" and requested clearance to route towards Dalkeith, Midlothian, about 42 nm east of GCH. This was approved. It was subsequently calculated that, at this point,

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1 Since the accident Glasgow City Heliport (GCH) has moved to a new location. See Section 1.10, Heliport information for more details. All distances referenced to GCH are measured from the location of the heliport at the time of the accident.

2 See Section 1.18.1 a description of how airborne tasks are managed by Police Scotland and Police Observers.

3 See Section 1.9, Communications, for a description of the Airwave communications network.

the fuel remaining would have been about 273 kg[4]. At 2122 hrs, the front seat observer informed the Police Scotland control room that they had been "STOOD DOWN" from the first task and were heading towards Dalkeith, for a routine surveillance task.

The helicopter initially transited at an altitude of 2,000 ft amsl and, as it cleared Glasgow Control Zone to the east, ATC advised the pilot to contact Edinburgh ATC. On initial contact, Edinburgh ATC instructed the pilot not to fly above 2,000 ft amsl and to route via the Cobbinshaw (Reservoir) visual reporting point. As the helicopter approached Cobbinshaw, ATC cleared the pilot to fly direct to Dalkeith, not above 3,000 ft amsl. This was to allow the helicopter enough vertical clearance above the Pentland Hills, to the south of Edinburgh. Just before arriving at Dalkeith, the pilot informed ATC that he would be operating over Dalkeith at about 800 ft, would be remaining outside Edinburgh's Control Zone and "HOVERING THERE ABOUT FIVE TO TEN MINUTES".

The helicopter arrived at Dalkeith at 2141 hrs, with an estimated 203 kg of fuel, and commenced its task at 2142 hrs. It remained there for about three minutes, at an altitude of approximately 1,200 ft amsl. Radar recordings provided limited information on the helicopter's track and altitude, due to its height and intervening obstacles, but some evidence was recovered from the helicopter's Forward Looking Infra-red (FLIR) camera system (see paragraph 1.11.5).

On completion of this task, at 2145 hrs, the helicopter flew back towards Glasgow, with approximately 192 kg of fuel remaining. The pilot advised ATC that they were "COMPLETE DALKEITH" and requested clearance to climb to 3,000 ft amsl, routing via Cobbinshaw. ATC cleared the helicopter to enter the Edinburgh Control Zone, initially not above 2,000 ft amsl, and re-cleared it to not above 3,000 ft amsl a few minutes later.

After flying at 3,000 ft amsl for three minutes, the helicopter descended to 2,000 ft amsl, on ATC's request, as it passed Cobbinshaw. At 2156 hrs, ATC requested the pilot inform them when he needed to contact Glasgow ATC and was told that there was no known traffic to affect the helicopter en route. In response, the pilot advised Edinburgh ATC that they were routing south of the restricted area at Shotts, North Lanarkshire[5]. Two minutes later, the pilot advised Edinburgh ATC that he was contacting Glasgow ATC. One minute after that, at 2159 hrs, he called Glasgow ATC and informed them of the helicopter's position, south of the restricted area, and that it was heading towards Bothwell, South Lanarkshire, "BEFORE RECOVERY". Glasgow ATC cleared

4 The fuel remaining figures used in the History of the flight are based on fuel usage rates calculated by the manufacturer. See Section 1.11.6, Fuel consumption, for more details.

5 The restricted area at Shotts is circular area of airspace with a 2 nm radius. It is from the surface to 2,800 ft amsl centred on the prison to the north-west of Shotts. Helicopters are prohibited from flying through this area, but police helicopters are not.

the helicopter to enter the Glasgow Control Zone, not above 2,000 ft amsl, which was acknowledged by the pilot. Having been at that altitude for five minutes, the helicopter descended to 1,500 ft amsl for two minutes, as it approached Bothwell.

It was not possible to determine precise timings but it was calculated that, before the helicopter reached Bothwell, the pilot was presented with a LOW FUEL 1[6] warning caption, with the associated aural attention-getter. This aural attention-getter was acknowledged[7] by the pilot. The warning caption then extinguished, before re-appearing after an undetermined interval. This, too, was acknowledged by the pilot. The caption extinguished again. The LOW FUEL 2 warning caption then illuminated, with the associated aural attention-getter, and was also acknowledged. The LOW FUEL 1 caption then re-appeared a third time, in addition to the LOW FUEL 2 caption. This was acknowledged, before extinguishing again, leaving the LOW FUEL 2 warning. The LOW FUEL 1 warning caption then re-illuminated once more and was, again, acknowledged. After this, the LOW FUEL 1 and LOW FUEL 2 warnings captions remained illuminated for the rest of the flight.

At 2206 hrs, the helicopter arrived at Bothwell with an estimated 122 kg of fuel remaining and orbited once, to the right, while it carried out a routine surveillance task. This took approximately two minutes. It then flew north-west, about 1.5 nm, and commenced a three-minute task at Uddingston, South Lanarkshire, at 2209 hrs, with an estimated 113 kg of fuel remaining. Again, it orbited once to the right. As the helicopter left this task, it initially tracked west-south-west for nearly one minute, before turning onto a north-easterly track and flying about 1.5 nm towards Bargeddie, North Lanarkshire. At 2214 hrs, with an estimated 100 kg of fuel remaining, the helicopter carried out a further routine surveillance task, orbiting three times to the right at Bargeddie. No radio transmissions were received from the pilot during each of these three surveillance tasks.

At 2219 hrs, the pilot informed ATC that they were complete in the Bothwell area and were returning to GCH. ATC confirmed that the helicopter was clear to enter the Glasgow Control Zone, not above 2,000 ft amsl, and this clearance was verbally acknowledged by the pilot. There was no indication of any fault with the helicopter or any other concern. No further radio transmissions were received from the pilot. At this time, the fuel remaining was calculated to have been 86 kg.

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6 See Appendix A for a list of the actions that should be taken when a LOW FUEL warning is activated and paragraph 1.6.7 for a description of the low fuel warning sensor.

7 The warning caption and aural attention getter, 'gong', are triggered simultaneously. Only the gong can be cancelled (acknowledged), by the pilot pressing the CDS (Cockpit Display System)/AUDIO RES (reset) switch on the cyclic control.

The helicopter tracked towards GCH at an altitude of about 1,000 ft amsl, with a ground speed of approximately 100 kt. Between 2221:35 hrs and 2221:45 hrs, when the helicopter was about 2.7 nm east of GCH, the right engine flamed out, leaving the pilot with one engine inoperative (OEI). Approximately 32 seconds later, about 1.8 nm east of GCH, the left engine flamed out.

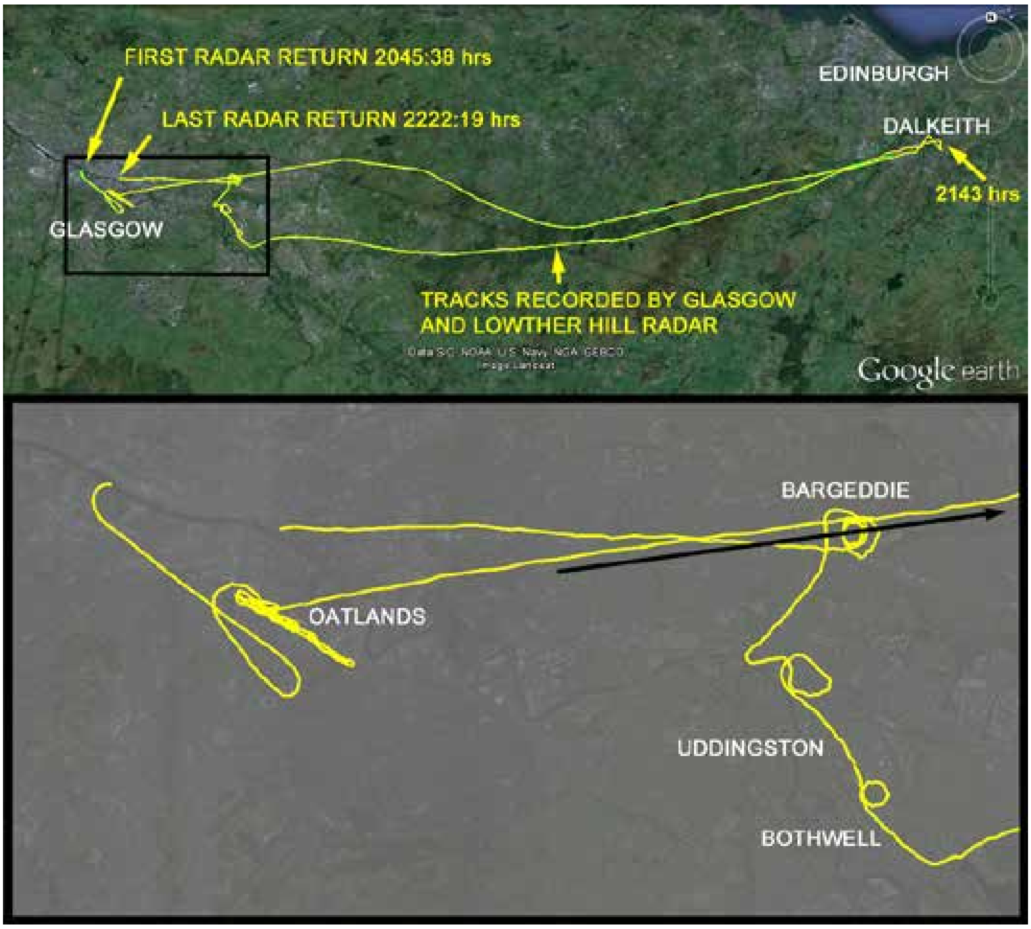


**Figure 1**

Overview of the helicopter's flight path

After the second engine had flamed out, the ROTOR RPM[8] warning caption illuminated, accompanied by its aural tone. This indicated that the speed of the rotor had decreased below 97%. This warning then extinguished, re-illuminated and extinguished again. It finally re-illuminated and stayed on for the remainder of the flight, as the helicopter descended.

The last recorded radar position, at 2222:19 hrs, showed the helicopter at an altitude of approximately 390 ft amsl, close to the accident site.

8 See Appendix A for the actions to be taken by the pilot in the event of a ROTOR RPM warning.

The helicopter was seen by several witnesses who were in the vicinity of the car park bounded by Stockwell Street, Osborne Street, Howard Street and King Street. During the final part of its descent, some of the witnesses described hearing noises similar to a "misfiring car" and a "backfire", as well as numerous "bangs". There was then silence, as the helicopter descended rapidly. It struck the roof of The Clutha Vaults Bar, a single storey building on Stockwell Street, with a high rate of descent and in an upright attitude. Evidence indicated that the helicopter's main rotor blades and Fenestron tail rotor were not rotating at the moment of impact. The force of the impact caused the roof to collapse and the helicopter entered the space below.

## 1.2 Injuries to persons

The three occupants of the helicopter and six people in, or adjacent to, The Clutha Vaults Bar were fatally injured. Thirty-two other people suffered injuries, 12 seriously. One of those seriously injured subsequently died of his injuries on 12 December 2013.

| Injuries | Crew | Passengers[9] | Others |
|---|---|---|---|
| Fatal | 1 | 2 | 7 |
| Serious | | | 11 |
| Minor/None | | | |

## 1.3 Damage to the helicopter

The helicopter was destroyed.

## 1.4 Other damage

The roof of the Clutha Vaults bar collapsed when the helicopter struck the building, causing severe damage to the ceiling and the bar area beneath.

[9] Civil Aviation Publication CAP 612, Police Air *Operations Manual, Part One, states: 'Flight Crew. The Air Navigation Order defines flight crew as follows: 'Flight Crew' in relation to an aircraft means those members of the crew of the aircraft who respectively undertake to act as pilot, flight navigator, flight engineer and flight radio telephony operator of the aircraft. All other persons on board the aircraft, including the police observer, are regarded as passengers.'*

Within this report the Police Observers are generically referred to as 'crew' as they have duties that are assigned to them. See paragraph 1.17.2.2 for more details on CAP 612.

## 1.5 Personnel Information

### 1.5.1 Pilot

| | | |
|---|---|---|
| Age: | 51 years | |
| Licence: | Commercial Pilot's Licence | |
| Licence expiry date: | 18 November 2022 | |
| Helicopter Ratings: | EC135 | |
| Operator Proficiency Check: | Valid until 28 February 2014 | |
| Licence Proficiency Check: | Valid until 31 January 2014 | |
| Police line check: | Valid until 31 October 2014 | |
| Medical certificate: | Valid until 12 May 2014 | |
| Flying Experience: | Total all types: | 5,592 hours |
| | On Type: | 646 hours |
| | Last 84 days | 40 hours |
| | Last 28 days | 22 hours |
| | Last 24 hours: | 0 hours |
| Previous rest period: | 12 hours | |
| Emergency and safety equipment: | Valid until 31 December 2013 | |
| Crew Resource Management training: | Valid until 15 November 2014 | |

During the three days prior to the accident, the pilot had been on a day off, followed by two day shifts (0730-1930 hrs). On the evening of the accident, he had reported for a night shift, which was scheduled from 1930 hrs to 0730 hrs

The pilot had been trained to fly helicopters in the Royal Air Force (RAF). Predominantly, he flew the Boeing Chinook HC2/3 and saw operational service in Afghanistan, Bosnia, Iraq, and Northern Ireland. He was a Qualified Helicopter Instructor on the Eurocopter Squirrel HT1/2 and Chinook HC2/3, and an Instrument Rating Examiner on the Chinook HC2/3. He was also the RAF's Chinook display pilot in 2007. His later assessments rated him an above average pilot.

The pilot left the RAF in 2008 and joined the operator the same year, when he completed his rating for the EC135.

1.5.2 Police Observers

1.5.2.1 Front seat observer

| | |
|---|---|
| Age: | 36 years |
| Police line check: | Valid until 31 December 2013 |
| Previous rest period: | 12 hours |
| Emergency and safety equipment: | Valid until 31 December 2013 |
| Crew Resource Management training: | Valid until 24 April 2014 |
| Initially qualified: | 2011 |

1.5.2.2 Rear seat observer

| | |
|---|---|
| Age: | 43 years |
| Police line check: | Valid until 31 January 2014 |
| Previous rest period: | 12 hours |
| Emergency and safety equipment: | Valid until 31 January 2014 |
| Crew Resource Management training: | Valid until 17 January 2014 |
| Initially qualified: | 2006 |

Both observers were on the same team and flew together regularly. For the three days prior to the accident they had both been on an early shift (0730-1530 hrs), with three rest days prior to that. On the evening of the accident, they had reported for a late shift, which was due to last from 1530 hrs to 2359 hrs.

There is no requirement for Police Observers to record their flying experience in a log book.

**1.6 Aircraft information**

1.6.1 General

| | |
|---|---|
| Manufacturer: | Eurocopter (Deutschland) |
| Type: | EC135 T2+ |
| Power plants: | Two Turbomeca Arrius 2B2 turboshaft engines |
| Build serial number: | 0546 |
| Year of manufacture: | 2007 |
| Total airframe hours: | 6,351 hrs |
| Total landings: | 9,385 |
| Certificate of Registration No: | G-SPAO/R2 |
| Registered Owner: | Bond Air Services Ltd |
| Date of issue: | 24 October 2007 |
| Issuing Authority: | UK CAA |
| Certificate of Airworthiness: | Issued by the UK CAA on 14 August 2008 |
| Airworthiness Review Certificate: | Valid until 4 September 2014 |

1.6.2 Aircraft description

The Eurocopter (now Airbus Helicopters) (Deutschland) EC135 type is a twin-engine light utility helicopter of metal and composite construction. G-SPAO was powered by two Turbomeca Arrius 2B2 engines driving a conventional transmission system. The main rotor gearbox on the type is mounted on an anti-resonance rotor isolation system (ARIS) on the transmission deck. Yaw control is provided by a Fenestron tail rotor system fitted with 10 blades.

The helicopter can be configured for two pilot operations by fitting an additional set of cyclic, collective and yaw pedal controls at the front left seat. The flying controls are assisted by duplex hydraulic servos and include a three-axis autopilot and stability augmentation system (SAS).

G-SPAO was the T2+ variant, with a design maximum takeoff weight of 2,910 kg. It was fitted with additional equipment and a seating arrangement for police operations, with a crew of up to four, including the pilot.

1.6.3 Warnings, cautions and system displays

The cockpit displays for warnings, cautions and system information, and the pilot-operated CDS/AUDIO RES (reset) switch, are shown in Figure 2.

1.6.3.1 Warning Unit

The Warning Unit (WU) is situated centrally on the instrument panel just beneath the cockpit glareshield (see Figure 2). This provides visual and audio indications when warning conditions are triggered. The WU accommodates eight warning captions. They appear red when illuminated and are unlit when inactive. Each caption simultaneously initiates an audible attention-getter ‘gong’. The audio for some of the warnings can be silenced using the audio reset button on the top of the cyclic control stick but a visual warning cannot be cleared while the warning condition remains. All warning gongs are audible to the pilot and Observers, through their headsets. All warning captions can be dimmed for night operation.

The WU provides only the audible element of the warnings associated with the First Limit Indicator (FLI)[10] on the Vehicle and Engine Monitoring Display (VEMD), which displays the visual warnings.

Section 1.11.4.3 describes the limited recording capability of the WU and the evidence retrieved during the investigation.

[10] The First Limit Indicator (FLI) is a gauge with two needles, indicating to the pilot the value of the limiting engine parameter (turbine outlet temperature (TOT), torque (TRQ) or $N_1$ (gas producer rpm) on each engine, with the three parameters shown digitally to the left and right of the gauge, for the respective engine. The parameter that is nearest to its limit is indicated by the needle and its numerical value is highlighted by a white rectangle.


**Figure 2**

Warnings, cautions and systems displays

1.6.3.2 Central Panel Display System (CPDS)

The CPDS comprises the Caution Advisory Display (CAD) and the VEMD, (see Figure 2). The CAD displays caution and advisory messages and fuel contents indications. The VEMD consists of two screens, which display engine and transmission parameters and limits, and can present data relating to the helicopter's systems (eg electrical system, autopilot). The CAD and VEMD are linked, so, if one of the units or screens fails, the remaining screens can display the missing information and log a fault.

Caution messages are displayed in the top half of the CAD – fuel contents indications are displayed in the lower half. The top half is further divided into three columns. The left and right columns display messages on pairs of components, to reflect the side of the aircraft concerned; for example, the left (No 1) generator or the right (No 2) pitot heater. The central column displays common system information; for example, the forward transfer fuel pump. When a new caution illuminates, any pre-existing caption(s) disappear, temporarily, and the new caption is highlighted by horizontal yellow flashing bars at the top and bottom of that screen. The master caution caption, to the right of the WU, also illuminates. When acknowledged, using the audio reset CDS/AUDIO RES (reset) switch on the top of the cyclic stick, the flashing bars and master caution caption clear but the caution remains, together with other captions that were previously present. If the condition clears, the caution disappears. Normally, no CAD caution captions are illuminated.

Section 1.6.5 provides more detail on the fuel contents indications and Section 1.11.4.1 describes the recording capability of the CPDS units and the evidence retrieved.

### 1.6.4 Fuel System

#### 1.6.4.1 Tank arrangement

The aircraft fuel storage system in the EC135 consists of two impact-resistant tanks positioned beneath the cabin floor. The forward tank (known as the main tank), is a single volume without baffles or major internal obstruction, whilst the aft tank (known as the supply tank) has a longitudinal divider in its lower section, creating two separate cells, referred to as the No 1 (left) and No 2 (right) supply tank cells, respectively (see Figure 2). These cells are connected by the undivided volume of the upper section of the supply tank. Fuel is drawn from the No 1 supply tank cell for the No 1 engine, whilst the No 2 engine draws fuel from the No 2 supply tank cell.

The No 1 supply tank cell capacity is 49 kg, whilst the No 2 cell is slightly smaller at 44.5 kg. This difference is achieved by including an intrusion into the volume at the bottom of the No 2 cell. The 4.5 kg difference in volume is to provide a time interval between engine flame-outs, should fuel exhaustion occur. The volume of the upper section of the supply tank is symmetrically disposed either side of the aircraft centre-line. The main tank capacity is 474.5 kg, which, when added to the supply tank cell fuel quantities, gives a total fuel capacity of 568 kg, of which 7.6 kg is considered to be unusable fuel.

Two overflow channels connect the main tank to the supply tank. So, with the system fully replenished, or almost so, fuel can flow freely between the two tanks. The overflow channels are positioned with their lower edges close to the level of the top of the supply tank divider. See Figure 3.

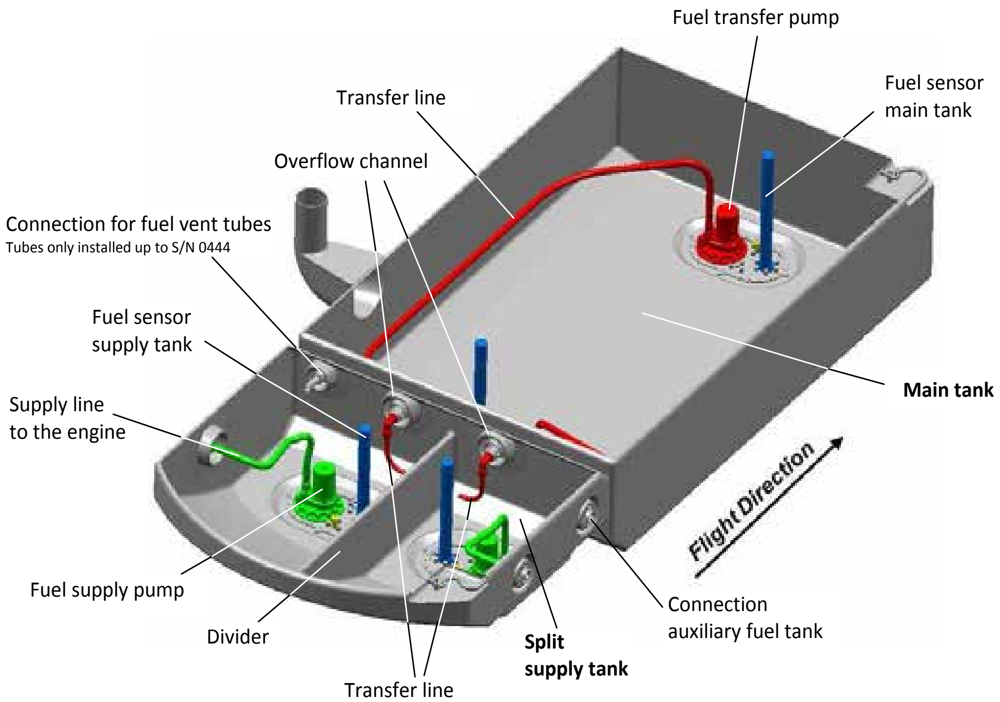


**Figure 3**

EC135 fuel tank arrangement

1.6.4.2 Fuel tank vent system

The EC135 fuel tank group is fitted with a vent system which allows for the increase in the volume of the fuel, due to expansion in high ambient temperatures. It also allows a flow of air into and out of the tanks during the operation of the helicopter and refuelling. In addition, it is designed to prevent fuel spillage in the event of the helicopter rolling over on the ground during an accident.

Vent pipes are connected to the top of the main and supply tanks. In the case of the main tank, the vent pipe is situated on its right side at the forward end. The vent pipe for the supply tank is at its aft end. The vent pipes lead to a polythene expansion tank situated against and inside the fuselage structure on the right side of the helicopter, above the level of the top of the fuel tanks. Two vent hoses lead upwards away from the expansion tank, across the top of the fuselage at transmission deck level and down the left side of the fuselage, venting to atmosphere in the vicinity of the fuel filler neck.

1.6.4.2.1 Engine fuel return and fuel tank vent system

A fuel return line is attached to both engines on the EC135 variants equipped with Turbomeca Arrius engines, in addition to the fuel tank vent system. This system is included to increase the start-up reliability of the engines by clearing any air bubbles trapped in the fuel lines, thus eliminating brief stoppages in the fuel flow. Also, any unburnt fuel in the manifolds will be routed away from the injector nozzles and combustion chamber, to prevent a build-up of carbon deposits. Purged fuel is routed into the fuel system expansion box via a collector assembly connected to the fuel vent lines.

In summary, the purged fuel return system is designed to collect waste fuel and return it to the main and supply tanks to prevent overboard discharge directly into the environment.

Both engines are fitted with a system of overboard discharge pipes to prevent the build-up of unwanted fuel and lubricants within chambers and galleries in the engine and its fuel system. The discharge pipes are connected to small drain bottles mounted beneath the engines. Fluid which has collected in the drain bottles is removed by the venturi effect created by engine exhaust gas passing over the discharge pipe. Unwanted fluids pass along the discharge pipe and, combined with the hot exhaust, are burnt off.

1.6.4.2.2 Fuel transfer

Prime pumps (shown as 'supply pumps' in Figure 3) at the bottom of each supply tank cell feed their respective engine fuel control units, for starting and during certain emergency conditions. They are normally OFF during flight.

When the main and supply tanks are full of fuel, above the supply tank divider and overflow channel levels, fuel can flow freely between the main and supply tanks. However, to ensure a constant transfer of fuel into the supply tanks, there are two electrical transfer pumps fitted towards the forward and aft ends of the main tank. In normal operation, one or both of these transfer pumps should be running constantly, to deliver fuel via non-return valves into a common transfer manifold. The manifold feeds two fuel delivery pipes, each of which passes through one of the two overflow channels, into the supply tank, terminating above the top of No 1 and No 2 supply tank cells respectively. Thus, with either or both transfer pumps delivering fuel and the engines running, both supply cells are continuously replenished from the main tank, and the latter's contents decrease.

Each fuel transfer pump is capable of delivering 10 kg of fuel per minute to the supply tank, which is more than the maximum rate of fuel consumption of both engines, combined. This excess fuel delivery capability means that, when the fuel level in the main tank is lower than the overflow channels, excess transfer pump delivery overflows from the supply tank back into the main tank, via the overflow channels. So, with one or more transfer pumps operating, the supply tank contents will be maintained at least level with the lowest point of the overflow channels, as long as a useable amount of fuel remains in the main tank.

The transfer pumps are referred to as the forward and aft transfer pumps, respectively. In flight, as the depth of the fuel in the main tank reduces and the pitch attitude of the helicopter changes, one or other of the transfer pump inlets can become uncovered, causing the associated pump to run dry. The dry running (ie offloading of the pump) is detected by the fuel control and indication system software, which produces an F PUMP AFT or F PUMP FWD caution caption on the CAD display in the CPDS. The appearance of this caution caption prompts a procedure in the manufacturer's *Pilot's Checklist Emergency and Malfunction Procedures* (see Appendix A). Although the pumps are capable of running dry for up to 20 minutes, this feature is included in order to protect the pumps from running without fuel cooling or lubrication.

The quantity of fuel in the main tank determines the helicopter's pitch attitude at which the main fuel transfer pumps become exposed. With small quantities of fuel, only small positive or negative pitch attitudes are required for the transfer pumps to run dry. Similarly, larger pitch attitudes are required when there is a greater quantity of fuel in the main tank.

An algorithm is built into the CPDS software to prevent intermittent fuel transfer pump captions appearing during dynamic manoeuvres in flight, as the fuel moves about in the main tank. This inhibits the caption until there has been a continuous period of three minutes during which the pump has run dry. If, within the three-minute period, the pump becomes re-immersed in fuel, the three-minute delay is reset to zero to await the next dry running condition.

The F PUMP AFT and F PUMP FWD caution captions will also illuminate after three minutes if the fuel transfer pumps are switched OFF while immersed in fuel or become blocked. A message is not provided for the situation where a pump has been switched OFF, after running dry, and is then re-submerged in fuel.

### 1.6.5 Fuel contents system

#### 1.6.5.1 Fuel sensors

The fuel contents indicating system includes four capacitance sensors, one positioned near each end of the main tank and one in each cell in the supply tank. They are all mounted on removable metal plates, positioned at the geometrically lowest points in the tanks, and extend vertically the full tank depth. (The removable plates also carry the transfer and priming pumps in the main and supply tanks respectively.) The different tank depths dictate that the main tank sensors are slightly longer than the supply tank sensors. The top of each sensor is located in a small rubber cup bonded into the structure of the tank.

The fuel gauge displays are signalled by the variation in the frequency of the current in the circuits incorporating the tank level sensors. The sensors are typical of aviation fuel gauge units, being capacitors in which the 'plates' take the form of concentric tubes and the dielectric is the material occupying the space between the tubes. With fuel occupying the full depth of a tank, the dielectric is aviation fuel, whilst in an empty tank the dielectric is air. The difference in dielectric characteristics between air and fuel results in a different capacitance, and different frequency, when the tank is full from that when it is empty. Hence, the low frequency created with a full tank of fuel contrasts with the high frequency with an empty tank. Proportionate frequencies are created at intermediate fuel levels.

In the EC135, the concentric tubes on the fuel sensors are deliberately weakened to ensure they do not puncture the skin during a vertical impact on the relevant tank. This weakening takes the form of very fine diagonally orientated cuts passing almost completely through the tubes. These fine cuts are positioned so that an end load on any of the tubes causes it to fail benignly and the two remaining halves to slide past one another applying little loading to the tank skin as each tank is compressed. These fine cuts, together with two small drain holes positioned at the bottom of the outer tube, are the only connection between the fuel in the tank and that between the concentric tubes.

1.6.5.2 Fuel contents gauges

The frequencies generated by the four individual sensor circuits are processed by software within the CPDS unit to provide indications on the CAD, both pictorially and numerically, of the fuel masses allocated to the main tank and actually present in each of the supply tank cells.

If a very low frequency registers, significantly below that appropriate to full fuel tanks, the software detects an impossible situation and the relevant pictorial and numerical fuel displays on the CAD are supplemented by F QTY FAIL or F QTY DEGR captions[11]. The F QTY FAIL caption indicates that one of the supply tank sensors has failed or both main tank sensors have failed. Under these circumstances, the respective graphic on the CPDS indicates zero. The CAD caption F QTY DEGR indicates that one of the two main tank sensors has failed and that the fuel tank indication is degraded and no longer reliable. In this case, the CPDS graphic will not change to zero but will show a fuel quantity based on a more conservative calculation within the indication algorithm, so as not to show more fuel than is available.

In the supply tank, the sensor tubes measure the fuel in their respective supply tank cell (ie on each side of the divider) and the fuel which is in the supply tank above the top of the divider. The measured contents detected by each sensor, less the fixed capacity of its supply tank cell, is added by the software

[11] See Appendix A for the actions to be taken in the event of an F QTY FAIL and F QTY DEGR.

to the amount in the main tank, to produce a total which is displayed as main tank contents. Thus, the fuel in the supply tank above the level of the divider is treated as part of the main tank contents. See Figure 4.

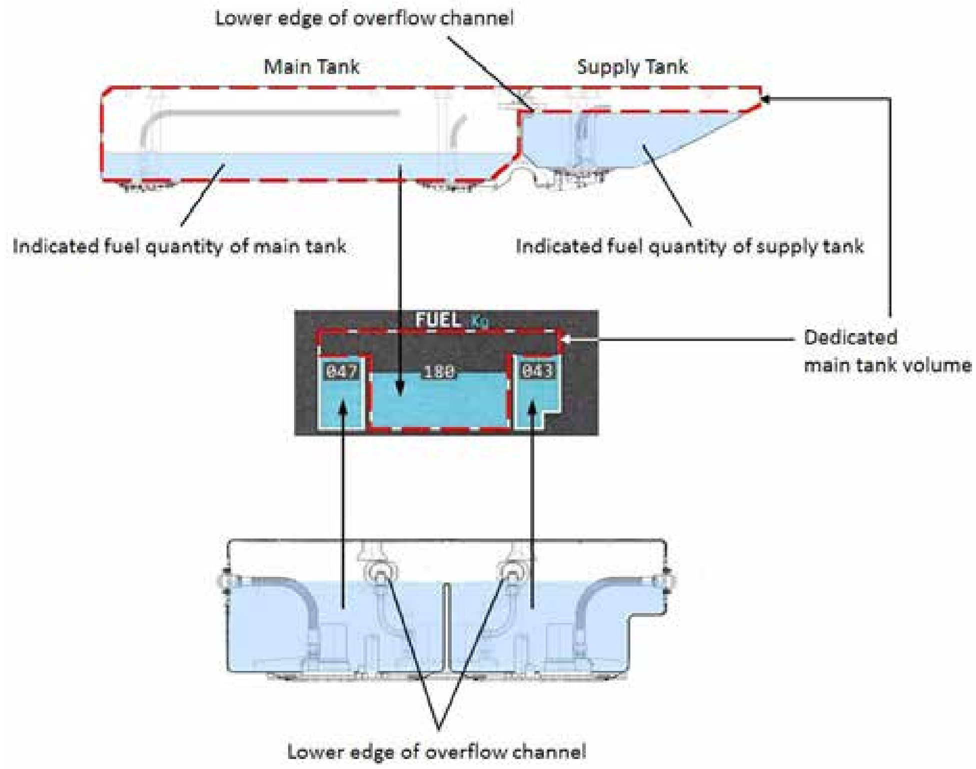


**Figure 4**

Fuel tank contents indication schematic

1.6.5.3 Manufacturer's Information Notice

To clarify and enhance the EC135 Training Manual, the manufacturer issued an Information Notice (IN) to operators in March 2014 (see Appendix B). IN 2693-I-28, dated 5 March 2014, explained in detail the logic of the supply and main tank contents indication system and the effect that aircraft pitch has on the movement of fuel and its quantity measurement. It clarified the way in which the fuel in the supply tank above the divider is measured by the sensors and allocated, by the software, to the main tank and added to the actual quantity in the main tank. This is shown to the pilot on the display as a single main tank contents figure. In addition, the IN detailed the effect that aircraft pitch has on fuel in the supply tank, as it rises and falls within the sensors. If the fuel is at or above the divider level and aircraft pitch causes the fuel to rise up the sensor, it will be added to the main tank contents while the pitch angle remains.

As the helicopter pitch attitude changes during flight, the fuel within the main tank rises and falls around the forward and aft fuel sensors, which causes their outputs to differ. These varying outputs are taken into account in the fuel quantity indication software, which uses a set of algorithm tables within the display driver to compensate for positive and negative pitch. It is accepted that fuel movement may be dynamic in nature, so the system is designed to display conservative tank contents figures.

1.6.6 Fuel consumption

An examination of the fuel uplift and quantities on landing, recorded in the Tech Log Sector Record, indicated that G-SPAO's fuel consumption was, on average, 3.3 kg/min. It also showed that, over the course of 125 sectors flown, from the end of October 2013 to the date of the accident, the minimum landing fuel recorded was 100 kg, with an average landing fuel of 243 kg.

The quantities recorded by the pilots and engineers in the Tech Log Sector Record are those read directly from the display on the CAD in the helicopter.

1.6.7 Fuel contents cautions and warnings

In addition to the fuel system caution captions already described, an amber FUEL caption is triggered by the contents level software and displayed on the CAD display when the level in one of the supply tank cells drops below a certain quantity. This caption is normally activated when the No 1 supply tank cell content falls below between 34 and 36 kg or the No 2 supply tank cell content falls below between 30 and 32 kg. The FUEL caution illuminates when the fuel level in either supply tank cell reaches the appropriate range and does not distinguish between the two cells.

A separate low fuel warning system is signalled by thermistors[12] which are attached to the outside of the fuel sensor capacitance tubes in the supply tank cells. The fuel cools the thermistors, when covered, but, once the fuel level falls below the thermistors, the cooling ceases and the thermistors heat up, altering their resistance. This triggers the LOW FUEL 1 or LOW FUEL 2 red warning caption, as appropriate, to illuminate on the WU (see Figure 2). An audio attention-getter, in the form of a 'gong', is also initiated. These warnings are activated when the fuel level falls below between 26 and 34 kg in the No 1 supply tank cell or below between 22 and 30 kg in the No 2 supply tank cell. The LOW FUEL warning feature is independent of the fuel contents indication system and the amber FUEL caption.

When the helicopter is in a level attitude the thermistors will trigger at the same time, if the same quantity of fuel has been removed from both supply tank cells. However, one thermistor is mounted slightly forward of the other. So, when the helicopter is not level, one thermistor will tend to trigger before the

[12] Thermistor – A resistor based on a semiconductor having high negative temperature coefficient of resistance.

other. In addition, if a thermistor is just exposed, an increased nose-down attitude will temporarily cover the sensor, clearing the warning until more fuel has been used and the fuel sensor is exposed once more. The converse is true for an increased nose-up pitch attitude. Similarly, a lateral force, such as in an unbalanced turn, with the fuel level close to the thermistor, may generate an early warning or delay it. The tendency for the helicopter's pitch attitude or a lateral force to affect the onset of the low fuel warning diminishes as the fuel levels in the supply tank cells decrease.

As with the LOW FUEL warnings, the *Pilot's Checklist Emergency and Malfunction Procedures* (see Appendix A) contains the actions that should be taken when the amber FUEL caption illuminates.

1.6.8 Main rotor head and main rotor blades

The EC135 main rotor head is of a rigid design and composite construction. There are four main rotor blades, each of which is attached to the steel alloy rotor hub shaft flange plates by two bolts. At the root of each blade there is a 'flexbeam', made of a cruciform section composite material, which absorbs the centrifugal tensile loads. It is designed to twist, to accommodate pitch changes, bend in the vertical plane, to absorb flapping loads, and bend in the horizontal plane, to absorb lead and lag drag loads. The flexbeam is surrounded by the blade cuff.

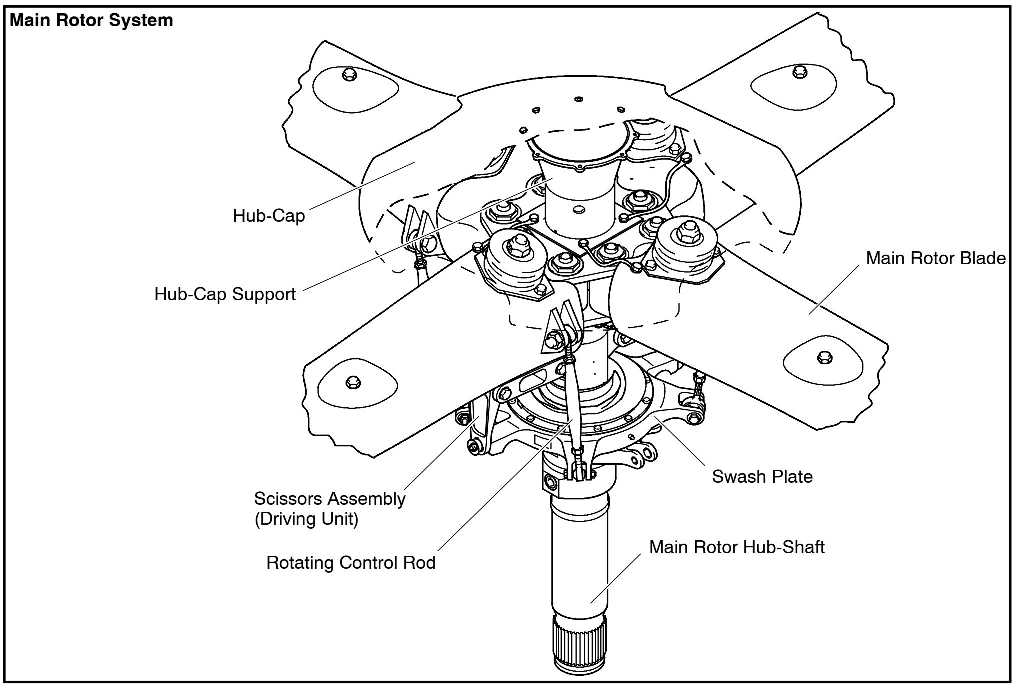


**Figure 5**

EC135 main rotor head assembly

The blade cuff is integrated into the blade skin and surrounds the flexbeam to provide a streamlined transition from the aerofoil section of the blade to the blade root (see Figures 6 and 7). The pitch angle of the main rotor blade is adjusted through a pitch horn, integral to the cuff. The cuff and flexbeam are held in alignment by a link rod, which passes through a spherical bearing in the flexbeam, and is attached to elastomeric[13] mountings on the upper and lower surfaces of the blade cuff. The elastomeric mountings provide sufficient in-plane lead-lag damping of the main rotor blade to prevent ground and air resonance, within the normal operating $N_r$ (rotational speed of the rotor blades) range.

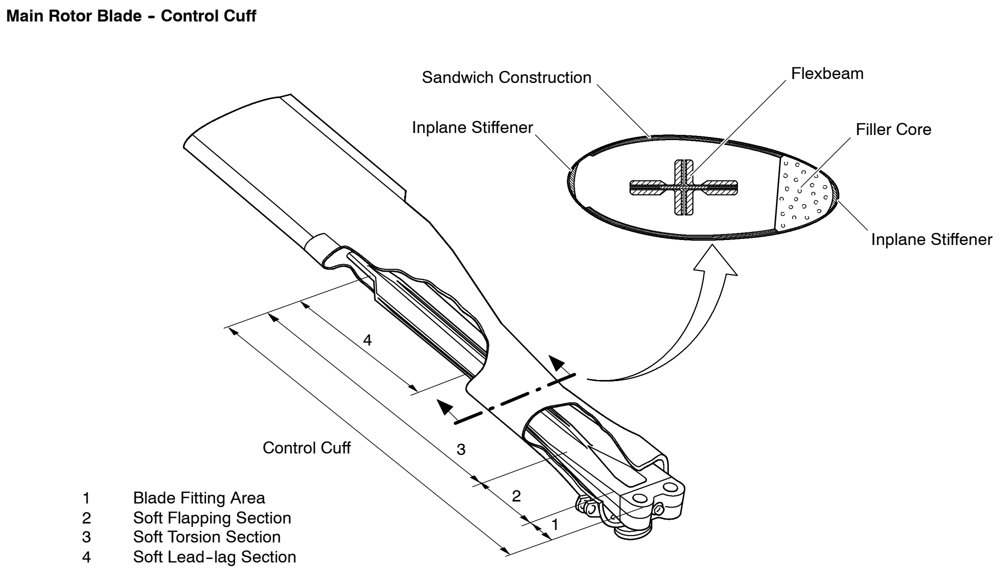


**Figure 6**

EC135 main rotor blade

1.6.9 Maintenance information

Documentation indicated that the helicopter was maintained in accordance with the manufacturer's recommendations and servicing routines. The majority of the recorded maintenance work consisted of routine servicing operations, minor defect rectifications and role equipment changes.

The routine servicing operations include a daily hot (engines running) compressor washing procedure, in accordance with the Engine Maintenance Manual (EMM).

Maintenance activities carried out during November 2013 included an engine clean, on 2 November 2013, detailed as: '*Carry out chemical cleaning of*

13 Elastomeric Damper – In this case, a device made up of a stack of metal and rubber (or neoprene) discs attached between loaded components to allow a degree of flexure in shear and rotation but remain rigid under compressive loads.

*compressor air path iaw EMM 71-03-610-801*'. This action was recorded as being carried out, using Ardrox 6367 engine wash, at 6,266 aircraft hours. In accordance with the service schedule, this activity was repeated on the night of 17/18 November 2013, at 6,309 aircraft hours, and recorded as *'#1 and #2 eng compressor air path cleaning carried out'*. These activities are commonly referred to as 'cold compressor washes'.

Later during November, the No 1 engine injector manifold was changed, to comply with a special instruction. This was followed by an engine power assurance check on 28 November 2013.

Examination of the maintenance records also identified work carried out on the fuel contents indication system. On 9 July 2013 a Work Order[14] was raised, at 5,929 aircraft hours, stating: *'Fuel contents indication inaccurate over/ under reading'*. The action taken was recorded as: *'Aft fuel sensor in main tank replaced with's' item iaw* [in accordance with] *AMM* [Aircraft Maintenance Manual] *28-40-00, 4-1. A/C refuelled iaw AMM 28-40-00, 5-3. On completion of refuelling to 310 kg it was noted that after 5 minutes contents fell to 296 kg. Suspect fwd sensor transferred to deferred defects log iaw ops manual Vol 1 Part B3 Section 28(8)'*. This was recorded in the Deferred Defects (DD) log as; *'Main fuel quantity indication spurious. Suspect fwd sensor unit. VMC flights only'*. This deferred defect was rectified on 11 July 2013, by replacing the forward fuel sensor in the main tank with the sensor unit which had been removed from the aft position as a result of the Work Order on 9 July 2013.

On 10 October 2013, a Tech Log entry was made because: '*No 1 supply tank indications failed with F QTY FAIL caption'*. This defect was transferred to DD log with an open Work Order. Subsequent rectification work took place on 11 October 2013, when the No 1 supply tank sensor was replaced with a serviceable item. An additional entry recorded that *'3 way inline junction has broken off, bullet[15] stuck inside hole B on wiring loom to No 1 supply sensor; bullet connector replaced and reconnected as per AMM 28-40-00, 4-1*'. Further work also recorded the main fuel tank aft contents sensor being replaced with a serviceable item, for fault diagnosis. This was due to the contents being seen to decrease, for a period, before increasing again, while refuelling. As this work progressed another problem was encountered, which was recorded as: *'During defuel of aircraft No 2 supply tank quantity indication stuck at 11 kg with tank empty.'* To cure this problem, the No 2 supply tank cell contents sensor was removed, cleaned, flushed with clean fuel and dried with warm air.

14 Work Order - A pre-printed form to record the detailed actions taken during maintenance tasks. Entries are certified by the personal stamp of an appropriate licensed engineer. When completed, these documents are held in the operator's archive and form a permanent record of work carried out on an aircraft.

15 A small metal electrical wire termination designed to push fit into a corresponding socket. The termination is shaped like a bullet, hence the description.

Every time a sensor was removed for replacement or cleaning, the fuel tank group was drained of all fuel, refilled and functionally checked, in accordance with the AMM.

There were no defects recorded in G-SPAO's Tech Log, or entries for work carried out, after any of the three flights conducted on 29 November 2013. The penultimate flight entry recorded a takeoff time at 1310 hrs and landing at 1435 hrs.

1.6.9.1 Fuel system indications

The operator had experienced occasional erroneous fuel quantity indications on EC135 helicopters. When diagnostic or rectification action was taken, no fault with the fuel sensor or quantifiable contamination of the fuel was found. Replacement of the fuel sensor units seemed to correct the fault. The evidence suggested that water contamination may have been the root cause but the exact mechanism was not fully understood. As a precaution, the manufacturer issued IN 2535-I-28 on 21 January 2013 (see Appendix C), drawing operators' attention to the possibility of water contamination and reiterating the procedures set out in the AMM to mitigate the problem.

When the manufacturer tested the fuel sensors that were returned from the worldwide fleet, for repair, it found about 70% had no fault.

Across the operator's EC135 Emergency Medical Services (EMS) fleet, maintained under a cold compressor washing schedule, there were instances of water and engine cleaning fluid ingress into the fuel systems. On a number of occasions this seemed to result in erroneous or unusual contents indications. Both these repetitive issues occurred randomly over a period of at least ten years.

1.6.9.2 Maintenance procedures

During the investigation, the helicopter manufacturer issued amendments to the AMMs and introduced new periodic component inspections. The manufacturer also issued two INs and published Service Bulletin EC135-71-047 (Modification of the fuel pump drain), dated 14 April 2014, and 2 ASBs, EC135-28A-18 &19 (see Appendices D and E). The INs were as follows;

IN 2671-I-28 - Information concerning the fuel indication system, dated 12 December 2013

IN 2673-S-28 - Information concerning LOW FUEL WARNING, dated 16 December 2013

1.6.10 Weight and balance

The helicopter's zero fuel weight was 2,427.67 kg. With 400 kg of fuel onboard, its takeoff weight was 2,827.67 kg, within the EC135's maximum takeoff weight of 2,910 kg. Its longitudinal centre of gravity (C of G) was 4,264 mm aft of datum, again within the permitted range.

1.6.11 Night Vision Imaging Systems (NVIS)

The Night Vision Goggles (NVGs) worn by the pilot and Police Observers were similar in design to a small set of binoculars. They were mounted on the front of the helmet and comprised two independently powered image intensifying tubes attached to a central mechanism on which the tubes could be swivelled up, for stowage, and down to the horizontal, when in use. The technique for their use was to adjust the elevation and width of the tube centres and focus, so that when the user looked through the tubes at an image, the instrument panel was fully visible below the bottom of each tube. When the NVGs were not in use they could be pivoted 90° up, into the stowed position, to enable normal vision. A counterweight was attached to the back of the helmet, using 'Velcro' surfaces, to balance the weight of the NVGs on the front of the helmet. When flying over the city, the NVGs would normally be switched OFF and rotated to the stowed position. However, the NVGs could also be removed, safely, from the helmet mount, using one hand.

To use NVGs, the lighting in the cockpit has to be NVIS compatible. The cockpit lighting can be selected between DAY/NIGHT/NVG by a single three-position switch on the overhead panel. Selecting the NVG switch position ensures that the instrument and other cockpit lighting emits light at a frequency that does not degrade the NVGs. As a consequence, the instrument displays are less bright and the colour tends to appear washed out. With the NVGs in the stowed position, all illuminated instruments and switches are still readable and the helicopter can be operated with NVG lighting.

GCH was equipped with four closed circuit television (CCTV) cameras which recorded an image every two seconds but not simultaneously. As the pilot and Police Observers walked out to the helicopter, they were all recorded wearing helmet-mounted Night Vision Goggles (NVGs) in the stowed position.

After the accident, the pilot's NVGs were found to the right of his seat. The attachment mechanism and helmet mounting bracket were inspected and showed no signs of damage or distress.

## 1.7 Meteorological information

### 1.7.1 General

The Met Office provided an aftercast of the weather situation for the area in which the helicopter had operated. The synoptic situation at 1800 hrs on 29 November 2013 showed a large area of high pressure positioned to the southwest of the UK, with a moderate to strong north-westerly flow affecting Scotland.

Glasgow and the 'Central Belt'[16] were free from cloud, with visibility between 20 and 45 km. The surface wind was from the northwest at about 10 to 15 kt, with isolated gusts up to about 30 kt over higher ground. The winds between 2,000 and 5,000 ft amsl were north-westerly, between 25 and 30 kt. The temperature was between 4 and 7°C, with the dew point between -2 and 2°C. The freezing level was at approximately 3,000 ft amsl.

The forecast data indicated a risk of moderate turbulence, with a risk of severe turbulence in places. This moved eastwards through the evening, as winds eased from the west.

It was a moonless night.

### 1.7.2 Actual weather reports

#### 1.7.2.1 Glasgow Airport

At 2050 hrs, about five minutes after the helicopter took off from GCH, the weather at Glasgow International Airport (GIA), 4.5 nm west of GCH, was: visibility greater than 10 km, with the wind from 280° at 9 kt, FEW clouds at 4,000 ft, temperature 6°C, dew point 2°C and the QNH was 1024 hPa.

At 2220 hrs, just before the accident, the weather at Glasgow Airport was CAVOK, with the wind from 300° at 7 kt, temperature 5°C, dew point 2°C and the QNH was 1025 hPa.

#### 1.7.2.2 Edinburgh Airport

At 2120 hrs, about 20 minutes before the task at Dalkeith was commenced, the weather at Edinburgh Airport, 11.7 nm north-west of the task, was CAVOK, with the wind from 300° at 8 kt, temperature 6°C, dew point 0°C and the QNH was 1023 hPa.

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[16] The 'Central Belt' of Scotland is the area of highest population density within Scotland. It lies between the Highlands to the north and the Southern Uplands to the south.

At 2150 hrs, about 5 minutes after the task at Dalkeith was completed, the weather at Edinburgh Airport was CAVOK, with the wind from 280° at 9 kt, temperature 6°C, dew point 0°C and the QNH was 1023 hPa.

1.7.3 Weather minima

Police Air Operations Manual (PAOM) Part 2, *3.2 Aeroplane Weather Minima*, states that the weather minima for visual contact flight operations at night are 1,200 ft cloud base and 5 km visibility for an instrument-rated pilot.

## 1.8 Aids to navigation

1.8.1 Pilot's equipment

The helicopter was fitted with a Navigation Management System that included GPS and conventional navigation aids, such as VOR and ILS systems, to assist the pilot with navigation. There was a Navigation Display (ND) on the pilot's instrument panel, situated below the Primary Flight Display (PFD), on which he could display the most appropriate source. A wind indication and the actual track were also displayed.

1.8.2 Police Observers' equipment

The helicopter was fitted with a Honeywell Skyforce Observer mission system, for use in the support of Police operations. This system incorporates a navigational aid that combines the GPS facility with a moving map. The rear seat Observer's station had the majority of the controls and displays for the mission system and role equipment fitted to the helicopter. The front seat Observer's station also had a mission system display.

Observers can enter defined points in the mission system's moving map display, to aid navigation to an address on the ground. This is usually done by the rear seat Observer. As the helicopter approaches a defined point, a 'proximity warning' will produce a visual and audio alert. The proximity warning is usually set to trigger at a range of 2 nm. If the location is selected when the helicopter is less than 2 nm, no warnings are given. The audio warning is a single beep, which is quieter than the helicopter generated warnings, and is audible to the pilot and both Observers. The visual alert is a red box that appears at the top middle of the mission display, with the words '*WPT 2NM'*. This will be displayed on the mission display of both Observers if the map display is selected at the time.

The function and accuracy of navigational aids was not considered a factor in this accident.

## 1.9 Communications

The pilot was in contact with ATC by VHF radio. These transmissions were recorded.

The helicopter was also equipped with Airwave. Airwave is the communications network used as the primary system for voice and data communications by the emergency services in the UK. The Airwave radios on board allowed the Police Observers to communicate with other police officers and police control rooms. All Airwave activity is recorded.

The helicopter had three Airwave communication terminals and each Police Observer had a personal issue Airwave handset. The helicopter terminals were configured to provide a periodic automatic message, to ensure the system tracked the helicopter's location. The personal handsets also generated periodic GPS based positional reports.

The pilot and Observers were able to receive ATC and Airwave transmissions and any audible warnings within the cockpit, including those related to low fuel.

The pilot and both Observers had their own set of radio controls. This allowed each of them to select/deselect ATC and/or Airwave channels and adjust the radio and internal cockpit volumes. It is usual for the pilot to monitor and transmit on the two available ATC channels, while the Observers operate up to three Airwave channels. In order to enhance their situational awareness, pilots may also monitor the Airwave channels and Observers may monitor both ATC channels.

## 1.10 Heliport information

At the time of the accident, Glasgow City Heliport (GCH) was located at Stobcross Quay, Glasgow, within the grounds of the Scottish Exhibition and Conference Centre, approximately 1.5 nm from the City Centre.

GCH was the operating base for the Police Scotland Air Support Unit and the Scottish Ambulance Service EC135 helicopters. The heliport was established to support 24-hour operations and had facilities, equipment and the staff to carry out maintenance and servicing activities. The ground facilities consisted of a maintenance hangar, and ground handling equipment and parking for five small to medium sized helicopters on a metalled hardstanding. There was also a 16,000 litre bulk fuel tank within the site. Four CCTV cameras covered various areas of the heliport.

Immediately after the accident, fuel samples were taken from the bulk fuel tank by the staff at the heliport and quarantined, before being taken into custody by the AAIB. A tool and equipment check was also carried out, under the supervision of the AAIB. All items were present and correct.

In May 2014, GCH moved to a new location at Linthouse Road, Govan, about 1.5 nm west of Stobcross Quay. All distances in this report, based on GCH, are measured from its location at the time of the accident.

The elevation of the heliport was 10 ft amsl.

## 1.11 Flight recorders

The helicopter was not required to have, and was not fitted with, flight recorders. Other sources of information were analysed to establish events associated with the accident flight. Non-Volatile Memory (NVM), from various items of equipment recovered from the helicopter wreckage, yielded records of system warnings and fault codes. External to the helicopter, recordings of CCTV, radar returns, ATC radio transmissions and police equipment usage were also examined. The radar recordings included accurate UTC time stamps[17], providing the best source of time for the flight. Other sources of data were aligned with those timings.

### 1.11.1 Radar

Radar recordings were obtained from the radar facilities at Lowther Hill, South Lanarkshire and Glasgow Airport. The accuracy of a recorded radar track is affected by a number of factors, some of which alter as an aircraft's location varies relative to a radar facility and surrounding terrain. The Glasgow Airport radar recordings were used for the start and end of the flight and the Lowther Hill data was used for the eastern portion of the flight. Both provided equally accurate altitude data, as this was provided by the helicopter's transponder, which was not affected by the helicopter's geographical location. The first and last recorded radar returns were timed at 2045:38 hrs and 2222:19 hrs respectively.

The radar track started as the helicopter was climbing through an altitude of 315 ft amsl, on departure from the heliport. The helicopter was not detected as it lifted off at GCH, due to the line-of-sight limitations of radar.

17 A time stamp is a record of the time at which a recorded sample or event occurred.

### 1.11.2 CCTV

The recordings from four CCTV cameras at GCH were analysed to establish the time the helicopter took off, so that the other sources of recorded data could be aligned. The cameras covered various operational areas of the heliport and captured an image every two seconds but not simultaneously. The images included time stamps but did not correlate with the time line of other sources of information.

There was no obvious overlap between the CCTV recordings and the radar. However, after the helicopter departed from the areas covered by the CCTV cameras, one captured the sweeping illumination of buildings on the opposite bank of the river, most likely caused by the helicopter's search light. This could only be achieved during a limited period at the start of the radar track. Allowing for errors in the correlation methods, the CCTV time stamps were between 12 minutes and 10 seconds and 12 minutes and 13 seconds slow. All CCTV reported times were corrected to UTC and it was calculated that the helicopter took off at approximately 2044:13 hrs.

CCTV recordings from other locations were also examined but none captured the period immediately preceding the accident.

### 1.11.3 ATC radio transmissions

ATC radio transmissions were recorded by Glasgow Airport ATC.

### 1.11.4 Avionics

Some of the helicopter's avionic systems recorded pertinent information in NVM. Recorded information included warnings to the crew and system fault codes, as well as general system timers. However, none of the recordings provided a continuous recording of helicopter parameters, nor were any time-stamped to a clock aligned to UTC. Some did not record any time-stamps.

The NVM content of the helicopter's avionic systems, which recorded configuration information, was checked against the expected build standard and no discrepancies were found.

#### 1.11.4.1 Central Panel Display System

The Central Panel Display System (CPDS) provides some of the instrument displays and caution messages for the pilot, using a Vehicle and Engine Monitoring Display (VEMD) and a Caution and Advisory Display (CAD). The units use the same flight timing and flight numbering system. A new flight number is generated as soon as the criteria to signal the end of the previous flight have been met.

1.11.4.1.1 Vehicle and Engine Monitoring Display

The VEMD has two independent processing channels, hosted on separate circuit boards with their own NVM. The NVM records include fault codes for the last 256 faults and flight summary reports for the last 32 flights.

None of the last 256 fault codes in the recovered NVM records related to the accident flight.

Flight summary reports include various cumulative operating times at the point the flight is deemed to have ended; namely, when the $N_1$ values of both engines are less than 50% and the main transmission gearbox oil pressure (XMSN OP) is less than 1 bar. The recorded parameters include a cumulative flight timer and two engine timers.

The flight timer starts increasing when the $N_1$ value of at least one engine is greater than 50%, the main gearbox oil pressure is greater than 1 bar and the collective pitch applied to the main rotor blades is greater than 28.5%. Tests on another helicopter of the same type showed that, whilst these criteria can be met without lifting into the air, in normal operation the flight timer is likely to be triggered when the helicopter lifts off the ground.

The engine timers start increasing as soon as the flight timer start criteria have been met and the relevant engine has an $N_1$ greater than 10%. This timer stops when the end of flight criteria ($N_1$s of both engines below 50% and the transmission oil pressure less than 1 bar) have been met or the engine $N_1$ drops below 10%, whichever occurs first.

The accident flight was recorded as flight 8959. The pertinent recorded parameters are given in Table 1.

| VEMD | Increase in flight time (hh:mm:ss) | Increase in the left engine operating time (hh:mm:ss.ss) | Increase in the right engine operating time (hh:mm:ss.ss) |
|---|---|---|---|
| 1 | 01:38:04 | 01:38:04.35 | 01:37:45.50 |
| 2 | 01:38:04 | 01:38:04.35 | 01:37:45.60 |

**Table 1**

VEMD timers

The right engine operating time was less than the flight time. Therefore, the engine $N_1$ had reduced to 10% 1 hour 37 minutes and 45 seconds after lift-off, slightly less than 19 seconds before the end-of-flight criteria had been met.

The left engine operating time matched the flight time (the difference of less than a second was likely to be associated with the software loops). This meant that at the point the flight time stop criteria were reached, the left engine $N_1$ was greater than the engine timer stop criteria of 10% and less than the 50% $N_1$ trigger for the end-of-flight timer. Therefore, 1 hour 38 minutes and 4 seconds after lift-off the left engine had an $N_1$ of between 50% and 10% and the main gearbox oil pressure was less than 1 bar.

A flight number of 8960 was also recorded, indicating that, during the accident flight, the logic used to signal the end of flight 8959 had been triggered before electrical power was lost. Flight 8960 had an operating time of 0.15 seconds recorded and 0.00 seconds recorded on the flight and engine times.

Also recorded on both VEMDs, against the flight summary for flight 8959, was a message which indicated the need to download the fault records from the Flight Control Display Modules (FCDMs). These are discussed later in this section.

If the CAD had failed during the accident flight, a fault relating to the communications between the CAD and VEMD would have been recorded in the VEMD NVM. No such fault was recorded.

#### 1.11.4.1.2 Caution and Advisory Display

The CAD records the last 256 logged failures and system configuration data.

None of the 256 logged faults were associated with the accident flight (8959). However, there was a fault code (FAIL code 20) associated with the subsequent flight report (8960). The fact that the fault was logged after the system status had transitioned from flight to ground indicated that it was not relevant to the sequence of events that led to the loss of engine power during the accident.

#### 1.11.4.2 Flight Control Display Module

The two FCDMs operate as separate symmetrical channels that provide the flight instrument displays with information. They independently record system faults into NVM. The faults recorded for the accident flight, flight number 8959, are given in Table 2.

| FCDM S/N | Fault source | Time (hh:mm:ss) | Specifics (milliseconds) |
|---|---|---|---|
| E0490 | VOR IO | 01:38:02.5 | Glide Slope not received for 273 ms |
| | RADALT IO | 01:38:03 | Height not received for 627 ms |
| E0897 | VOR IO | 01:38:02.5 | VOR Freq not received for 302 ms |
| | RADALT IO | 01:38:03 | Height not received for 681 ms |

**Table 2**

FCDM recorded faults for the accident flight

The VOR and RADALT systems are powered from the Avionic-Shed Bus 1 busbar which is automatically disconnected in the event of the loss of electrical power from both engine-driven generators. Power to the RADALT can be re-established by switching the SHED BUS switch, located at the rear of the overhead panel in the cockpit, from NORM to EMERG. This also restores power to the steerable landing light.

1.11.4.3 Warning Unit (WU)

The WU contains NVM which records a snapshot of the state of all visual and audible warnings when the status of one of them changes. The visual and audio elements of the same warning are treated separately. Therefore, if an audio attention-getter is acknowledged (and cancelled) by the pilot, a snapshot will be recorded with the remaining, uncancellable visual element (caption) shown as active. If a warning condition ceases, then both the audio (if still present) and visual elements will switch to the inactive state in a new snapshot. The NVM records the last 31 snapshots. There are no time-stamps recorded against the warning status changes.

The warnings recorded in the NVM for the accident flight, after the normal start-up sequence warnings had cleared, are shown in Table 3.

After the normal start-up sequence warnings had cleared, the next recorded snapshot showed that a LOW FUEL 1 warning (caption and audio) was triggered, relating to the level of fuel in the supply tank cell supplying the left engine. The audio attention-getter was acknowledged and then the caption cleared. The LOW FUEL 1 warning was triggered again, the audio attention-getter was acknowledged once more and the warning then cleared for the second time.

| Chronological order (no time stamps) | Warnings (x = active) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LOW FUEL 1 | | LOW FUEL 2 | | ROTOR RPM | | Alarm Gong 1 | | BAT DISCH | | AP ATRIM | |
| | Visual | Aural | Visual | Aural | Visual | Aural | Visual | Aural | Visual | Aural | Visual | Aural |
| Oldest after normal start sequence | x | x | | | | | | | | | | |
| | x | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | x | x | | | | | | | | | | |
| | x | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | x | x | | | | | | | | |
| | | | x | | | | | | | | | |
| | x | x | x | | | | | | | | | |
| | x | | x | | | | | | | | | |
| | | | x | | | | | | | | | |
| | x | x | x | | | | | | | | | |
| | x | | x | | | | | | | | | |
| | x | | x | | | | x | x | | | | |
| | x | | x | | | | | | | | | |
| | x | | x | | x | x | | | | | | |
| | x | | x | | | | | | | | | |
| | x | | x | | x | x | | | | | | |
| | x | | x | | | | | | | | | |
| | x | | x | | x | x | | | | | | |
| | x | | x | | x | x | | | x | x | | |
| Last recorded status | x | | x | | x | x | | | x | x | x | x |

**Table 3**

Warning Unit - warnings recorded in the NVM
(an empty row indicates a period without any warnings)

The next warning was LOW FUEL 2, relating to the level of fuel in the supply tank cell supplying the right engine. The audio attention-getter was acknowledged and the caption on the WU remained for the rest of the flight.

This was followed by another sequence of a LOW FUEL 1 warning, the audio attention-getter being acknowledged and the caption clearing. A further, final onset of this warning was followed by the audio attention-getter being acknowledged and the warning caption remaining for the rest of the flight.

An Alarm Gong 1 condition, related to the First Limit Indicator (FLI), was then recorded as active and then inactive. There are a number of causes of this warning condition, all but one of which would have triggered a change in the NVM of one of the other system downloads, which was not evident. The remaining condition is an engine limit warning, which occurs when one engine becomes inoperative, before the system has reset the trigger to the higher one engine inoperative limit.

The next recorded warning was ROTOR RPM signifying an $N_r$ of less than 97%. This warning cleared, returned, cleared again and then returned and remained active. The subsequent BAT DISCH warning indicated that the battery was providing electrical power. The final warning was related to the autopilot.

1.11.4.4 Full Authority Digital Engine Control units

The engines are controlled via two Full Authority Digital Engine Control units (FADECs), one per engine. They control engine start-up, fuel supply and engine health monitoring. Detected events are recorded to NVM, with a time-stamp that relates to when the FADEC was switched on. The FADECs were serviceable when tested at the manufacturer's facility, where they were also downloaded. The results were analysed by the engine manufacturer and the following is an extract from their report:

> *'The right FADEC recorded that 1 hour 42 minutes and 21 seconds after the right FADEC was powered, a 'P3 drift or engine flame-out' message was recorded, indicating a flameout. This was triggered by an inconsistency between the fuel flow limitation datum and the fuel flow anti-surge law. The recorded engine parameters at the moment of this event included a Max $N_1$ of 76.37%. There was no indication of a problem with the engine itself.*
>
> *The left FADEC recorded entering a higher power one-engine-inoperative (OEI) regime 1 hour 42 minutes and 22 seconds after power was applied to the left FADEC. The FADECs do not record transitions from two-engine to lower power OEI operations but will record when the onside engine enters a higher power OEI regime. Typically this will occur shortly after loss of power from one engine as the remaining engine takes up the load. A 'P3 drift or engine flameout' event was recorded with a time stamp of 1 hour 42 minutes and 54 seconds. There was no indication of a problem with the engine itself.'*

Throughout these records, the engine switches were recorded in the FLIGHT position.

Electrical power is normally applied to the two FADECs in quick succession, as part of the helicopter start-up procedure. Engine starts occur later. If power was applied to the FADECs at the same time, the recorded flameout events were 32 seconds apart.

1.11.5 Role equipment

The installed police systems could record camera images and audio, as required by the Police Observer. The recording was not routinely left running and the helicopter was not on task at the time of the accident.

The helicopter was equipped with a Forward Looking Infra-red (FLIR) camera system which was controllable in azimuth and elevation and had the capability to record the images displayed on the system operator's monitor. A recording of the FLIR camera was recovered. The embedded date stamp was 29 November 2013 and the time stamp started at 2143:33 hrs, ending at 2144:40 hrs. This enabled analysis of the helicopter's manoeuvres whilst it was on task at Dalkeith. The image recording commenced with the lens on a high magnification setting. This was changed to the Wide Field Of View (WFOV) low magnification setting for the last 19 seconds.

A study was carried out using the recorded images, a detailed map of the area and Google Earth images of the area to establish the track of the helicopter over the ground. The track was estimated to be elliptical in shape, starting 400 m from the central location, increasing to 500 m and then reducing to 200 m. The arc of coverage of the recording was approximately 270° of the circumference. The circumference distance and time travelled meant that the groundspeed was calculated to be between 30 kt and 50 kt.

The system is also capable of creating a GPS track log but the default setting is that this is not enabled. No track logs were recorded.

### 1.11.6 Fuel consumption

The helicopter manufacturer provided fuel consumption calculations, using the flight path, as depicted by the recorded radar data, and commonly used airspeeds for the relevant parts of the flight. It was calculated that 329 kg of fuel would have been used during the flight, leaving 71 kg (89 litres) of fuel remaining (based on the helicopter departing GCH with 400 kg of fuel),

It was concluded that the transfer of fuel from the main tank to the supply tank stopped while the helicopter was returning to Glasgow from Dalkeith, leaving only the fuel in the supply tank available to the engines. It was estimated that this occurred during the latter stage of the cruise at 3,000 ft, during the descent to 2,000 ft or in the early stage of the cruise at 2,000 ft. The exact time this occurred could not be determined, as it was affected by the accuracy of the fuel burn modelling and the capacity of the supply tank. The supply tank capacity is affected by the pitch attitude of the helicopter because fuel can spill from the supply tank back into the main tank, via the connecting overflow channels. Also, the pitch attitude of a helicopter is dynamic, constantly varying, whereas the modelling of the pitch attitude during the flight was based on low sample rate radar data which relied on assumptions, with associated margins for error.

The LOW FUEL warnings were calculated to have been activated as the helicopter approached Bothwell. These warnings were also sensitive to the pitch attitude of the helicopter and the calculations were, again, subject to the limitations of modelling. The location of the warning sensors in the supply tank are such that the transition to a nose-up pitch attitude can initiate the onset of the LOW FUEL warnings, if they have not been triggered already.

## 1.11.7 Time line

The amalgamated recorded data, with times, is shown in Figures 7 and 8.

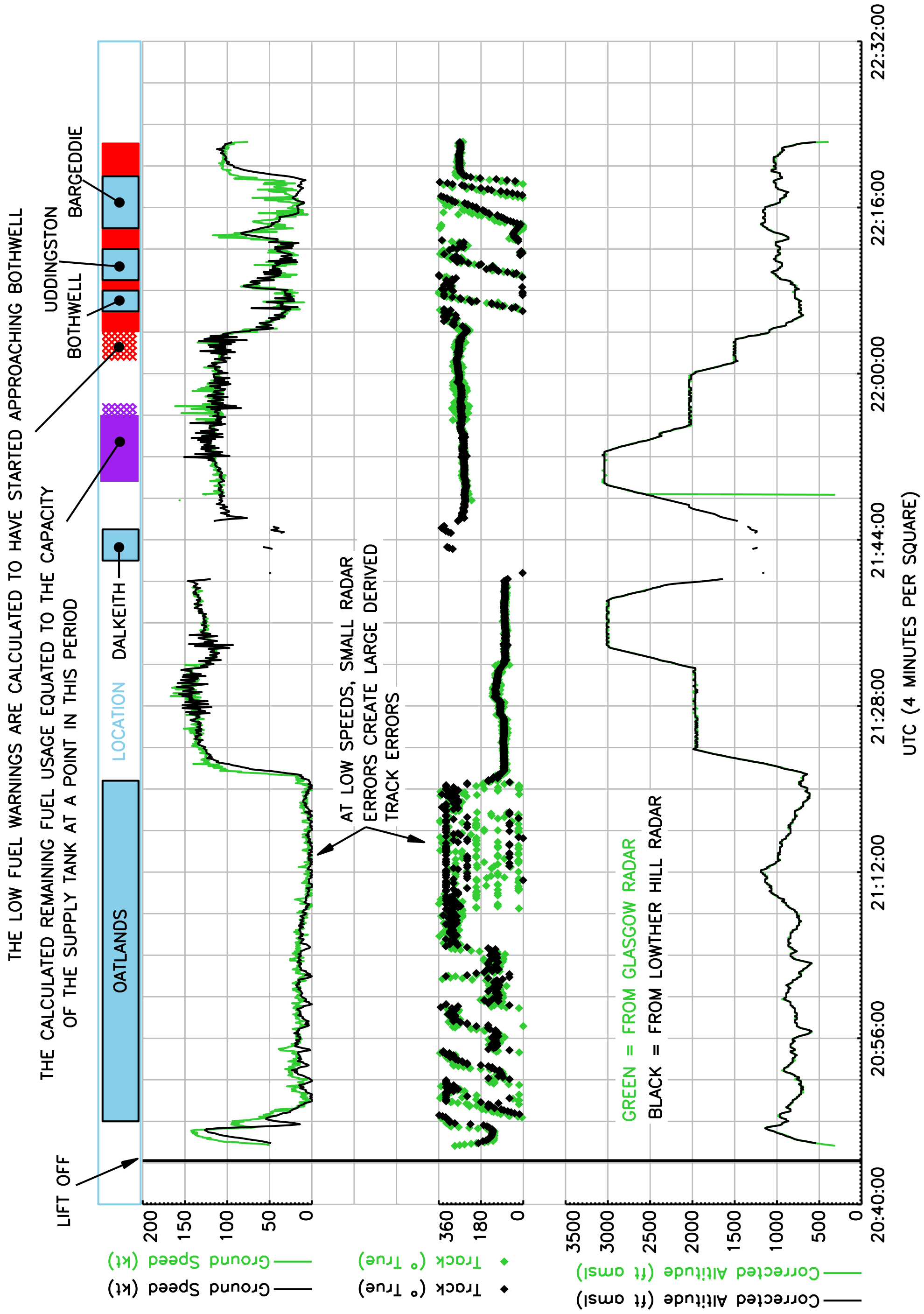



**Figure 7**

Derived speed and track information, with calculated fuel contents

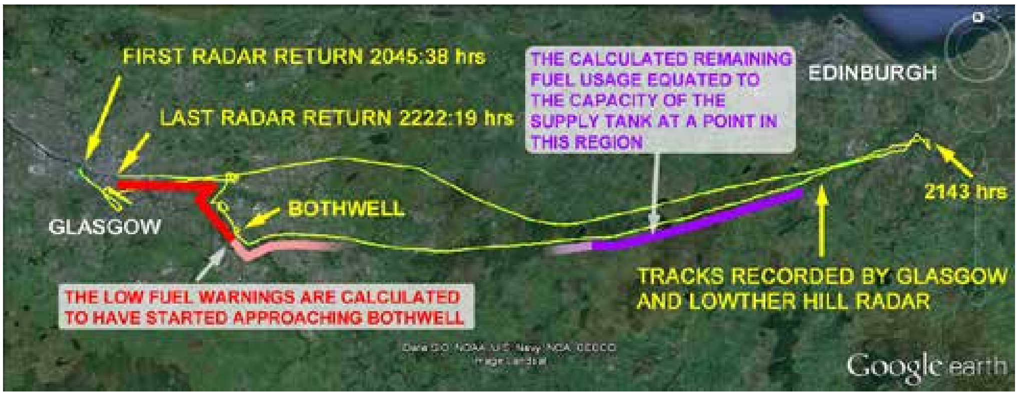



**Figure 8**

Helicopter's track, with calculated fuel contents

The majority of the NVM data relates to the sequence of events at the end of the flight (see Figure 9). UTC referenced time-stamps were not available, so a series of time correlations were used to correct the timings of the events. The time ranges for the events reflect the limitations of the accuracy of these methods.

The flight path at the end of the flight, derived from radar recordings, is shown in Figure 10.

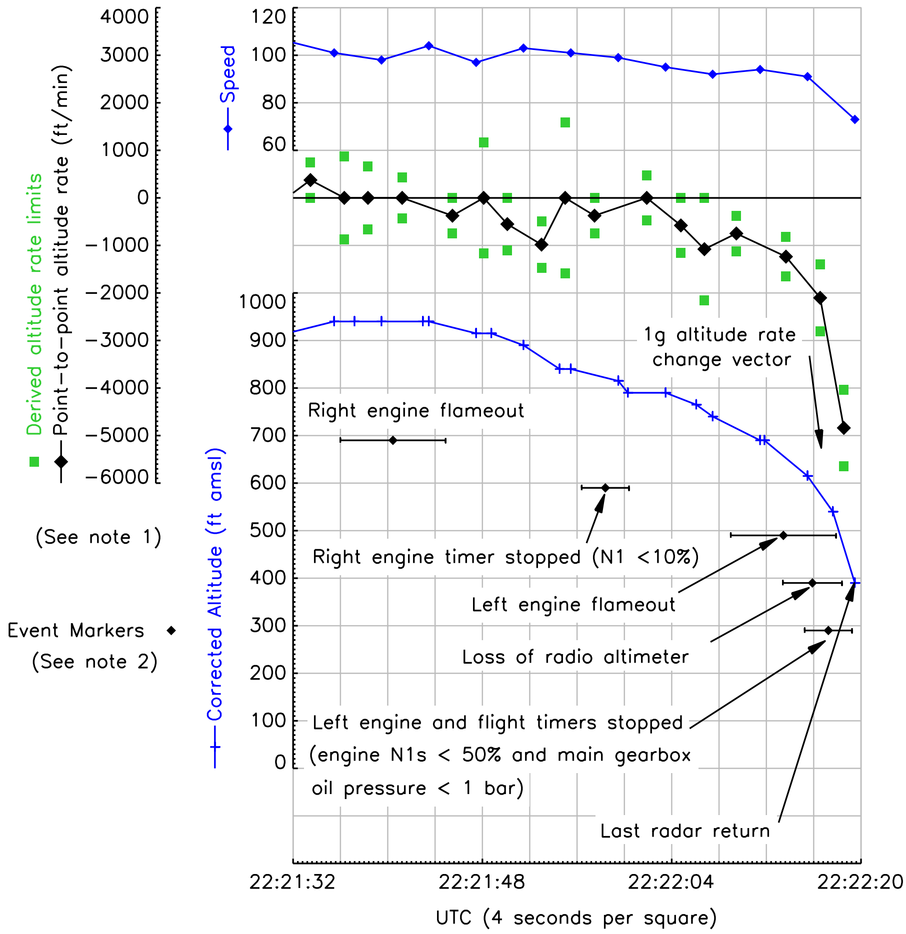
1.11.8 Flight recorders in aircraft

1.11.8.1 Current requirements

Many helicopter operations in the UK, including Helicopter Emergency Medical Services (HEMS), are regulated by EASA. However, State aircraft, which Civil Air Publication (CAP) 393, *Air Navigation: The Order and the Regulations,* Section 1*, The Air Navigation Order (ANO) 2009* (the ANO) defines as '*aircraft engaged in military, customs, police or similar services* [including Search and Rescue]', are subject to national regulation. In the UK, the requirements for State aircraft are primarily defined in the ANO and are subject to CAA amendment and/or exemption.

The ANO 2009, Part 4, *Equipment of aircraft*, Article 37(2) and Schedule 4, paragraph 4(16)(c)(i), requires carriage of flight recorders, as specified at paragraph 5, Scale SS(1) or SS(3), and is applicable to public transport helicopters which have *'… a maximum total weight authorised of more than 2730kg but not more than 7000kg or with a maximum approved passenger seating configuration of more than 9 or both.'* It specifies the following:

> *'(1) A four channel cockpit voice recorder capable of recording and retaining the data recorded during at least the last 30 minutes of its operation and a flight data recorder capable of recording and retaining the data recorded during at least the last eight hours of*




NOTES:
1. Derived altitude rate data uses combined Lowther Hill and Glasgow radar data. Calculations from radar returns less than one second apart were removed for clarity.
2. Event marker bars show the period in which the event occurred and reflects uncertainty in the precise time.

**Figure 9**

Radar data and related events at the end of the flight

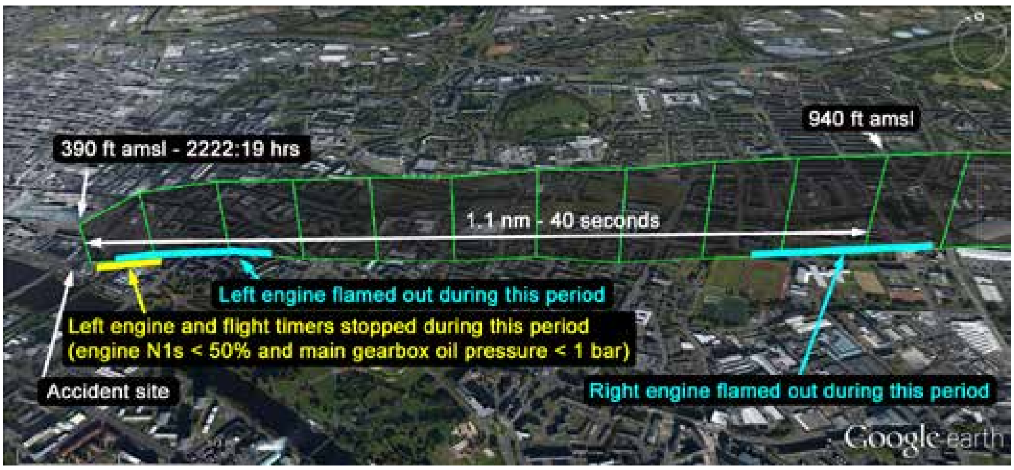



**Figure 10**

Flight path at the end of the flight

> *its operation being the data required to determine by reference to a time scale the following matters accurately in respect of the helicopter or gyroplane—*
>
> *(a) flight path;*
>
> *(b) speed;*
>
> *(c) attitude;*
>
> *(d) engine power;*
>
> *(e) main rotor speed;*
>
> *(f) outside air temperature;*
>
> *(g) position of pilot's primary flight controls;*
>
> *(h) use of VHF transmitters;*
>
> *(i) use of automatic flight controls (if any);*
>
> *(j) use of stability augmentation system (if any);*
>
> *(k) cockpit warnings relating to the master warning system; and*
>
> *(l) selection of hydraulic system and cockpit warnings of failure of essential hydraulic systems.'*

This requirement is not provisional on the date of the first Certificate of Airworthiness (C of A).

The requirement in the ANO is at variance with Joint Aviation Requirements (JAR) JAR–OPS 3, *Commercial Air Transportation (Helicopters)*, and the Standards and Recommended Practices in ICAO Annex 6, *Operation of Aircraft, Part III, International Operations — Helicopters*, in which the lower maximum total weight authorised limit is 3,175 kg and older aircraft are exempt. Recognising this, the CAA issued two General Exemptions: *Official Record Series* (ORS) 4 988 (also referred to as E 3680) and ORS 4 989 (also referred to as E 3681), to align the ANO requirements with JAR-OPS 3 and ICAO Annex 6 Part III, pending amendment to the ANO. These exemptions were in force at the time of the accident.

ORS 4 988 introduced an exemption for helicopters, with a first individual C of A on or before 31 July 1999, to carry FDRs, in accordance with Schedule 4 Scale SS(1) or SS(3), provided that the helicopter is equipped with a CVR. However, due to the inclusion of a specific clause, this exemption is not applicable to a '*flight operated under and in accordance with a Police Air Operators Certificate* [PAOC]'. ORS 4 989 increased the lower maximum total weight authorised limit, for this FDR requirement, from 2,730 kg to 3,175 kg, in line with the ICAO and JAR-OPS 3 requirements.

The police helicopter involved in this accident had a maximum approved gross mass of 2,910 kg. So, under both ORS 4 988 and ORS 4 989, it was not required to carry flight recorders. Exemptions ORS 4 988 and ORS 4 989 expired on 27 October 2014. They have since been amalgamated into ORS 4 1047 (General Exemption E 3875), without changing the requirements.

In summary, the helicopter was not required to be fitted with any type of flight recorder.

1.11.8.2 Previous AAIB investigations involving police aircraft

The AAIB records show eight previous investigations involving police aircraft. Two of these involved fixed-wing aircraft and the rest were helicopters (see Table 4). None of these aircraft were fitted with flight recorders.

| REGISTRATION | DATE | TYPE |
|---|---|---|
| G-BSWR | 13 July 2011 | BN2T Islander (fixed wing) |
| G-SEWP | 28 October 2010 | AS355F2 |
| G-SPAU | 17 February 2002 | EC135T1 |
| G-DPPH | 25 December 2001 | A109E |
| G-SAEW | 21 April 2000 | AS355F2 |
| G-EMAU | 9 October 1998 | AS355N |
| G-EYEI | 24 January 1990 | Bell 206B II |
| G-KATY | 15 May 1985 | Edgley EA7 Optica (fixed wing) |

**Table 4**

AAIB investigations involving police aircraft

At the time of writing there were 32 helicopters and two fixed-wing aircraft operating under UK PAOCs.

1.11.8.3 Previous AAIB Safety Recommendations

There have been three AAIB helicopter investigations (aircraft that were not operating in support of police operations) that have resulted in flight recorder related Safety Recommendations.

G-MASK – 26 July 1998 – AS355F1

The report on this fatal air-ambulance helicopter accident made the following Safety Recommendation:

**Safety Recommendation 2000-1**

It is recommended that the CAA should:

(a) Encourage the development of a suitable lightweight and low-cost Voice, Data and Combined recorder and the installation of such equipment by operators.

(b) Consider whether such flight recorders should be introduced for operations such as dedicated police and HEMS operations involving as they do, the exposure of third parties to risk not present in normal Public Transport operations.

The CAA responded:

*'The CAA accepts this Recommendation. The CAA will encourage the development of a suitable lightweight and low-cost Voice, Data and Combined recorder and the installation of such equipment by operators. In addition, the CAA will consider whether such flight recorders should be introduced for operations such as dedicated police and HEMS operations.*

*Target date – December 2000.*

*CAA Action*

*(a) The CAA has encouraged flight recorder manufacturers to begin the development and production of suitable lightweight and low cost Voice, Data and Combined recorders for the types of small helicopters currently engaged in police and Helicopter Emergency Medical Service (HEMS) operations.*

*(b) The CAA has considered requiring helicopters engaged in police and HEMS operations to be equipped with a flight recorder. However, with no suitable lightweight and low cost recorder currently being available this cannot be mandated at this time. If and when suitable lightweight and low cost flight recorders become available, the CAA will reassess the flight recorder requirements. Consideration will be given to mandating the requirement for helicopters engaged in police and HEMS operations to be equipped with a flight recorder.'*

G-CSPJ – 19 July 2003 – Hughes 369HS

This was a fatal accident during a private flight. The report documented the benefits of flight recorder evidence when investigating helicopter accidents and the issues associated with fitting flight recorders to smaller helicopters. It made the following Safety Recommendations:

**Safety Recommendation 2004-84**

The Department for Transport should urge the International Civil Aviation Organisation (ICAO) to promote the safety benefits of fitting, as a minimum, cockpit voice recording equipment to all aircraft operating with a Certificate of Airworthiness in the Commercial Air Transport category, regardless of weight or age.

**Safety Recommendation 2004-85**

The Department for Transport should urge the International Civil Aviation Organisation (ICAO) to promote research into the design and development of inexpensive, lightweight, airborne flight data and voice recording equipment.

G-BXLI – 22 January 2005 – Bell 206B Jet Ranger III

This was also a fatal accident during a private flight. The report referenced the above G-CSPJ Safety Recommendations and a further investigation relating to a fixed wing investigation. Subsequent to the G-CSPJ investigation, EASA became the pertinent regulatory authority, so the above Safety Recommendations were addressed to EASA as follows:

**Safety Recommendation 2005-100**

The European Aviation Safety Agency should promote research into the design and development of inexpensive, lightweight, airborne flight data and voice recording equipment.

**Safety Recommendation 2005-101**

The European Aviation Safety Agency should promote the safety benefits of fitting, as a minimum, cockpit voice recording equipment to all aircraft operated for the purpose of commercial air transport, regardless of weight or age.

1.11.8.4 Flight recorder technology

Historically, the costs associated with recorder requirements have been based on standard flight recorders and older avionic technologies. However, lightweight recorder specifications have been developed (EUROCAE document ED-155 '*MINIMUM OPERATIONAL PERFORMANCE SPECIFICATION FOR LIGHTWEIGHT FLIGHT RECORDING SYSTEMS*') to reduce the costs of installations. Modern avionics, with data buses, also offer greater opportunity to interface with aircraft systems than older analogue systems.

The helicopter manufacturer of G-SPAO offers a flight recorder installation as a customer option. The manufacturer has also begun to fit an image/audio/data recorder, as standard, to some of its range of helicopters, albeit without meeting crash-protection requirements. Other helicopter manufacturers also offer such options.

1.11.8.5 ICAO Standards and Recommended Practices

The relevant ICAO Standards and Recommended Practices, relating to flight recorders for helicopters of the type involved in this accident, reference two EUROCAE standards. FDR and Airborne Image Recorder (AIR) requirements are defined in EUROCAE ED-112A, *Minimum Operational Performance Specifications for Crash Protected Airborne Recorder Systems*, and Aircraft Data Recording System (ADRS) requirements are defined in EUROCAE ED-155, *Minimum Operational Performance Specifications for Lightweight Flight Recorder Systems*.

ICAO Annex 6, Part III, paragraph 4.3.1.2.4 states:

> *'All turbine-engined helicopters of a maximum certificated take-off mass of over 2250 kg, up to and including 3180 kg for which the application for type certification was submitted to a Contracting State on or after 1 January 2018 shall be equipped with:*
>
> *a) a Type IVA FDR* [A Type IVA FDR shall record the parameters required to determine accurately the helicopter flight path, speed, attitude, engine power, operation and configuration]*; or*
>
> *b) a Class C AIR capable of recording flight path and speed parameters displayed to the pilot(s); or*
>
> *c) an ADRS capable of recording the essential parameters defined in Table A5-3 of Appendix 5.'*

The essential parameters referenced in Table A5-3 of Appendix 5 are: heading, pitch and roll attitude, yaw rate, pitch rate, roll rate, positioning system latitude/longitude, estimated position error, altitude, time, ground speed, track, normal acceleration, longitudinal acceleration and lateral acceleration. Recommended parameters are also defined in the table.

There are no ICAO Standards or Recommended practices for CVRs on helicopters with a maximum total authorised weight mass below 3,180 kg.

1.11.8.5 EASA regulations

EASA regulations do not require a helicopter type with the maximum total authorised weight of the EC135 to be fitted with a flight recorder capability. However, with reference to the above ICAO Standards, and Safety Recommendations from several European States, EASA is reviewing the need to extend flight recorder requirements to lighter aircraft under Rule Making Task (RMT) 0271&0272. EASA RMT.0271 encompasses helicopters of the weight category of the EC135.

The terms of reference of RMT.0271&0272 include:

> *'…the need for in-flight recording will be assessed for categories of aircraft and types of operation covered by the air operations rules (current and under adoption) and for which there is no flight recorder carriage requirement. In particular:*
>
> > *— aeroplanes and helicopters of a model not eligible for carrying a flight recorder according to Regulation (EU) No 965/2012 on Air Operations, and subject to ICAO provisions on in-flight recording or subject to safety recommendations related to inflight recording…'*

EASA are also reviewing *'Recorders installation and maintenance thereof - certification aspects'* under RMT.0249; this includes powering CVRs and their respective cockpit area microphones. Recorder Independent Power Supplies (RIPS) have been developed and are in use to provide an additional 10 minutes of power to flight recorders when normal electrical power is lost. A RIPS is applicable to audio and image recording only, as it is not practical to power all the source systems required for data recording for 10 minutes after the loss of normal power.

## 1.12 Wreckage and impact information

### 1.12.1 The accident site

The helicopter descended into the middle of the bar area of the Clutha Vaults Bar, towards the left side of the building. The roof above this area consisted of upper and lower wooden roof and ceiling beams, creating a void. Plywood boards and roofing felt formed the roof. This structure was supported on load bearing brick and mortar walls. A rigid steel joist (RSJ) reinforced the roof within the void and was supported by two brick pillars and positioned approximately across the middle of the left bar area, parallel to the front wall of the building.

The roof collapsed downwards, as the helicopter penetrated the structure, and numerous beam and roof boards were disrupted. This created a pile of debris on which the helicopter came to rest. The RSJ, which was slightly offset from the point of impact, was displaced from its supporting pillars. The disruption and roof collapse created large amounts of brick, mortar and plaster debris which covered everything in a very thick layer of dust.

The right side of the bar area, apart from the dust and small splinters and fragments, remained intact.

The extent of the damage rendered the building unsafe and liable to further roof collapse, if disturbed. To ensure the safety of all concerned, substantial shoring was carried out, before the victims and helicopter could be removed. The shoring included additional support for the bar floor, in the cellar beneath, to take the weight of the helicopter, debris and rescue teams. This time-consuming activity required specialist teams and equipment, and was carried out, in consultation with AAIB personnel, so as not to disturb or destroy any of the material evidence.

All the fatalities on the ground and the majority of injuries were sustained by those in the immediate vicinity of the roof collapse, in the left bar area.

The elevation of the roof of the Clutha Vaults Bar was approximately 20 ft amsl.

### 1.12.2 The helicopter

The disruption to the airframe was consistent with the helicopter having struck and penetrated the flat roof of a single story building, with no forward speed but a high rate of descent.

The impact caused substantial crushing damage of the cabin structure, whilst the tail-boom structure fractured forward of the Fenestron, causing the latter to rest on the roof of the building. The cabin section came to rest at an approximately 45° nose-down attitude but remained upright within the collapsed building structure.

On examination, the main rotor and the Fenestron tail rotor exhibited no evidence of rotation at impact. Similarly, the fractured high-speed Fenestron drive shaft had suffered a pure bending failure, whilst not rotating.

Extraction of building debris from the region of the helicopter's instrument panel enabled access to be gained to the engine control panel. The engine control panel switches for the FADECs were found set to ON and the ENG I and ENG II switches were guarded in the FLIGHT position.

There was significant displacement of the cockpit overhead switch panel which appeared to have been driven downwards on to the upper surface of the instrument panel coaming. Photographs taken by the first responders appeared to show at least one of the prime pump switches in the OFF position. When examined by the AAIB after the accident site had been stabilised, both the No 1 and No 2 prime pump switches were found to be in the ON position. In addition, both the fuel transfer pump switches (XFER F and A) were found in the OFF position. The cockpit three-position DAY/NIGHT/NVG lighting switch on the overhead panel was found in the NVG position and the SHED BUS switch was found in the NORM position. Following progressive removal of building debris and shoring up of the remaining timber and masonry structure, the helicopter was ultimately freed and lifted from the wrecked building, preserving the angle of fore and aft inclination at which it had come to rest.

Fuel was then extracted from the fuel tanks via the supply tank drain points and the forward drain of the main tank. The main tank produced approximately 95 litres (76 kg), whilst approximately 0.5 litres (0.4 kg) was extracted from the No 1 supply tank drain. No measureable amount was recovered from the No 2 supply tank drain.

The helicopter wreckage was recovered to the AAIB's facilities in Farnborough, Hampshire, where a full examination was carried out.

### 1.12.3 The fuselage and landing gear

An examination of the helicopter structure found the landing skid cross beams to have bent outwards and upwards. The main lift frames had crushed downwards and impinged on the rear seat headrest frames, causing severe damage to the seats and injury to the seat occupant. All the seats had stroked fully downwards and imparted loads into the seat mounting rails, causing severe distortion of the cabin floor. As a result of this crushing and distortion it is estimated that the cabin volume had decreased, during the impact process, by at least 50%.

Evidence based on the radar data, eyewitness reports and the helicopter structure indicated that it struck the roof of the building with a high rate of descent. The remains of the building roof and debris on which the helicopter was resting, showed that the helicopter was brought to a stop over a very short distance. Calculations suggested deceleration force in excess of 70g.

1.12.4 Fuel system examination

An examination of the helicopter fuel system components was carried out, with items being removed as required. Despite extensive damage to the aircraft structure, the majority of components were removed using the normal techniques and processes detailed in the Aircraft Maintenance Manual (AMM). The flexible tank system was left in situ and the four pump and sensor equipment plates were removed to enable a visual examination of the internal components of the fuel tank system. Examination revealed significant deformation and flexure of the structure supporting and locating the tanks but no tank rupture had taken place. No contaminants were found.

The whole of the fuel transfer system was found to be intact and unblocked, and the two fuel transfer pumps in the main tank and the supply tank prime pumps ran correctly when powered electrically and tested.

The airframe fuel shut-off valves were found set in the OPEN position, the position for normal flight operation.

1.12.4.1 Fuel tank contents sensors

The concentric tubes of all four fuel level sensor units were found to have failed structurally in a manner consistent with axial loading at impact, as designed, and had not punctured the tank skin during the accident.

An example of each of the two sensor types, the longer type used in the main tank and the shorter type used in the supply tank, was supplied by the manufacturer. The concentric tubes of these two new sensors were then deliberately fractured, exploiting the slot feature of the design. The lower sections of the deliberately fractured sample sensors were then each tested electrically in a special calibration tank. This was filled to a series of different fuel depths. The corresponding impact fractured sensors from G-SPAO were then subjected to the same test. They produced similar output frequencies to those produced by the appropriate sample sensors when the test tank was filled to the same series of fuel levels.

The sensors from G-SPAO had very small amounts of fine debris trapped within the tubes. This debris was analysed and found to consist mainly of silica-based particles, consistent in size and distribution with those commonly found in aircraft fuel tanks. Testing of the damaged sensors showed that all four functioned in a manner which indicated they were capable of operating correctly before the accident. Also, there was no evidence of pre-impact defects in the wiring and gauging system.

The undamaged low fuel warning thermistors on the damaged sensors from the supply tanks were tested and were also found to work correctly.

1.12.4.2 Other fuel system components

The non-return valves incorporated in the pump delivery outlets, although in one case damaged, functioned correctly. A detailed examination and test programme was carried out on the pump power supply and tank contents indication system wiring within the wrecked structure. This revealed that the damage or failure that was found was consistent with the effects of the impact, salvage or further dismantling of the aircraft. All the relevant circuit breakers in both the fuel contents indication system and the pump power supply systems were correctly set when first viewed at the accident site and remained so, and demonstrated correct continuity during the wiring tests.

1.12.5 Engines and transmission

Rotation by hand of the No 2 engine power turbine caused both the main rotor head and the fractured Fenestron shaft to rotate. The same result could not be achieved with the No 1 engine power turbine because impact damage and structural distortion had caused disengagement of the drive from the No 1 turbine shaft to the main rotor gearbox. The absence of mechanical damage on the material surface where the drive shaft disengaged was consistent with no rotation at impact. However, hand rotation of the No 1 engine input shaft (to the gearbox) resulted in corresponding rotation of the main rotor head and Fenestron shaft. Also, rotation of the turbine caused the output drive flange, on the engine side of the drive line separation, to rotate.

On disengagement of the connecting flanges between the hydraulic pumps and the main rotor gearbox, it was confirmed that the pump drives within the gearbox rotated normally when the rotor head was turned.

The engines were strip-examined at the manufacturer's facility under the direct supervision of the AAIB. Neither engine showed any evidence of pre-accident damage, fault or failure. There was a small amount of damage to various peripheral components on the engines all of which was attributable to the impact during the accident.

The No 1 engine centrifugal compressor had a series of parallel curved rub marks on its outer casing. These were consistent with slight deformation of the engine structure during the impact and the outer casing coming into contact with the compressor impeller, whilst it was rotating at extremely low speed. This rub was momentary, produced fine metal burrs and indicated that the impeller had low energy and was brought to a stop at that point.

Similarly, there were marks on the No 2 engine compressor casing surface. These showed that the compressor impeller was rotating even more slowly than the No 1 engine impeller when the impact occurred. Clearly defined marks had been left in the casing, indicating 10 to 15° of compressor rotation prior to it stopping.

The condition of the rotating components within the gas generator (compressor and turbines) of each engine confirmed that there was no power output at the point of impact.

Examination of the ancillary high load and high energy components within each engine showed them to be in an undamaged condition. It was also noted that there was nothing to indicate overspeed or over-torque on either of the free power turbines, their shafts or reduction gear trains.

### 1.12.6 Fuel metering units

The No 1 engine LP and HP fuel pump assembly and metering unit was found to have partially fuel-filled galleries and was able to self-bleed on the test bench. During a functional test, it performed correctly in all respects, producing fuel control pressures and flow outputs within acceptable tolerances, in accordance with the factory test protocols.

The No 2 engine LP and HP fuel pump assembly and metering unit was found to be completely dry of fuel, consistent with the empty No 2 supply tank, so was unable to self-bleed. The metering unit was manually bled and a full functional test was carried out. The metering unit was found to be functional in all respects and produced tolerances within those set out in the factory test protocol.

Both the gallery fuel valves were bench-tested. This confirmed that the engine stop valves were fully open. These valves receive an electrical signal to shut off the fuel to the engine, when selected by the pilot via the engine switches.

### 1.12.7 Main rotor head and main rotor blade examination

The remains of the main rotor blades were removed from the aircraft under AAIB supervision. It was noted that all the blades were correctly fitted, locked and bonded. The yellow[18], blue and green blades were original fit, and the red blade had been replaced on 11 November 2013 due to rotor imbalance. The four corresponding pitch change rods were also examined and found to be undamaged and correctly assembled and locked. The overall length of each pitch change rod was measured and assessed against the reference measurement of the datum (yellow) rod. All the rod measurements were found to be within the acceptable range.

It was noted that all the elastomeric dampers had small areas of dis-bond between the elastomeric material and metallic discs, as well as the spherical bearing rod, indicating a degree of overload.

It was also found that all four main rotor blade cuffs had varying degrees of chafe and contact marks on their internal surfaces, where they appeared to have contacted the flexbeams violently. The marks were measured and recorded on a CATIA[19] drawing, using the end face of the blade cuff as the datum. This produced an accurate map of the damage. The maps were compared with data held by the manufacturer and showed that this set of main rotor blades experienced an extreme version of a phenomenon known as lead-lag resonance.

Lead-lag resonance is known to occur with the design of main rotor head and blades fitted to the EC135. It occurs when the $N_r$ is either increasing or decaying through the range of 60% to 70% $N_r$. The blades violently advance and retard in the horizontal plane, at high frequency, forcing the flexbeam to bend. The range of movement and the frequency of the resonance is outside the control capabilities of the elastomeric drag damper. In extreme cases, permanent damage is inflicted on the inside faces of the blade cuffs as they are brought into contact with the flexbeams, in a hammering action.

It is possible for lead-lag resonance to occur during start-up or shut-down, and is caused when a cyclic or collective control input is made. To the outside observer it manifests itself as a violent movement of the blades out of the plane of rotation, coupled with a very distinctive cracking sound, caused by the composite material fracturing. This is avoided by leaving the collective lever fully depressed and the cyclic stick centralised until normal operating rpm is reached.

In this case, the evidence showed that very severe lead-lag resonance had occurred, at an extreme coning angle, indicating that the helicopter was airborne with a high degree of collective pitch applied and that the $N_r$ was less than the 75% minimum for rotor rpm recovery.

18 The EC135 main rotor blades and their associated pitch change rods are identified using bands of coloured tape.

19 CATIA - Computer Aided Three-dimensional Interactive Application. This is a software system which enables the highly accurate creation of 2D and 3D designs and drawings of components and assemblies.

### 1.12.8 Flying controls

The helicopter was configured for single pilot operations, with a single set of cyclic, collective and yaw pedal controls at the front right seat. Examination of the mechanical parts of the flying control system revealed that all operating rods and levers were intact and correctly connected, other than where obvious impact damage was evident. Similarly, all connections between the outputs of the electro-hydraulic rams and the main rotor head remained intact.

The electro-hydraulic flying control servos were removed from the aircraft and put through a comprehensive series of factory tests on the manufacturer's test benches. All the components were found to operate within factory test parameters, with some minor shortcomings. These shortcomings were all attributable to the damage to external components caused in the accident.

### 1.12.9 Hydraulic pumps and reservoirs

The No 1 and No 2 hydraulic pumps were examined and tested on the manufacturer's test bench, in accordance with the factory test procedures. The No 1 pump was undamaged and in good condition. The No 2 pump mounting flange was damaged, with two of the four bolt lugs fractured and the internal sealing plate ruptured. This damage was attributable to the impact during the accident. During test, both pumps operated correctly without leakage and produced outputs within acceptable tolerances.

The No 1 and No 2 hydraulic reservoirs were both intact and contained hydraulic fluid which was in good condition, uncontaminated and to the correct specification.

### 1.12.10 Cabin heating and ventilation

The EC135 is fitted with cabin heating and ventilation system which uses hot air bled from the engines, mixed with outside air, to create a comfortable cabin environment and demisting for the windscreen. The system automatically maintains the selected settings. In G-SPAO the system was set to norm with the bleed heating set to off and the ventilation blower was set to a mid-range position on the control rheostat. Air conditioning was not installed.

## 1.13 Medical and pathological information

Two forensic pathologists, assisted by a consultant aviation pathologist from the Royal Air Force Centre of Aviation Medicine, carried out the post-mortem examinations on those fatally injured in the helicopter.

The pilot's and Police Observers' post-mortem examinations identified injuries that suggest they were exposed to a peak deceleration in excess of 100g. The injuries were also consistent with the helicopter having crashed in an approximately upright orientation, with a high rate of descent and little forward speed. The examinations concluded that they suffered fatal injuries as a result of the helicopter crash. Toxicological examination showed no evidence of alcohol or drugs.

## 1.14 Fire

Despite the presence of damaged mains electrical equipment, dust and flammable materials in the bar, and the severe disruption to the helicopter, there was no post-impact fire.

## 1.15 Crashworthiness

The accident was not survivable, as the pilot and Police Observers were exposed to forces outside the tolerances of the human body.

### 1.15.1 EC135 crashworthiness

The EC135 family of helicopters was certified in 1996 and exceeds the original JAR 27.561 and current Certification Standard (CS) 27.561 crashworthiness design regulations. The main lift frames were designed to carry the loads of the heavy mass items (ie the gearbox and engines) installed above and behind the cabin. The regulatory downward load factor is currently 12g and the EC135 has a load factor of 20g. The energy absorption is provided by twin skid landing gear and the depth of the subfloor structure. The fuel tank system, contained within the subfloor structure, is designed to deform with the subfloor in an impact and retain fuel-tight integrity.

G-SPAO was fitted with seat frames which were designed to stroke downwards during impact, to absorb and reduce the deceleration on the occupants to a safe level, up to a maximum of 14g. The cabin floor and seat mounting frame attachments were designed to withstand downward load factors up to 20g.

## 1.16 Tests and research

### 1.16.1 Fuel

Fuel samples from the aircraft and bulk storage associated with the aircraft were tested and found to be of the correct specification and free of contamination.

### 1.16.2 EC135 T2+, G-NWEM

On 11 December 2013, another EC135 T2+, G-NWEM, one of the operator's EMS fleet, landed at City Airport, Manchester, on completion of a task. Its pilot reported that the helicopter appeared to be displaying contradictory fuel indications and low fuel warnings. The operator withdrew the aircraft from service and the AAIB began enquiries into the incident because of the line of investigation into the fuel and related systems within G-SPAO and the possible implications for the EC135 fleet.

A ground run was carried out, starting with the fuel system indicating 47 kg and 43 kg of fuel in the left and right supply tank cells, respectively, and 41 kg in the main tank. During the ground run the main fuel tank contents were seen (by reference to the fuel gauge on the CAD) to deplete, with the forward and aft fuel transfer pumps OFF. When the main tank contents had depleted to approximately 20 kg, the LOW FUEL 1 and then the LOW FUEL 2 warnings illuminated on the Warning Unit, with an indicated 47 kg and 43 kg still in the supply tank cells. At no stage did the FUEL caution illuminate. See Figure 11.


**Figure 11**

G-NWEM fuel indications during ground run

The manufacturer removed and tested the fuel sensor units under the supervision of the AAIB. The test results indicated abnormalities within the sensor unit outputs, which appeared to be the cause of the false tank contents indication.

All four of the sensor units (forward and aft main tank sensors and left and right supply tank sensors) were taken to the AAIB's premises for further testing. This was carried out approximately 48 hours after the incident. Prior to testing, the sensors were examined and found to be dry of fuel but contained tiny amounts of fine debris between and at the bottom of the concentric tubes of the sensor units. This debris was left in place during the tests. During the initial tests, all the sensor units produced readings within the factory set tolerances and could be considered serviceable. The fuel sensor abnormalities seemed to have cleared over the intervening 48-hour period.

A small amount of water, 0.5 ml, was then introduced into the fuel and sensor within the test vessel. It was observed that a water globule immediately attached itself to the sensor concentric tubes, travelled to the bottom and lodged in the interconnecting balance hole between the tubes. Fuel level output testing was carried out with the water in place and resulted in the sensor producing a full fuel signal, regardless of fuel quantity, even when the test vessel was empty of fuel. This demonstrated that sensor output corruption was possible when water was introduced, albeit in an artificial environment.

Based on the evidence from G-NWEM and the test results, the manufacturer issued Alert Service Bulletins (ASB) EC135-28A-018 and EC135-28A-019 on 19 December 2013 (see Appendices D and E). These ASBs instructed operators to carry out a check of the fuel indication system and drew their attention to possible erroneous indications in the fuel contents system, for which there was an amendment to the Flight Manual.

Analysis of the results, in response to ASB EC135-28A-018, found that 6.6% of all test probes failed with an over-reading of at least 1 kg and that 2% showed an over-reading greater than 3 kg. The operator reported that 14 of the 22 EC135 helicopters in their EMS fleet failed the test and only 1 out of 16 EC135 helicopters which support police operations failed the test. The operator's EMS fleet were under a cold compressor wash regime at the time.

### 1.16.3 EC135 fuel system simulation and testing

To investigate the EC135 fuel system behaviour in more detail, the manufacturer constructed a test rig on a fully articulated platform. The test rig was fitted with tank indication and fuel transfer systems, as well as prime pumps in the supply tank. External pumps, representing the engines, delivered fuel from the supply tank to a separate storage tank. These pumps had a delivery capability which could be adjusted to match the fuel consumption of each engine. The main and supply tanks were modified to include fuel-tight, clear viewing panels at the top of the tanks. A test regime was developed to establish how the fuel tank, pump, indication and warning systems worked at various aircraft attitudes. A second set of tests was also carried out using fuel which had been deliberately contaminated with water, compressor washing fluid and anti-ice fluid.

The first set of tests confirmed that the EC135 fuel system is able to display fuel contents accurately, when the helicopter is operated in accordance with its Flight Manual and flown within and beyond its certified envelope. The tests also demonstrated that the fuel system was able to perform correctly during the type of flying carried out to achieve the Police tasking on the night of the accident.

The second set of tests introduced pure water and a water/compressor washing fluid mix to the fuel. The pure water contamination was based on the experience of G-NWEM and the effect of water on the sensor found during the experiments at the AAIB. The introduction of the water/compressor washing fluid mix was based on reports from the operator that they had found hitherto unexplained compressor washing fluid in minute quantities within the fuel systems of their EC135s. In addition, for completeness, testing was carried out with anti-ice fluid contaminated fuel. The water and additive contamination used the same, highest 5:1, proportions allowable in the EC135 compressor wash procedure. During the testing, the fuel was contaminated in varying degrees up to a maximum of 0.1%.

The results showed that free water globules had no influence on the fuel contents indication system. It was noted that the water congregated at the bottom of the fuel tanks and tended to migrate towards the metallic surfaces of the various components in the tanks. It was also observed that these globules were unaffected by the general flow and movement of fuel in the tanks. However, if the water or mixed water/additive mix was emulsified[20] in the fuel, the results were different.

Emulsification tended to occur when fuel and free contaminants passed through the fuel pumps and were agitated by the pump impellor. This could be seen as the pumped fuel emerged from the submerged transfer pipe outlets as a milky stream. This stream gradually caused the main, larger volume of the fuel, into which it had entered, to become opaque. If the fuel was left in this state, with the test rig dormant and stationary for approximately two hours, the contaminants precipitated out and the fuel cleared.

[20] Emulsion - An apparently dissolved suspension of one fluid within another. In this case manifesting itself as ‘milky wisps’ exiting pipe outlets and leading to a general ‘cloudiness’ within the bulk of the fuel.

Testing concluded that when fuel contamination, from whichever source, formed an emulsion, it caused fuel sensor output frequency drift. This manifested itself as the CAD fuel contents display over-reading, for the main and supply tanks.

The emulsification within the fuel dissipated over time as the water precipitated back into droplets or globules. These also accumulated on or around the metallic surfaces, such as the pump and sensor mounting plates, at the bottom of the fuel tanks. In addition, globules formed, over time, within the concentric tubes of the fuel contents sensors and became trapped. The accumulation of trapped globules affected the dielectric characteristic of the fuel, in a similar way to the emulsification, causing a constant frequency drift. An over-reading, therefore, remained even though the fuel appeared to be clear.

The operator reported that water and compressor washing fluid was entering the fuel tanks of their EC135 fleet under a cold compressor washing routine and this appeared to be happening at random. Furthermore, it seemed to occur a few flying hours after the compressor wash. Using the test rig, it was found that a water and fuel mix, which accumulated in the ventilation system expansion tank, could find its way back into the fuel tanks, due to helicopter pitch and roll movements. However, for this to occur, there needed to be approximately 800 ml of water-contaminated fuel in the expansion tank, enough to cause the water globules at the bottom of the fuel mix to overflow the small lips created in the base of the tank by the ventilation line pipe unions. This explained the in-service experience, that the phenomenon occurred randomly and could not be predicted.

**Figure 12**

EC135 Articulated Fuel System Test Rig

While fuel system contamination was considered to be due to the cold compressor washing routines applied to some of the EC135 fleet, other possible sources of water contamination were also identified. These included:

- Atmospheric condensation within bulk fuel storage systems or within the aircraft fuel tanks themselves, when only partially full, and
- Gravity refuelling operations carried out during inclement weather, such as rain, hail or snow.

1.16.4 Engine rundown simulation

Helicopter manufacturer EC135 simulations indicated that an engine would run down to an $N_1$ of 10% in 19±1.5 secs after shutting off fuel to it in flight, while the other engine continued to operate.

Simulation of a double engine failure at 40 kt indicated that, with full collective pitch applied and maintained, the $N_r$ would reduce to the range conducive to main rotor blade cuff cracking (60% to 70% $N_r$) within two to three seconds. 50% $N_r$ would be reached after approximately 4.5 seconds.

1.16.5 Main transmission gear box oil pressure decay

The oil pressure for the main transmission gear box is generated via the main gear box and is relative to $N_r$. Tests on an EC135 indicated that, during a normal shutdown, the transmission oil pressure reduced to 1 bar as the $N_r$ reduced through 37%.

1.16.6 Helicopter pitch attitude modelling

The fuel capacity of the supply tank and the amounts of fuel in the tanks that would trigger cautions and warnings, or allow the transfer pumps to run dry, are all dependant on the pitch attitude of the helicopter.

The pitch attitude of the helicopter was modelled using a generic engineering model of an EC135 and the radar data. However, the limitations of the radar data meant that it did not reflect the dynamic behaviour of the helicopter. Trial flights undertaken on helicopters that were representative of the accident flight, and G-SPAO's configuration, showed that the nose-down pitch attitudes adopted during parts of the accident flight profile were probably larger than the generic EC135 modelling indicated. This meant that the times when pumps may have run dry or the low fuel warnings may have been triggered were narrowed down to periods of time, rather than calculated precisely (see Figure 8, page 37).

### 1.16.7 Warning unit testing

Testing of the warning unit at the manufacturer's facility showed that all the indicator lamps operated correctly, using both the bright and dimmed settings. Initially, the unit drew more current than normal and did not generate the required audio attention-getters associated with the visual warnings. After a few minutes of testing, one of the tantalum capacitors, connected across the power supply of the audio amplifier, partially disintegrated. Subsequently, the current used by the unit returned to normal and the audio attention-getters operated correctly.

Only one other failure of this capacitor was known to the unit manufacturer. The warning unit was analysed by an independent electronics testing facility to assess the capacitor failure and establish whether the fault condition was likely to have existed prior to the impact.

It was reported that tantalum capacitor resilience to surge current damage is significantly reduced by mechanical stress. It is likely that this mechanism initiated the failure in the component. This led to a reduced resistance across its contacts, drawing more current during the testing. The larger current resulted in a build-up of heat that ultimately resulted in the further failure of the component which created an open circuit.

The balance of probability linked the onset of the failure with a current surge during the accident impact. It was acknowledged that mechanical stress alone may have been sufficient to initiate the component failure sequence.

It was also observed that the capacitor did not have the voltage rating recommended by the manufacturer for the purpose for which it was being used.

### 1.16.8 Flight and static trials

#### 1.16.8.1 Flight trials

Two flights were undertaken in an EC135 helicopter, similarly equipped to G-SPAO, using the evidence provided by the recorded radar data from the accident flight and a short FLIR image recording taken during G-SPAO's surveillance task at Dalkeith.

Using the recorded FLIR images (see paragraph 1.11.5), a detailed map of the area and Google Earth images of the area, an approximation of the helicopter's track over the ground at Dalkeith was established. The track was estimated to be elliptical in shape, and the arc of coverage of the recording was approximately 270° of its circumference. From the circumferential distance and time travelled, the groundspeed was calculated to be between 30 kt and 50 kt.

Two test points were identified, to establish the indicated fuel quantity in the main tank at which the F PUMP FWD or F PUMP AFT caution messages could illuminate on the CAD, at speeds similar to those on the accident flight, initiating the requirement for the transfer pumps to be switched OFF.

The two flight trials were carried out using an aircraft with a zero fuel weight of 2,407.8 kg and a C of G which was 4,231 mm aft of the datum. This compared with the accident aircraft, which had a zero fuel weight of 2,427.67 kg, and a C of G which was 4,279 mm aft of datum, for the same amount of fuel. The aircraft used in the trial had Pratt & Whitney engines and also a lower drag coefficient, as it was fitted with less external role equipment.

One test point replicated the orbit at Dalkeith, as much as possible. The orbit was flown at 30 kt, with an indicated nose-up attitude of 5-7°, in level flight. The fuel on board at the start of this test consisted of 47 kg and 43 kg in the left and right supply tank cells respectively, with 97 kg in the main tank. After four minutes, the indicated fuel in the left and right supply tank cells remained the same and the amount in the main tank had reduced to 82 kg. The F PUMP FWD caution caption did not illuminate.

The next test point replicated, as near as possible, G-SPAO's radar profile from completion of the task at Dalkeith to the commencement of the task at Bothwell, starting with a similar amount of fuel. Maximum Continuous Power (MCP) was used throughout the profile. During this trial, the F PUMP AFT caution caption illuminated while flying level with indicated fuel levels of 63 kg in the main tank, and 39 kg and 34 kg in the left and right supply tank cells respectively – a total of 136 kg.

The aircraft was also flown at MCP with an indicated nose-down pitch attitude of 6.6°. The helicopter achieved a maximum IAS of 128 KIAS, with a rate of descent of 300 ft/min.

For another test point, the aircraft was flown in an orbit to the right, at approximately 30 KIAS, with an indicated nose-up pitch attitude of about 7.5° and both fuel transfer pumps selected OFF. With no 'virtual fuel' above the supply tank cells, the helicopter was flown out of balance, with 20° angle of bank and insufficient right yaw pedal, such that the slip ball was one ball's width to the right. This caused fuel to move from the left cell to the right cell in the supply tank, reducing the 4 kg design difference between the two cells. This demonstrated that it was possible for the two cells to have similar amounts of fuel, reducing the time difference between flame outs, should fuel starvation occur.

In addition, at fixed speeds of 20, 30 and 40 KIAS, in straight and level flight, the helicopter's indicated nose up attitude was recorded as being 8°, 7.5° and 5° respectively.

Also, in straight and level flight, with a 5° nose-down pitch attitude, at 120 KIAS and a nearly full supply tank, with the fuel transfer pumps OFF, fuel indications showed that the quantity in the main tank increased as the amount in the supply tank cells decreased, ie fuel spilled from the supply tank into the main tank. In one minute, the indications showed that 12 kg moved from the supply tank to the main tank.

1.16.8.2 Static trials

Further trials with a static aircraft measured how much fuel will flow from a full supply tank to the main tank, at various aircraft pitch attitudes, without constant replenishment by the fuel transfer pumps. The supply tank was filled with fuel, level with the bottom of the overflow channels, and the aircraft was progressively tilted to 5° nose-down.

A total of 36 kg of fuel (indicated) flowed from the supply tanks into the main tank. With the fuel transfer pumps OFF, the quantity in the supply tank cells could be reduced by an amount which equated to 11 minutes of engine running time, based on 3.3 kg per min fuel consumption.

1.16.9 Manufacturer's flight trials

The manufacturer also carried out a flight trial using an EC135 with a zero fuel weight of 2,423 kg and a C of G 4,264 mm aft of datum. This compared with the accident aircraft, which had a zero fuel weight of 2,427.67 kg and a C of G 4,279 mm aft of datum. The trial aircraft had Pratt & Whitney engines and a comparable drag coefficient, as it was fitted with similar external role equipment.

The first test point flown was a right-hand orbit, at 40 KIAS and a radius of about 300 m, to establish whether the F PUMP FWD caution caption could have illuminated during the task at Dalkeith. The test was commenced with 47 kg and 43 kg in the left and right supply tank cells respectively, and 111 kg in the main tank – a total of 201 kg. During this test, the helicopter's pitch attitude varied between +1° and +5° nose-up and the angle of bank between 4° and 10°. The F PUMP FWD caution message illuminated after 15 min; this was longer than the 4 minutes that G-SPAO was on task at Dalkeith. The total fuel quantity indicated was 166 kg. The manufacturer concluded that, given the likely conditions and length of time G-SPAO was at Dalkeith, it was probable that the F PUMP FWD caution message did not illuminate.

The second test point involved flying the aircraft straight and level, with approximately 3° nose-down pitch, at about 120 KIAS. The test was commenced with 47 and 43 kg in the left and right supply tanks, respectively, and 67 kg in the main tank. The aim was to establish whether the F PUMP AFT caution message could have illuminated whilst G-SPAO was transiting from Dalkeith to Bothwell. The F PUMP AFT caution message illuminated after 10 mins, with 41 kg indicated in the main tank. This equated to a fuel consumption of 26 kg, at a rate of 2.6 kg/min. However, a consumption rate of 3.2 kg/min was measured, which should have resulted in 35 kg remaining in the main tank. The additional 6 kg was considered to be due to fuel spilling back from the supply tanks, into the main tank, through the overflow channels.

The manufacturer concluded that, on the basis of this part of the trial, the F PUMP AFT caution message would not have illuminated in the area where it was estimated that both transfer pumps were switched OFF during the accident flight.

The third test point was flown with MCP set on the collective control, with an indicated attitude of 6° nose-down. This was to confirm whether, in this configuration, the helicopter would exceed $V_{NE}$. During the test, an average rate of descent of 350 ft/min and an average TAS of 139 kt were recorded.

## 1.17 Organisational and management information

### 1.17.1 General

The operator provides helicopters and pilots in support of Police and Air Ambulance operations in the UK, with a fleet of more than 26 aircraft operating from 22 bases. They have a fleet of 23 EC135s. Two EC135s were based at GCH to support Police Scotland and the Scottish Ambulance Service.

The operator is a Type Rating Training Organization (TRTO) and provides EC135 type rating conversion courses.

The operator is authorised to carry out helicopter flying and continued airworthiness under a National Air Operators Certificate (NAOC) number 2153 Issue 13, dated 21 November 2011. NAOC 2153, Issue 15, includes authorisation to operate Eurocopter BO105 and EC135 helicopters and is dated 22 May 2012. The helicopter was being operated on behalf of Police Scotland and was authorised under Police Air Operator’s Certificate (PAOC) number 035/2, dated 1 August 2002.

1.17.2 Procedures

1.17.2.1 Police air operations

UK Police aircraft operate under a PAOC and are regulated by the CAA.

Civil Aviation Publication (CAP) 612, *Police Air Operations Manual* (PAOM) *Part 1*, sets out joint CAA/Home Office policy for the conduct of police air operations. Applicants for a PAOC are required to produce a PAOM Part 2, to include information relevant to that operator.

1.17.2.2 Police Observers

In the PAOM, Part 1, Section 1*, Administration,* Chapter 4*, Flight Crew and Police Observer Responsibilities,* it states:

> *'5 Duties of the Police Observer*
>
> *5.1 When a police observer is carried he may, when satisfactorily trained in accordance with Part D (which may be amplified in the PAOM Part 2), be authorised by the aircraft commander to operate such aircraft systems and equipment as are necessary for the successful completion of the police task. The systems and equipment that the police observer may operate shall be specified in the PAOM Part 2.'*

Accordingly, the operator's PAOM Part 2 states:

> *'2.4.2 DUTIES OF THE POLICE OBSERVER*
>
> *A police observer who has successfully completed the prescribed training and testing may act as cockpit assistant in order to decrease pilot workload, although it should be noted that the aircraft captain remains responsible for monitoring the functions of the police observer. As cockpit assistant, the police observer may select RT and navaid frequencies on request, but he may not carry out vital actions such as arming Floats or the CAT A/High Nr button on the EC135. However, he may read out a checklist.*
>
> *The police observer may, in response to a briefing and request by the captain, undertake any of the following duties:*
>
> *1. Monitor or adjust nominated items of equipment*
>
> *2. Read out checklists…'*

Additionally, the *Police Air Observer Training Course* states,

> *'The Air Observer may be asked to look up a particular emergency drill and check the pilot's response or action to particular items. It is therefore important that you are familiar with the layout and terminology.'*

Front seat observers do not operate helicopter related system switches, unless in an emergency situation and at the request of the pilot, eg when the pilot is flying the helicopter and cannot take his hands off the flying controls.

The primary duties of the front seat observer are the operation of the FLIR Television/IR camera, to assist the pilot and rear seat observer with navigation, using visual references and maps, and to assist the pilot as and when directed.

The primary duties of the rear seat observer are the navigation to and from each task, utilising police role equipment and navigational aids, and Police radio communications.

The front seat observer normally assumes 'operational command' of the tasking of the aircraft. However, when two experienced observers fly together, the more experienced observer will normally assume operational command in relation to the tasking of the helicopter.

Given that both observers were experienced it is likely that they would alternate operational command. However, it is not known who had operational command on the accident flight.

1.17.2.3 Radio Altimeters

Referring to the requirement for a radio altimeter in police helicopters, the PAOM Part 1, Section 2*, Flight Planning,* Chapter 12*, Altimeter Testing and Setting Procedures,* states:

> *'5 Radio Altimeter (RADALT) – Helicopters*
>
> *5.1 An analogue RADALT, fitted with visual and audio warnings, is recommended for all flights but* ***shall be installed for night flying*** [AAIB bold] *and any flight involving three or more minutes' flight time over water.'*

The RADALT's audio warning is audible to the pilot and the Observers.

RADALTs are also required to be fitted for other types of commercial air transport helicopter operations regulated by the EASA.

1.17.2.4 Fuel policy

The fuel policy for the police helicopter operations, on which G-SPAO was engaged, is included in PAOM, Part 1 and the operator's PAOM Part 2 and Operations Manuals. Extracts from these manuals are included in Appendix F to this report.

1.17.2.4.1 Safety action

On 20 December 2013, the operator issued an amendment to its Operations Manual, Part A, '*8.1.7.3 Fuel Calculations*'. This replaced the Minimum Land on Allowance (MLA) with Final Reserve Fuel (FRF), and increased the VFR and IFR/night FRFs to 90 kg and the unusable fuel to 8 kg. It stated:

> *'An Emergency condition can be considered to exist if the Commander believes that the helicopter will land below Final Reserve Fuel (FRF).*
>
> *8.1.7.3 Fuel Calculations*
>
> *When calculating remaining endurance the following formula is to be used*
>
> $$\frac{\textit{Total fuel} - \textit{FRF}}{\textit{Fuel consumption}} = \textit{Endurance}$$
>
> *For normal operations the following nominal figures are to be used*
>
> | | |
> |---|---|
> | *Final Reserve Fuel IFR/ Night / navigating by means other than by reference to visual landmarks (30 minutes)* | *90 kg* |
> | *Unusable fuel (Not indicated)'* | *8 kg* |

These figures were also incorporated in their Operations Manual, Part B, which provides information on the helicopter type and related operational procedures.

The operator also issued the following Safety Notice to all its pilots on the same date:

> *'As a result of [the incident involving G-NWEM]… we have conducted detailed examinations and tests on our fleet of EC135s. These tests were to evaluate the function and accuracy of the fuel indicator system on the supply tanks. As a result of these tests it was deemed necessary to replace the sender units from the supply tanks on a number of our aircraft.*
>
> *Until such a time as we have an approved maintenance program in place to perform functional checks of these units we have deemed it necessary to maintain a **Final Reserve Fuel (FRF) 90Kgs.** When completing fuel calculations as per Reference B [Operations Manual Part A 8.1.7.3], please use 90kgs as the FRF for all flights (VFR & IFR) until further notice.'*

This Safety Notice remains extant and a reminder Safety Notice reiterating its contents was issued by the operator on 15 February 2015.

1.17.2.5 Emergency landing and ditching

The operator's Operations Manual EC135 Part B/3, Section 2, *Emergency Procedures,* includes guidance and procedures for a total loss of engine power. Extracts relating to a total loss of power from the engines are included in Appendix E to this report.

1.17.2.6 Manufacturer's flight reference cards

The manufacturer's flight reference cards for the aircraft type include pilot checklists for emergency and malfunction procedures. Those that were relevant to the circumstances of this accident are included at Appendix A to this report.

1.17.2.6.1 Safety action

On 19 December 2013 the manufacturer issued Alert Service Bulletin EC135-28A-019 (see Appendix E). This ASB introduced a temporary revision of the Flight Manual, to cover a possible incorrect fuel level indication of the supply tanks.

The ASB amended the LOW FUEL checklist by adding the following to the end of the action items:

> *'WARNING THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION'*

1.17.3 Pilot training

1.17.3.1 Introduction

The requirements for pilot (flight crew) training for police helicopter operations are provided in the PAOM, Part 1, Part D, *Training.* It states:

> *'1.1* ***General***
>
> *1.1.1 This section is issued in compliance with JAR-FCL 2* [Flight Crew Licensing (Helicopter)].*'*

Further, in Appendix A, Operator Proficiency Check, it states:

> *'1.6 The requirements of JAR-FCL must be completed every 12 months and may be combined with the OPC* [Operator Proficiency Check][21]*.*
>
> *1.8 Periods of Validity*
>
> *1.8.1 Operator Proficiency Check*
>
> *1.8.1.1 The period of validity of an OPC shall be six calendar months in addition to the remainder of the month of issue….*
>
> *1.8.1.2 An OPC conducted at night shall qualify a pilot for day and night, and pilots of multi-engine helicopters shall complete a night section at alternate OPCs.'*

In addition, JAR-FCL 2 states:

> *'JAR–FCL 2.245 Type ratings – Validity, revalidation and renewal*
>
> *(a) Type ratings, helicopter – Validity. Type ratings* [Licence Proficiency Check (LPC)[22]] *for helicopters are valid for one year from the date of issue, or the date of expiry if revalidated within the validity period.'*

The operator stated that an OPC is conducted every 6 months in both the simulator and the aircraft, and a combined LPC and OPC is conducted annually in the simulator only.

An OPC assessment is completed in two parts. One part is flown in the aircraft, for about 20 mins, and full use of the automatics is permitted. This is flown

21 An OPC is a requirement for pilots flying commercial air transport operations. During the OPC the pilot is required to demonstrate competence in normal and emergency procedures.
22 A LPC is an annual proficiency check that is required in order to maintain a rating on a pilot's licence.

under VFR, normally in the visual circuit. The second part is flown in the simulator and is a mix of instrument flying (IF), where full use of the automatics is permitted, and visual night flying. About one hour is IF and 1 hour is visual flying.

A joint OPC/LPC is a manually flown assessment in the simulator.

These two training sessions are flown 6 months apart, in a yearly cycle.

1.17.3.2 Autorotation

The requirement for pilots to be able to carry out an autorotation is specified in PAOM Part 1, Part D, *Training*. It states:

> *'Appendix A. Operator Proficiency Check*
>
> ***2 Schedule***
>
> *.....*
> *8 Autorotation and power recovery to a designated area* (rotary)*
> *Periodicity for Police Operations 6 months*
>
> *NOTE**:** Items marked * may be completed in IMC or simulated IMC.'*

Autorotations are flown annually on the aircraft during OPCs, to a powered recovery, and 6 monthly in the simulator, to the ground.

The operator instructs pilots that, if time is available, once an autorotation has been entered and the $N_r$ is stable, the SHED BUS switch should be selected to EMERG, a MAYDAY call should be made and, then, the engines shutdown, as stated in the EC135's '*Pilot's Checklist - Emergency And Malfunction Procedures'*. Switching the SHED BUS switch to EMERG provides power to the steerable landing light and the RADALT, when the generators are off-line. The operator's training notes state that it can be difficult to locate the SHED BUS switch in an emergency, and pilots are instructed to become familiar with the position of the switch within the cockpit.

The operator commented that during recurrent training most autorotations are commenced from between 1,000 and 2,000 ft agl, as this is the height at which most operations are flown.

The EC135's normal rate of descent in a stabilised autorotation, at 75 kt, is approximately 2,000 ft/min.

#### 1.17.3.3 Fuel system

The pilot was instructed on the technicalities of the EC135's fuel system during the ground school component of his initial conversion to the EC135, in 2008, including the requirement to land within 10 minutes of being presented with a LOW FUEL warning.

JAR–FCL 2.240 provides the requirements for helicopter type ratings. Appendix 3 to JAR–FCL 2.240, lists the contents of the LPC and OPC for multi-engine single-pilot helicopters. Section 3 lists the normal and abnormal operations that can be tested during a test or check. It states that '*A mandatory minimum of 3 items shall be selected from this section*.' The fuel system is one of the systems listed, to be tested at least once every 18 months.

The operator commented that it was unusual for their examiners to test a low fuel scenario that would result in a LOW FUEL warning illuminating. This was because most OPCs and LPCs were based around handling the helicopter at high weights (high fuel quantities), so that a pilot's handling of a heavy helicopter, with one-engine-inoperative (OEI), could be assessed. It was deemed unrealistic for a scenario to change over a short period of time to a low fuel quantity. Also, it was rare for pilots to get a LOW FUEL warning. A fuel leak was covered by the operator's examiners.

During the investigation, attention was drawn to the EC135 System Description Section (SDS) of the AMM. This publication was part of a series produced by the helicopter manufacturer to inform engineers and technicians about the systems' features within the EC135.

Chapter 28-10-00 2, under the title *'Fuel Tanks with Equipment Plates'* (page 1, paragraph B), gives information on the reason for the difference in volume between the supply tank cells (described earlier in this report). It explains that it allows for unintentional non-activation of both fuel transfer pumps, leading to flameout of both engines as the supply tank cells run dry. The difference in volume allows time for a pilot to set the fuel transfer pumps to ON. It states that the time between the right (No 2) and left (No 1) engine flameouts will be 3 - 4 minutes.

## 1.18 Additional information

### 1.18.1 Police helicopter tasking

Tasks allocated to Police Scotland's Air Support Unit (ASU) are categorised as either 'routine' or 'non-routine.' Non-routine tasks are allocated, generally at short notice, by the police force control room. The first task that G-SPAO undertook at Oatlands was a non-routine task.

A list of routine task requests is kept in a folder in the police operations room at GCH and on the helicopter. Crews can either plan ahead or, if they are airborne and have time, they can cover any that are in the area, depending on location and weather. They manage all their own requests, so would not normally leave a note of their intentions at GCH. After landing, they log each individual task completed.

During tasks at a specific location, the helicopter is normally positioned in a low speed orbit to allow the FLIR camera best access to the location of interest. The helicopter may be flown out of balance, during certain stages of the orbit, to provide the camera with its best view of the location. The pilot's priority remains the safety of the helicopter and the crew. During a task, the pilot's attention will be split between monitoring the flight instruments and checking the helicopter's flight path relative to the location of interest.

When conducting a task using thermal imaging, each Police Observer in the crew has a specific role. The front seat observer's (FSO) role involves operating the FLIR camera, while the rear seat observer (RSO) navigates the aircraft to the location.

For each task, the RSO enters the location in the Honeywell Skyforce Observer mission system. He then tells the pilot the bearing and distance to that location, as provided by the mission system.

En route, the RSO updates the pilot on the aircraft's position, the distance to the location and any obstacles or airspace restrictions, such as Control Zones. As the location is approached, the pilot adjusts the helicopter's height and speed, in preparation for the task.

The RSO refers to a more detailed map, either on the mission system or an earlier prepared printout carried in the tasking folder, to identify the specific location of interest. The RSO then directs the pilot to the location, using visual references on the ground. Since the FSO sits in the front left seat, the location will not be visible to them when it is positioned on the right of the aircraft, ie when the helicopter is orbiting to the right. The FSO acquires the location with the FLIR camera, guided by instructions from the RSO, as necessary.

1.18.2 Previous events

1.18.2.1 Autorotations

The manufacturer was aware of one other event involving an EC135 that resulted in an autorotation.

The Hungarian Transportation Safety Bureau reported on an accident involving an EC135 T2, registration HA-ECE, which occurred on 31 July 2008.

HA-ECE, was flying as an air ambulance when it suffered a double engine failure and entered autorotation; it was destroyed after a heavy landing. The investigation determined that the loss of the right engine was probably caused by a technical malfunction and that the left engine was most likely inadvertently shut down. The report commented that the pilot should have been able to perform a successful autorotation. The significant descent rate and the hard touchdown indicated that the autorotation was initiated with delay, the cause of which was unknown. Of the five people on board, two, including the pilot, suffered fatal injuries.

1.18.2.2 Fuel pump switching errors

The manufacturer provided a list of nine previous occurrences, between 1981 and 2014, involving twin-engine helicopters it had manufactured, where a contributory factor was the incorrect selection of fuel pump switches, leading to fuel starvation. Five of the nine occurrences involved the BO105 and the other four involved the BK117. Seven of the nine occurrences involved both fuel transfer pumps switches being in the OFF position, with five of those being attributed to the transfer pumps not being selected ON before takeoff. One of the other two events was attributed to an inoperative low fuel warning light and the remaining one to the cockpit lighting being dimmed for night flying during a day flight. This led to the annunciator light not being visible when illuminated.

Up to the accident to G-SPAO, the EC135 had accumulated more than three million flying hours, over a period of about 20 years, and there had not previously been a reported instance of fuel starvation.

# 2 Analysis

## 2.1 Operations

### 2.1.1 The flight

(Please note: The helicopter was not fitted with a cockpit voice or flight data recorder. However, some data relating to the helicopter's operation was recorded in non-crash-protected non-volatile memory (NVM) in the systems on board. As a result of the limitations of this evidence, the calculated timings of the fuel related warnings could not be corroborated.)

The evidence indicated that the helicopter departed GCH with 400 kg of fuel on board. The crew, of one pilot and two Police Observers, was normal. Their first task, in the Oatlands district of Glasgow, was non-routine and involved participation in the search for a person believed to have been struck by a train. The helicopter remained in the area for 33 minutes and there was no indication, from the radio transmissions between the pilot and ATC, or between the Police Observers and their colleagues on the ground, of any problem with the helicopter or the crew. Having been stood down from that task, with an estimated 273 kg of fuel remaining, the helicopter transited 42 nm to the east to carry out a routine task at Dalkeith, It was a moonless night, with little, if any, cloud and good visibility. The winds between 2,000 and 5,000 ft amsl were from the north-west at 25 to 30 kt and the freezing level was at approximately 3,000 ft amsl.

The task at Dalkeith, which lasted four minutes, was a routine surveillance task, during which approximately one minute of FLIR video was recorded by the crew. It was calculated that this task involved orbiting at a speed of between 30 kt and 50 kt. Consideration was given to the possibility that, during the task, the forward fuel transfer pump in the main tank ran dry for more than three minutes. This would have triggered the F PUMP FWD (forward) caution caption and prompted the pilot to switch OFF the forward transfer pump, in accordance with the procedures. However, flight trials and modelling of the fuel levels calculated to have been present in the main tank at the time suggested that it was unlikely that the forward pump was exposed long enough to illuminate this caution message.

During the task, there was no indication from the crew of any concern with the helicopter or themselves. The pilot made the expected radio calls to ATC and complied with their clearances and instructions. On completion of this task, at 2145 hrs, it was estimated that the helicopter had a total of 193 kg of fuel remaining. The helicopter then flew back towards Glasgow, at a ground speed of about 110 kt, climbing and descending in accordance with the ATC clearances, and routing to the south of a restricted area. It was estimated that, while the helicopter was in the latter stage of its cruise at 3,000 ft amsl, in the descent to 2,000 ft amsl or in the early stage of the cruise at 2,000 ft, the transfer of fuel from the main tank to the supply tank ceased, leaving only the fuel in the supply tank available to the engines. It was concluded that this was due to the fuel transfer pumps in the main fuel tank being switched OFF, either simultaneously or in sequence.

Trials conducted during the investigation suggested that it was possible that the aft fuel transfer pump in the main tank could have run dry, prompting the procedure which requires the pump to be switched OFF. During the trials, the F PUMP AFT caution caption illuminated with a total of 136 kg indicated in the fuel tanks (63 kg in the main tank, and 39 kg and 34 kg of fuel in the left and right supply tank cells respectively). This implied that the pump was exposed some three minutes earlier, with approximately 146 kg of fuel on board. This fuel state was estimated to have occurred on the accident flight at approximately 2159 hrs, when the helicopter was about to descend from an altitude of 2,000 ft, as it approached Bothwell. However, this was two minutes later than the period during which the fuel transfer pumps were calculated to have been switched OFF.

While the possibility of the aft fuel transfer pump running dry could not be discounted, it was concluded that the forward fuel transfer pump was not likely to have run dry. There was no explanation as to why the aft fuel transfer pump and the forward fuel transfer pump were both switched OFF. The indicated quantity in the main tank, when that occurred, would probably have been less than the 76 kg recovered after the accident. This difference is attributed to fuel entering the main tank as a result of overspill from the supply tanks, after the fuel transfer pumps had been switched off. The amount of overspill would have depended on the nose-down attitude of the aircraft at the time.

At 2159 hrs, when the pilot transferred to Glasgow ATC and advised them that he was south of the restricted area at Shotts (North Lanarkshire) and heading towards Bothwell, South Lanarkshire, before recovering back to GCH, he gave no indication of any problem with the helicopter or the crew.

It was calculated that, as the helicopter approached Bothwell, the LOW FUEL warnings began. The pilot was presented with an intermittent LOW FUEL 1 warning, which became permanent, and a LOW FUEL 2 warning. The warnings were accompanied by aural attention-getters, which should have been heard by all members of the crew. The warnings were acknowledged and, once permanent, continued to illuminate for the remainder of the flight. In these circumstances, the *Pilot's Checklist Emergency and Malfunction Procedures* call for the fuel transfer pumps to be selected ON, if there is a positive indication of fuel in the main tank, and a check that the fuel transfer pump circuit breakers are IN. If the warning(s) remains, the pilot is instructed to switch the air conditioning OFF (if installed) and switch the bleed air OFF, if the OAT is greater than 5°C. The procedures also state that, as a memory item, the helicopter is to land within 10 minutes if the warning remains ON.

The fuel transfer pump circuit breakers were found IN after the accident and the bleed air was in the OFF position but it is likely that the checklist was not completed. As the evidence indicates, the fuel transfer pump switches were not selected ON and the helicopter did not land within 10 minutes. In this situation, the only fuel available to feed the engines was the quantity of fuel in the supply tank cells.

The low fuel warnings may have occurred at the same time as the RSO received the audio and visual warning that there was 2 nm to go to the task location. At this point he would also have been providing more detailed navigational guidance to the pilot, and FSO, if the FLIR was being operated.

There was no recording of this phase of the flight in the FLIR system. However, the recording facility is not necessarily used, so the task at Bothwell, which began at 2206 hrs, may have included thermal imaging, with the consequent verbal exchanges between the crew during the helicopter's one orbit to the right, lasting about 80 seconds.

On completion of the task, the helicopter transited to Uddington, a flight time of about one minute and distance of about 1.5 nm. No transmissions were received from the crew and, again, the helicopter conducted one orbit, to the right. This lasted 2 minutes 20 seconds, during which the FLIR system may, again, have been operated by the FSO. On completion, the helicopter appeared to route back towards GCH but, after nearly a minute, it turned from a west-south-westerly track onto a north-easterly track, towards Bargeddie. Once more, no radio transmissions were received from the crew and, without a cockpit voice recording, it is not possible to know what conversations and discussions took place between the crew members, to explain why the task at Bargeddie was undertaken, with the LOW FUEL warnings having been active for at least eight minutes.

The helicopter completed three orbits to the right over Bargeddie, after which, at 2219 hrs, the pilot informed ATC that they were complete in the Bothwell area and returning to GCH, a distance of 7.5 nm. Again, there was no indication of any concern or mention of any problem in the radio call from the pilot. Similarly, the Police Observers made no calls on the Airwave system. The FLIR system may have been used during this final task and verbal exchanges probably took place within the helicopter but no evidence was recovered which could explain the reason for the 5 minutes spent in that location or provide any indication of the crew's awareness of the fuel situation. It was calculated that, as the helicopter left Bargeddie, a total of 87 kg of fuel remained on board.

At a calculated time of 2221:36 hrs (+ or – 5 secs), with the helicopter at an altitude of approximately 950 ft amsl and about 2.7 nm east of GCH, the right engine flamed out. The output from the left engine increased to the power required for single-engine operation but the warning limit was still temporarily set for two-engine operation and this mismatch generated a transient Alarm Gong 1 warning. The ground speed was maintained and the helicopter started to descend.

The engine flameout should have been accompanied by ENG FAIL, ENG OIL P, FUEL PRESS and GEN DISCON caution indications and the instruments should have indicated a power loss. In this situation, the *Emergency and Malfunction Procedures* instruct the pilot to establish a OEI flight condition, identify the affected engine, carry out a single-engine emergency shutdown, if the situation allows for OEI flight, and land as soon as practicable.

Shutting down the engine would have involved switching the right engine ENG MAIN SW to IDLE, checking the indications, to ensure the correct engine has been identified, then switching OFF. This is a memory item, which should be carried out without reference to the checklist. The evidence indicated that this switch was not selected OFF. The procedure also advises the pilot that, if the engine continues to run, to rotate the respective twist grip to the minimum fuel stop. This would not have applied, as the engine had run down. The activity and verbal exchanges that took place in the helicopter, when the right engine flamed out, and the reason for the right engine ENG MAIN SW not being found at IDLE or OFF could not be determined, due to the lack of cockpit voice and flight data recorders fitted to the aircraft.

Thirty-two seconds after the right engine flamed out, at a calculated time of 2222:13 hrs (+ or - 5 secs), the left engine flamed out. The helicopter was at an altitude of between 700 ft and 500 ft amsl. Thereafter, it appeared to descend rapidly, at an increasing rate of descent.

The same, corresponding caution indications should have appeared for the left engine as for the right engine flameout, with the addition of the ROTOR RPM warning when the $N_r$ decreased below 97%. In this situation, the *Emergency and Malfunction Procedures* instruct the pilot to enter autorotation (again, a memory item), using the collective to maintain the $N_r$ within limits. The procedures recommend an airspeed of 75 kt, noting that 90 kt should be used to achieve the maximum range and 60 kt for the minimum rate of descent. Then, as memory items, the pilot should switch both ENG MAIN SWs and both FADEC SWS OFF.

The operator instructs pilots that, if time is available after an autorotation has been entered and the $N_r$ is stable, the SHED BUS switch should be selected to EMERG, to provide power to the steerable landing light and the RADALT, a MAYDAY call should be made and, then, the engines shutdown. The operator recognises that it can be difficult to locate the SHED BUS switch in an emergency.

The variation of the $N_r$ below and above 97%, and the reduction in the helicopter's forward speed indicated that an attempt was made to maintain the rotor speed. However, the switch selections were not made and no MAYDAY transmission was received from the pilot.

During the pilot's recurrent training, most autorotations were commenced from between 1,000 and 2,000 ft agl. On the accident flight, from a height of between 500 and 750 ft agl, the pilot would have had proportionally less time to establish a stable autorotation, before carrying out a flare recovery and landing, on the basis of a nominal rate of descent of about 2,000 ft/min in stable autorotation at 75 kt.

When the helicopter was between 650 ft and 500 ft amsl, a BAT DISCH warning was recorded, indicating that the battery was the only source of electrical power. This is likely to be the point at which the systems supplied by the Avionic Shed Bus 1, including the radio altimeter and steerable landing light, were lost.

Without the RADALT, the pilot did not have accurate height information. Also, he did not have the benefit of a steerable landing light to improve the visual cues. While it was not possible to determine how much this adversely affected his ability to carry out an autorotation and a successful flare recovery, it was apparent that the situation involved attempting a forced landing at night, in a built-up area of Glasgow city centre.

A few seconds after the second engine flamed out, the CPDS end of flight criteria were met. This indicated that the $N_r$ had decreased below 75% (the minimum recoverable rotor rpm in autorotation) and below the range (60-70%) where lead-lag resonance can occur, in a short period of time. This is likely to have been the result of collective pitch being applied to the rotor blades.

The examination of the main rotor head and main rotor blades, after the accident, corroborated the evidence that, before the helicopter struck the roof of the Clutha Vaults Bar, the main rotor blades had experienced very severe lead-lag resonance, at an extreme coning angle. When the helicopter struck the roof, the main rotor and Fenestron tail rotor had stopped rotating. This was further evidence that collective pitch had been applied during the helicopter's final descent.

The *Emergency and Malfunction Procedures* advise pilots to flare at a height of 100 ft agl and establish the landing attitude for the touchdown, maintaining heading and applying the collective lever to reduce the rate of descent and cushion the touchdown.

The evidence at the accident site indicated that the helicopter had no forward speed at impact, which implied that a flare manoeuvre had been carried out during the final descent. Flaring the helicopter also had the potential to increase the $N_{r,}$ if the speed of the rotors was above 75%. However, the height at which the flare manoeuvre was carried out could not be determined. It was possible that the pilot had also selected the landing attitude.

The final, autopilot, warning was either the result of the degradation of its associated systems or due to the impact sequence.

The impact was estimated to have exceeded the design specification of the helicopter and the tolerances of the human body. It was also severe enough for the helicopter to penetrate the roof and ceiling of the building, inflicting injuries on those below, some of which were fatal. However, there was no fire, which probably prevented further injury or loss of life.

### 2.1.2 Fuel system management

The fact that the aircraft flew for as long as it did indicated that the fuel transfer pumps had been ON during much of the flight and that they were then switched OFF. The CAD F PUMP AFT or F PUMP FWD caution captions cater for three conditions:

- A fuel transfer pump remaining exposed (dry) for more than three minutes, when the aircraft attitude and fuel contents so conspire.
- A fuel transfer pump remaining OFF for more than three minutes, after being selected OFF while immersed in fuel (wet).
- A fuel transfer pump becomes blocked.

It was considered conceivable that the F PUMP AFT caution message may have been triggered as the helicopter was returning from its task at Dalkeith, due to that pump running dry. Its appearance on the CAD would have been accompanied by flashing horizontal bars on the display panel and the illumination of the master caution light. Meanwhile, the contents of the supply and main tanks would have been displayed in graphical and digital format.

When this caution message appears, the procedure in the *Pilot's Checklist Emergency and Malfunction Procedures* prompts the pilot to check the fuel level in the main tank and, if it is sufficient to keep both fuel pumps wet, to check that the FUEL PUMP XFER-A switch is ON and that the XFER-A PUMP circuit breaker is IN. If the caution remains, the pilot is instructed to switch the FUEL PUMP XFER-A OFF. A note with the procedure advises the pilot that: '*In hover conditions the unusable fuel can be up to 71 kg*'.

It was not considered likely that the forward fuel transfer pump ran dry or became blocked during the flight and there was no evidence to indicate why it was switched off. Three minutes after it was switched off, the F PUMP FWD caption would have illuminated, accompanied by the flashing horizontal bars on the CAD display panel and the illumination of the master caution light. If the forward and aft fuel transfer pumps were both, accidentally, switched off together, the flashing horizontal bars and master caution light would have illuminated in the same way as they would if only one of the switches had been selected to the OFF position.

The evidence showed that the CAD was operational but without recorded data it was not possible to establish when any F PUMP FWD, F PUMP AFT or FUEL caution messages occurred.

The EC135's fuel system has no provision for an indication to the crew to advise them when a pump, which has been exposed (runs dry) and switched OFF, becomes re-submerged in fuel. This presents an opportunity for the transfer pumps to remain OFF when it would be appropriate for them to be ON.

However, it was established that the LOW FUEL 1 and 2 warnings were activated and acknowledged. Whether and how the pilot followed the relevant procedure in the *Pilot's Checklist Emergency and Malfunction Procedures* could not be established. With a positive indication of fuel in the main tank, the procedure prompts the pilot to check that the fuel transfer pump switches are ON, that the fuel transfer pump circuit breakers are in and, if the warning light remains on, to switch OFF the air conditioning (if installed) and switch OFF the bleed air if the OAT is less than 5°C. It then states: *'LAND WITHIN 10 MINUTES'*.

It was not possible to discover what discussions took place between the crew in response to the warnings, of which all three crew members would have been aware. However, the evidence indicated that the memory action to land within 10 minutes, if the warning remains, was not followed. On the limited evidence available, it could not be established why this did not happen. There was no indication of any concern in the radio transmissions that were received from the pilot or Police Observers throughout the flight.

Additionally, there was no evidence to indicate that the FUEL caution message did not activate. This caution message is normally triggered before the LOW FUEL warnings but it may occur at about the same time. It also prompts a procedure in the *Pilot's Checklist Emergency and Malfunction Procedures,* which includes switching ON the forward and aft fuel transfer pumps, if there is an indication of fuel in the main tank. Whether it occurred and how the pilot responded was not recorded and could not be determined.

After the accident, both fuel prime pump switches were found in the ON position. Normally, they are not required to be ON for any procedure, other than for starting the engines before flight. It was considered possible that they moved to that position during the accident sequence or had been switched ON prior to that, but the reason could not be determined.

Seven of nine incident/accident reports between 1981 and 2014, involving the manufacturer's helicopters, recorded the selection of both fuel transfer pumps to OFF as the primary cause of fuel starvation. Five of these seven occurrences were attributed to an omission to select the transfer pumps ON before takeoff. A further two fuel starvation events referred to the fuel boost transfer pumps or fuel feed tank pumps being OFF. Extensive 'heads-up' (external visual reference) flying was recorded as a factor in two cases, and difficulty in detecting caution lights, due to direct sunlight on the instrument panel, was recorded in another two cases. On this flight, the instrument lighting in G-SPAO had been dimmed for night lighting conditions and NVG operations.

Whilst the selection of both fuel transfer pumps to OFF has occurred before in other types of helicopter, this was the first fuel starvation accident involving an EC135 in more than three million flight hours of operation, over a period of about 20 years.

In summary, the investigation could not establish why a pilot with over 5,500 hours flying experience in military and civil helicopters, who had been a Qualified Helicopter Instructor and an Instrument Rating Examiner, with previous assessments as an above average pilot, did not complete the actions detailed in the *Pilot's Checklist Emergency and Malfunction Procedures* for the LOW FUEL 1 and LOW FUEL 2 warnings.

### 2.1.3 Fuel policy

The PAOM Part 1 provides guidance for fuel planning, advising that fuel for 30 minutes at endurance speed (burning 170 kg/hr) should be included for a flight over a non-hostile environment at night, in addition to fuel for start, run-up and taxi allowance, as appropriate, and the duration of the task.

At the time of the accident, the operator's Operations Manual stated that the Final Reserve Fuel IFR was 85 kg, with a Minimum Land on Allowance (MLA) of 40 kg, and that:

> *'Company policy is that the aircraft should not land with less than 60kg of fuel in the tanks.*
>
> *If it appears to the aircraft Commander that the Final Reserve Fuel may be required, a PAN call should be made. If the Final Reserve fuel is then subsequently reached, this should be upgraded to a MAYDAY.'*

Since the helicopter had 76 kg of fuel on board at the time of the accident, the pilot might have been expected to make a PAN call, upgrading it to a MAYDAY on reaching the Final Reserve Fuel IFR, if he was aware of the fuel state. Again, due to the lack of evidence that might otherwise have been provided by cockpit voice and flight data recorders, the investigation was unable to determine the reasons for this apparent omission.

Following the accident, the operator amended their Operations Manual procedure on fuel calculations, replacing the Minimum Land on Allowance (MLA) with Final Reserve Fuel (FRF), and increasing the VFR and IFR/night FRFs to 90 kg.

### 2.1.4 Training

The pilot had been instructed on the technicalities of the EC135's fuel system during the ground school component of his initial conversion to the EC135, in 2008, including the requirement to land within 10 minutes after being presented with a LOW FUEL warning. He had also undergone training on the normal and abnormal operation of the fuel system in his most recent OPC and LPC checks, in accordance with the requirements of section 3 of JAR-FCL 2.240.

However, it was considered unrealistic to instigate a scenario leading to a LOW FUEL warning in the simulator. So, it was understood that the pilot had not been assessed on his actions in the event of a LOW FUEL warning.

### 2.1.5 Double engine flameout

The EC135 is able to fly in the OEI mode, in the event that one of the engines ceases to provide power. There has only been one previous occurrence, recorded by the manufacturer, of an EC135 suffering a total loss of engine power.

Calculations determined that, in the G-SPAO investigation, the first engine flamed out about 40 seconds before the helicopter crashed. At the time, the helicopter was flying at an altitude of about 950 ft, over a congested city, at night and about 3 nm from landing back at GCH. The OM Part B states:

> *'Following a single engine failure it is particularly important to be prepared for the failure of the second engine.'*

The difference in quantity between the left and right supply tank cells, if they had contained the same level of fuel, would have been 4.5 kg. Calculations, based on the average fuel consumption rate and consultation with the manufacturer, showed that this represents a flight time of no more than 1 minute and 30 seconds, with the second, left engine in OEI mode, before it too will flameout if the fuel transfer pumps are OFF and fuel in the supply tank cells is exhausted.

In this accident, the engines flamed out within 32 seconds of each other, which suggested that there was a lower level of fuel in the left supply tank cell. This may have been due to fuel spilling from the left cell to the right cell, when the fuel levels were near the top of the divider. Trials confirmed that this can occur during unbalanced flight.

The pilot may have been about to action the '*Single Engine Failure – Flight*' (memory) checklist, when the second (left) engine flamed out. His priority would then have been to control the helicopter, enter autorotation and maintain the rotor rpm.

It was estimated that the left engine flamed out about 8 seconds before the helicopter crashed. The ROTOR RPM warning then illuminated and extinguished twice, suggesting that the pilot was actively trying to maintain the rotor rpm. It then illuminated for a third time and remained ON.

2.1.5.1 Safety action

> The helicopter manufacturer's EC135 SDS of the AMM states that the 4 kg difference in volume between the two supply tank cells allows time for a pilot to set the fuel transfer pumps to ON, if both pumps have unintentionally been selected OFF, potentially leading to flameout of both engines as the supply tank cells run dry. It states, incorrectly, that the time between the right (No 2) and left (No 1) engines flaming out will be 3 to 4 minutes.
>
> Corrective action is being taken by the manufacturer to amend the potential engine flameout interval to a more accurate figure in the next revision of the SDS manual, scheduled for publication in December 2015.

2.1.6 Autorotation

The guarded SHED BUS switch, at the rear of the overhead panel, gives the pilot the ability to recover non-essential electrical services, including the radio altimeter (RADALT) and the steerable landing light, if both generators trip off-line. This will be the case in the event of a double engine flameout. Battery power is recovered to those systems when the guard is lifted and the switch is moved from NORM to EMERG.

The operator's instructors instilled in its pilots that, once an autorotation has been entered and the $N_r$ is stable, the SHED BUS switch should be selected to EMERG, a MAYDAY call transmitted and then the engines shut down, if time is available. In this case, there was limited time for the pilot to take his hand off the collective, locate the correct guarded switch at the rear of the overhead panel and move it, to re-activate the RADALT and steerable landing light.

The SHED BUS switch was found guarded in the NORM position, although the pilot may have attempted to reach it. Thus, the RADALT and the steerable landing light were not available to him after the second engine had flamed out.

The 'Autorotation' emergency checklist states that the flare attitude should be established at approximately 100 ft agl. This would be difficult to judge at night without the aid of a RADALT and steerable landing light, and could result in a flare recovery being initiated at a different height.

Damage to the main rotor blades indicated that severe lead-lag resonance took place with the rotor blades at an extreme coning angle. This showed that the helicopter was airborne with a high degree of collective control applied and that the rotor rpm had reduced to a level from which it was irrecoverable.

The RADALT and the steerable landing light are optional equipment and are not standard on the EC135 helicopter. However, a RADALT is required for UK police night flying operations, in accordance with Civil Aviation Publication (CAP) 612, *Police Air Operations Manual*, Part 1. In the event of an autorotation at night, if the shed bus switch is not changed from NORM to EMERG, a pilot will not have accurate height information on which to judge the flare and landing. Also, he will not have the benefit of the landing light to enhance the visual cues.

Radio altimeters are also required to be fitted for several commercial air transport helicopter operations, as regulated by the European Aviation Safety Agency, and the same situation could exist on those aircraft. Therefore, the following Safety Recommendation is made:

**Safety Recommendation 2015-030**

It is recommended that, when the European Aviation Safety Agency requires a radio altimeter to be fitted to a helicopter operating under an Air Operator's Certificate, it also stipulates that the equipment is capable of being powered in all phases of flight, including emergency situations, without intervention by the crew.

To address the immediate situation as it applies to helicopters operating under a Police Air Operator's Certificate in the UK, the following Safety Recommendation is also made:

**Safety Recommendation 2015-031**

It is recommended that, when the Civil Aviation Authority require a radio altimeter to be fitted to a helicopter operating under a Police Air Operator's Certificate, it also stipulates that the equipment is capable of being powered in all phases of flight, including emergency situations, without intervention by the crew.

2.1.7 NVGs

The pilot's NVGs were not attached to his helmet and were found to the right of his seat after the accident. It could not be determined when they had been removed.

The investigation considered that the NVGs may only have contributed to the accident if the pilot had been distracted by removing them during the autorotation. Their presence in the mounted, but stowed, position would still have permitted normal visual manoeuvring of the helicopter. Pilots usually flew over the city without using NVGs and there was no evidence to indicate that the pilot was not following this common practice.

## 2.2 Engineering

2.2.1 Introduction

It was evident from the absence of main rotor blade, tail rotor drive shaft or Fenestron rotational damage that the rotor system was not turning at the time of impact.

Rotation of the main rotor system and Fenestron drive shaft, which was evident when the No 2 engine power turbine was rotated by hand during wreckage examination, indicated that, had that engine been operating with the LP spool rotating and delivering power, the rotor system would also have been turning.

Hence, the stationary condition of the rotor system, as found, was consistent with the No 2 engine not delivering power at impact.

Also, the indications were that No 1 engine was not operating at the time of impact, since hand-rotation of the power turbine caused the disengaged forward coupling to rotate. In addition, similar rotation of the gearbox-side of the coupling caused rotation of the rotor head and fractured tail drive shaft.

The absence of any evidence of high speed rotation of engine components at impact, found during strip examination, was consistent with the above findings. This was corroborated by the recorded data, from the two FADECs, which showed that the engines had flamed out sequentially. Consequently, it followed that the cessation of operation of both engines led to initiation of the descent of the helicopter from its intended flight path.

The fuel tank geometry and post-impact orientation of the helicopter structure ensured that fuel was not able to drain into the main tank from the supply tank, between the time of impact and the time residual fuel was drained and measured. It was concluded, therefore, that the measured amounts represented the fuel disposition at the time of impact and this was not materially different from that at the time of engine flame out. Absence of fuel in the supply tanks, therefore, caused both engines to flame out sequentially.

2.2.2 Main and tail rotor system

Total loss of rotational speed of the rotor system during the subsequent unpowered descent is consistent with a higher than optimum main rotor blade pitch being applied and maintained during some part of the descent.

The physical damage identified on the main rotor blades was typical of lead-lag resonance. This occurs when the main rotor speed decays through the region of 60%-70% $N_r$ and can be brought about when significant main rotor blade pitch is applied to an unpowered rotor system.

Evidence of blade coning during lead-lag resonance also confirmed that the latter occurred before impact. Ear-witness evidence was also consistent with lead-lag resonance occurring whilst the helicopter was still airborne. Lead-lag resonance in flight occurs at a rotor speed below the minimum $N_r$ (75% $N_r$) from which it is irrecoverable in autorotation.

2.2.3 Engines

Strip examination of the engines and fuel control units, together with functional testing of the FADEC units, revealed no evidence of pre-impact defects capable of causing power loss. The engine stop valves were found fully open, indicating that normal engine shutdown or securing action had not taken place. This, together with the evidence from the fuel metering units and the absence of fuel in both supply tank cells, confirmed that the engines flamed out due to fuel starvation.

2.2.4 Fuel Transfer System

Examination of the fuel transfer system revealed the following:

- All tanks remained fuel tight.
- All internal tank pipework remained undamaged and permitted unrestricted flow.
- The transfer pumps functioned on initial test and, together with their non-return valves, performed in accordance with design specifications.
- No evidence of pre-impact failure in the fuel transfer pump wiring, switches or circuit breakers was found.
- The fuel pump power circuit-breakers were found in the closed position and passed current correctly.

Consequently, the absence of fuel in the supply tanks at the time of the impact was the result of the fuel transfer pump switches being in the OFF position from the time the fuel quantity in the main tank reached approximately 76 kg. If either or both of the fuel transfer pump switches had been selected ON, fuel would have been transferred to both supply tank cells and the engines would have been able to draw on that fuel to sustain their operation.

2.2.5 G-NWEM incident and subsequent tests

The occurrence with G-NWEM demonstrated that erroneous fuel contents indications were possible and had the potential to mislead.

Tests at the AAIB, after the G-NWEM incident, showed that water within the sensor units had a significant effect on the output frequency. Further tests by the manufacturer demonstrated that water in the fuel tanks can lead to emulsification within the fuel. The emulsified fuel can interact with the fuel tank content sensors leading to an erroneous fuel quantity display. It was also found that, although the emulsification dissipates over time, any emulsified water in the fuel within the sensors reforms as droplets and globules, which become trapped at the bottom of the sensors between the concentric tubes. This results in a frequency drift which increases as more droplets form after repeated emulsification events. The evidence indicated that this was the case in G-NWEM.

In summary, fuel water emulsification has a very subtle effect that does not cause contents indication software to detect the false and implausible output from the fuel sensors.

It was deduced that, if a progressive reduction in contamination occurs, as fuel is used, the result will be a progressive reduction in error in the output frequency, leading to the level indications progressively approaching the correct figures.

Small amounts of water in the main tank sensors will correspondingly result in over-reading of the main tank contents, with no effect on the supply tank contents indication.

2.2.6 Fuel contents indications

With 400 kg of fuel in the helicopter at the start of the flight, it was calculated, from the recorded flight path, that approximately 329 kg of fuel would have been consumed, leaving 71 kg remaining at the time of the accident. This was consistent with the 76 kg of fuel that was found in the helicopter. None of the fuel tanks had been ruptured in the accident and the 76 kg of fuel was found in the main tank, during recovery of the wreckage.

Furthermore, the fuel drained from the aircraft after the accident was found to be of the correct specification and was not contaminated with water or any other substances. There was no free water found within the tanks or other fuel system components when they were disassembled. Although the sensors and pumps were damaged in the accident, careful testing showed them to be serviceable and to be working correctly. The aircraft wiring and other components in the system were also found to be serviceable.

The G-NWEM incident initiated detailed fuel system testing and research which resulted in a better understanding of the effects of water contamination in EC135 fuel systems. This led to a number of safety actions by the helicopter and engine manufacturers and by the operator. With regard to G-SPAO, its fuel system could, under some circumstances, be affected by water contamination in similar ways to G-NWEM and other EC135 helicopters. There was documentary evidence within the maintenance records that this occurred in July and October 2013. These problems were addressed and rectified at the time.

It was concluded that there was no evidence that the fuel system in G-SPAO was indicating incorrectly in the lead up to the accident.

2.2.6.1 Erroneous indications

Following the issue of ASB EC135-28A-018, analysis of the results found that 6.6% of all tested sensors failed with an over-reading of at least 1 kg and that 2% showed an over-reading greater than 3 kg.

Prior to this, the manufacturer had been aware that operators were periodically returning 'defective' EC135 fuel sensors for testing, diagnosis and repair. In most cases they were found to perform correctly on test. Since these sensors had been removed, stored and transported, they generally arrived dry at the manufacturer's premises. The fact that they then performed correctly during test in uncontaminated fuel suggested that the surface conditions or the effective dielectric constant may have differed between that experienced on test and that occurring in service.

Following the tests conducted as a result of the G-NWEM incident, it became apparent that the problems were related to water ingress via the fuel tank vent system following cold compressor washing operations. This water was then emulsified in the fuel as it was moved around the fuel tanks by the transfer fuel pumps. That also explained why the sensors, having been removed and transported, arriving dry at the manufacturer and free of any contamination, performed correctly during test in uncontaminated fuel.

2.2.6.1.1 Safety action

Consultations between the operator, the engine manufacturer and the airframe manufacturer identified the need to address the possibility of fuel contamination brought about by cold chemical engine compressor-wash operations. It was found that water and cleaning agent ingress into the fuel tanks, via the vent system, can only take place during the cold compressor washing process and not following a hot compressor washing process. Accordingly the engine manufacturer issued a concession (TMUK/3995/02122014/CON dated 8 December 2014), to the operator, to authorise the suspension of the cold compressor washing process while continuing with the daily hot washing process, in accordance with the EMM.

2.2.7 Fuel pump switch positions

2.2.7.1 Prime pump switches

The supply tank prime pump switches are not guarded or gated, so they could have been moved during the impact sequence or the victim recovery operation, prior to the helicopter being lifted from the building. Therefore, the pre-impact position of the prime pump switches could not be verified beyond doubt.

The No 1 and No 2 prime pumps are used during the engine start procedure to supply a positive head of fuel to the engine driven LP and HP pumps. After engine start the prime pumps are normally selected OFF and remain so throughout flight. Thus, the position in which they appeared to be in the immediate aftermath of the accident was unusual.

It is possible that they had been selected ON, at a point unknown, prior to the accident. If this was the case, it would not have adversely affected the supply of fuel to the engines. The fuel transfer pump switches are, however, in close proximity to the prime pump switches, so unintentional selection of the inappropriate switches was possible.

2.2.7.2 Fuel transfer pump switches

The forward and aft main tank fuel transfer pump switches were found in the OFF position, when the switch panel was examined by the AAIB. These two switches were located alongside the prime pump switches and, like the prime switches, were of the simple unguarded toggle type. They are retained at their selected positions by light internal spring pressure and intended to be operated by light finger forces. Therefore, they could have been moved during the recovery operation, for the same reason as the prime pump switches. Equally, the possibility of one or both switches being moved during the impact sequence cannot, on the evidence of the switches alone, be ruled out. However, separate evidence that the transfer pump switches must have been in the OFF position before the accident was obtained during the investigation, as described earlier.

2.2.8 Fuel consumption

The manufacturer's fuel consumption calculations were based on a simplified flight profile derived from the radar flight path and no wind. Using a takeoff fuel mass of 400 kg, the helicopter would have used 329 kg, leaving 71 kg remaining. This compared with the 76 kg that was recovered from the helicopter and suggests that the starting fuel figure of 400 kg correlated with the indicated fuel reported to be in the helicopter at the start of the flight. Consequently, there was no gross error in the indicated fuel quantity whilst the helicopter was on the ground.

2.2.9 EC135 crashworthiness

Calculations indicated a decelerative force in excess of 70g occurred during the accident. A force of this magnitude was outside the crashworthiness capabilities of the helicopter, so it was not able to afford any protection to its occupants.

The fuel tank system exceeded its designed capabilities and remained fuel-tight. Thus, the risk of fire was greatly reduced and, secondly, the quantity of fuel retained within the tank system, together with its distribution, was fundamental evidence in the investigation.

## 2.3 Flight recorders

The helicopter was not required to have, and was not fitted with, flight recorders. However, data and recordings were recovered from non-volatile memory (NVM) in the helicopter's Warning Unit, Vehicle and Engine Monitoring Display, Caution and Advisory Display, Flight Control Display Module, Full Authority Digital Engine Control units and from the Forward Looking Infra-red (FLIR) camera system. Also, recordings of radar returns, ATC radio transmissions, police equipment and CCTV were obtained and analysed.

Despite this, the investigation was unable to determine, with certainty, the circumstances that led to fuel in the helicopter's supply tank reducing to the level at which both engines flamed out, in sequence, while 76 kg remained in the main tank. Nor was it able to ascertain why, following the double engine flameout, the helicopter was not established in a stable autorotative descent, from which a flare recovery, near the surface, could be achieved. In addition, it is not known why no emergency radio transmission or indication of a problem with the helicopter was received from the pilot.

Whilst the evidence indicates that the CAD and warning unit were operational during the flight, it is not known at what time the warnings occurred and what cautions were or were not generated. Nor was it possible to establish the information and indications that were presented to the pilot at the time of the warnings and any cautions. In addition, there was no record of the actions by the pilot or Police Observers and their interaction and conversations.

Flight recorders, compliant with the ANO 2009 requirement for larger helicopters, could have provided most, but not all, of this information. Information on the instrument displays, switch selections and crew actions would not have been included entirely. Also, the circumstances associated with the autorotation would not have been captured because power to flight recorders, had they been fitted, may have been shed after the second engine flamed out. Recorder Independent Power Supplies (RIPS) have been developed and are in use to provide 10 minutes of power to flight recorders under circumstances such as these.

The AAIB has investigated eight other accidents involving police aircraft since 1985, not all of which had sufficient evidence to enable a complete understanding of the circumstances of the accident. Police helicopter operations, as with other State operated aircraft, are regulated by national regulatory authorities (ie the CAA in the UK), rather than EASA. To enable the circumstances of any accidents and serious incidents, involving current and future helicopters operating under a Police Air Operator's Certificate, to be thoroughly investigated, consideration has also been given to the different technical issues presented by current and future helicopters. Consequently, the following Safety Recommendations are separated by the date on which a helicopter is issued with its first Certificate of Airworthiness. Safety Recommendation 2015-032 is made for current helicopters or those due to receive a certificate of Airworthiness in the relatively near future:

**Safety Recommendation 2015-032**

It is recommended that the Civil Aviation Authority requires all helicopters operating under a Police Air Operators Certificate, and first issued with an individual Certificate of Airworthiness before 1 January 2018, to be equipped with a recording capability that captures data, audio and images in crash-survivable memory. They should, as far as reasonably practicable, record at least the parameters specified in The Air Navigation Order, Schedule 4, Scale SS(1) or SS(3) as appropriate. They should be capable of recording at least the last two hours of (a) communications by the crew, including Police Observers carried in support of the helicopter's operation, and (b) images of the cockpit environment. The image recordings should have sufficient coverage, quality and frame rate characteristics to include actions by the crew, control selections and instrument displays that are not captured by the data recorder. The audio and image recorders should be capable of operating for at least 10 minutes after the loss of the normal electrical supply.

Safety Recommendation 2015-033 is made for helicopters that will be issued with their first individual Certificate of Airworthiness further in the future:

**Safety Recommendation 2015-033**

It is recommended that the Civil Aviation Authority requires all helicopters operating under a Police Air Operators Certificate, and first issued with an individual Certificate of Airworthiness on or after 1 January 2018, to be fitted with flight recorders that record data, audio and images in crash-survivable memory. These should record at least the parameters specified in The Air Navigation Order, Schedule 4, Scale SS(1) or SS(3), as appropriate. They should be capable of recording at least the last two hours of (a) communications by the crew, including Police Observers carried in support of the helicopter's operation, and (b) cockpit image recordings. The image recordings should have sufficient coverage, quality and frame rate characteristics to include control selections and instrument displays that are not captured by the other data recorders. The audio and image recorders should be capable of operating for at least 10 minutes after the loss of the normal electrical supply.

Other State aircraft, such as search and rescue operations and police aeroplanes are not covered by the above recommendations. While many of those aircraft require flight recorders, future, lighter helicopters may not. Also, there is no current requirement for the fitting of image recorders. To address this, the following Safety Recommendation is made:

**Safety Recommendation 2015 - 034**

It is recommended that the Civil Aviation Authority considers applying the requirements of AAIB Safety Recommendation 2015-032 and AAIB Safety Recommendation 2015 - 033 to State aircraft not already covered by these Safety Recommendations.

The above Safety Recommendations address UK State aircraft but the same rationale applies to EASA regulated HEMS operations. EASA are reviewing the need to extend flight recorder requirements to lighter aircraft, under Rule Making Task (RMT) 0271&0272, and powering some flight recorder functions for 10 minutes, after the loss of normal power, under RMT.0249. These reference current EU requirements, ICAO Standards and previous Safety Recommendations from European States.

The ICAO standard includes fuel quantity recordings but not fuel control selections, and neither are referenced in the current EU requirements. Image recording is not required. Also, the EU and ICAO recorder standards are not applicable to helicopters in the same weight category as G-SPAO. Therefore, the limitations of the UK ANO, discussed above, also apply to the EASA proposed standards. To address the mismatch, the following recommendation is made:

**Safety Recommendation 2015 - 035**

It is recommended that the European Aviation Safety Agency mandate the ICAO Annex 6 flight recorder requirements for all helicopter emergency medical service operations, regardless of aircraft weight. The last two hours of flight crew communications and cockpit area audio should be recorded. The cockpit area audio recording should continue for 10 minutes after the loss of normal electrical power.

Aircraft flight data and audio recorders do not capture all the relevant circumstances associated with an accident, as discussed. Recording all switch selections, instrument displays and crew actions, amongst others, would provide more information on the circumstances of an accident. In turn, this would give a greater probability of establishing the causes of an accident and the measures necessary to prevent a recurrence. Therefore, the following Safety Recommendation is made:

**Safety Recommendation 2015 - 036**

It is recommended that the European Aviation Safety Agency mandate image flight recorder requirements for all helicopter emergency medical service operations, regardless of aircraft weight. The image recordings should have sufficient coverage, quality and frame rate characteristics to include actions by the crew, control selections and instrument displays that are not captured by a data recorder. The recording should be of the last two hours of operation, including at least 10 minutes after the loss of normal electrical power to the flight recorder.

## 2.4 Safety actions

During the investigation, the helicopter manufacturer issued amendments to the AMMs and introduced new periodic component inspections. The manufacturer has also issued two Information Notices (IN) and published Service Bulletin EC135-71-047 (Modification of the fuel pump drain), dated 14 April 2014 and 2 ASBs (EC135-28A-18 &19 previously referred to in this report). The INs were as follows;

IN 2671-I-28 - Information concerning the fuel indication system, dated 12 December 2013

IN 2673-S-28 - Information concerning LOW FUEL WARNING, dated 16 December 2013

The helicopter manufacturer is progressing with a series of modifications to the EC135 fuel system.

*Fuel sensors*

The investigation and test work arising from the G-NWEM incident revealed that, under certain circumstances, water globule contamination can produce erroneous outputs in the current design of fuel contents sensors fitted to the EC135 helicopter. A modification of the mechanical design of the fuel quantity sensor has been initiated, with the supplier, to reduce the susceptibility of the sensor to water contamination.

The target date for the introduction of this EC135 product improvement is scheduled for the fourth quarter in 2016.

*Fuel transfer pumps*

The helicopter manufacturer will be introducing changes to the fuel transfer pump management logic, for future avionic suites, to reduce pilot workload and simplify the operation of the fuel transfer pumps. The transfer pumps will be switched ON for takeoff and only switched OFF after landing. In addition, the dry-run indication for the fuel transfer pumps will be omitted in the future avionics logic due to the improved dry-run capabilities of the later generation of pumps. This change applies to the H145 (formerly called the EC145 T2) and will be included in the next update to the H135 (the latest version of the former EC135), subject to certification scheduled to take place in 2016.

However, this change is not proposed for the current EC135 fleet, with CPDS avionics, as the existing fuel pump caution signal does not differentiate between a dry-running pump and pump-blockage. There are fuel transfer pumps in use in the existing EC135 fleet which do not have the improved dry-run capability and, therefore, must be operated in accordance with the current flight manual.

Further safety actions included:

*Compressor wash procedure*

Consultations between the operator, engine and aircraft manufacturers identified the need to address the possibility of fuel contamination as a result of the cold chemical engine compressor wash routines. It was found that water and cleaning agent ingress into the fuel tanks via the vent system can only take place during the cold compressor washing process and not following a hot compressor washing process. Accordingly, in July 2014 the engine manufacturer issued an amendment to the cold compressor washing procedure that introduced a process allowing the operator to measure the quantity of water entering the engine fluid drain and return system. This was followed by a concession to the operator, TMUK/3995/02122014/CON, dated 8 December 2014, to authorise the suspension of the cold compressor washing process but continue with the daily hot washing process, in accordance with the EMM.

*Engine fuel drain system*

The investigation highlighted a number of issues regarding the way in which contaminants can enter the fuel supply system. Both the engine and the airframe manufacturers examined the interface between the airframe and the discharge and removal of excess or unwanted fluids from the engines. It was found that the engine fuel drain system can, in some cases, be overwhelmed and unwanted fluids can find their way back into the fuel tank vent system. To address this, the aircraft manufacturer issued Service Bulletin (SB) EC135-71-047, dated 14 April 2014, recommending the retrofitting of vent hoses to the high pressure (HP) fuel pump drain lines. This modification prevents unwanted fluids held in the drain bottles being sucked through the HP fuel pumps during engine start-up and shutdown procedures.

# 3 Conclusion

## (a) Findings

1. The pilot was properly licensed and qualified to conduct the flight, and was well rested.
2. The helicopter was certified, equipped and maintained in accordance with existing regulations and approved procedures.
3. The helicopter was not required to have and was not fitted with flight recorders. However, some recorded evidence was recovered from non-volatile memory in the helicopter's systems.
4. The helicopter took off with about 400 kg of fuel.
5. The evidence indicated that the main tank forward and aft fuel transfer pumps were OFF from a point on the helicopter's route between Dalkeith and Bothwell.
6. There was no evidence to indicate that the fuel contents display system was operating incorrectly.
7. It is not known when the FUEL caution caption was displayed on the Caution and Advisory Display (CAD).
8. The LOW FUEL warnings were triggered during the flight, and it was estimated that this occurred before the helicopter reached Bothwell.
9. The LOW FUEL warning audio attention-getters were acknowledged five times.
10. It was calculated that the helicopter did not land within 10 minutes of the activation of a continuous LOW FUEL warning, as stipulated in the Pilot's Checklist *Emergency and Malfunction Procedures*.
11. ATC was not advised of any problem with the helicopter.
12. Both engines flamed out due to fuel starvation, about 32 seconds apart, as the helicopter was returning to Glasgow City Heliport.
13. The single engine emergency shutdown checklist was not completed following the first engine flameout.
14. The radio altimeter and the steerable landing light ceased to be powered following the second engine flameout.
15. The SHED BUS switch was not selected to EMERG, to repower the radio altimeter and steerable landing light.

16. The rotor rpm decreased below 97% and recovered twice before it decreased a third and final time.
17. The main rotor blades suffered lead-lag resonance, which, on the EC135 type, occurs between 60 to 70% $N_r$ when a control input is made to change the pitch of the main rotor blades.
18. The transmission system, main rotor blades and Fenestron were not being driven and were not rotating at the point of impact.
19. No significant pre-impact technical defect was identified in any part of the aircraft or its systems.
20. The No 1 and No 2 engine control switches were correctly configured for flight.
21. The No 1 and No 2 fuel shut-off valves were correctly set to OPEN.
22. There was no usable fuel in the supply tank cells when the engines flamed out.
23. There was 76 kg (73 kg usable) of fuel in the main tank when the engines flamed out.
24. When tested, the fuel samples taken from G-SPAO were unadulterated, free from water contamination and within specification.
25. The impact forces were in excess of the design and certification crashworthiness requirements of the EC135 fuselage structure and crew seats.
26. The flexible fuel tanks exceeded their crashworthiness requirement and remained fuel-tight after impact.
27. The fuel sensors collapsed in accordance with their design during deformation of the fuel tanks.
28. There was no fire.
29. The accident was not survivable.

**(b) Causal Factors**

The investigation identified the following causal factors:

1. 73 kg of usable fuel in the main tank became unusable as a result of the fuel transfer pumps being switched OFF for unknown reasons.
2. It was calculated that the helicopter did not land within the 10-minute period specified in the *Pilot's Checklist Emergency and Malfunction Procedures*, following continuous activation of the LOW FUEL warnings, for unknown reasons.

3. Both engines flamed out sequentially while the helicopter was airborne, as a result of fuel starvation, due to depletion of the supply tank contents.

4. A successful autorotation and landing was not achieved, for unknown reasons.

**(c) Contributory factors**

The investigation identified the following contributory factors:

1. Incorrect management of the fuel system allows useable fuel to remain in the main tank while the contents in the supply tank become depleted.
2. The RADALT and steerable landing light were unpowered after the second engine flamed out, leading to a loss of height information and reduced visual cues.
3. Both engines flamed out when the helicopter was flying over a built-up area.

# 4 Safety Recommendations

## 4.1 Safety Recommendations

The following Safety Recommendations have been made:

**Safety Recommendation 2015-030**

It is recommended that, when the European Aviation Safety Agency requires a radio altimeter to be fitted to a helicopter operating under an Air Operator's Certificate, it also stipulates that the equipment is capable of being powered in all phases of flight, including emergency situations, without intervention by the crew.

**Safety Recommendation 2015-031**

It is recommended that, when the Civil Aviation Authority require a radio altimeter to be fitted to a helicopter operating under a Police Air Operator's Certificate, it also stipulates that the equipment is capable of being powered in all phases of flight, including emergency situations, without intervention by the crew.

**Safety Recommendation 2015 - 032**

It is recommended that the Civil Aviation Authority requires all helicopters operating under a Police Air Operators Certificate, and first issued with an individual Certificate of Airworthiness before 1 January 2018, to be equipped with a recording capability that captures data, audio and images in crash-survivable memory. They should, as far as reasonably practicable, record at least the parameters specified in The Air Navigation Order, Schedule 4, Scale SS(1) or SS(3) as appropriate. They should be capable of recording at least the last two hours of (a) communications by the crew, including Police Observers carried in support of the helicopter's operation, and (b) images of the cockpit environment. The image recordings should have sufficient coverage, quality and frame rate characteristics to include actions by the crew, control selections and instrument displays that are not captured by the data recorder. The audio and image recorders should be capable of operating for at least 10 minutes after the loss of the normal electrical supply.

**Safety Recommendation 2015-033**

It is recommended that the Civil Aviation Authority requires all helicopters operating under a Police Air Operators Certificate, and first issued with an individual Certificate of Airworthiness on or after 1 January 2018, to be fitted with flight recorders that record data, audio and images in crash-survivable memory. These should record at least the parameters specified in The Air

Navigation Order, Schedule 4, Scale SS(1) or SS(3), as appropriate. They should be capable of recording at least the last two hours of (a) communications by the crew, including Police Observers carried in support of the helicopter's operation, and (b) cockpit image recordings. The image recordings should have sufficient coverage, quality and frame rate characteristics to include control selections and instrument displays that are not captured by the other data recorders. The audio and image recorders should be capable of operating for at least 10 minutes after the loss of the normal electrical supply.

**Safety Recommendation 2015 - 034**

It is recommended that the Civil Aviation Authority considers applying the requirements of AAIB Safety Recommendation 2015 - 032 and AAIB Safety Recommendation 2015 - 033 to State aircraft not already covered by these Safety Recommendations.

**Safety Recommendation 2015 - 035**

It is recommended that the European Aviation Safety Agency mandate the ICAO Annex 6 flight recorder requirements for all helicopter emergency medical service operations, regardless of aircraft weight. The last two hours of flight crew communications and cockpit area audio should be recorded. The cockpit area audio recording should continue for 10 minutes after the loss of normal electrical power.

**Safety Recommendation 2015 - 036**

It is recommended that the European Aviation Safety Agency mandate image flight recorder requirements for all helicopter emergency medical service operations, regardless of aircraft weight. The image recordings should have sufficient coverage, quality and frame rate characteristics to include actions by the crew, control selections and instrument displays that are not captured by a data recorder. The recording should be of the last two hours of operation, including at least 10 minutes after the loss of normal electrical power to the flight recorder.

## 4.2 Summary of safety actions

*The operator's fuel policy*

On 20 December 2013, the operator issued an amendment to its Operations Manual, Part A, '*8.1.7.3 Fuel Calculations*'. This replaced the Minimum Land on Allowance (MLA) with Final Reserve Fuel (FRF), and increased the VFR and IFR/night FRFs to 90 kg and the unusable fuel to 8 kg. It stated:

> *'An Emergency condition can be considered to exist if the Commander believes that the helicopter will land below Final Reserve Fuel (FRF).*
>
> *8.1.7.3 Fuel Calculations*
>
> *When calculating remaining endurance the following formula is to be used*
>
> $$\frac{\textit{Total fuel} - \textit{FRF}}{\textit{Fuel consumption}} = \textit{Endurance}$$
>
> *For normal operations the following nominal figures are to be used*
>
> | | |
> |---|---|
> | *Final Reserve Fuel IFR/ Night / navigating by means other than by reference to visual landmarks (30 minutes)* | *90 kg* |
> | *Unusable fuel (Not indicated)* | *8 kg'* |

These figures were also incorporated in their Operations Manual, Part B, which provides information on the helicopter type and related operational procedures.

The operator also issued the following safety notice to all its pilots on the same date:

> *'… we have conducted detailed examinations and tests on our fleet of EC135s. These tests were to evaluate the function and accuracy of the fuel indicator system on the supply tanks. As a result of these test it was deemed necessary to replace the sender units from the supply tanks on a number of our aircraft.*

> *Until such a time as we have an approved maintenance program in place to perform functional checks of these units we have deemed it necessary to maintain a **Final Reserve Fuel (FRF) 90Kgs.** When completing fuel calculations as per Reference B [Operations Manual Part A 8.1.7.3], please use 90kgs as the FRF for all flights (VFR & IFR) until further notice.'*

*Alert Service Bulletins by the helicopter manufacturer*

On 19 December 2013, the helicopter manufacturer issued ASBs EC135-28A-018 & EC135-28A-019 (see Appendices D and E). The purpose of the ASBs was to inform operators that the EC135 fuel contents indication system appeared, in some circumstances, to give erroneous fuel quantity indications, and to obtain data as to its extent. Secondly, the LOW FUEL checklist in the Flight Manual was amended.

In addition, the helicopter manufacturer is progressing with a series of changes to the EC135 fuel system. These include:

*Fuel sensors*

The investigation and test work arising from the G-NWEM incident revealed that, under certain circumstances, water globule contamination can produce erroneous outputs in the present design of fuel contents sensors fitted to the EC135 helicopter. A modification of the mechanical design of the fuel quantity sensor has been initiated, with the supplier, to reduce the susceptibility of the sensor to water contamination.

The target date for the introduction of this EC135 product improvement is scheduled for the fourth quarter in 2016.

*Fuel transfer pumps*

The helicopter manufacturer will be introducing changes to the fuel transfer pump management logic, for future avionic suites, to reduce pilot workload and simplify the operation of the fuel transfer pumps. The transfer pumps will be switched ON during takeoff and only switched OFF after landing. In addition, the dry-run indication for the fuel transfer pumps will be omitted in the future avionics logic due to the improved dry-run capabilities of the later generation of pumps. This change already applies to the current version of the EC145 and will be included in the next update to the EC135, subject to certification scheduled to take place next year.

However, this change is not proposed for the current EC135 fleet, with CPDS avionics, as the existing fuel pump caution signal does not differentiate between a dry-running pump and pump-blockage. There are fuel transfer pumps in use in the existing EC135 fleet which do not have the improved dry-run capability and, therefore, must be operated in accordance with the current flight manual.

*Timescale*

It is anticipated that these improvements will be made available to the existing EC135 fleet at the end of 2015 and will be presented to operators by an optional Service Bulletin.

Further safety actions included:

*Compressor wash procedure*

Consultations between the operator, engine and aircraft manufacturers identified the need to address the possibility of fuel contamination as a result of the cold chemical engine compressor wash routines. It was found that water and cleaning agent ingress into the fuel tanks via the vent system can only take place during the cold compressor washing process and not following a hot compressor washing process. Accordingly, in July 2014 the engine manufacturer issued an amendment to the cold compressor washing procedure that introduced a process by which operator could measure the quantity of water entering the engine fluid drain and return system. This was followed by a concession to the operator, TMUK/3995/02122014/CON, dated 8 December 2014, to authorise the suspension of the cold compressor washing process but continue with the daily hot washing process, in accordance with the EMM.

*Engine fuel drain system*

The investigation highlighted a number of issues regarding the way in which contaminants can enter the fuel supply system. Both the engine and the airframe manufacturers examined the interface between the airframe and the discharge and removal of excess or unwanted fluids from the engines. It was found that the engine fuel drain system can in some case be overwhelmed and unwanted fluids can find their way back into the fuel tank vent system. To address this, the aircraft manufacturer issued Service Bulletin (SB) EC135-71-047, dated 14 April 2014, recommending the retrofitting of vent hoses to the high pressure (HP) fuel pump drain lines. This modification prevents unwanted fluids held in the drain bottles being sucked through the HP fuel pumps during engine start-up and shut-down procedures.

# Appendix A

## Extracts from the manufacturer's flight reference cards

*'EC 135 T2 (CPDS [Central Panel Display System]) PILOT'S CHECKLIST EMERGENCY AND MALFUNCTION PROCEDURES' [card I-E-7]*

*Emergency procedure steps which shall be performed immediately without reference to either this manual or the pilot's checklist are written in **boldface letters** and shall be committed to memory.…*

***NOTE** The type of emergency and the emergency conditions combined with the pilot's analysis of the condition of the helicopter and his proficiency are of prime importance in determining the urgency of a landing.*

*<u>The following terms are used to reflect the degree of urgency of an emergency landing:</u>*

***LAND IMMEDIATELY***

*The urgency of landing is paramount. Primary consideration is to assure survival of the occupants. Landing in water, trees or other unsafe areas should be considered only as a last resort.*

***LAND AS SOON AS POSSIBLE (LAND ASAP)***

*Land without delay at the nearest adequate site (i.e. open field) at which a safe approach and landing can be made.*

Page I-E-8 states:

*'The term **"OEI flight condition ....– Establish"** is used as a leading step in some engine emergency procedures to express the following:*

1. *In case that power of affected engine tends to zero:*

   *– Maintain the normal engine within OEI limits.*

   *– Attempt to obtain a safe single engine flight condition. If a climb is necessary to reach a safe flight altitude, attempt to obtain Vy= 65 kts (best rate of climb) or VTOSS = 40 kts (best climb gradient speed).*

   *– Continue with the remaining steps of the relevant procedure.*

**Appendix A cont**

Checklists for fuel system related caution and warning captions are:

**F QTY DEGR**

(MISC)

**CAUTION** THE DEGRADED FUEL QUANTITY INDICATION REPRESENTS THE MINIMUM FUEL LEVEL WITHIN PITCH ATTITUDE RANGES OF –3° TO +6°.

Set pitch attitude between –0° and +/–1° before reading fuel quantity, then calculate remaining flight endurance in accordance with that "degraded" fuel quantity indication.

**NOTE** In this attitude for endurance calculations conservative fuel quantity is displayed.

---

**F QTY FAIL**

(MISC)

**CAUTION** THE FUEL QUANTITY INDICATION SYSTEM HAS FAILED. **DO NOT** CALCULATE FLIGHT ENDURANCE ACCORDING THE FUEL QUANTITY INDICATION. FUEL QUANTITY INFORMATION ONLY BY **LOW FUEL** WARNING LIGHT ON THE WARNING PANEL AND BY GONG.

LAND AS SOON AS PRACTICABLE

## Appendix A cont

### F PUMP AFT

(MISC)

| | | |
|---|---|---|
| 1. Fuel level in the main tank | – | Check |
| <u>If main tank fuel quantity is sufficient to keep both fuel pumps wet:</u> | | |
| 2. FUEL PUMP XFER-A sw | – | Check ON |
| 3. XFER-A PUMP cb | – | Check in |
| If F PUMP AFT indication remains on: | | |
| 4. FUEL PUMP XFER-A sw | – | OFF |
| <u>If main fuel tank fuel quantity is low:</u> | | |
| 2. FUEL PUMP XFER-A sw | – | OFF |

**NOTE** Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.

### F PUMP FWD

(MISC)

| | | |
|---|---|---|
| 1. Fuel level in the main tank | – | Check |
| <u>If main tank fuel quantity is sufficient to keep both fuel pumps wet:</u> | | |
| 2. FUEL PUMP XFER-F sw | – | Check ON |
| 3. XFER-F PUMP cb | – | Check in |
| If F PUMP FWD indications remains on: | | |
| 4. FUEL PUMP XFER-F sw | – | OFF |
| <u>If main tank fuel quantity is low:</u> | | |
| 2. FUEL PUMP XFER-F sw | – | OFF |

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In forward flight conditions the unusable fuel can be up to 59 kg. The quantity of unusable fuel can be reduced to 3.6 kg when flying with 80 KIAS or less.

## Appendix A cont

**FUEL**

(MISC)

**NOTE**
- *For H/C with 680 liters fuel tank:* The fuel quantities of supply tanks begin to decrease. Caution appears when fuel quantity is approx. 40 kg (tank 1) or 35 kg (tank 2).
- *For H/C with 710 liters fuel tank:* The fuel quantities of supply tanks begin to decrease. Caution appears when fuel quantity is approx. 36 kg/45 ltr (tank 1) or 32kg/40 ltr (tank 2).

| | |
|---|---|
| 1. Fuel quantity indication of main tank/supply tanks (CAD) | – Check |
| If there is still fuel indication in the main tank: | |
| 2. FUEL PUMP XFER–A and –F sw | – Check ON |
| If main tank fuel indication shows zero | |
| 2. FUEL PUMP XFER–A and –F sw | – Check OFF |
| 3. LAND AS SOON AS PRACTICABLE | |

**NOTE** Be prepared for LOW FUEL warning. [1]

**LOW FUEL 1** / **LOW FUEL 2**

LOW FUEL 1 (SYSTEM I) and/ or LOW FUEL 2 (SYSTEM II)

and activated warning GONG

| | |
|---|---|
| 1. Fuel quantity indication | – Check |
| If positive fuel indication in the main tank: | |
| 2. Both fuel pump XFER sw (F + A) | – Check ON |
| 3. Both fuel pump XFER circuit breaker (F + A) | – Check in |
| If FUEL LOW warning light remains on: | |
| 4. Air condition (if installed) | – Switch OFF |
| 5. Bleed Air | – Switch OFF (if OAT > 5°C) |

***EFFECTIVITY*** *For H/C with 680 liters fuel tank (673 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 8 MINUTES**

***EFFECTIVITY*** *For H/C with 710 liters fuel tank (701 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 10 MINUTES**

***EFFECTIVITY*** *All*

[1] G-SPAO was fitted with 710 litre fuel tank.

## Appendix A cont

The procedures related to a single-engine failure, double-engine failure and autorotation are:

**SINGLE ENGINE FAILURE – FLIGHT**

Conditions/Indications

– Slight jerk in the yaw axis, nose left
– Possible change in noise level

Affected engine:

– **ENG FAIL** caution indication (CAD & FLI)
– **ENG OIL P** caution indication
– **FUEL PRESS** caution indication
– **GEN DISCON** caution indication
– Instruments indicate power loss

| | |
|---|---|
| **1. OEI flight condition** | **– Establish** |
| **2. Affected engine** | **– Identify** |
| **3. Single eng emer shutdown** | **– Perform** |
| 4. LAND AS SOON AS PRACTICABLE | |

**SINGLE ENGINE EMER SHUTDOWN**

**NOTE**
- Before performing an inflight single engine emergency shutdown, determine if the situation will allow for OEI flight.
- Make certain that:
  - the controls of the affected eng are selected, and
  - the collective lever is adjusted to maintain the normal eng within the OEI limits.
  - START cb is not pulled
- In case of a single engine failure/ emergency shutdown, the bleed air heating will be switched off automatically. Depending on the power margin of the normal engine, the bleed air heating may be re-engaged by selecting heater switch position EMER.
- If CAD message BLEED AIR remains on after single engine failure, the system must be switched off manually. Depending on the power margin of the normal engine, the bleed air heating may be re-engaged.

| | |
|---|---|
| **1. ENG MAIN sw (affected eng)** | **– IDLE, check indications, then OFF** |
| If there is an indication that the engine is still running: | |
| 2. Respective TWIST GRIP | – Turn to min. fuel stop, verify correct engine, then shut off |

**CAUTION** AVOID CARRYING OUT A VENTILATION IMMEDIATELY AFTER SHUTDOWN WHEN 30 SEC. COOLING RUN (ENGINE IN IDLE) WAS NOT PERFORMED. IN THIS CASE WAIT 1 MIN. BEFORE ENGINE VENTILATION.

**NOTE** A ventilation is only possible when the START cb is not pulled.

## Appendix A cont

**DOUBLE ENGINE FAILURE – FLIGHT**

Conditions/Indications

- Yawing motion nose left
- $N_{RO}$ and both $N_2$ decrease
- **ROTOR RPM** warning ($N_{RO}$ low) on
- Both **ENG FAIL** caution indications (CAD & FLI)
- Both **ENG OIL P** caution indications
- Both **FUEL PRESS** caution indications
- Both **GEN DISCON** caution indications
- Instruments indicate power loss

| | |
|---|---|
| **Autorotation** | **– Perform** |

**AUTOROTATION**

| | |
|---|---|
| **1. Collective lever** | **– Reduce to maintain $N_{RO}$ within limits** |
| **2. Airspeed** | **– 75 KIAS recommended** |

**NOTE** Maximum range airspeed . . . . . . . . . . . . . . **90 KIAS**
Minimum rate-of-descent airspeed . . . . . . **60 KIAS**

| | |
|---|---|
| **3. Double eng emer shutdown** | **– Perform** |
| AT APPROX. 100 FT AGL: | |
| 4. Flare attitude | – Establish |
| TOUCHDOWN: | |
| 5. Landing attitude | – Establish |
| 6. Heading | – Maintain |
| 7. Collective lever | – Increase to stop descent and cushion landing |
| AFTER TOUCHDOWN: | |
| 8. Collective lever | – Lower **slowly** to prevent an abrupt stop of the helicopter |
| 9. Cyclic stick | – Maintain in neutral position |
| **10. BAT MSTR sw** | **– OFF** |

## Appendix A cont

**DOUBLE ENGINE EMERGENCY SHUTDOWN**

- **ON GROUND**

| | |
|---|---|
| **1. Both ENG MAIN sw** | **– OFF** |
| **2. Both FADEC sw** | **– OFF** |
| **3. Both fuel PRIME PUMP sw** | **– OFF** |
| **4. BAT MSTR sw** | **– OFF** |
| If there is an indication that the engines are still running: | |
| **5. Both TWIST GRIPS** | **– Turn to shut off** |

- **IN FLIGHT**

| | |
|---|---|
| **1. Both ENG MAIN sw** | **– OFF** |
| **2. Both FADEC sw** | **– OFF** |
| If there is an indication that the engines are still running: | |
| **3. Both TWIST GRIPS** | **– Turn to shut off** |

**NOTE** The shut off valves are inoperative when the START cb is pulled.

**Appendix A cont**

**ROTOR RPM**

**ROTOR RPM**

Conditions/Indications

$N_{RO}$ LOW

– $N_{RO}$ **97%** or less - steady light

– Audio signal - intermittent low tone (800 Hz)

$N_{RO}$ HIGH

– $N_{RO}$ **106%** or above - flashing light and warning GONG

– Audio signal at **112%** or above - flashing light and continuous high tone (2400 Hz)

$N_{RO}$ LOW / $N_{RO}$ HIGH

| | |
|---|---|
| **1. Rotor RPM indicator** | – **Check** |
| **2. Collective lever** | – **Adjust as necessary to maintain $N_{RO}$ within normal range** |

**NOTE** If in addition to the above indications $N_{RO}$ is below both $N_2$ suspect $N_{RO}$ indication system failure. In this case maintain torque above 10% to keep $N_2$ and Rotor RPM matched.

# Appendix B

## Airbus Helicopters Information Notice 2693-I-28, dated 5 March 2014

AIRBUS HELICOPTERS

No. 2693-I-28

# Information Notice

**SUBJECT:** **FUEL SYSTEM**

**Information on the logic of the fuel supply indication**

| For the attention of | |
|---|---|
| | |

| AFFECTED HELICOPTERS | Model(s) | |
|---|---|---|
| | Civil | Military |
| EC135 | T1, T2, T2+, P1, P2, P2+, 635 T1, 635 T2+, 635 P2+ | – |

With this information notice, Airbus Helicopters Deutschland would like to inform you about the logic of the fuel supply indication of the main tank and the split supply tank.



## Appendix B cont

AIRBUS HELICOPTERS

# No. 2693-I-28

The fuel system of the helicopter comprises two fuel tanks: A main tank and a split supply tank. During flight, two transfer pumps continuously feed fuel from the main tank to the supply tank via the transfer lines. Any excess of transferred fuel is routed back into the main tank via two overflow channels.

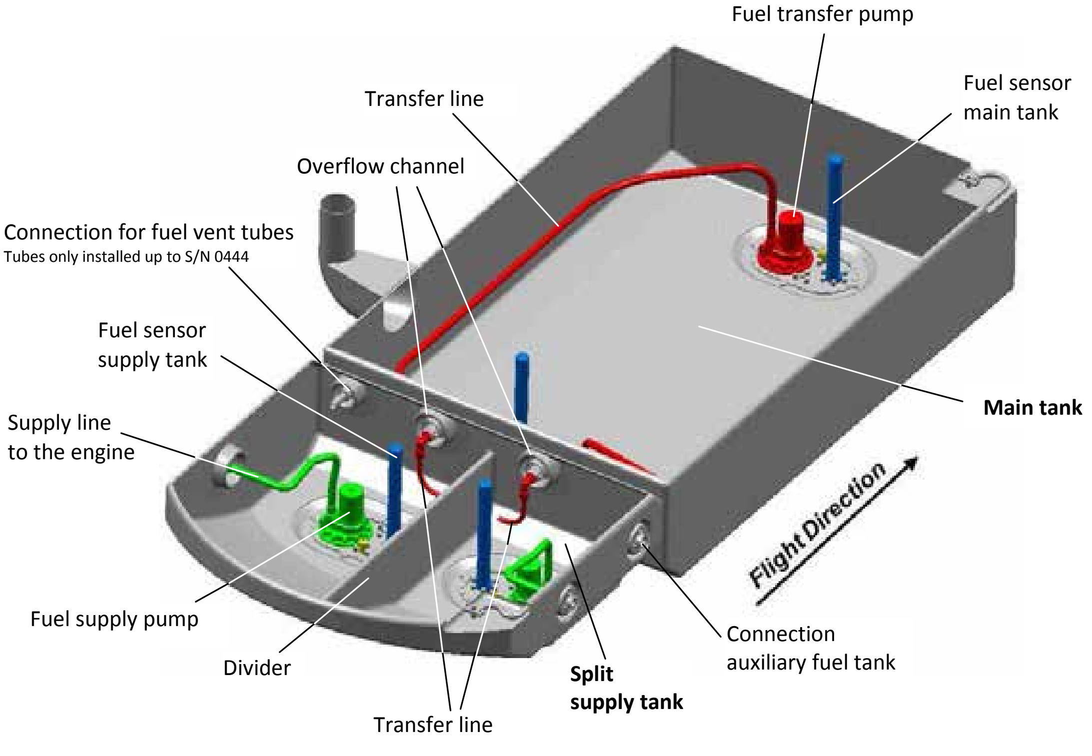



Figure 1: Overview, EC135 fuel tank (isometric view)



## Appendix B cont

**AIRBUS HELICOPTERS**

**No. 2693-I-28**

The display system indicates the fuel quantity in the main tank and in the two supply tank chambers. The indicated fuel quantity of the two supply tank chambers represents the quantity measured up to the lower edge of the overflow channels (see Figure 2). The fuel quantity measured above the overflow channels located in the supply tank is added to the fuel quantity indicated for the main tank.

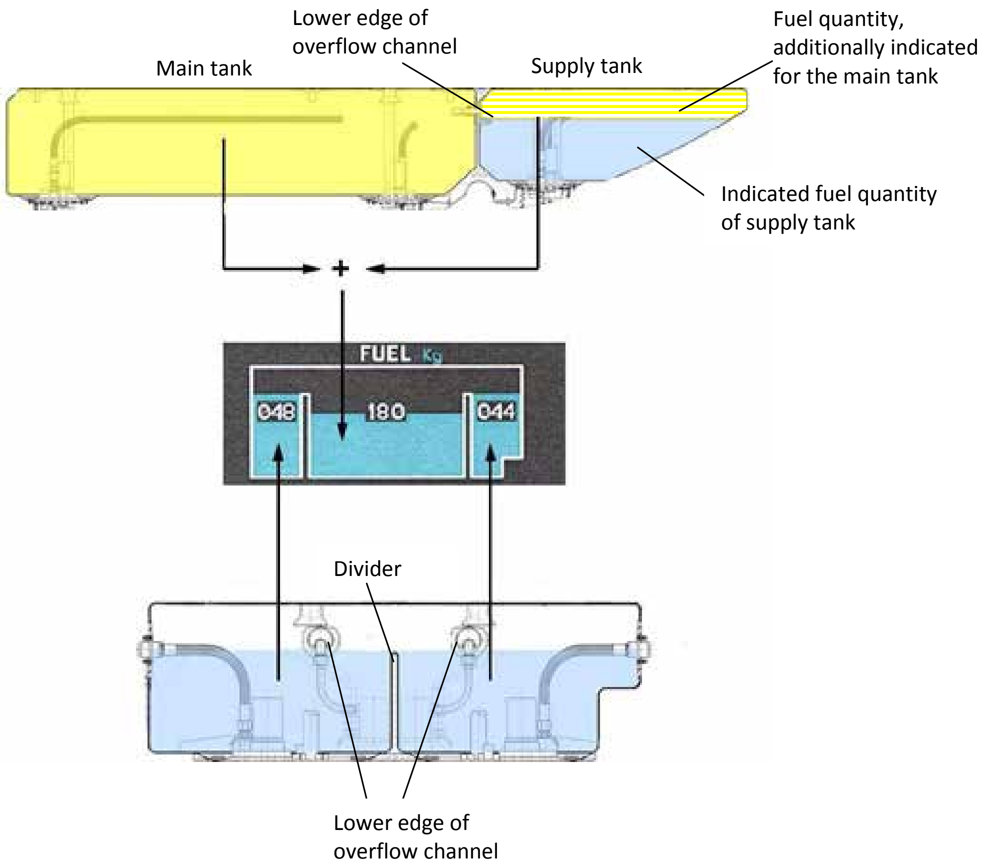



Figure 2: Fuel tank and fuel supply indication

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*This document is also available on the internet: www.airbushelicopters.com/techpub*

## Appendix B cont

AIRBUS HELICOPTERS

**No. 2693-I-28**

The actual maximum fuel quantity in the supply tank is defined for a pitch angle of 0° (see Figure 3).

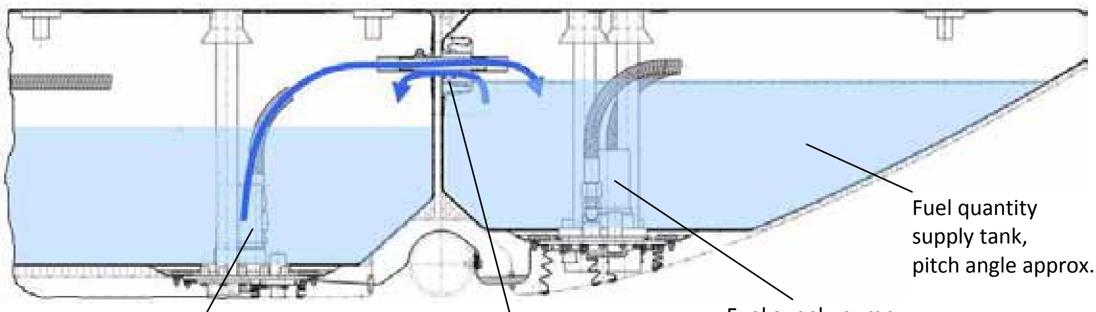


Figure 3: Supply tank, pitch angle approx. 0°

The actual fuel quantity in the supply tank varies depending on the inclination of the helicopter. At "nose-down" pitch angles (e.g. during fast forward flight), the fuel quantity in the supply tank decreases (A-A, Figure 4). The fuel quantity indication of the supply tank also decreases but stabilizes at a certain level (depending on the pitch angle).

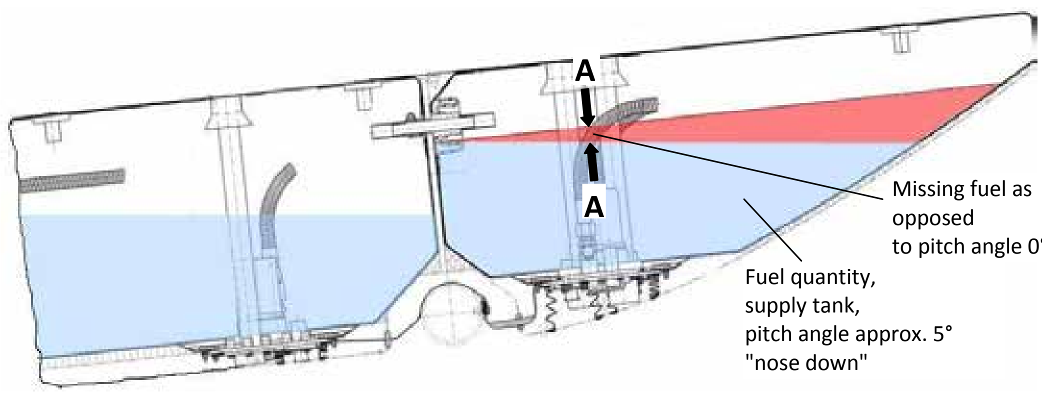


Figure 4: Supply tank, pitch angle approx. 5° „nose down“



 

**Appendix B cont**

AIRBUS HELICOPTERS

**No. 2693-I-28**

At "nose-up" pitch angles (e.g. hover flight or when the helicopter is on the ground), the fuel quantity in the supply tank increases (see Figure 5). The additional fuel in the supply tank (A-A, Figure 5) is added to the fuel quantity displayed for the main tank. Therefore, in case of a certain fuel quantity and at certain pitch angles of the helicopter, a residual amount of fuel in the main tank may still be indicated although the main tank is already empty. At constant pitch angles and with decreasing fuel quantity, the fuel quantity indication of the main tank decreases before the fuel quantity indication of the supply tank also decreases.

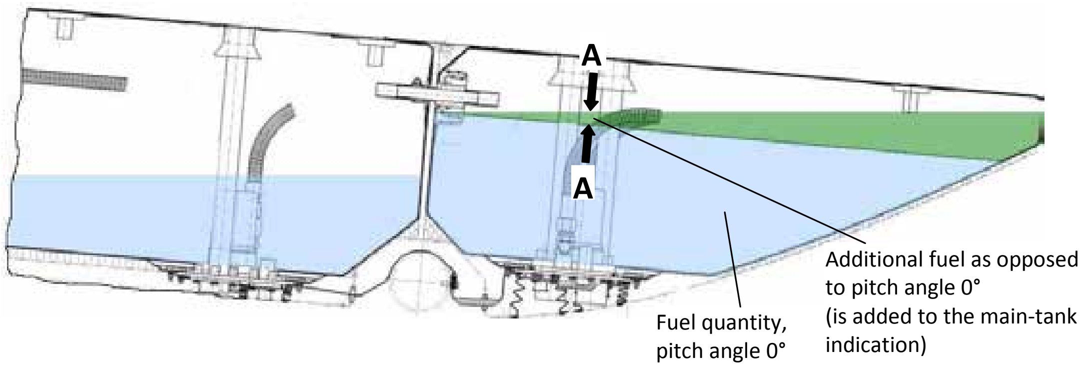


Figure 5: Supply tank, pitch angle approx. 5° „nose up“



 

# Appendix C

## Eurocopter Information Notice 2535-I-28, dated 21 January 2013

EUROCOPTER
AN EADS COMPANY

No. 2535-I-28

# Information Notice

**Subject** **FUEL SYSTEM – Water contamination of the Fuel System**

Notes about possible water contamination of the fuel system

**For the attention of**

| AFFECTED HELICOPTERS | Model(s) | |
|---|---|---|
| | Civil | Military |
| MBB BK117 | C-2 | – |
| EC135 | T1, T2, T2+, P1, P2, P2+, 635 T1 , 635 T2+, 635 P2+ | – |

EUROCOPTER has been informed about several fuel quantity indication failures. Following the replacement of the affected fuel probe, the indication returned to normal and the functional check of the fuel quantity indication system has been performed successfully.

When the subject probes have been returned to EUROCOPTER for repair, the probes showed no external damage or contamination within the two concentric metal tubes and most of the probes have been tested, with the result, "no fault found" (NFF). To investigate the reason for these NFF's EUROCOPTER performed several tests to simulate the failures. As a result from these tests, the most probable root cause is contamination of the fuel probe with water.

These tests have shown - when water is entering the space between the two concentric metal tubes of the probe - it will decrease the output signal (frequency) of the probe. In case of a high concentration of water, the frequency can decrease to such a level that the CAD recognizes the probe as failed – showing either an F QTY DEGR or F QTY FAIL caution on the CAD. Also there is a potential risk that the CAD shows a higher fuel quantity level compared to the actual fuel level within the fuel tank system.

In addition, customers have reported, when removing the defective sensor from the helicopter, that after removing the water by the use of shop air and warming up the sensor for a certain period of time, the sensor has been working again without any fault.

It should be noted that even for operators that regularly drain the fuel tanks, a couple drops of water concentrated between the metal tubes of the sensor may be enough to affect the signal.

There are several possibilities for the fuel system to be contaminated with water:

- Condensation within the fuel tank system. This is mainly caused when the fuel tanks are not completely filled and the helicopter is parked outside and/or is exposed to great changes in temperature
- Heavy rain during refueling of the helicopter – water is entering through the filler neck
- Contaminated fuel from the source – for example fuel truck, tank, supply system or barrels

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*This document is also available on the internet: www.eurocopter.com/techpub*

**Appendix C cont**

EUROCOPTER
AN EADS COMPANY

**No. 2535-I-28**

- For EC135 when performing an engine compressor wash, the water from the combustion chamber is drained into the drain bottle. On some helicopters there is a chance that water from the drain bottle is sucked into the engine fuel system via the Fuel Control Unit. Operating the prime pumps prior to the next engine start will allow the water to enter the helicopter fuel system through the fuel return line and the fuel expansion box. From the fuel tank expansion box the water will then flow back into the RH Supply Tank.

Therefore, as explained in the AMM Task 71-65-00, 7-1, it is recommended to follow the procedure and to disconnect the combustion chamber drain tube before prior to starting the compressor wash process.

Due to the reason mentioned above, EUROCOPTER wants to point out the importance of keeping the fuel system free of water and other contamination. When draining the fuel system, in reference to the documents listed below, it must be performed before the helicopter is moved, in order to allow the maximum amount of water to be drained from the tank.

Information for draining the fuel system can be found in the following documents:

| | **EC135** | **BK117C-2** |
|---|---|---|
| **AMM, Chapter** | 12-30-00, 3-5 | 12-30-00, 3-16 |
| **MSM, Chapter** | 05-25-00, 6-1 | 05-25-00, 6-1 |
| **FLM, Section** | 4 – Preflight Check | 4 – Preflight Check |
| **FLM, Section** | 8.3 – Drainage Procedure | 8.3 – Drainage Procedure |

In addition EUROCOPTER wants to point out that water – if not drained from the fuel system – can cause different malfunctions within the fuel and engine system.

If there is doubt that the fuel system is free of water, EUROCOPTER recommends to take a fuel sample from the helicopter tank system and to test it for the presence of water by using commercially available Test Strips, for example the SHELL Water Detectors or another commercially available product.



 

## Appendix D

### Eurocopter Alert Service Bulletin EC135-28A-018

EUROCOPTER
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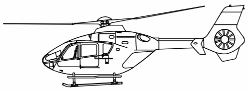
**ASB** EC135-28A-018



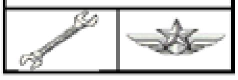
Valid for versions: T1, T2, T2+, P1, P2, P2+
635 T1, 635 T2+, 635 P2+

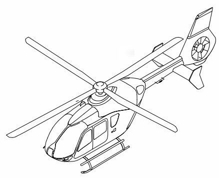
# ALERT SERVICE BULLETIN

**SUBJECT:** **FUEL SYSTEM – Supply Tank Indication**

**System check**

| For the attention of |
|---|





| Revision No. | Date of issue |
|---|---|
| Revision 0 | 2013-12-19 |

**Summary:**

This Alert Service Bulletin introduces a one time system check of the supply tanks.

**Compliance:**

Compliance with this Alert Service Bulletin is mandatory.

**Appendix D cont**



# 1. PLANNING INFORMATION

## 1.A. EFFECTIVITY

### 1.A.1. Helicopters/installed equipment

EC135 T1, T2, T2+, P1, P2, P2+, 635 T1, 635 T2+, 635 P2+, up to and including S/N 1144.

### 1.A.2. Non-installed equipment

Not applicable.

## 1.B. ASSOCIATED REQUIREMENTS

Not applicable.

## 1.C. REASON

Eurocopter was informed of an issue involving the fuel indication system.

Tests have confirmed that the affected fuel content probes generate erroneously high signals if contamination with water occurs. In each case an incorrect frequency is being transmitted to the indicating system. That leads to an erroneously high indication of fuel quantity and prevents the amber FUEL caution light from operating.

The red LOW FUEL 1 & 2 warning lights continue to operate correctly.

## 1.D. DESCRIPTION

Perform system check of the supply tank indication system.

## 1.E. COMPLIANCE

### 1.E.1. Compliance at the works

Helicopters/installed equipment:

See section 1.E.2.

Non-installed equipment:

Not applicable.

### 1.E.2. Compliance in service

Helicopters/installed equipment:

The fuel system must be checked IAW Section 3.B.2 within 30 flight hours or within 4 weeks, whichever occurs first, after receipt of this Alert Service Bulletin.
Perform the following measurements subject to the results of the fuel system check:

(a) No further measures are necessary if the FUEL caution illuminates within the limitations given in Section 3.B.2.(g) and the LOW FUEL warning illuminates within the limitations given on page 8 of this Alert Service Bulletin.





**Appendix D cont**

EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-018

(b) Clean the fuel sensors IAW Section 3.B.3 and repeat the fuel system check IAW Section 3.B.2 of this Alert Service Bulletin,

- if the FUEL caution does not illuminate within the limitations given in Section 3.B.2.(g) and / or
- if the LOW FUEL warning does not illuminate within the limitations given on page 8.

(c) Replace fuel sensors before next flight, if the LOW FUEL warning does not illuminate at all.

(d) Cleaned fuel sensors (Section 3.B.3) that do not pass the fuel system check IAW Section 3.B.2 of this Alert Service Bulletin must be replaced within the time specified in the MMEL.

(e) Until the accomplishment of the fuel system check IAW Section 3.B.2 of this Alert Service Bulletin the application of the MMEL section 28-6, 28-7 and 28-10 on LOW FUEL of supply tank 1 & 2 is not permitted.

Non-installed equipment:

Not applicable.

**1.F. APPROVAL**

Approval of this document:

The technical content of this document is approved under the authority of DOA No. EASA.21J.034

**1.G. MANPOWER**

| Qualification | Mechanic | Electrician | Pilot | Others |
|---|---|---|---|---|
| Time for operations | approx. 1 h | - | approx. 1 h | - |

**1.H. WEIGHT AND BALANCE**

Not applicable.

**1.I. EFFECT ON ELECTRICAL LOADS**

Not applicable.

**1.J. SOFTWARE MODIFICATION EMBODIMENT RECORD**

Not applicable.

**1.K. REFERENCES**

Not applicable.

**1.L. DOCUMENTS AFFECTED**

Changes to the AMM EC135, and AMM EC135/635 which are required as a result of this Alert Service Bulletin will be incorporated with one of the next revisions.





**Appendix D cont**



**1.M. INTERCHANGEABILITY OR MIXABILITY OF PARTS**

Interchangeability:

Not applicable.

Mixability:

Not applicable.

## 2. MATERIAL INFORMATION

**2.A. MATERIAL: PRICE - AVAILABILITY - PROCUREMENT**

Not applicable.

**2.B. INFORMATION CONCERNING INDUSTRIAL SUPPORT**

Not applicable.

**2.C. MATERIAL REQUIRED FOR EACH HELICOPTER/COMPONENT**

Not applicable.





**Appendix D cont**

EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-018

## 3. ACCOMPLISHMENT INSTRUCTIONS

### 3.A. GENERAL

Not applicable.

### 3.B. OPERATIONAL PROCEDURE

#### 3.B.1. Preliminary steps

Make sure that a ground pre-flight check IAW FLM, including a fuel sediment/water check for each fuel tank drain, has been performed before complying with this ASB.

#### 3.B.2. Supply Fuel Tank check

**NOTE** Use the reply form sheet on page 8 to note down all results of the check.

**NOTE** The main tank level should be below 250 kg. Otherwise, the check will take a very long time.

**CAUTION** THE FOLLOWING CHECK MUST BE PERFORMED WITH ENGINES RUNNING. DO NOT PERFORM THIS CHECK BY MEANS OF DEFUELING THROUGH THE PRIME PUMPS OR DRAINING FROM THE DRAIN VALVES.

(a) Park the helicopter on a firm level floor.

(b) Note down the quantity displayed for SUPPLY #1, MAIN and SUPPLY #2.

(c) Start the engines in accordance with the Flight Manual. [ENG I and ENG II in FLIGHT; Collective pitch locked]. Start the clock.

(d) Note down any discrepancies or fluctuations of fuel tank quantities and/or any fuel system related cautions or warnings, both audio and visual, displayed during the start process.

(e) Confirm that the main tank fuel quantity level is decreasing until the main tank fuel quantity level falls below the level indicated in the supply tanks on the CAD graphical indication. Info: That indicates that the main tank level corresponds to the lower section of the overflow channel between the main and supply tanks.

(f) Switch off the FUEL PUMP XFER-A and FUEL PUMP XFER-F.

(g) Confirm that the supply tank 1 & 2 quantity indication decreases and continue until the FUEL caution illuminates on the CAD. The FUEL caution illuminates as soon as the first limit is reached:
680 liters: 38-40kg remaining in supply tank 1, 33-35kg remaining in supply tank 2.
710 liters: 34-36kg remaining in supply tank 1, 30-32kg remaining in supply tank 2.
Note: It is not unusual if the main tank level continues to decrease during the first minutes. This can be explained by the fuel system architecture of the helicopter and is a normal behavior.
Note: There is no FUEL caution for CDS and CPDS before version 2002.





**Appendix D cont**



(h) Note down the SUPPLY #1, MAIN and SUPPLY #2 contents at the moment the FUEL caution is illuminated.

(i) Monitor the level reduction of supply tank 1 and supply tank 2 until the LOW FUEL 1 and LOW FUEL 2 warnings illuminate. It does not matter which LOW FUEL warning illuminates first.

(j) Note down the SUPPLY #1 and SUPPLY #2 contents at the time each LOW FUEL warning light illuminates.

(k) Switch on the FUEL PUMP XFER-F and FUEL PUMP XFER-A. Note: Make sure that a sufficient amount of fuel is in the main tank.

(l) Confirm that the supply tanks 1 and 2 are replenished to maximum and relevant warnings and caution no longer appear.

(m) Shutdown the engines.

(n) Note down the SUPPLY #1, MAIN and SUPPLY #2 fuel quantities.

(o) Stop the clock.

(p) See Section 1.E.2 of this Alert Service Bulletin for the measurements necessary and proceed accordingly. If no further measurements are necessary proceed with Section 3.B.4.

**3.B.3. Cleaning of fuel system and fuel sensors**

**NOTE** Water contamination or sediments can cause wrong fuel quantity indications. The following procedure describes how to clean the sensors.

(a) Drain the fuel tank system at all four drain points and check for the presence of water and any other contaminations.

(b) Drain the LH and RH Supply Tanks completely.

(c) Remove the LH and RH Supply tank fuel sensors IAW the AMM.

(d) Perform a detailed visual inspection of the supply tank fuel sensors - especially in between the two concentric tubes for any signs of contamination.

(e) Flush the supply tank fuel sensors by using fresh fuel or isopropyl alcohol.

(f) Blow the sensors dry by using nitrogen or dry compressed air.

**CAUTION** DO NOT OVERHEAT THE SENSORS.

(g) Put the sensors into an oven for 30 min. with a temperature of 50 - 60 degrees (C) or heat the sensors by other means.

(h) Let the sensors cool down to room temperature for approx. 30 min. before reinstalling it.



**Appendix D cont**



(i) Reinstall the sensors IAW the AMM.

(j) Accomplish Section 3.B.2.

**3.B.4. Feedback of information**

(a) Return the reply form sheet on page 8 to ECD.

**3.C. IDENTIFICATION**

Identification of this document:

Confirm accomplishment of this Alert Service Bulletin by making an entry into the historical record of the helicopter.

**3.D. OPERATING AND MAINTENANCE INSTRUCTIONS**

Flight Manual (FLM):

Not applicable.

Aircraft Maintenance Manual (AMM):

Not applicable.

## 4. APPENDIX

Not applicable.

## Appendix D cont

EUROCOPTER
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**ASB** EC135-28A-018

# Telefax

**Reply form sheet for ASB EC135-28A-018 "System check of supply tank"**
Note: An electronic form of the reply form sheet is available on www.ecdefeed.com.
Please fill out the reply form sheet completely and send it to the following FAX No. / e-mail.

To Eurocopter Deutschland GmbH Customer Support
FAX 0049 906 714111 or e-mail: Vehicle.ecd.technical-support@eurocopter.com

☐ First system check ☐ System check after cleaning sensors

HELICOPTER S/N and version:

Total FUEL at Start of Engines

CONTENTS

| | SUPPLY #1 | MAIN | SUPPLY #2 |
|---|---|---|---|
| Time at start of engines | | | |
| Time when XFER pumps SW off | | | |
| Time when FUEL caution illuminates | | | |
| Time when LOW FUEL 1 warning illuminates | | | |
| Time when LOW FUEL 2 warning illuminates | | | |
| Time at shutdown of engines | | | |

OAT P'Alt Note any nose up/down pitch angle

Limitations 710 Liters:
LOW FUEL 1 illuminated: 26-34kg remaining in supply tank 1
LOW FUEL 2 illuminated: 22-30kg remaining in supply tank 2
Limitations 680 Liters:
LOW FUEL 1 illuminated: At least 16kg
LOW FUEL 2 illuminated: At least 16kg

Date:__________ Signature:____________________

**Please copy page! Original page remains in Alert Service Bulletin!**

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## Appendix E

## Eurocopter Alert Service Bulletin EC135-28A-019

EUROCOPTER
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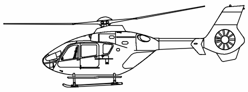
**ASB** EC135-28A-019



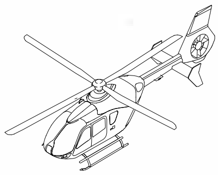
Valid for Version(s): T1, T2, T2+, P1, P2, P2+
635 T1, 635 T2+, 635 P2+

# ALERT SERVICE BULLETIN

**SUBJECT:** **FUEL SYSTEM – Fuel Monitoring and Fuel Quantity Indication**

**Flight Manual enhancement to cover possible incorrect fuel level indication of the supply tanks**

For the attention of



| Revision No. | Date of issue |
|---|---|
| Revision 0 | 2013-12-19 |

**Summary:**

With this Alert Service Bulletin, Eurocopter distributes a temporary Revision of the Flight Manual (FLM). This temporary Revision will enhance the FLM in order to cover a possible incorrect fuel level indication of the supply tanks.

**Compliance:**

Compliance with this Alert Service Bulletin is mandatory.





**Appendix E cont**

EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

## 1. PLANNING INFORMATION

### 1.A. EFFECTIVITY

#### 1.A.1. Helicopters/installed equipment

EC135, T1, T2, T2+, P1, P2, P2+, 635 T1, 635 T2+, 635 P2+, all S/N.

#### 1.A.2. Non-installed equipment

Not applicable.

### 1.B. ASSOCIATED REQUIREMENTS

Not applicable.

### 1.C. REASON

Eurocopter has been informed of an issue involving the fuel indication system. The first analysis shows that the indication of the fuel quantity in the supply tanks could be incorrect.

For this Reason a temporary Revision of the FLM, Section 3 will be distributed with this Alert Service Bulletin. Main changes are:

♦ Additional warning for the “LOW FUEL” warning.

♦ Additional information about F PUMP Conditions/Indications.

### 1.D. DESCRIPTION

Insert the temporary Revision into the affected FLM.

### 1.E. COMPLIANCE

#### 1.E.1. Compliance at the works

<u>Helicopters/installed equipment:</u>

Not applicable.

<u>Non-installed equipment:</u>

Not applicable.

#### 1.E.2. Compliance in service

<u>Helicopters/installed equipment:</u>

Immediately after the receipt of this Alert Service Bulletin a copy of the version-related temporary Revision for the FLM, Section 3 must be cut out and inserted into the FLM i.a.w. Section 3.B.1.

After accomplishment of the measures given in this Alert Service Bulletin, the pilots must be informed on its content and on their attention must be drawn to the fact that they must comply with the temporary Revision of the FLM, Section 3.

<u>Non-installed equipment:</u>

Not applicable.





**Appendix E cont**



**1.F. APPROVAL**

Approval of this document:

The technical content of this document is approved under the authority of DOA No. EASA.21J.034.

**1.G. MANPOWER**

Not applicable.

**1.H. WEIGHT AND BALANCE**

Not applicable.

**1.I. EFFECT ON ELECTRICAL LOADS**

Not applicable.

**1.J. SOFTWARE MODIFICATION EMBODIMENT RECORD**

Not applicable.

**1.K. REFERENCES**

Not applicable.

**1.L. DOCUMENTS AFFECTED**

The changes to the FLM, Section 3 are incorporated with the following temporary revisions:

- EC135 T2+ Temp. Rev. 7
- EC635 T2+ Temp. Rev. 7
- EC135 P2+ Temp. Rev. 8
- EC635 P2+ Temp. Rev. 8
- EC135 P2 (CPDS) Temp. Rev. 13
- EC135 T2 (CPDS) Temp. Rev. 14
- EC135 T1 (CPDS) Temp. Rev. 19
- EC635 T1 (CPDS) Temp. Rev. 19
- EC135 P1 (CPDS) Temp. Rev. 16
- EC135 T1 (CDS) Temp. Rev. 25
- EC135 P1 (CDS) Temp. Rev. 22

**1.M. INTERCHANGEABILITY OR MIXABILITY OF PARTS**

Interchangeability:

Not applicable.

Mixability:

Not applicable.

**Appendix E cont**



## 2. MATERIAL INFORMATION

### 2.A. MATERIAL: PRICE - AVAILABILITY - PROCUREMENT

Not applicable.

### 2.B. INFORMATION CONCERNING INDUSTRIAL SUPPORT

Not applicable.

### 2.C. MATERIAL REQUIRED FOR EACH HELICOPTER/COMPONENT

Not applicable.

### 2.D. MATERIAL TO BE RETURNED

Not applicable.





## Appendix E cont

EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

### 3. ACCOMPLISHMENT INSTRUCTIONS

#### 3.A. GENERAL

Not applicable.

#### 3.B. OPERATIONAL PROCEDURE

#### 3.B.1. Verfahren

(a) Copy the version-related temporary Revision which is attached to this Alert Service Bulletin. Cut it out and insert it into the FLM.

#### 3.C. IDENTIFICATION

Not applicable.

#### 3.D. OPERATING AND MAINTENANCE INSTRUCTIONS

Flight Manual (FLM):

Not applicable.

Aircraft Maintenance Manual (AMM):

Not applicable.

### 4. APPENDIX

| | | |
|---|---|---|
| - EC135 T2+ | Temp. Rev. 7 | Page 6-7 |
| - EC635 T2+ | Temp. Rev. 7 | Page 8-9 |
| - EC135 P2+ | Temp. Rev. 8 | Page 10-12 |
| - EC635 P2+ | Temp. Rev. 8 | Page 13-15 |
| - EC135 P2 (CPDS) | Temp. Rev. 13 | Page 16-18 |
| - EC135 T2 (CPDS) | Temp. Rev. 14 | Page 19-20 |
| - EC135 T1 (CPDS) | Temp. Rev. 19 | Page 21-22 |
| - EC635 T1 (CPDS) | Temp. Rev. 19 | Page 23-24 |
| - EC135 P1 (CPDS) | Temp. Rev. 16 | Page 25-27 |
| - EC135 T1 (CDS) | Temp. Rev. 25 | Page 28-30 |
| - EC135 P1 (CDS) | Temp. Rev. 22 | Page 31-32 |

**Appendix E cont**

EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

EUROCOPTER FLIGHT MANUAL EC 135 T2+

Emergency and Malfunction Procedures

### WARNING LIGHT INDICATIONS

**LIMIT**

(ON VEMD)

**Conditions/Indications**

One of the following limits is exceeded:

– Torque, TOT, ΔN1, Mastmoment, OEI 30 sec. time limit, OEI 2.0 min. time limit, TOP time limit

Warning GONG will be activated

**Procedure**

| | | |
|---|---|---|
| 1. | Respective parameter | – Reduce |

### WARNING LIGHT INDICATIONS

**LOW FUEL 1** (SYSTEM I) and / or **LOW FUEL 2** (SYSTEM II)

**Conditions/Indications**

– Respective supply tank fuel quantity below threshold value
– Warning GONG will be activated

**Procedure**

| | | |
|---|---|---|
| 1. | Fuel quantity indication | – Check |
| | If positive fuel indication in the main tank: | |
| 2. | Both fuel pump XFER sw (F + A) | – Check ON |
| 3. | Both fuel pump XFER circuit breaker (F + A) | – Check in |
| | If FUEL LOW warning light remains on: | |
| 4. | Air Condition (if installed) | – Switch OFF |
| 5. | Bleed Air | – Switch OFF (If OAT > 5° C) |

***EFFECTIVITY*** *For helicopters with 680 liters fuel tank (673 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 8 MINUTES**

***EFFECTIVITY*** *For helicopters with 710 liters fuel tank (701 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 10 MINUTES**

***EFFECTIVITY*** *All*

**WARNING** THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.

EASA APPROVED
Temp.Rev. 7 **3 - 8**

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## Appendix E cont

EUROCOPTER
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**ASB** EC135-28A-019

FLIGHT MANUAL EC 135 T2+
Emergency and Malfunction Procedures

EUROCOPTER
AN EADS COMPANY

**CAUTION INDICATIONS**

**F PUMP AFT** and **F PUMP FWD**
(MISC) (MISC)

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

| | | |
|---|---|---|
| 1. | Fuel quantity indication of main tank/supply tanks (CAD) | – Check |
| 2. | FUEL PUMP XFER-A and –F sw | – Check ON |
| 3. | FUEL PUMP XFER-A and –F cb | – Check in |
| 4. | LAND AS SOON AS PRACTICABLE | |

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning

**CAUTION INDICATIONS**

**F PUMP AFT**
(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

1. Fuel level in the main tank – Check

<u>If main tank fuel quantity is sufficient to keep both fuel pumps wet:</u>

2. FUEL PUMP XFER-A sw – Check ON
3. XFER-A PUMP circuit breaker – Check in

If F PUMP AFT indication remains on:

4. FUEL PUMP XFER-A sw – OFF

<u>If main tank fuel quantity is low:</u>

2. FUEL PUMP XFER-A sw OFF

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.

3 - 25 EASA APPROVED
Temp.Rev. 7

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EUROCOPTER
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**ASB** EC135-28A-019

EUROCOPTER

FLIGHT MANUAL EC 635 T2+

Emergency and Malfunction Procedures

**WARNING LIGHT INDICATIONS**

LIMIT

(ON VEMD)

**Conditions/Indications**

One of the following limits is exceeded:

– Torque, TOT, ΔN1, Mastmoment, OEI 30 sec. time limit, OEI 2.0 min. time limit, TOP time limit

Warning GONG will be activated

**Procedure**

| | | |
|---|---|---|
| 1. | Respective parameter | – Reduce |

**WARNING LIGHT INDICATIONS**

LOW FUEL 1 (SYSTEM I) and / or LOW FUEL 2 (SYSTEM II)

**Conditions/Indications**

– Respective supply tank fuel quantity below threshold value
– Warning GONG will be activated

**Procedure**

| | | |
|---|---|---|
| 1. | Fuel quantity indication | – Check |
| | If positive fuel indication in the main tank: | |
| 2. | Both fuel pump XFER sw (F + A) | – Check ON |
| 3. | Both fuel pump XFER circuit breaker (F + A) | – Check in |
| | If FUEL LOW warning light remains on: | |
| 4. | Air Condition (if installed) | – Switch OFF |
| 5. | Bleed Air | – Switch OFF (If OAT > 5°C) |

***EFFECTIVITY*** *For helicopters with 680 liters fuel tank (673 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 8 MINUTES**

***EFFECTIVITY*** *For helicopters with 710 liters fuel tank (701 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 10 MINUTES**

***EFFECTIVITY*** *All*

**WARNING** THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.

EASA APPROVED
Temp.Rev. 7 3 - 8

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## Appendix E cont

EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

FLIGHT MANUAL EC 635 T2+

Emergency and Malfunction Procedures

EUROCOPTER AN EADS COMPANY

### CAUTION INDICATIONS

**F PUMP AFT** and **F PUMP FWD**

(MISC) (MISC)

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

| | |
|---|---|
| 1. Fuel quantity indication of main tank/supply tanks (CAD) | – Check |
| 2. FUEL PUMP XFER-A and –F sw | – Check ON |
| 3. FUEL PUMP XFER-A and –F cb | – Check in |
| 4. LAND AS SOON AS PRACTICABLE | |

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning.

### CAUTION INDICATIONS

**F PUMP AFT**

(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

| | |
|---|---|
| 1. Fuel level in the main tank | – Check |
| If main tank fuel quantity is sufficient to keep both fuel pumps wet: | |
| 2. FUEL PUMP XFER-A sw | – Check ON |
| 3. XFER-A PUMP circuit breaker | – Check in |
| If F PUMP AFT indication remains on: | |
| 4. FUEL PUMP XFER-A sw | – OFF |
| If main tank fuel quantity is low: | |
| 2. FUEL PUMP XFER-A sw | OFF |

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.

3 - 25 EASA APPROVED TempRev. 7

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**Appendix E cont**

EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

EUROCOPTER FLIGHT MANUAL EC 135 P2+

Emergency and Malfunction Procedures

**WARNING LIGHT INDICATIONS**

LIMIT

(ON VEMD)

**Conditions/Indications**

One of the following limits is exceeded:

– Torque, TOT, N1, Mastmoment, OEI 30 sec. time limit, OEI 2.0 min. time limit, TOP time limit

Warning GONG will be activated

**Procedure**

1. Respective parameter – Reduce

**NOTE** If the counter time limit for OEI 30sec./ 2.0 min. power is exceeded, ENG EXCEED caution will also illuminate.

**WARNING LIGHT INDICATIONS**

LOW FUEL 1 (SYSTEM I) and / or LOW FUEL 2 (SYSTEM II)

**Conditions/Indications**

– Respective supply tank fuel quantity below threshold value
– Warning GONG will be activated

**Procedure**

1. Fuel quantity indication – Check

If positive fuel indication in the main tank:

2. Both fuel pump XFER sw (F + A) – Check ON
3. Both fuel pump XFER circuit breaker (F + A) – Check in

If FUEL LOW warning light remains on:

4. Air Condition (if installed) – Switch OFF
5. Bleed Air – Switch OFF (If OAT > 5°C)

***EFFECTIVITY*** *For helicopters with 680 liters fuel tank (673 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 8 MINUTES**

***EFFECTIVITY*** *For helicopters with 710 liters fuel tank (701 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 10 MINUTES**

***EFFECTIVITY*** *All*

**WARNING** THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.

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EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

FLIGHT MANUAL EC 135 P2+ EUROCOPTER

Emergency and Malfunction Procedures

**CAUTION INDICATIONS**

**F FLT CT** (SYSTEM I) or **F FLT CT** (SYSTEM II)

**Conditions/Indications**

Test of cables and connectors to the sensor failed during CPDS EXTERNAL TEST

**CAUTION** FUEL FILT CAUTION IS NOT AVAILABLE.

**Procedure**

Do not start engines. Maintenance action required.

**CAUTION INDICATIONS**

**F PUMP AFT** (MISC) and **F PUMP FWD** (MISC)

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

1. Fuel quantity indication of main tank/supply tanks (CAD) – Check
2. FUEL PUMP XFER-A and –F sw – Check ON
3. FUEL PUMP XFER-A and –F cb – Check in
4. LAND AS SOON AS PRACTICABLE

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning.

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EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

EUROCOPTER
AN EADS COMPANY

FLIGHT MANUAL EC 135 P2+
Emergency and Malfunction Procedures

**CAUTION INDICATIONS**

**F PUMP AFT**

(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

1. Fuel level in the main tank – Check

<u>If main tank fuel quantity is sufficient to keep both fuel pumps wet:</u>

2. FUEL PUMP XFER-A sw – Check ON
3. XFER-A PUMP circuit breaker – Check in

If F PUMP AFT indication remains on:

4. FUEL PUMP XFER-A sw – OFF

<u>If main tank fuel quantity is low:</u>

2. FUEL PUMP XFER-A sw OFF

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.

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**WARNING LIGHT INDICATIONS**

**LIMIT**

(ON VEMD)

**Conditions/Indications**

One of the following limits is exceeded:

– Torque, TOT, N1, Mastmoment, OEI 30 sec. time limit, OEI 2.0 min. time limit, TOP time limit

Warning GONG will be activated

**Procedure**

1. Respective parameter – Reduce

**NOTE** If the counter time limit for OEI 30sec./ 2.0 min. power is exceeded, ENG EXCEED caution will also illuminate.

**WARNING LIGHT INDICATIONS**

**LOW FUEL 1** (SYSTEM I) and / or **LOW FUEL 2** (SYSTEM II)

**Conditions/Indications**

– Respective supply tank fuel quantity below threshold value
– Warning GONG will be activated

**Procedure**

1. Fuel quantity indication – Check

If positive fuel indication in the main tank:

2. Both fuel pump XFER sw (F + A) – Check ON
3. Both fuel pump XFER circuit breaker (F + A) – Check in

If FUEL LOW warning light remains on:

4. Air Condition (if installed) – Switch OFF
5. Bleed Air – Switch OFF (If OAT > 5°C)

***EFFECTIVITY*** *For helicopters with 680 liters fuel tank (673 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 8 MINUTES**

***EFFECTIVITY*** *For helicopters with 710 liters fuel tank (701 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 10 MINUTES**

***EFFECTIVITY*** *All*

**WARNING** THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.



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## Appendix E cont

EUROCOPTER
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**ASB** EC135-28A-019

FLIGHT MANUAL EC 635 P2+
Emergency and Malfunction Procedures

EUROCOPTER
AN EADS COMPANY

**CAUTION INDICATIONS**

**F FLT CT** (SYSTEM I) or **F FLT CT** (SYSTEM II)

**Conditions/Indications**

Test of cables and connectors to the sensor failed during CPDS EXTERNAL TEST

**CAUTION** FUEL FILT CAUTION IS NOT AVAILABLE.

**Procedure**

Do not start engines. Maintenance action required.

**CAUTION INDICATIONS**

**F PUMP AFT** (MISC) and **F PUMP FWD** (MISC)

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

1. Fuel quantity indication of main tank/supply tanks (CAD) – Check
2. FUEL PUMP XFER-A and –F sw – Check ON
3. FUEL PUMP XFER-A and –F cb – Check in
4. LAND AS SOON AS PRACTICABLE

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning.

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EUROCOPTER
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**ASB** EC135-28A-019

EUROCOPTER
AN EADS COMPANY

FLIGHT MANUAL EC 635 P2+

Emergency and Malfunction Procedures

**CAUTION INDICATIONS**

**F PUMP AFT**

(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

| | | |
|---|---|---|
| 1. | Fuel level in the main tank | – Check |

If main tank fuel quantity is sufficient to keep both fuel pumps wet:

| | | |
|---|---|---|
| 2. | FUEL PUMP XFER-A sw | – Check ON |
| 3. | XFER-A PUMP circuit breaker | – Check in |

If F PUMP AFT indication remains on:

| | | |
|---|---|---|
| 4. | FUEL PUMP XFER-A sw | – OFF |

If main tank fuel quantity is low:

| | | |
|---|---|---|
| 2. | FUEL PUMP XFER-A sw | OFF |

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.

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EUROCOPTER
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**ASB** EC135-28A-019

EUROCOPTER FLIGHT MANUAL EC 135 P2 (CPDS)

Emergency and Malfunction Procedures

**WARNING LIGHT INDICATIONS**

LIMIT

(ON VEMD)

**Conditions/Indications**

One of the following limits is exceeded:

- Torque, TOT, N1, Mastmoment, OEI 30 sec. time limit, OEI 2.0 min. time limit, TOP time limit

Warning GONG will be activated

**Procedure**

1. Respective parameter – Reduce

**NOTE** If the counter time limit for OEI 30sec./ 2.0 min. power is exceeded, ENG EXCEED caution will also illuminate.

**WARNING LIGHT INDICATIONS**

LOW FUEL 1 (SYSTEM I) and / or LOW FUEL 2 (SYSTEM II)

**Conditions/Indications**

- Respective supply tank fuel quantity below threshold value
- Warning GONG will be activated

**Procedure**

1. Fuel quantity indication – Check

If positive fuel indication in the main tank:

2. Both fuel pump XFER sw (F + A) – Check ON
3. Both fuel pump XFER circuit breaker (F + A) – Check in

If FUEL LOW warning light remains on:

4. Air Condition (if installed) – Switch OFF
5. Bleed Air – Switch OFF (If OAT > 5°C)

***EFFECTIVITY*** *For helicopters with 680 liters fuel tank (673 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 8 MINUTES**

***EFFECTIVITY*** *For helicopters with 710 liters fuel tank (701 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 10 MINUTES**

***EFFECTIVITY*** *All*

**WARNING** THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.

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EUROCOPTER
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**ASB** EC135-28A-019

EUROCOPTER
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FLIGHT MANUAL EC 135 P2 (CPDS)
Emergency and Malfunction Procedures

**CAUTION INDICATIONS**

**F FLT CT** (SYSTEM I) or **F FLT CT** (SYSTEM II)

**Conditions/Indications**

Test of cables and connectors to the sensor failed during CPDS EXTERNAL TEST

**CAUTION** FUEL FILT CAUTION IS NOT AVAILABLE.

**Procedure**

Do not start engines. Maintenance action required.

**CAUTION INDICATIONS**

**F PUMP AFT** (MISC) and **F PUMP FWD** (MISC)

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

1. Fuel quantity indication of main tank/supply tanks (CAD) – Check
2. FUEL PUMP XFER-A and –F sw – Check ON
3. FUEL PUMP XFER-A and –F cb – Check in
4. LAND AS SOON AS PRACTICABLE

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning.

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## CAUTION INDICATIONS

### F PUMP AFT

(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

1. Fuel level in the main tank – Check

If main tank fuel quantity is sufficient to keep both fuel pumps wet:

2. FUEL PUMP XFER-A sw – Check ON
3. XFER-A PUMP circuit breaker – Check in

If F PUMP AFT indication remains on:

4. FUEL PUMP XFER-A sw – OFF

If main tank fuel quantity is low:

2. FUEL PUMP XFER-A sw OFF

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.



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EUROCOPTER
AN EADS COMPANY

ASB EC135-28A-019

EUROCOPTER FLIGHT MANUAL EC 135 T2 (CPDS)

Emergency and Malfunction Procedures

### WARNING LIGHT INDICATIONS

LIMIT
(ON VEMD)

**Conditions/Indications**

One of the following limits is exceeded:

– Torque, TOT, ΔN1, Mastmoment, OEI 30 sec. time limit, OEI 2.0 min. time limit, TOP time limit

Warning GONG will be activated

**Procedure**

1. Respective parameter – Reduce

### WARNING LIGHT INDICATIONS

LOW FUEL 1 (SYSTEM I) and / or LOW FUEL 2 (SYSTEM II)

**Conditions/Indications**

– Respective supply tank fuel quantity below threshold value
– Warning GONG will be activated

**Procedure**

1. Fuel quantity indication – Check

If positive fuel indication in the main tank:

2. Both fuel pump XFER sw (F + A) – Check ON
3. Both fuel pump XFER circuit breaker (F + A) – Check in

If FUEL LOW warning light remains on:

4. Air Condition (if installed) – Switch OFF
5. Bleed Air – Switch OFF (If OAT > 5°C)

***EFFECTIVITY*** *For helicopters with 680 liters fuel tank (673 liters if selfsealing supplytanks are installed)*

**6. LAND WITHIN 8 MINUTES**

***EFFECTIVITY*** *For helicopters with 710 liters fuel tank (701 liters if selfsealing supply tanks are installed)*

**6. LAND WITHIN 10 MINUTES**

***EFFECTIVITY*** *All*

**WARNING** THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.

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**CAUTION INDICATIONS**

**F PUMP AFT** and **F PUMP FWD**

(MISC) (MISC)

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

1. Fuel quantity indication of main tank/supply tanks (CAD) – Check
2. FUEL PUMP XFER-A and –F sw – Check ON
3. FUEL PUMP XFER-A and –F cb – Check in
4. LAND AS SOON AS PRACTICABLE

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning.

**CAUTION INDICATIONS**

**F PUMP AFT**

(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

1. Fuel level in the main tank – Check

<u>If main tank fuel quantity is sufficient to keep both fuel pumps wet:</u>

2. FUEL PUMP XFER-A sw – Check ON
3. XFER-A PUMP circuit breaker – Check in

If F PUMP AFT indication remains on:

4. FUEL PUMP XFER-A sw – OFF

<u>If main tank fuel quantity is low:</u>

2. FUEL PUMP XFER-A sw OFF

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.



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**WARNING LIGHT INDICATIONS**

LIMIT
(ON VEMD)

**Conditions/Indications**

One of the following limits is exceeded:

– Torque, TOT, ΔN1, Mastmoment, OEI 2.5 min. time limit, TOP time limit

Warning GONG will be activated

**Procedure**

1. Respective parameter – Reduce

**WARNING LIGHT INDICATIONS**

| LOW FUEL 1 (SYSTEM I) | and / or | LOW FUEL 2 (SYSTEM II) |
|---|---|---|

**Conditions/Indications**

– Respective supply tank fuel quantity below threshold value

– Warning GONG will be activated

**Procedure**

1. Fuel quantity indication – Check

If positive fuel indication in the main tank:

2. Both fuel pump XFER sw (F + A) – Check ON
3. Both fuel pump XFER circuit breaker (F + A) – Check in

If FUEL LOW warning light remains on:

4. Air Condition (if installed) – Switch OFF
5. Bleed Air – Switch OFF (If OAT > 5°C)
6. **LAND WITHIN 8 MINUTES**

WARNING THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.



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**CAUTION INDICATIONS**

**F PUMP AFT** (MISC) and **F PUMP FWD** (MISC)

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

| | | |
|---|---|---|
| 1. | Fuel quantity indication of main tank/supply tanks (CAD) | – Check |
| 2. | FUEL PUMP XFER-A and –F sw | – Check ON |
| 3. | FUEL PUMP XFER-A and –F cb | – Check in |
| 4. | LAND AS SOON AS PRACTICABLE | |

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning.

**CAUTION INDICATIONS**

**F PUMP AFT**

(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

1. Fuel level in the main tank – Check

If main tank fuel quantity is sufficient to keep both fuel pumps wet:

2. FUEL PUMP XFER-A sw – Check ON
3. XFER-A PUMP circuit breaker – Check in

If F PUMP AFT indication remains on:

4. FUEL PUMP XFER-A sw – OFF

If main tank fuel quantity is low:

2. FUEL PUMP XFER-A sw OFF

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.



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EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

EUROCOPTER FLIGHT MANUAL EC 635 T1 (CPDS)

Emergency and Malfunction Procedures

**WARNING LIGHT INDICATIONS**

**LIMIT**

(ON VEMD)

**Conditions/Indications**

One of the following limits is exceeded:

– Torque, TOT, ΔN1, Mastmoment, OEI 2.5 min. time limit, TOP time limit

Warning GONG will be activated

**Procedure**

1. Respective parameter – Reduce

**WARNING LIGHT INDICATIONS**

**LOW FUEL 1** (SYSTEM I) and / or **LOW FUEL 2** (SYSTEM II)

**Conditions/Indications**

– Respective supply tank fuel quantity below threshold value

– Warning GONG will be activated

**Procedure**

1. Fuel quantity indication – Check

<u>If positive fuel indication in the main tank:</u>

2. Both fuel pump XFER sw (F + A) – Check ON
3. Both fuel pump XFER circuit breaker (F + A) – Check in

<u>If FUEL LOW warning light remains on:</u>

4. Air Condition (if installed) – Switch OFF
5. Bleed Air – Switch OFF (If OAT > 5° C)
6. **LAND WITHIN 8 MINUTES**

**WARNING** THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.

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**ASB** EC135-28A-019

EUROCOPTER
AN EADS COMPANY

FLIGHT MANUAL EC 635 T1 (CPDS)

Emergency and Malfunction Procedures

### CAUTION INDICATIONS

**F PUMP AFT** and **F PUMP FWD**

(MISC) (MISC)

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

1. Fuel quantity indication of main tank/supply tanks (CAD) – Check
2. FUEL PUMP XFER-A and –F sw – Check ON
3. FUEL PUMP XFER-A and –F cb – Check in
4. LAND AS SOON AS PRACTICABLE

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning.

### CAUTION INDICATIONS

**F PUMP AFT**

(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

1. Fuel level in the main tank – Check

<u>If main tank fuel quantity is sufficient to keep both fuel pumps wet:</u>

2. FUEL PUMP XFER-A sw – Check ON
3. XFER-A PUMP circuit breaker – Check in

If F PUMP AFT indication remains on:

4. FUEL PUMP XFER-A sw – OFF

<u>If main tank fuel quantity is low:</u>

2. FUEL PUMP XFER-A sw OFF

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.

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EUROCOPTER
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**ASB** EC135-28A-019

EUROCOPTER FLIGHT MANUAL EC 135 P1 (CPDS)
Emergency and Malfunction Procedures

**WARNING LIGHT INDICATIONS**

**LIMIT**
(ON VEMD)

**Conditions/Indications**

One of the following limits is exceeded:

– Torque, TOT, N1, Mastmoment, OEI 2.5 min. time limit, TOP time limit

Warning GONG will be activated

**Procedure**

| | |
|---|---|
| 1. Respective parameter | – Reduce |

**WARNING LIGHT INDICATIONS**

**LOW FUEL 1** (SYSTEM I) and / or **LOW FUEL 2** (SYSTEM II)

**Conditions/Indications**

– Respective supply tank fuel quantity below threshold value

– Warning GONG will be activated

**Procedure**

| | |
|---|---|
| 1. Fuel quantity indication | – Check |
| <u>If positive fuel indication in the main tank:</u> | |
| 2. Both fuel pump XFER sw (F + A) | – Check ON |
| 3. Both fuel pump XFER circuit breaker (F + A) | – Check in |
| <u>If FUEL LOW warning light remains on:</u> | |
| 4. Air Condition (if installed) | – Switch OFF |
| 5. Bleed Air | – Switch OFF (If OAT > 5°C) |
| **6. LAND WITHIN 8 MINUTES** | |

**WARNING** THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.

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EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

FLIGHT MANUAL EC 135 P1 (CPDS)

Emergency and Malfunction Procedures

EUROCOPTER
AN EADS COMPANY

**CAUTION INDICATIONS**

| | | |
|---|---|---|
| **F FLT CT** (SYSTEM I) | or | **F FLT CT** (SYSTEM II) |

**Conditions/Indications**

Test of cables and connectors to the sensor failed during CPDS EXTERNAL TEST

**CAUTION** FUEL FILT CAUTION IS NOT AVAILABLE.

**Procedure**

Do not start engines. Maintenance action required.

**CAUTION INDICATIONS**

| | | |
|---|---|---|
| **F PUMP AFT** (MISC) | and | **F PUMP FWD** (MISC) |

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

1. Fuel quantity indication of main tank/supply tanks (CAD) – Check
2. FUEL PUMP XFER-A and –F sw – Check ON
3. FUEL PUMP XFER-A and –F cb – Check in
4. LAND AS SOON AS PRACTICABLE

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning.

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AN EADS COMPANY

**ASB** EC135-28A-019

EUROCOPTER
AN EADS COMPANY

FLIGHT MANUAL EC 135 P1 (CPDS)

Emergency and Malfunction Procedures

**CAUTION INDICATIONS**

**F PUMP AFT**

(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

1. Fuel level in the main tank – Check

If main tank fuel quantity is sufficient to keep both fuel pumps wet:

2. FUEL PUMP XFER-A sw – Check ON
3. XFER-A PUMP circuit breaker – Check in

If F PUMP AFT indication remains on:

4. FUEL PUMP XFER-A sw – OFF

If main tank fuel quantity is low:

2. FUEL PUMP XFER-A sw OFF

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.

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EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

EUROCOPTER

FLIGHT MANUAL EC 135 T1 (CDS)

Emergency and Malfunction Procedures

**WARNING LIGHT INDICATIONS**

| LOW FUEL 1 (SYSTEM I) | and / or | LOW FUEL 2 (SYSTEM II) |
|---|---|---|

**Conditions/Indications**

– Respective supply tank fuel quantity below threshold value

– Respective LOW indication light (red) on CDS FUEL display may come on

– Warning GONG will be activated

**Procedure**

1. Fuel quantity indication – Check

<u>If positive fuel indication in the main tank:</u>

2. Both fuel pump XFER sw (F + A) – Check ON
3. Both fuel pump XFER circuit breaker (F + A) – Check in

<u>If FUEL LOW warning light remains on:</u>

4. Air Condition (if installed) – Switch OFF
5. Bleed Air – Switch OFF (If OAT > 5 °C)
6. **LAND WITHIN 8 MINUTES**

**WARNING** THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.

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## Appendix E cont

EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

EUROCOPTER FLIGHT MANUAL EC 135 T1 (CDS)

Emergency and Malfunction Procedures

**NOTE** If the flight situation requires maximum engine power, the torque setting of the affected engine may be increased. However, rotor speed and engine parameters shall be observed closely.

5. LAND AS SOON AS PRACTICABLE

After landing:

| | |
|---|---|
| **6. Respective TWIST GRIP** | **– Reduce, before lowering the collective pitch lever to full down position (to keep $N_2/N_{RO}$ within limits)** |

**CAUTION** THERE IS NO $N_{RO}$ GOVERNING FOLLOWING FADEC FAILURES OF BOTH ENGINES. $N_{RO}$ AND POWER MUST BE CONTROLLED BY THE PILOT USING A COMBINATION OF COLLECTIVE AND TWIST GRIP MOVES.

**NOTE** Perform appropriate logbook entry. Maintenance action is required.

**CAUTION INDICATIONS**

**F PUMP AFT** and **F PUMP FWD**

(MISC) (MISC)

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

| | |
|---|---|
| 1. Fuel quantity indication of main tank/supply tanks (CAD) | – Check |
| 2. FUEL PUMP XFER-A and –F sw | – Check ON |
| 3. FUEL PUMP XFER-A and –F cb | – Check in |

4. LAND AS SOON AS PRACTICABLE

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning.

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EUROCOPTER
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**ASB** EC135-28A-019

FLIGHT MANUAL EC 135 T1 (CDS)
Emergency and Malfunction Procedures

EUROCOPTER
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**CAUTION INDICATIONS**

**F PUMP AFT**

(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

1. Fuel level in the main tank – Check

If main tank fuel quantity is sufficient to keep both fuel pumps wet:

2. FUEL PUMP XFER-A sw – Check ON
3. XFER-A PUMP circuit breaker – Check in

If F PUMP AFT indication remains on:

4. FUEL PUMP XFER-A sw – OFF

If main tank fuel quantity is low:

2. FUEL PUMP XFER-A sw OFF

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.

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## Appendix E cont



EUROCOPTER
FLIGHT MANUAL EC 135 P1 (CDS)
Emergency and Malfunction Procedures

### WARNING LIGHT INDICATIONS

| LOW FUEL 1 (SYSTEM I) | and / or | LOW FUEL 2 (SYSTEM II) |
|---|---|---|

**Conditions/Indications**

- Respective supply tank fuel quantity below threshold value
- Respective LOW indication light (red) on CDS FUEL display may come on
- Warning GONG will be activated

**Procedure**

| | |
|---|---|
| 1. Fuel quantity indication | – Check |
| If positive fuel indication in the main tank: | |
| 2. Both fuel pump XFER sw (F + A) | – Check ON |
| 3. Both fuel pump XFER circuit breaker (F + A) | – Check in |
| If FUEL LOW warning light remains on: | |
| 4. Air Condition (if installed) | – Switch OFF |
| 5. Bleed Air | – Switch OFF (If OAT > 5°C) |
| **6. LAND WITHIN 8 MINUTES** | |

**WARNING** THE "LOW FUEL" WARNING OVERRULES THE FUEL QUANTITY INDICATION.

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EUROCOPTER
AN EADS COMPANY

**ASB** EC135-28A-019

EUROCOPTER
AN EADS COMPANY

FLIGHT MANUAL EC 135 P1 (CDS)

Emergency and Malfunction Procedures

**CAUTION INDICATIONS**

**F PUMP AFT** and **F PUMP FWD**

(MISC) (MISC)

**Conditions/Indications**

Failure of fuel transfer pumps, or dry run.

**Procedure**

1. Fuel quantity indication of main tank/supply tanks (CAD) – Check
2. FUEL PUMP XFER-A and –F sw – Check ON
3. FUEL PUMP XFER-A and –F cb – Check in
4. LAND AS SOON AS PRACTICABLE

**NOTE**
- Remaining flight time is approx. 30 min with max endurance speed (Vy) or approx. 20 min with max range speed.
- Be prepared for LOW FUEL warning.

**CAUTION INDICATIONS**

**F PUMP AFT**

(MISC)

**Conditions/Indications**

Failure of aft fuel transfer pump, or dry run.

**Procedure**

1. Fuel level in the main tank – Check

If main tank fuel quantity is sufficient to keep both fuel pumps wet:

2. FUEL PUMP XFER-A sw – Check ON
3. XFER-A PUMP circuit breaker – Check in

If F PUMP AFT indication remains on:

4. FUEL PUMP XFER-A sw – OFF

If main tank fuel quantity is low:

2. FUEL PUMP XFER-A sw OFF

**NOTE**
- Each fuel transfer pump is capable of feeding more fuel than both engines will consume.
- In hover flight conditions the unusable fuel can be up to 71 kg. The quantity of unusable fuel can be reduced to 7.5 kg when flying with 80 KIAS or more.

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## Appendix F

### Fuel Policy - extracts from the Police Air Operations Manual (PAOM), Part 1 and the operator's PAOM, Part 2 and Operations Manuals

PAOM Part 1 Section 2, *Flight Planning*, Chapter 5, *Pre-Flight Briefing*, provides the following guidance for fuel planning:

'***3 Fuel Planning***

3.1 The appropriate formula from those set out in paragraph 4 below shall be applied for calculating the fuel required for a given flight.

3.2 Fuel consumption rates shall be stipulated in the appropriate aircraft type supplement of the PAOM Part 2.

***4 Fuel Formulae***

*The following fuel calculations are to be based on usable fuel.*

……

*4.3* ***VFR Radius of Action Operations Aeroplanes and Helicopters***[1]

*a) Fuel for the duration of the task,*

*PLUS*

*b) fuel to refuelling point, PLUS*

*c) i) fuel for 20 minutes, at endurance speed, for a flight over a non-hostile environment by day;*

*OR*

*ii) fuel for 30 minutes, at endurance speed*[2]*, for a flight over hostile terrain or water at any time, or over a non-hostile environment at night,*

*PLUS*

*d) start, run-up (if appropriate) and taxi allowance.*

[1] Radius of action operations are operated from and to the same operating base.
[2] The fuel burn at endurance speed was 170 kg/hr.

**Appendix F cont**

Regarding fuel monitoring, it states:

***6 Fuel Monitoring***

*6.1 Fuel monitoring shall be carried out at regular intervals.*

*6.2 On reaching the operating area, the aircraft commander shall establish, from the appropriate fuel formula, the minimum fuel state at which he should leave the area in order to arrive at his refuelling point with the proper reserves of fuel.*

*6.3 The PAOM Part 2 shall include advice to the commander on the options that would require his consideration if at any stage it appeared that the fuel remaining was less than the fuel required..'*

Consequently, PAOM Part 2, Section 2, *Flight Planning*, states:

**'2.5.3 *FUEL MONITORING***

*Airborne fuel usage must be monitored with the aim of ensuring that throughout the flight the fuel on board remains sufficient to satisfy the requirements listed in the CAP 612. If it becomes apparent that the fuel remaining is close to the minimum specified in the Type Technical notes, then to assist the aircraft commander in making a decision the following shall be adopted:*

*1. General*

*a. en route*

*i. adjust aircraft speed*

*ii. obtain a more direct routing*

*iii. fly at a different flight level*

*iv. land and refuel*

*v. select an alternative aerodrome which is closer than the planned, destination airfield specified in the ATC flight plan, should one have been filed.*

*b. Overhead the destination.*

*When close to overhead the destination, flight may continue to the intended destination provided that the fuel remaining is not less than the Minimum Landing Allowance (MLA) as shown in the Type Technical notes.*

**Appendix F cont**

*2. Helicopters.*

*Whilst it is a requirement for helicopters to follow the same general rules as those above, the ability of the helicopter to land safely away from aerodromes has to be taken into account. MLA fuel still applies for helicopters and it should be noted that, on reaching this quantity, the aircraft is to land at the nearest permitted site, notifying ATC and police control of the fact.*

*Fuel burn on the EC135 is averaged at 200kg/hr …. Fuel checks are to be carried out at intervals of not less than 10 minutes. If at any stage fuel usage appears to threaten the planned fuel required the aircraft should divert to the nearest available refuel site. Fuel usage charts over various airspeeds can be found in the relevant RFM. These should be used for critical planning, for example, single engine transits or strong headwinds.'*

The operator's Operations Manual Part B, Section 7.2, *Fuel Planning*, stated:

*'7.2.3 Fuel Allowances*

| *Condition* | *Fuel Allowance in Kgs* |
|---|---|
| *Start-up Allowance* | *10* |
| *Instrument Approach* | *20* |
| *Final Reserve Fuel IFR* | *85* |
| *Final Reserve Fuel VFR* | *67* |
| *Minimum Land on Allowance* | *40 (within FRF)* |

*Company policy is that the aircraft should not land with less than 60kg of fuel in the tanks.*

*If it appears to the aircraft Commander that the Final Reserve Fuel may be required, a PAN call should be made. If the Final Reserve fuel is then subsequently reached, this should be upgraded to a MAYDAY.*

*7.3 Fuel Consumption*

*…*

| *Condition* | *Fuel Consumption* |
|---|---|
| *AEO[3] Cruise – 120 kts* | *200 kg/hr* |
| *AEO Loiter[4] @65 kts* | *170 kg/hr'* |

[3] AEO is an abbreviation of all engines operating.

[4] Loiter speed is the same as endurance speed.

## Appendix G

### Emergency landing and ditching
### - extracts from operator's Operations Manual

The operator's Operations Manual EC135 Part B/3, Section 2, *Emergency Procedures* includes guidance and procedures for a total loss of engine power. It states:

> ***'2.12 EMERGENCY LANDING AND DITCHING***
>
> ***Emergency Procedures Following Double Engine Failure***
>
> *This Information is provided to cover all aspects of Total Power Loss, Autorotation and Subsequent Engine Off Landing (EOL). Overland and Overwater EOL's will be covered, with advice for the Night and IMC cases…*
>
> *The reason for providing information in this form is to gather all the available information into one place, thus providing a comprehensive reference. The information is gathered from Manufacturers, existing Ops Manual procedures and from experience gathered whilst training and operating in service. This information is designed to supplement the Flight Manual, which remains the authoritative document.*
>
> ***2.12.1 Total Power Loss***
>
> *A total loss of power to the rotor, due either to engine or transmission failure, will result in a very rapid decay of rotor RPM. The rate of decay will depend on the amount of power being used at the time of failure and will be greatest in high power and low speed conditions. As a general guide, the rotor RPM will decay to the transient power-off minimum in approximately 2 seconds.*
>
> *Following a single engine failure it is particularly important to be prepared for the failure of the second engine. Engine failures can have common causes, e.g. icing, fuel contamination or possible damage to the operative engine following a serious first engine failure. When carrying out air tests or training with one engine retarded, the live engine is often working at high power and a failure of this will cause rapid rotor decay. Pilots should familiarise themselves with the indications of a second engine failure (usually this will only be the low rotor RPM warning as RPM decays) and maintain a hand on the collective as much as possible to reduce the delay before the collective is lowered should the second engine fail.*
>
> *In the event of total power loss in anything other than hovering flight, the prime consideration must be to contain RRPM [Rotor RPM] within safe limits by lowering the collective lever fully and immediately.*

 

**Appendix G cont**

*The single most important aspect of a successful autorotation is the maintenance of sufficient RRPM. Do not allow your attention to be diverted away from this function for any more time than is absolutely necessary.* ***Loss of RRPM will be fatal.*** *High RRPM during the flare should be seen as a positive result of good RRPM management during the descent and will contribute to a successful outcome.*

***2.12.2 Drills in Autorotation***

- *MAYDAY call " MAYDAY, MAYDAY, MAYDAY, {ATS service}, Helimed {xx}, double engine failure, intend forced landing, {position}, {x} souls on board"*
- *Lights* — *ON at night*
- *Warn passengers* — *"Attention, prepare for an emergency landing"*
- *Floatation equipment* — *Arm, i.a.w appropriate FLM [Flight Manual] Supplement*
- *Engine clean-up* — *Perform (If time permits, pilots may wish to consider re-starting at least one engine)*
- *Warn Passengers* — *"Brace, brace, brace"*

*2.12.2.1 EOL over Land*

- *At approximately 100' AGL (higher if heavy) initiate flare*
- *Reduce groundspeed as much as possible*
- *Level the aircraft and use collective lever to cushion landing*

***Note: With the attitude of the helicopter in the "level attitude", speed will increase slightly. However, avoid high nose up altitudes on touch down due to the close ground proximity of the tail fin.***

*2.12.2.3 EOL at Night or in IMC*

- *Select and maintain 10° Nose Up until speed reaches 75kts and then re-adjust*
- *Turn shortest arc into wind using ≤ 20° AoB*
- *Use RADALT [Radio Altimeter] to establish flare height*
- *Progressively reduce flare until level at 10' RADALT height*
- *Use collective to cushion landing'*

Unless otherwise indicated, recommendations in this report are addressed to the appropriate regulatory authorities having responsibility for the matters with which the recommendation is concerned. It is for those authorities to decide what action is taken. In the United Kingdom the responsible authority is the Civil Aviation Authority, CAA House, 45-49 Kingsway, London WC2B 6TE or the European Aviation Safety Agency, Postfach 10 12 53, D-50452 Koeln, Germany.