

Aircraft Accident Report No: 3/2015

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

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 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*.

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.

Footnote

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

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 autorotation², 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.

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.

Footnote

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.

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.

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 nonvolatile 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.

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 crashsurvivable 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.

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

$$\frac{\text{Total fuel} - \text{FRF}}{\text{Fuel consumption}} = \text{Endurance}$$

For normal operations the following nominal figures are to be used

<i>Final Reserve Fuel IFR/ Night / navigating by means other than by reference to visual landmarks (30 minutes)</i>	<i>90 kg</i>
<i>Unusable fuel (Not indicated)</i>	<i>8 kg'</i>

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 EC13528A-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.