Aircraft Accident Report No: 2/2014

This report was published on 11 June 2014 and is available in full on the AAIB Website www.gov.uk

Report on the accidents to Eurocopter EC225 LP Super Puma G-REDW, 34 nm east of Aberdeen, Scotland on 10 May 2012 and G-CHCN, 32 nm southwest of Sumburgh, Shetland Islands on 22 October 2012

ACCIDENT INVOLVING G-REDW (EW/C2012/05/01)

Aircraft Type and registration:	EC225 LP Super Puma, G-REDW
Registered Owners and Operators:	Bond Offshore Helicopters Ltd
Nationality:	British
Date & Time (UTC):	10 May 2012 at 1114 hrs
Location:	34 nm east of Aberdeen

ACCIDENT INVOLVING G-CHCN (EW/C2012/10/03)

Aircraft Type and registration:	EC225 LP Super Puma, G-CHCN
Registered Owners and Operators:	CHC Scotia Ltd
Nationality:	British
Date & Time (UTC):	22 October 2012 at 1425 hrs
Location:	32 nm southwest of Sumburgh, Shetland Islands

Introduction

The Air Accidents Investigation Branch (AAIB) was notified at 1112 hrs on 10 May 2012 that an EC225 LP Super Puma, G-REDW, was preparing to ditch in the North Sea approximately 32 nm east of Aberdeen.

On 22 October 2012 the AAIB was notified at 1428 hrs that an EC225 LP Super Puma, G-CHCN, had ditched in the North Sea approximately 32 nm southwest of Sumburgh, Shetland Islands.

In both cases the AAIB deployed a team to Aberdeen to commence an investigation. In accordance with established International arrangements the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA), representing the State of Manufacture of the helicopter, and the European Aviation Safety Agency (EASA), the Regulator responsible for the certification and continued airworthiness of the helicopter, were informed of the accidents. The BEA appointed an Accredited Representative to lead a team of investigators from the BEA and Eurocopter[1] (the helicopter manufacturer). The EASA, the helicopter operators and the UK Civil Aviation Authority (CAA) also provided assistance to the AAIB team.

Owing to the similarities of the circumstances that led to the two accidents, the Chief Inspector of Air Accidents ordered that the investigations be combined into a single report.

Synopsis

While operating over the North Sea, in daylight, the crews of G-REDW and G-CHCN experienced a loss of main rotor gearbox oil pressure, which required them to activate the emergency lubrication system. This system uses a mixture of glycol and water to provide 30 minutes of alternative cooling and lubrication. Both helicopters should have been able to fly to the nearest airport; however, shortly after the system had activated, a warning illuminated indicating that the emergency lubrication system had failed. This required the crews to ditch their helicopters immediately in the North Sea. Both ditchings were successful and the crew and passengers evacuated into the helicopter's liferafts before being rescued. There were no serious injuries.

The loss of oil pressure on both helicopters was caused by a failure of the bevel gear vertical shaft in the main rotor gearbox which drives the oil pumps. The shafts had failed as result of a circumferential fatigue crack in the area where the two parts of the shaft are welded together.

On G-REDW the crack initiated from a small corrosion pit on the countersink of the 4 mm manufacturing hole in the weld. The corrosion probably resulted from the presence of moisture within the gap between the PTFE plug and the countersink. The shaft on G-REDW had accumulated 167 flying hours since new.

On G-CHCN, the crack initiated from a small corrosion pit located on a feature on the shaft described as the inner radius. Debris that contained iron oxide and moisture had become trapped on the inner radius, which led to the formation of corrosion pits. The shaft fitted to G-CHCN had accumulated 3,845 flying hours; this was more than any other EC225 LP shaft.

The stress in the areas where the cracks initiated was found to be higher than that predicted during the certification of the shaft. However, the safety factor of the shaft was still adequate, providing there were no surface defects such as corrosion.

The emergency lubrication system operated in both cases but the system warning light illuminated as a result of an incompatibility between the helicopter wiring and the pressure switches. This meant the warning light would always illuminate after the crew activated the emergency lubrication system.

Footnote

[1] On 1 January 2014 Eurocopter changed its name to Airbus Helicopters.

A number of other safety issues were identified concerning emergency checklists, the crash position indicator and liferafts.

Ten Safety Recommendations have been made. In addition, the helicopter manufacturer carried out several safety actions and is redesigning the bevel gear vertical shaft taking into account the findings of the investigation. Other organisations have also initiated a number of safety actions as a result of this investigation.

The following causal factors were identified in the ditching of both helicopters:

a A 360º circumferential high-cycle fatigue crack led to the failure of the main gearbox bevel gear vertical shaft and loss of drive to the oil pumps.

b The incompatibility between the aircraft wiring and the internal configuration of the pressure switches in both the bleed-air and water/glycol (Hydrosafe 620) supplies resulted in the illumination of the MGB EMLUB caption.

The following factors contributed to the failure of the EC225 LP main gearbox bevel gear vertical shafts:

a The helicopter manufacturer's Finite Element Model underestimated the maximum stress in the area of the weld.

b Residual stresses, introduced during the welding operation, were not fully taken into account during the design of the shaft.

c Corrosion pits were present on both shafts from which fatigue cracks initiated:

i On G-REDW the corrosion pit was located at the inner countersink in the 4.2 mm hole and probably resulted from the presence of moisture within the gap between the PTFE plug and the countersink.

ii On G-CHCN the corrosion pit was located at the inner radius and probably resulted from moisture trapped within an iron oxide deposit that had collected in this area.

Findings

General

1. The bevel gear vertical shafts on both G-REDW and G-CHCN failed as a result of a 360º circumferential high-cycle fatigue crack.

2. Failure of the bevel gear vertical shaft resulted in the loss of drive to the main and standby oil pumps.

3. Loss of oil pressure from the main and standby pumps required the use of the emergency lubrication system.

4. Within a minute of the crews activating the emergency lubrication system, the MGB EMLUB caption illuminated.

5. The emergency procedure required the crew to *'land immediately'* if the MGB EMLUB caption illuminates.

6. Both helicopters ditched in the North Sea; the flotation system activated and the helicopters remained upright.

7. In both accidents, the passengers and crew evacuated the helicopters onto liferafts.

8. There were no reported serious injuries.

9. Neither helicopter sustained any structural damage as a result of the ditching.

Operational aspects

10. Both crews were properly licensed, qualified to conduct the flights and rested.

11. The flights were uneventful until the indication of the loss of the MGB oil pressure.

12. In each case the flight crew actioned the appropriate checklists.

13. The crew of G-CHCN were aware of the accident to G-REDW and had read reports on the initial findings, including the fact that the emergency lubrication system had operated.

14. It took 8 minutes and 55 seconds from the loss of oil pressure until G-REDW ditched.

15. It took 7 minutes and 6 seconds from loss of oil pressure until G-CHCN ditched.

16. The helicopter manufacturer does not provide an emergency checklist and is not required to do so.

17. The operators are responsible for providing their own checklists based on the manufacturer's documentation.

G-REDW CPI

18. The CPI did not deploy automatically following the ditching, nor was it manually activated by the flight crew.

19. In May 2012, the operator's Emergency Procedures contained no requirement for manual activation of the CPI.

20. No defects were found with the components in the system which would have prevented automatic deployment of the CPI.

21. The failure of the CPI to deploy did not adversely affect the search and rescue effort.

G-CHCN CPI

22. The CPI was selected manually by the flight crew to TRANSMIT during the final preparations for the ditching.

23. The design of the CPI system prevents automatic deployment, following manual activation, unless a system reset is performed.

CPI Standards

24. The EASA determined that the Type 15-503 CPI system was not fully compliant with the Minimum Operational Performance Standards specified in EUROCAE ED-62.

Liferafts

25. G-REDW and G-CHCN were fitted with Type 18R MK3 liferafts.

26. Some of the passengers on G-REDW commented that the liferafts were slow to deploy.

27. The Type 18R MK3 liferaft did not meet the certification requirement for a maximum inflation time to a suitable boarding condition of 30 seconds at -30ºC.

28. During inflation of G-CHCN's left liferaft the mooring lines and rescue pack lines became entangled, preventing the liferaft from being used.

29. On G-CHCN, the co-pilot was able to un-twist the lines to free the raft.

30. The CMM for the Type 18R MK3 liferaft did not provide clear diagrams and descriptions on how to route the rescue pack and mooring lines.

31. An inspection of liferaft installations on a sample of Super Puma helicopters revealed two installations where the mooring lines were routed incorrectly. In one of these cases the rescue pack lines were twisted round the mooring lines.

32. The AMM for the Super Puma helicopters did not contain diagrams clearly depicting how the mooring and rescue pack lines should be routed.

33. The tests to certify the Type 18R MK3 liferaft installation on the Super Puma included two tests conducted with a sponson partially submerged in water. No deployment tests from a sponson were carried out in simulated choppy sea conditions.

34. The EASA certification requirements do not specify any deployment reliability or sea state conditions for externally mounted liferafts fitted to offshore helicopters.

35. Following the ditching of G-REDW and G-CHCN the occupants of the liferafts were concerned about the proximity of the rotor blades to the raft, so they cut the long mooring line.

36. The long mooring line on the Type 18R MK3 liferaft is 12 m long which is 8 m less than the 20 m length specified in the AMC to JAR-Ops 3.830.

37. The certification requirements relating to the length of the long mooring line on liferafts do not make any reference to the size and geometry of the helicopter.

Emergency lubrication system

38. In both accidents the emergency lubrication system, once activated, appeared to have successfully cooled and lubricated the main rotor gearbox.

39. A mixture of oil, water and glycol was found on the transmission decking aft of the MGB and down the sides of both helicopters.

40. EC225 LP helicopters, with MOD 0752520 embodied, have a pressure switch configuration that results in illumination of the MGB EMLUB failure caption once the system is activated and after the 30-second delay.

41. The bleed-air pressure from the engine is, under certain conditions, lower than the pressure used in the design and certification of the emergency lubrication system.

42. In some areas of the operational envelope, the Hydrosafe 620 and the bleed-air pressure is such that the pressure switches, which are within specification, can generate a low pressure signal when the emergency lubrication system is operating normally. This would result in an erroneous MGB EMLUB caption.

43. Both Hydrosafe 620 pumps were tested and operated to specification. Both pumps would have operated during the accident flights.

44. Several minutes after activation of the emergency lubrication system, the pressure in the Hydrosafe 620 system decreased to around 0.7 bar relative. This value is higher than the threshold for the pressure switches fitted to the accident helicopter, but lower than the maximum specification for these components.

MGB general

45. There were no external leaks from the MGB and the fluid found on the transmission decking and on the outside of the helicopter had come out of the MGB vent.

46. The MGB on both helicopters had been correctly assembled and with the exception of the damage to the bevel gear vertical shafts, there was no evidence of damage or signs of overheating to any other components in the gearboxes.

47. No additional loads, or resonant frequencies, were identified during the testing of the bevel gear vertical shaft and MGB other than those previously identified during the certification of the EC225 LP helicopter.

G-REDW history of the bevel gear vertical shaft

48. The shaft (M385) fitted to G-REDW was manufactured in March 2012 and had been kept in the manufacturer's stores for a year before it was fitted to the MGB.

49. At the time of the accident, the shaft fitted to G-REDW had flown 167 flying hours and approximately 20 million shaft cycles. The MGB had been fitted to the helicopter two months prior to the accident.

G-CHCN history of the bevel gear vertical shaft

50. The shaft (M122) fitted to G-CHCN was manufactured in April 2008.

51. The shaft, and its MGB, had undergone a 2,000 hour overhaul 1,813 flying hours and sixteen months prior to the accident.

52. At the time of the accident, the shaft had flown 3,845 flying hours and approximately 533 million shaft cycles. The shaft had remained with the MGB since new, but prior to its overhaul had been fitted to another helicopter.

53. At the time of the accident, the shaft fitted to G-CHCN was considered to be the fleet leader on the EC225 LP.

Bevel gear vertical shafts

54. 63% of EC225 LP shafts are scrapped at the first overhaul, of which approximately 50% are due to excessive wear on the splines that drive the first stage sun gear.

55. In comparison with the AS332 shaft, the EC225 shaft is 1.2 mm thicker in the area of the weld and incorporates a new feature identified as the inner radius. There is also approximately 15% more load on the splines that drive the first stage sun gear.

56. In common with other gearbox components, the bevel gear vertical shaft had no surface protection, other than the oil in the MGB, to protect it against corrosion.

Examination of the bevel gear vertical shafts

57. With the exception of the inner countersink on the shaft fitted to G-REDW (M385), both shafts had been manufactured to the design specification and the welds were correctly formed.

58. Corrosion was found in the inner countersink of the 4.2 mm hole on both shafts. This corrosion occurred after the PTFE plugs had been fitted into the 4.2 mm holes.

G-REDW bevel gear vertical shaft examination

59. The geometry of the inner countersink on the shaft fitted to G-REDW was outside the design tolerance.

60. The change in angle of the countersinks and the out of tolerance inner countersink on G-REDW were not factors in this accident.

G-CHCN bevel gear vertical shaft examination

61. A red deposit which contained iron oxide was found in the inside of the top section of the bevel gear vertical shaft fitted to G-CHCN.

62. The deposit on G-CHCN was concentrated in three rings located at the inner radius, and above and below the splines that drive the first stage sun gear.

63. Corrosions pits were discovered under the concentrated areas of deposits on the shaft fitted to G-CHCN. Corrosion pits were not discovered elsewhere on the shaft.

64. The deposit was found on a small number of EC225 LP shafts in the same areas as on the shaft fitted to G-CHCN. There was evidence of corrosion in the same areas as on G-CHCN.

Metallurgic examination of the bevel gear vertical shaft

65. Both shafts failed as a result of a 360º circumferential fatigue crack in the area of the weld that joined the two parts of the shaft.

66. The crack on the shaft fitted to G-REDW initiated in a corrosion pit 60 µm deep, located on the inner countersink in the 4.2 mm hole on the fusion line of the weld.

67. Cracks in the fusion line may initiate and propagate at stress levels lower than the fatigue limit of the weld.

68. The crack on the shaft fitted to G-CHCN initiated in a corrosion pit 60 µm deep located on the inner radius in the parent material.

69. It is difficult to detect corrosion pits visually approximately 60 µm deep located in the inner countersink or inside the shaft in the area of the weld.

70. Prior to these accidents, there had been no previous reports of cracks or corrosion on the Super Puma bevel gear vertical shafts.

71. The area of the shafts that failed is not subject to the carburising or nitriding case-hardening process.

72. The change in case-hardening and the high-strength low-alloy steel used in the bevel gear vertical shaft were not a factor in the accidents.

73. There was no evidence of corrosion fatigue on the fracture surfaces of either shaft.

74. Beachmarks and striations, which are characteristic of fatigue, were present on the fracture surfaces of both shafts.

75. It is not known how long it took for the cracks on the shafts to initiate and propagate to the first beachmark.

76. Beachmark analysis estimated that the time for the cracks to propagate from the first beachmark to the final failure of the shafts was 15 to 21 flying hours for G-REDW and 14 to 21 flying hours for G-CHCN.

77. The change from 16NCD13 steel to the 32CDV13 steel used in the manufacture of the EC225 shaft was not a factor in these accidents.

Stresses within the bevel gear vertical shaft

78. The EC225 bevel gear vertical shaft was classified at certification as a Critical Part.

79. The EC225 shaft was derived from the AS332 shaft and certification of the EC225 shaft was based on the results of an FEM.

80. The maximum stress in the area of the weld is similar on the AS332 and EC225 shaft.

81. In the initial fatigue substantiation document (Issue A) for the EC225 shaft, the 4.2 mm hole was identified as Critical Area 2. The inner radius was not identified as a critical area.

82. In the FEM used to establish the maximum stress for the certification of the EC225 shaft, the boundary conditions for the upper roller bearing were incorrect.

83. The maximum stress at the 4.2 mm hole occurs when the relative angle between the 4.2 mm and 29 mm hole is 40º. On the shaft fitted to G-REDW the relative angle between these features was 38º.

84. No account was taken of the relative position of the 4.2 mm hole in the weld and 29 mm lubrication hole in the original FEM.

85. Electron beam welding of the two parts of the shaft generates compressive and tensile residual stresses in the area of the weld.

86. There are significant tensile residual stresses, at a depth of 60 µm, in the inner countersink on the 4.2 mm hole and the inner radius in the locations where the cracks initiated in the shafts fitted to G-REDW and G-CHCN.

87. The original fatigue substantiation document for the EC225 shaft made no allowance for the residual stresses.

88. From the data in the initial fatigue substantiation document (Issue A) it was calculated that the safety factor at the 4.2 mm hole in the EC225 shaft was 5.4.

89. Following the revision of the FEM, and incorporation of residual stress, the manufacturer calculated that there was a safety factor of 2.1 at the 4.2 mm hole and 2.3 at the inner radius.

90. The different methods used in the certification of the AS332 and EC225 shafts meant that it was not readily apparent that the maximum stress in the area of the weld had been underestimated.

91. The EASA considered a safety factor of 2.1 for the 4.2 mm hole and 2.3 for the inner radius to be acceptable, providing there is no corrosion in these areas.

Moisture in MGB

92. Low levels of water were found in the oil sampled from a small number of EC225 LP helicopters operating from Aberdeen.

93. Moisture can enter the MGB through the vents located in the gearbox and mast.

94. Moisture in the atmosphere was assessed as previously causing corrosion on the inside of the rotor mast fitted to the EC225 LP helicopters, an area that was not protected by the oil mist in the MGB.

95. The iron oxide generated by wear of the splines that drive the first stage sun gear was trapped at the inner radius on G-CHCN.

96. The MGB oil lubrication system was unable to remove the deposit containing the iron oxide from the inside of the shaft.

97. Moisture in the oil and gearbox became trapped in the deposit resulting in the formation of corrosion pits.

HUMS

98. As the cracks propagated, the load in the shafts was redistributed into the upper bearings, which increased the vibration levels detected by HUMS MOD-45 indicator.

99. The HUMS MOD-45 indicator amber threshold would not have been exceeded until the combined cracks in the bevel gear vertical shaft reached a length of between 87 and 100 mm.

100. The HUMS MOD-45 indicator exceeded the 'learned' amber threshold on both G-REDW and G-CHCN's penultimate flight.

101. The time from the MOD-45 indicator exceeding its amber threshold and the shafts failing was 4.62 hours for G-REDW and 4.75 flying hours for G-CHCN.

102. On identifying the MOD-45 exceedence, the operator of G-REDW followed the appropriate maintenance procedures. These procedures allowed the helicopter to continue flying under 'close monitoring'.

103. Analysis of the HUMS data from G-CHCN, prior to the start of the first flight on the day of the accident, would not have detected an increasing trend on the HUMS MOD-45 indicator.

Safety Recommendations and actions

Safety Recommendation 2012-034 issued on 17 October 2012

It is recommended that the European Aviation Safety Agency requires Eurocopter to review the design of the main gearbox emergency lubrication system on the EC225 LP Super Puma to ensure that the system will provide the crew with an accurate indication of its status when activated.

In April 2013 the EASA provided the following response to the Safety Recommendation:

'The root cause of the in-flight Emergency Lubrication (EMLUB) false alarm has been identified. For both helicopters (registered G-REDW and G-CHCN) events, it has been caused by wiring discrepancies found between the electrical outputs of the Air & Glycol pressure-switches of the EMLUB system and the helicopter wiring harness connecting the switches to the EMLUB electronic card. This design non-conformity only exists on helicopters equipped with pressure-switches manufactured by the sensor supplier Industria. The corrective actions have consisted in the following: Eurocopter have developed, through design change MOD 07.53028, a fix at aircraft wiring harness level for helicopters equipped with Industria pressure-switches. The retrofit of the fleet with this EASA approved design change is handled with Eurocopter's Alert Service Bulletin No.05A032, which EASA mandated with Airworthiness Directive (AD) 2013-0037.

From the extensive design review of the EMLUB system, components examinations, system testing and analysis completed during the investigation, it has been furthermore determined that the actual average engine bleed-air pressures for the EMLUB air circuit are lower than the certified design specifications, and indirectly it may also affect the pressures normally expected in the Glycol circuit of the EMLUB system. This brings the potential of triggering the thresholds of the Air and Glycol pressure-switches in some marginal flight conditions. To address this additional EMLUB system issue, Eurocopter are currently designing new pressure-switches with redefined lower pressure thresholds. After their approval, EASA will require Installation of these redesigned pressure-switches for the fleet by another AD.'

This has been assessed by the AAIB as 'accepted – closed'.

Safety Recommendation 2013-006 issued on 18 March 2013

It is recommended that the European Aviation Safety Agency requires the manufacturers of aircraft equipped with a Type 15-503 Crash Position Indicator system, or similar Automatically Deployable Emergency Locator Transmitter, to review and amend, if necessary, the respective Flight Manuals to ensure they contain information about any features that could inhibit automatic deployment.

In September 2013 the EASA provided the following response to the Safety Recommendation:

'EASA, in cooperation with the manufacturer, has re-examined the requirements of the Emergency Locator Transmitter EUROCAE ED-62 and studied the system specifications again and it was concluded that the equipment is not 100% compliant to the Minimum Operational Performance Standards (MOPS). The manufacturer is preparing an update to change the behaviour of the system to only allow deployment and activation as being one event. Once the Service Bulletin is available EASA will prepare a corresponding Airworthiness Directive to mandate the system update.

This proposed solution, meeting the intent of the requirements, is still under discussion with the applicant to reach a final design change as the ultimate fix for the problem.'

This has been assessed by the AAIB as 'partially accepted – open'.

Safety Recommendation 2013-007 issued on 18 March 2013

It is recommended that the Federal Aviation Administration requires the manufacturers of aircraft equipped with a Type 15-503 Crash Position Indicator system, or similar Automatically Deployable Emergency Locator Transmitter, to review and amend, if necessary, the respective Flight Manuals to ensure they contain information about any features that could inhibit automatic deployment.

In April 2013 the FAA provided the following response to the Safety Recommendation:

'Depending on the type of operation and operating airspace, the FAA may require rotorcraft to have an operating ELT. However, the FAA does not require the installation of a deployable ELT or CPI on helicopters; therefore, the loss of this function is not considered an unsafe condition. In addition, the FAA can only require a change to a design through an airworthiness directive, which requires the determination of an unsafe condition. As a result, the FAA lacks the justification to adopt safety recommendation 13.031, and we plan no further actions.'

This has been assessed by the AAIB as 'rejected'.

The following additional Safety Recommendations have been made:

Safety Recommendation 2014-013

It is recommended that the European Aviation Safety Agency provide Acceptable Means of Compliance (AMC) material for Certification Specification (CS) 29.1585, in relation to Rotorcraft Flight Manuals, similar to that provided for Aeroplane Flight Manuals in AMC 25.1581 to include cockpit checklists and systems descriptions and associated procedures.

Safety Recommendation 2014-014

It is recommended that the liferaft manufacturer, Survitec Group Limited, revises the Component Maintenance Manual for the Type 18R MK3 liferaft to include clear instructions and diagrams on how to route the rescue pack lines and mooring lines when packing the liferaft.

Safety Recommendation 2014-015

It is recommended that the aircraft manufacturer, Eurocopter Group, revise the Super Puma Aircraft Maintenance Manual Task 25-66-01-061 'Removal-Installation of the Liferaft Assembly' to include clear instructions and diagrams on how to route the rescue pack lines and mooring lines when installing the liferaft.

Safety Recommendation 2014-016

It is recommended that the European Aviation Safety Agency review the installation of the Type 18R MK3 liferaft in the EC225 sponson to ensure that there is a high degree of deployment reliability in foreseeable sea conditions.

Safety Recommendation 2014-017

It is recommended that the European Aviation Safety Agency develop certification requirements for externally mounted liferafts fitted to offshore helicopters which ensure a high degree of deployment reliability in foreseeable sea conditions.

Safety Recommendation 2014-018

It is recommended that the European Aviation Safety Agency amend the regulatory requirements to require that the long mooring line on liferafts fitted to offshore helicopters is long enough to enable the liferaft to float at a safe distance from the helicopter and its rotor blades.

Safety Recommendation 2014-019

It is recommended that the European Aviation Safety Agency commission research into the fatigue performance of components manufactured from high-strength low-alloy steel. An aim of the research should be the prediction of the reduction in service-life and fatigue strength as a consequence of small defects such as scratches and corrosion pits.

Summary of safety actions

Main gearbox bevel gear vertical shaft

On 18 May 2012, shortly after the accident to G-REDW, the EASA issued Emergency Airworthiness Directive 2012-0087-E. This required helicopters with certain bevel gear vertical shafts and equipped with the Eurocopter VHM system to download the VHM data and to review the MOD-45 and MOD-75 indicators every 3 flight hours. Helicopters fitted with the affected bevel gear vertical shafts and not equipped with VHM were restricted to day VFR flights when flying over water.

On 11 June 2012, the EASA issued Airworthiness Directive 2012-0104 which superseded 2012-0087-E. This altered the applicability of bevel gear vertical shafts and also increased the time between VHM downloads to 4 flight hours.

On 14 June 2012, the EASA issued Airworthiness Directive 2012-0107 which superseded 2012-0104 which retained the requirements but changed the effective date.

On 28 June 2012, the EASA issued Emergency Airworthiness Directive 2012-0115E which superseded 2012-0107. This retained the requirements of 2012-0107; however, it now required inspection of the VHM indicators in accordance with Eurocopter AS332 ASB No. 01.00.82 or EC225 ASB No. 04A009 both dated 27 June 2012. For the EC225 LP the download interval remained at 4 flight hours.

On 25 October 2012, shortly after the accident to G-CHCN, the EASA issued Emergency Airworthiness Directive 2012-0225E. This superseded the previous EAD 2012-0115E. This retained the requirements of 2012-0115E but increased the applicability to all bevel gear vertical shafts and reduced the interval between VHM inspections; this became 3 flight hours on the EC225. Helicopters with an unserviceable VHM were prohibited flight over water. This referred to changes in Revision 1 to Eurocopter AS332 ASB No. 01.00.82 and EC225 ASB No. 04A009 both dated 24 October 2012.

On 25 October 2012, the CAA issued a Safety Directive SD-2012/002 which stated that UK operators must not conduct a public transport flight or a commercial air transport operation over a hostile environment with any AS332 or EC225 helicopter to which European Aviation Safety Agency Emergency Airworthiness Directive 2012-0225-E dated 25 October 2012 applies. The Norwegian CAA also issued a similar Safety Directive 2012208342-1.

On 21 November 2012, the EASA issued Emergency Airworthiness Directive 2012-0250E which reflected Revision 2 of Eurocopter AS332 ASB No. 01.00.82 and EC225 ASB No. 04A009 both dated 21 November 2012. This required the amendment of the Emergency procedures of the Eurocopter RFM, which introduced the need to reduce engine power to *“MAXIMUM CONTINUOUS TORQUE LIMITED TO 70% DURING LEVEL FLIGHTS AT IAS≥ 60 KTS”* when operating over areas where emergency landing to ground was not possible within 10 minutes at V_y. It also required the continued monitoring of the VHM at regular intervals. For helicopters not equipped with VHM, the AD restricted operations which did not enable emergency landing on the ground within 10 minutes at V_y.

On 9 July 2013, the EASA issued Emergency Airworthiness Directive 2013-0138E, superseding 2012-0250E, which reflected modifications and procedures, introduced by Eurocopter Service Bulletins EC225 ASB No. 04A009 Revision 2 dated 21 November 2012, ASB No. EC225-04A009 Revision 3 dated 8 July 2013, ASB No. EC225-45A010 dated 8 July 2013, ASB No. EC225-05A036 dated 8 July 2013, AS332 ASB No.01.00.82 Revision 2 dated 21 November 2012, ASB No.AS332-01.00.82 Revision 3 dated 8 July 2013, and ASB No. AS332-05.00.96 dated 8 July 2013. These introduced several modifications including the M’ARMS MOD-45 monitoring system. Prior to installing the modified system, the requirement for a regular download of VHM data remained. Also, they required the cleaning of the bevel gear vertical shaft and installation of improved MGB oil jets. For helicopters without VHM or an unserviceable VHM, the power restrictions remained and it introduced an ultrasonic inspection at regular intervals.

On 10 July 2013, the CAA issued Safety Directive SD-2013/001 which removed the restrictions on carrying out public transport or commercial air transport flights over a hostile environment providing certain actions in EASA AD 2013-0138E had been complied with. An updated CAA Safety Directive SD 2013/002 was issued on 16 July 2013 to reflect a revision to EASA AD 2013-0138E dated 15 July 2013.

On 18 December 2013, the EASA issued Emergency Airworthiness Directive 2013-0301, superseding 2013-0138R1, which reflected that some of the requirements in AD 2013-0138R1 had expired, and that Eurocopter issued ASB No.AS332-01.00.82 at Revision 4 dated 17 December 2013 to introduce an Ultrasonic NDT method to detect vertical shaft cracks as alternative method to the only Eddy Current inspection available so far for the AS 332 helicopters.

Additional safety actions

The helicopter manufacturer undertook a number of measures and safety actions to detect damage and prevent corrosion in the area of the 4.2 mm hole in the weld during manufacturing of the shaft. These included new tooling, a final polishing operation, improved inspection techniques, a sealant to fill the gap between the PTFE plug and countersink, a 5 μm inspection criterion for defects and a more detailed inspection at the end of the manufacturing process.

During the investigation the helicopter manufacturer issued several Safety Information Notices and repair letters to operators and maintenance organisations.

The helicopter manufacturer is currently working on a redesigned bevel gear vertical shaft which takes into account the findings of the investigation. The EASA is reviewing this redesign as part of the certification requirements and applying the knowledge gained in the investigation to assess the various safety factors.

Emergency lubrication system

On 22 February 2013, the EASA issued AD 2013-0037 which relates to Eurocopter EC225 EASB No. 05A032 dated 22 February 2013. The AD requires the air and glycol pressure-switches in the emergency lubrication system to be identified. Depending on the type fitted, the switches may require replacing and the helicopter wiring harness may need to be modified (MOD 07.53028). In addition, this AD requires scheduled electrical functional testing of the emergency lubrication system.

On 28 May 2013, the EASA issued AD 2013-0113 which relates to Eurocopter EASB No.04A010 dated 27 May 2013. This updated the RFM by amending the emergency procedure to require an immediate landing as soon as the emergency lubrication system was activated.

On 18 July 2013, the EASA issued AD 2013-0156 which superseded AD 2013-0037 and 2013-0113. The requirements of the previous ADs were retained pending modifications to the emergency lubrication system within 4 months. The modifications are specified in Eurocopter ASB No EC225 05A033 dated 14 July 2013 and introduces new glycol pump, new pressure switches, check of the aircraft wiring and new PCB. Once these modifications are complete the RFM is amended to reintroduce the "land as soon as possible maximum flight time 30 min" to the emergency procedure after the emergency lubrication system is activated.

Crash position indicator

The CPI manufacturer amended the Type 15-503 CPI Operating Manual to reflect that the CPI system must be reset following a manual TRANSMIT selection, in order to restore full automatic functionality.

On 18 March 2013, Eurocopter issued Safety Information Notice No. 2567-S-25, dated 18 March 2013 and amended the Flight Manual for all Eurocopter helicopters equipped with a Type 15-503 CPI system.

On 17 January 2014, the EASA issued Airworthiness Directive 2014-0019, introducing a temporary amendment of the AFM and installation of a placard near the CPI cockpit control panel, to prevent use of the manual TRANSMIT function over water, for all aircraft equipped with a Type 15-503-134 or Type 15-503-134-1 CPI system. This AD also requires replacement of the SIU with a modified SIU incorporating automatic deployment following a manual activation, as a terminating measure for the temporary AFM amendment and placard installation.

On 27 February 2014 the CAA published CAP 1144 *'ADELT Review Report',* which contains a number of recommendations aimed at optimisation of ADELT installation and designs to maximise the likelihood of an ADELT deploying and transmitting correctly.

Liferafts

The liferaft manufacturer has stated that they will review the CMM and publish a Service Letter highlighting to liferaft maintenance organisations the importance of the lines exiting the rear of the valise and not the front.

The EASA RMT.0120 working group is aware of the issues relating to the liferafts found in the investigation and is considering proposing changes to certification requirements for externally mounted liferafts that would also take aircraft attitude into account.

Other survival equipment

The operator of G-REDW has changed the type of immersion suit used by pilots to an orange and black, closed-neck-seal design.

The supplier of immersion suits has added a further layer of tape over the seam for the toes of the sock to all of its suits to provide increased resistance to damage.

The EBS manufacturer is upgrading the existing re-breathers to include a new means of locating and opening the mouthpiece cover, as well as a retaining strap to hold the mouthpiece in place prior to use when the cover is open.

Information on the following areas affecting survivability was passed to the EASA RMT.0120 and the relevant manufacturers for consideration:

Seasickness
Jettison handle positioning and emergency egress
Safety knives and line cutters
Immersion suits
Emergency Breathing Systems

Checklists

Following the accidents the operator of G-REDW made changes to their checklists based on the findings of this investigation.