ACCIDENT

Aircraft Type and Registration:	EC225 LP Super Puma, G-CHCN
No & Type of Engines:	2 Turbomeca Makila 2A1 turboshaft engines
Year of Manufacture:	2007 (Serial no: 2679)
Date & Time (UTC):	22 October 2012 at 1418 hrs
Location:	In the North Sea, approximately 32 nm southwest of Sumburgh, Shetland Islands
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 17
Injuries:	Crew - None Passengers - None
Nature of Damage:	Fracture of the Main Gear Box bevel gear vertical shaft
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	Approximately 12,000 hrs (approx 1,000 hrs on type)
Information Source:	AAIB Field Investigation

Background

This Special Bulletin contains information on the progress of the investigation into identifying the cause of the 360º circumferential crack in the bevel gear vertical shaft on G-CHCN (AAIB Special Bulletin S6/2012). It also compares the findings with those recorded previously on another EC225 LP accident involving a similar failure on G-REDW on 10 May 2012 (AAIB Special Bulletin S3/2012) and provides a further update on the investigation into both accidents.

The Chief Inspector of Air Accidents has ordered that the investigations into the accident to G-REDW on

10 May 2012 and to G-CHCN on 22 October 2012 be combined, and to publish an Inspector's Investigation Report.

History of the flight

The helicopter was on a planned flight from Aberdeen International Airport to the West Phoenix drilling rig, approximately 226 nm to the north.

The crew reported that, whilst in the cruise at about 140 kt and 3,000 ft amsl with approximately 81% total torque applied, the XMSN (transmission) caption illuminated on the Central Warning Panel (CWP). They added that the CHIP, M.P (main pressure), and the S/B.P (standby oil pump pressure) captions on the Vehicle Management System (VMS) also illuminated and the main gearbox oil pressure indicated zero. The MGB.P (main gear box oil pressure) caption then illuminated on the CWP. The crew actioned the '*Total Loss of MGB (Main Gear Box) Oil Pressure*' checklist, which required the activation of the MGB emergency lubrication system (EMLUB). However, within a minute the MGB EMLUB caption illuminated on the CWP indicating that the emergency lubrication system had failed. The crew carried out the '*Emergency Landing – Power ON*' checklist and successfully ditched the helicopter in the sea, close to a ship. There were no reported injuries.

Health and Usage Monitoring System (HUMS)

HUMS trend indicator MOD-45 is used to monitor the meshing frequency of the bevel gear and indicator MOD-70 the meshing frequency of the oil pump wheels. Both indicators have thresholds which are used to generate alerts when two out of five consecutive data points exceed the thresholds. This monitoring is carried out at a ground station post flight.

Figures 1 and 2 compare the MOD-45 and MOD-70 indicators for G-CHCN and G-REDW. The indicator values are plotted with respect to flying hours relative to the time at which the MGB oil pressure was lost; the period covered by each figure is 30 flying hours. Also plotted are the threshold values of these indicators unique to each helicopter[1] and applicable at the time of each accident.

At the time of the first accident in May 2012, the MOD-45 and MOD-70 indicators only included amber thresholds; these were 'learned' thresholds each with a maximum value of 0.6.

After the accident to G-REDW, Eurocopter published EC225 Service Bulletin No 45-001, in July 2012 that included the introduction of a red threshold and lowered the fleet-wide maximum threshold values for both indicators. For MOD-45 the amber alert was reduced to 0.3 and a red alert of 0.4 was introduced. For MOD-70 the amber alert was reduced to 0.4 and a red alert of 0.5 was introduced.

After the accident to G-CHCN, Eurocopter published an Emergency Alert Service Bulletin (ASB), on 21 November 2012, which removed the maximum amber alert threshold for MOD 45 and lowered the red alert threshold to 0.2. No change was made to indicator MOD-70 thresholds. These maximum thresholds are greater than G-CHCN's and G-REDW's 'learned' thresholds.

Both helicopters were operating within the published HUMS monitoring procedures valid at the time of their accidents.

Footnote

[1] These are 'learned' thresholds that are a function of the mean of the indicator values recorded to date. These will, therefore, vary from helicopter to helicopter. Eurocopter also publish 'maximum' thresholds that are applicable fleetwide which can, if required, be set sufficiently low to predominate existing 'learned' thresholds.

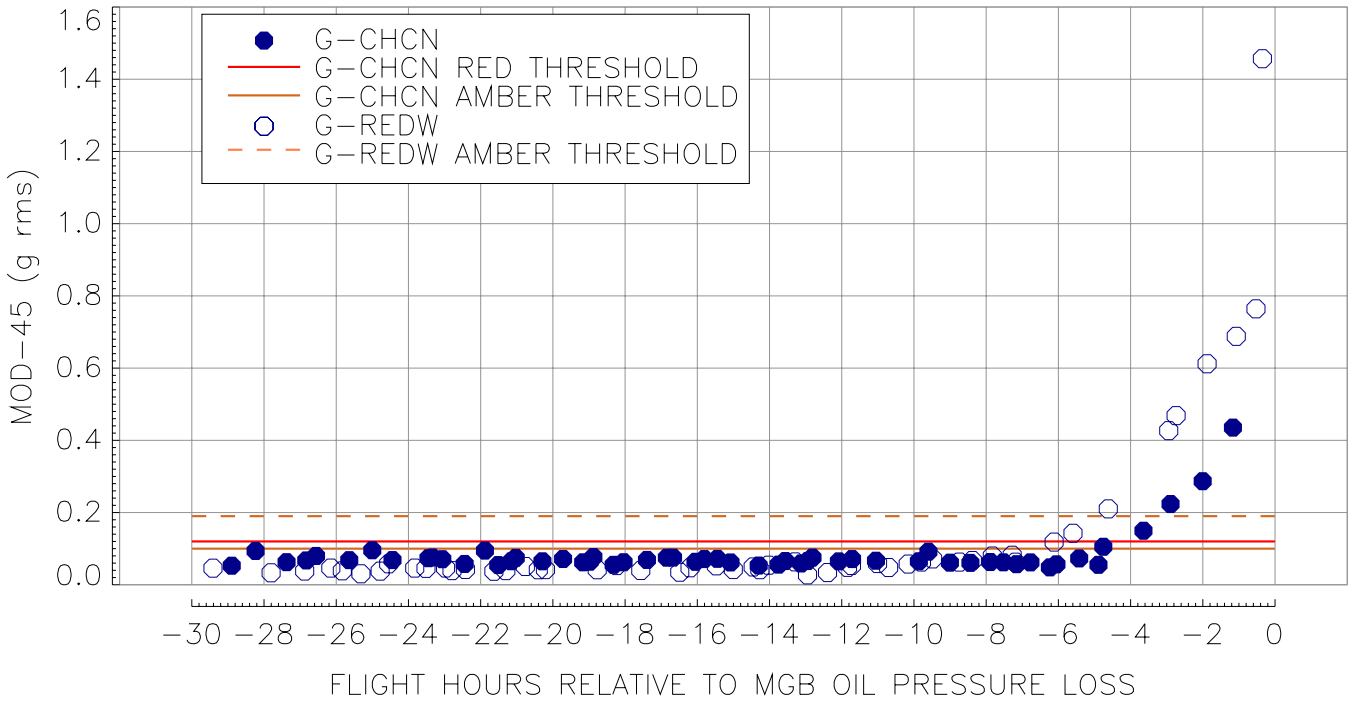

Figure 1

Comparison MOD-45 trend indications between G-CHCN and G-REDW

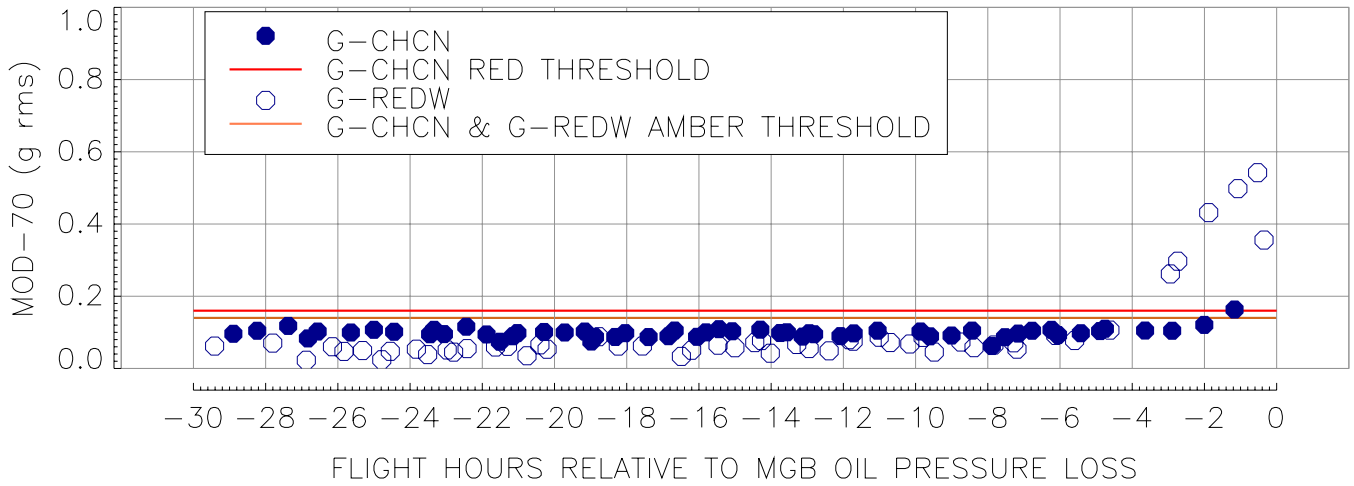

Figure 2

Comparison MOD-70 trend indications between G-CHCN and G-REDW

Figure 1 shows that the MOD-45 indicator for G-CHCN, exceeded its 'learned' amber threshold (0.10) 4.75 flying hours and its 'learned' red threshold (0.12) 3.63 flying hours prior to the loss of oil pressure. For G-REDW the MOD-45 indicator exceeded its 'learned' amber threshold (0.19) 4.62 flying hours before the loss of the MGB oil pressure.

Figure 2 shows that for the MOD-70 indicator, the first instance that it exceeded the 'learned' amber

threshold (0.14) for G-REDW was 2.95 flying hours before the loss of MGB oil pressure. However, for G-CHCN only the last recorded value of this indicator, which was captured 1.17 flying hours before the loss of the MGB oil pressure, exceeded both its amber (0.14) and red (0.16) 'learned' thresholds.

Aircraft information

A description of the development of the Eurocopter EC225 LP helicopter and a systems description of the Main Gear Box (MGB) and the emergency lubrication system was provided in AAIB Special Bulletin S3/2012. In comparison with the AS332 L2, the EC225 LP helicopter has a five-bladed spheriflex composite main rotor and uprated Turbomeca Makila 2A1 engines that deliver approximately 15% more torque to the main rotor system.

The helicopter manufacturer advised that the EC225 LP fleet has flown approximately 300,000 hours. In comparison, the AS332 variants have flown approximately 4.3 million hours.

MGB bevel gear vertical shaft

The bevel gear vertical shaft consists of a main bevel gear wheel and a vertical shaft that are joined together by an electron beam weld. To ensure the integrity of the weld, the disrupted material at the end of the weld is removed by drilling and reaming a diameter (Ø) 4 mm hole. The inner and outer surface of the weld region is then machined to remove the cap and root of the weld. A plug is fitted into the hole to prevent leakage of lubrication oil.

The bevel gear vertical shaft is supported in the gearbox by two upper bearings (roller and ball) mounted adjacent to each other above the bevel gear wheel, and a lower roller bearing mounted at the bottom of the vertical shaft above the oil pump drive wheels. Following the failure of the bevel gear vertical shaft, the bevel gear wheel will only be supported by the two upper bearings.

On bevel gear vertical shafts originally designed for the AS332 variants, both parts of the shaft are manufactured from 16NCD13 steel alloy. The gear teeth are surface hardened, by a process called carburising, prior to the bevel gear wheel being welded to the vertical shaft. The manufacturer's design does not require the vertical shaft, or the part of the bevel gear wheel that is welded to the vertical shaft, to be surface hardened.

The parent material and surface hardening process were changed for the EC225 LP to accommodate the increased loads and the elevated temperatures in the MGB during the operation of the emergency lubrication system. This was achieved by changing the parent material to 32CDV13 steel alloy and applying a different surface hardening process, called nitriding, to the teeth on the bevel gear wheel. The vertical shaft, which is also manufactured from this steel alloy, is not subject to the nitriding process. The 32CDV13 steel alloy shaft can also be fitted to the AS332 variants.

On G-REDW and G-CHCN, the cracks initiated and grew to failure in areas of the vertical shaft that had not been, nor were required to be, surface hardened.

The bevel gear vertical shaft has a life of 20,000 flying hours with a requirement for overhaul every 2,000 flying hours for the EC225 LP and a life of 50,000 flying hours and overhaul every 3,000 flying hours for the AS332 L2. According to the manufacturer, no shaft manufactured from 32CDV13 steel alloy has flown sufficient hours to reach its second overhaul, at 4,000 flying hours.

Engineering investigation

Overview of bevel gear vertical shafts fitted to G-REDW and G-CHCN

The bevel gear vertical shaft (serial number M385) fitted to G-REDW was manufactured in March 2011 and had operated for 167 flying hours[2], which equates to approximately 20 million shaft cycles since new[3]. The shaft (serial number M122) fitted to G-CHCN was manufactured in March 2008 and had operated for 3,845 flying hours which equates to approximately 553 million shaft cycles. Shaft M122 had remained with the same MGB since new and had operated for approximately 1,800 flying hours since the MGB had been overhauled. Its second overhaul was due in approximately 200 flying hours.

Failure of the bevel gear vertical shaft on G-REDW and G-CHCN

The failure of the bevel gear vertical shaft on both G-REDW and G-CHCN occurred as a result of high cycle fatigue cracking in the area of the weld and is thought to be as a result of the shaft bending (flexing) as it rotates.

On G-REDW, the first crack to develop was identified as Crack 'A', which initiated at a corrosion pit approximately 0.06 mm deep located in the inner countersink of the Ø 4 mm hole (Figure 3). The crack then propagated along the fusion line between the area of the weld which had been previously melted, and the heat affected zone in the parent material in the vertical shaft. A second crack, Crack 'B', initiated after Crack 'A' at a small

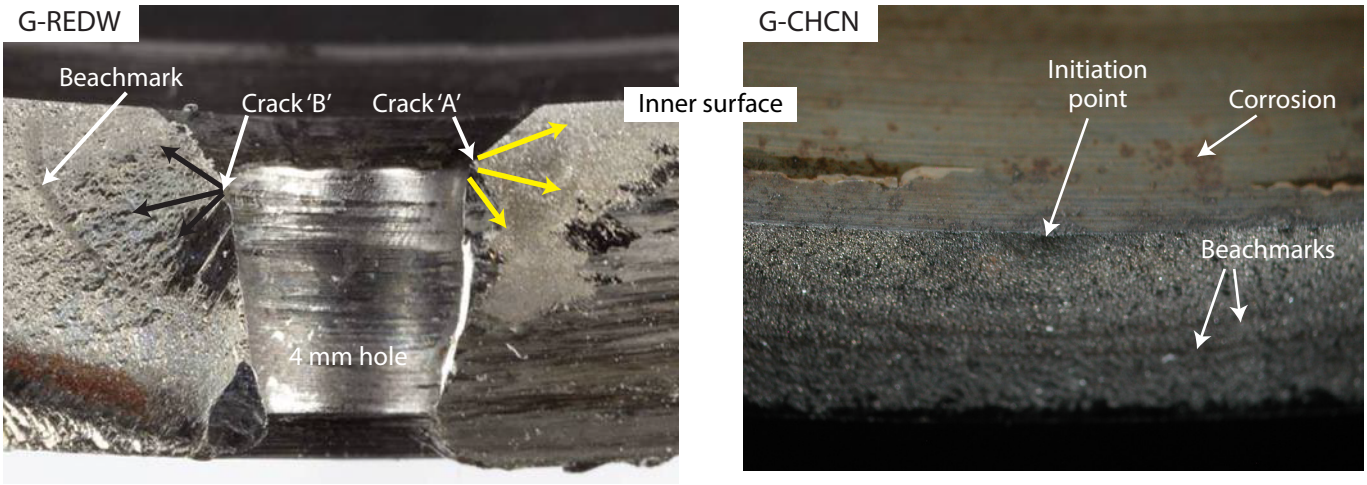

Figure 3

Location of crack initiation on G-REDW and G-CHCN

Footnote

[2] These flying hours are recorded by the flight crew in the helicopter's technical log and are taken as the time between the wheels off and wheels on the ground.

[3] A shaft cycle is defined as one rotation of the bevel gear vertical shaft, which rotates nine times faster than the main rotor.

scratch in the internal surface of the hole. Numerous corrosion pits that could only initially be detected by a scanning electron microscope were also present around the circumference of the inner countersink. Crack 'B' ran into a third crack identified as Crack 'C' (Figure 4).

On G-CHCN the fatigue crack initiated at an area of corrosion on the inner surface of the shaft (Figure 3), approximately 47° around the circumference from the Ø 4 mm hole (Figure 4). It has not yet been determined where the crack initiated in relation to the heat affected zone. Away from the initiation point, the crack propagated in both directions in the parent material in the vertical shaft. Small areas of corrosion were also visible in the machining marks around the inner flange that had been machined during manufacture to remove the root of the weld. The initial examination has not identified corrosion on any other part of the bevel gear vertical shaft.

The fracture surfaces of the shafts on G-REDW and G-CHCN both displayed characteristic fatigue beachmarks, which can be formed when an event such as an engine start or significant change in torque has taken place (Figure 4). Beachmarks can be difficult to identify and can be interpreted in a number of ways.

For G-REDW the first beachmark was identified at 4 mm from the initiation point. Crack growth estimates are complicated by variations in engine torque and the changing stiffness of the shaft as the crack grows to failure. A number of different models are being considered, one of which suggests that the time for the crack to grow from the first beachmark to failure could be

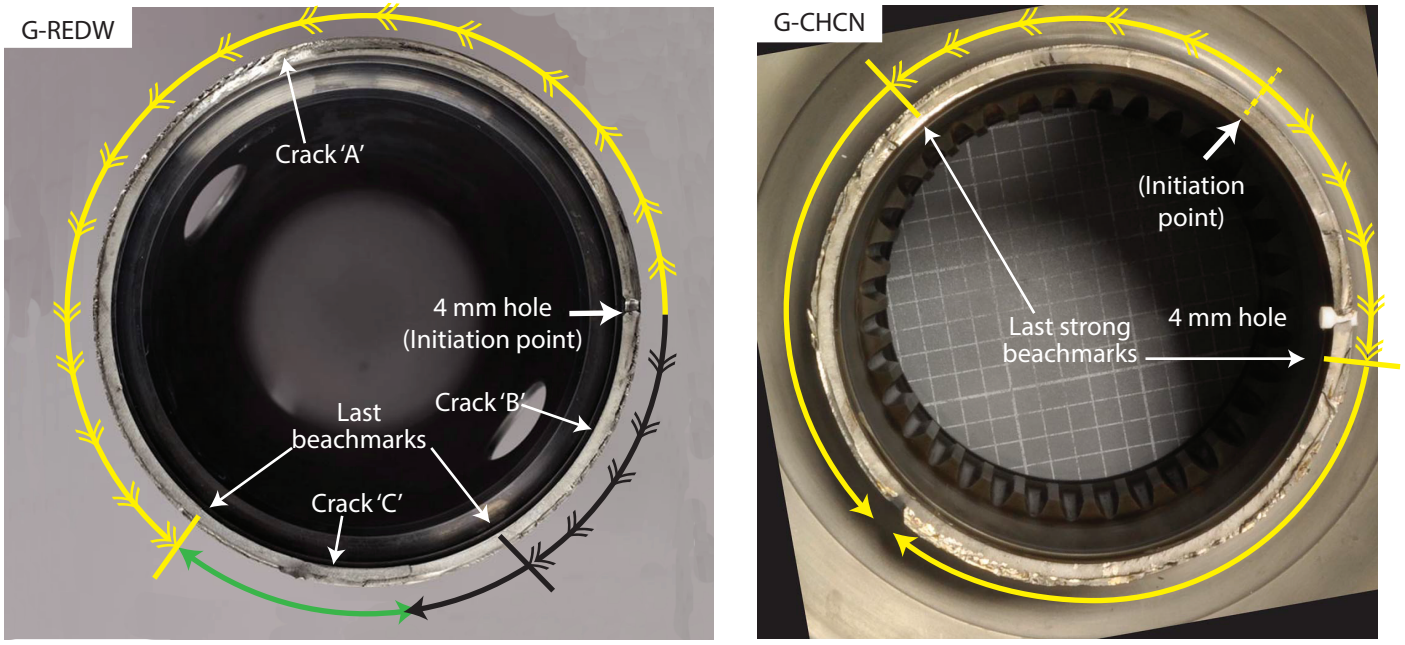

Figure 4
Location of beachmarks on G-REDW and G-CHCN

Cracks without beachmarks
Cracks with beachmarks

as low as 20 engine[4] hours. From the recorded data this corresponds to approximately 15 flying[5] hours. Another model has shown that the crack growth time could be as high as 31 flying hours. Detailed analysis of the beachmarks continues.

At present it is not possible to determine how long it took for the crack to initiate and grow to 4 mm. The growth of the crack from the last identified beachmarks could have occurred during the accident flight.

For G-CHCN, work continues to identify all the beachmarks on the fracture surface. The provisional examination and analysis indicates that the first beachmark was identified at 2 mm either side of the initiation point (giving a crack length of 4 mm). Early analysis shows that there is a possible close correlation in the crack propagation time in the shafts fitted to G-CHCN and G-REDW.

Condition of MGB on G-REDW and G-CHCN

Examination of the MGBs fitted to G-REDW and G-CHCN identified the presence of glycol throughout and no visual evidence of heat distress or significant damage to any other components in the MGB.

On G-REDW, light, unsymmetrical, marks were found on the bearing cages fitted to the upper roller and ball bearings that are believed to have occurred after the shaft failed. Part of the outer race on the lower roller bearing had broken away as a consequence of the shaft failure.

On G-CHCN, there was evidence of the rollers on the upper roller bearing having slipped along the outer race and there were light marks, similar to those seen on G-REDW, in the cage on the roller bearing. The lower roller bearing displayed no unusual marks.

Ongoing investigation into the failure of the bevel gear vertical shaft

The investigation has not identified the root causes of the failure of the bevel gear vertical shafts fitted to G-REDW and G-CHCN. It is possible that the failures occurred for different reasons.

To date the investigation has carried out a detailed examination of the MGB and the bevel gear vertical shaft fitted to G-REDW. A component fatigue test has been carried out on a new bevel gear vertical shaft and the stresses in the component, determined using finite element modelling, have been verified against the stresses measured on a shaft run in the manufacturer's dynamic test rig. A review of the manufacturing process of the bevel gear vertical shaft and the HUMS data from both accident aircraft has also been carried out.

The investigation is currently seeking to confirm the material properties and the in-flight dynamic loads on the MGB and bevel gear vertical shaft. On-going work, some of which is anticipated to extend into 2013, includes:

- Dimensional analysis, fractography and metallographic examination of the bevel gear vertical shaft and MGB fitted to G-CHCN.
- Tests on parent and welded material samples (coupons) to confirm the material properties of the 32CDV13 steel alloy, used

Footnote

[4] Engine hours are based on the first engine start to the last engine shut down, which closely corresponds to the times that the bevel gear vertical shaft is rotating.

[5] The flying hours used in the HUMS were established from the operation of the air / ground switch. In the AAIB calculation the flying hours were established using recorded data from the radio altimeter.

by the manufacturer in the design of the component, and the material's susceptibility to cracking from small features.

- A flight load and vibration analysis programme to confirm the predicted loads in the weld region, and to establish if there is an area in the flight envelope where the bevel gear vertical shaft might operate at one of its natural frequencies.

- Examination of a sample of shafts removed from EC225 LP helicopters and an analysis of oil removed from other EC225 LP helicopters operating out of Aberdeen.

Emergency Lubrication system investigation

The first in-flight activation of the emergency lubrication system on the EC225 LP was during the G-REDW accident on 10 May 2012. The second in-flight activation was during the G-CHCN accident on 22 October 2012. On both occasions the EMLUB failure caption illuminated, resulting in the ditching of the helicopters. The initial examination of both helicopters revealed that the emergency lubrication system had operated. The lack of visual evidence of heat damage to the gearbox components indicates that the system had lubricated and cooled the MGB during the short period[6] between the loss of oil pressure and the aircraft ditching.

On 17 October 2012 the AAIB published Special Bulletin S5/2012, which contained a description of the emergency lubrication system and included the following Safety Recommendation:

Safety Recommendation 2012-034

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.

Tests have been carried out on a ground test rig using a Turbomeca Makila 2A1 engine and all the parts of an EC225 bleed air system. The preliminary finding is that the bleed air pressure sensor was probably the source of the low-pressure signal that led to the MGB EMLUB caption illuminating on G-REDW. This pressure sensor has been tested and was found to operate within its specification. Tests on a complete emergency lubrication system, with and without an engine, and components from G-CHCN are ongoing.

Further safety action taken by Regulatory Authorities and Eurocopter

On 21 November 2012 Eurocopter issued revision 2 of EC225 ASB No.04A009 and revision 2 of AS332 ASB No.01.00.82. These were mandated by the EASA Emergency AD 2012-0250-E which superseded the previous EASA Emergency AD 2012-0225-E. These introduced operational changes and additional inspection requirements. The UK and Norwegian Civil Aviation Authorities have issued Safety Directives[7] that prohibit flight in a hostile environment of AS332 and EC225 helicopters that are applicable to the EASA AD.

Published 29 November 2012

Footnote

[6] Approximately 9 minutes for G-REDW and 7 minutes for G-CHCN.

Footnote

[7] UK CAA SD-2012/005.