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AAIB Air Accidents Investigation Branch

AAIB Bulletin S2/2013 *SPECIAL*

ACCIDENT 1

Aircraft Type and registration:	EC225 LP Super Puma, G-REDW
Date & Time (UTC):	10 May 2012 at 1114 hrs
Location:	20 nm east of Aberdeen

ACCIDENT 2

Aircraft Type and registration:	EC225 LP Super Puma, G-CHCN
Date & Time (UTC):	22 October 2012 at 1425 hrs
Location:	Approximately 32 nm southwest of Sumburgh, Shetland Islands
Information Source:	AAIB Field Investigations

Introduction

This Special Bulletin contains information on the progress of the investigation into the emergency lubrication systems and the Crash Position Indicators (CPI) for the accidents to G-REDW on 10 May 2012 and to G-CHCN on 22 October 2012. This follows the publication of previous Special Bulletins S2/2012, S3/2012, S5/2012, S6/2012 and S7/2012.

Emergency Lubrication

Background

On both G-REDW and G-CHCN the bevel gear vertical shaft fractured, leading to associated warnings of loss of Main Gear Box (MGB) oil pressure on the Central Warning Panel (CWP). Both crews actioned the '*Total Loss of MGB (Main Gear Box) Oil Pressure*' checklist, which required the activation of the MGB emergency lubrication system. However, in both cases, approximately 30 seconds, later the MGB EMLUB caption illuminated on the

CWP indicating that the emergency lubrication system had failed, resulting in the subsequent ditching of the helicopters. These are the only two known occasions in which the emergency lubrication system has been activated in operational flight. Strip examinations of the MGBs revealed the presence of glycol throughout and no visual evidence of heat damage, indicating that the system had lubricated and cooled the MGB.

MGB certification requirements

The EC225 LP was certified by the European Aviation Safety Agency (EASA) against the Joint Aviation Regulations (JAR) 29. The regulations require the helicopter to continue safe flight, at prescribed torque and main rotor speeds, for at least 30 minutes following the loss of the MGB lubrication system. This is met on the EC225 LP with an emergency lubrication system that uses a mixture of glycol and water, called Hydrosafe 620, which cools and lubricates the MGB. Certification included a test on a ground rig in which the oil was drained from a MGB and pressurised air (simulating engine bleed-air) and Hydrosafe 620 were sprayed into the gearbox. The test was run for more than 30 minutes and demonstrated that there was no significant damage to the MGB. Although the emergency lubrication sub-systems were tested individually, no test was carried out on the complete system during certification, either on a test rig or installed on the helicopter.

MGB lubrication system description

The MGB lubrication system includes two mechanically-driven oil pumps and a crew-activated emergency lubrication system (Figure 1). The latter comprises: a bleed-air supply from the left engine, a Hydrosafe 620 supply from an 11 litre reservoir, a series of small pipes around and inside the MGB (to deliver the Hydrosafe 620 in a spray), and monitoring and command systems on a dedicated Printed Circuit Board (PCB).

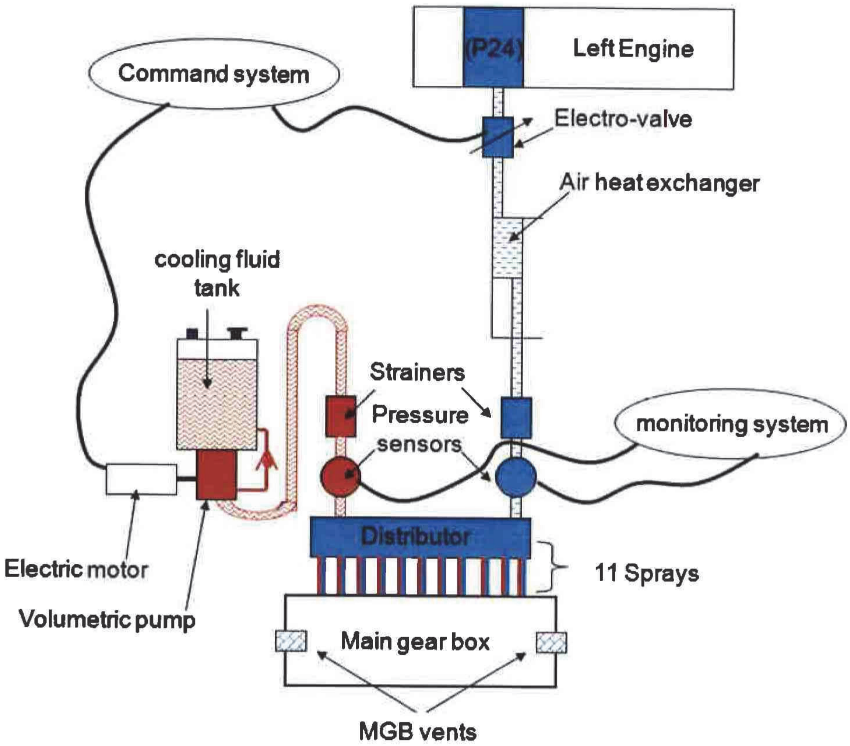


Figure 1

Schematic of the Emergency Lubrication System

A MGB EMLUB caption will illuminate if low pressure is detected by either of the two pressure switches, one in the Hydrosafe 620 line and the other in the bleed-air line. It will also illuminate if there is an erroneous signal detected by the PCB. The caption is inhibited for approximately 30 seconds after the emergency lubrication system is activated, to allow the system to reach a steady-state. The MGB EMLUB caption is not latched.

The low pressure signal is generated by either the Hydrosafe 620 or bleed-air pressure switches if the pressure does not exceed a specified threshold, p_{on}, when the system is activated, or if the pressure subsequently falls below a specified threshold, p_{off}.

The specified range for p_{on} for each pressure switch is between 0.6 and 1.0 bar (relative to ambient).

Emergency Lubrication System - wiring for the pressure switches

The pressure switches have three output pins, which are electrically connected to the PCB. The original standard pressure switches were constructed such that the wire from Pin 1 is common, the wire from Pin 2 carries the high pressure signal and the wire from Pin 3 the low pressure signal. However, following a modification in 2010 (MOD 0752520) the internal wiring of the switches was changed, owing to an error in the specification sent to the switch manufacturer. This resulted in the transposition of connections to Pin 1 and Pin 3 within the pressure switches. The wiring and internal schematic for the switches before and after MOD 0752520 is shown in Figure 2. The schematic is valid for both the Hydrosafe 620 and bleed-air switches.

Both G-REDW and G-CHCN had MOD 0752520 embodied. For helicopters with MOD 0752520, the MGB EMLUB caption will illuminate after a 30 second delay following activation of the emergency lubrication system, if there is:

- A pressure above the switch threshold which will result in an erroneous signal being detected by the PCB
- A pressure below the switch threshold which will result in detection of a low pressure condition
- An erroneous signal to the PCB for other reasons

In summary, the MGB EMLUB caption will illuminate for any of the three possible states - high pressure, low pressure or an erroneous signal - when the system is activated.

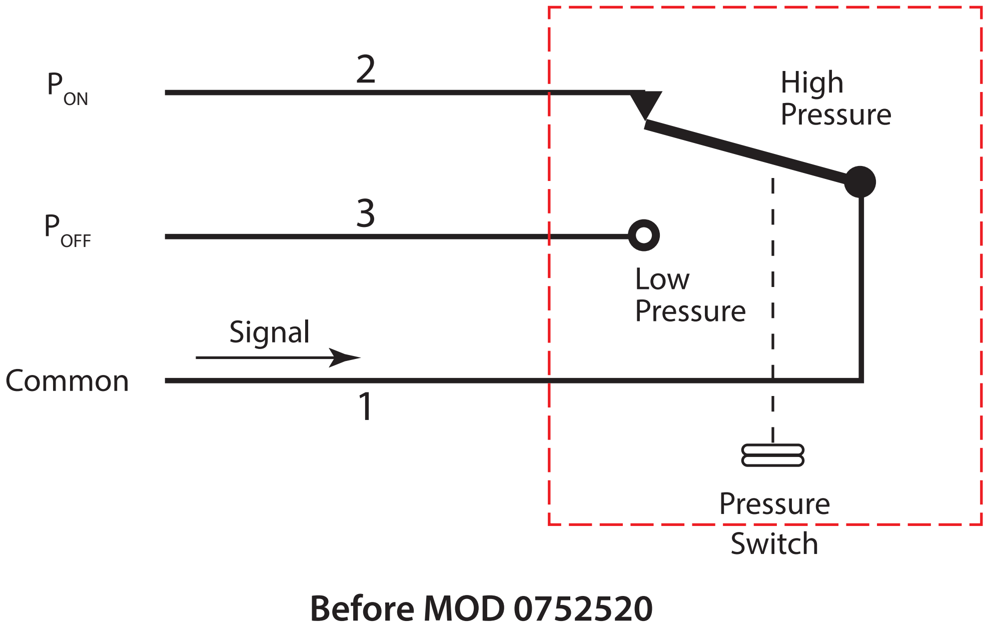
Emergency Lubrication System - bleed-air and Hydrosafe 620 pressure switches

The two pressure switches from both helicopters were tested. All four switches conformed to their respective acceptance tests, with activation thresholds (p_{on}) in the range of 0.61 to 0.68.

Emergency Lubrication System - Hydrosafe 620

Both Hydrosafe 620 pumps were tested and operated to specification. Thus there was evidence that the pumps were operating normally from the time the system was activated until the helicopter ditched.

Bench tests were carried out on an MGB with a failed bevel gear vertical shaft. The Hydrosafe 620 and bleed-air supplies were activated and temperatures were measured at the Hydrosafe 620 pressure switch



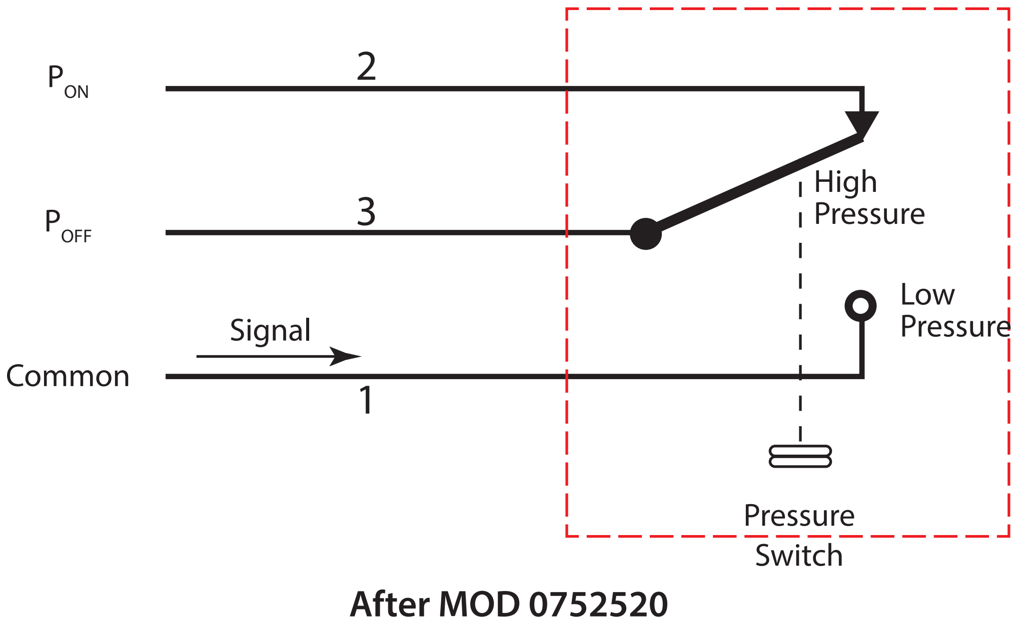


Figure 2

Schematic of wiring and pressure switches pre and post MOD 0752520 housing and MGB casing. It was found that after about 10 minutes the Hydrosafe 620 pressure had started to decrease 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.

Emergency Lubrication System - Engine tests

The engine and helicopter manufacturers tested the bleed-air output from several Makila 2A and Makila 2A1 engines. These included bench tests of the engines from G-REDW and G-CHCN, ground tests on in-service helicopters, and flight tests by the helicopter manufacturer. These tests revealed that the bleed-air pressure depends on the altitude, power setting and engine modification state, and under certain conditions was lower than the pressure used in the design and certification of the system.

Emergency Lubrication System - Bleed-air system

The components of the bleed-air systems from the accident helicopter were tested along with similar tests carried out on new components, in particular to understand the pressure losses in the system. The bleed-air supply was also tested on a ground rig, with and without the Hydrosafe 620 supply operating. From these tests and the engine tests, it was concluded that a bleed-air pressure switch with a p_{on} at the top end of the specified tolerance (1.0 bar) could generate an MGB EMLUB caption, even if all the parts of the emergency lubrication system were operating within their specifications.

Emergency Lubrication System - Printed Circuit Board

The PCBs, which controls and monitors the emergency lubrication system, were functionally tested and operated in accordance with the factory inspection test. The time delays for the PCBs from G-REDW and G-CHCN, during which a failure warning is inhibited, were measured and were consistent with the period of time between the crew's activation of the system and the illumination of the MGB EMLUB caption, derived from the Cockpit Voice Recorders.

Discussion

An error in the specification issued to the pressure switch manufacturer resulted in all EC225 LPs, with MOD 0752520 embodied, having a pressure switch configuration that results in illumination of the MGB EMLUB caption once the system is activated and after the 30 second delay. This was the most likely cause of the MGB EMLUB caption during the accident flights for G-REDW and G-CHCN.

The system was introduced on the EC225 LP to meet the 30 minute requirement in JAR 29. With the erroneous pressure switches, the MGB EMLUB caption will always illuminate after activation of the emergency lubrication system, requiring the crew to land immediately.

Eurocopter issued an Alert Service Bulletin (ASB) 05A032 on 22 February 2013, to modify the wiring on the helicopter, to be compatible with the pressure switches. The EASA issued Airworthiness Directive 2013-0037 on 22 February 2013 to mandate the ASB.

In October 2012 the AAIB made 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.

Since the Safety Recommendation was issued, it has been established that, 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, could generate a low pressure signal when the emergency lubrication system is operating normally. This would result in an erroneous MGB EMLUB caption.

The helicopter manufacturer is planning to introduce replacement pressure switches with lower thresholds and tighter tolerances, as well as improved maintenance procedures, that will provide the crew with an accurate indication of the status over the entire operating envelope of the helicopter.

Crash position indicator system

CPI system description

Both helicopters were equipped with an externally-mounted, deployable Type 15-503 crash position indicator (CPI). On G-REDW, the CPI was mounted on the lower left side of baggage hold at the rear of the main cabin. On G-CHCN the CPI was mounted on the left side of the tail boom, just aft of the main cabin.

The CPI system consists of the CPI beacon, a beacon release unit, a system interface unit, a cockpit control panel, a water activated switch and an aircraft identification unit (Figure 3). These components are located in various positions around the helicopter, and are connected by wiring which is integrated with the rest of the helicopter's wiring looms, and is therefore

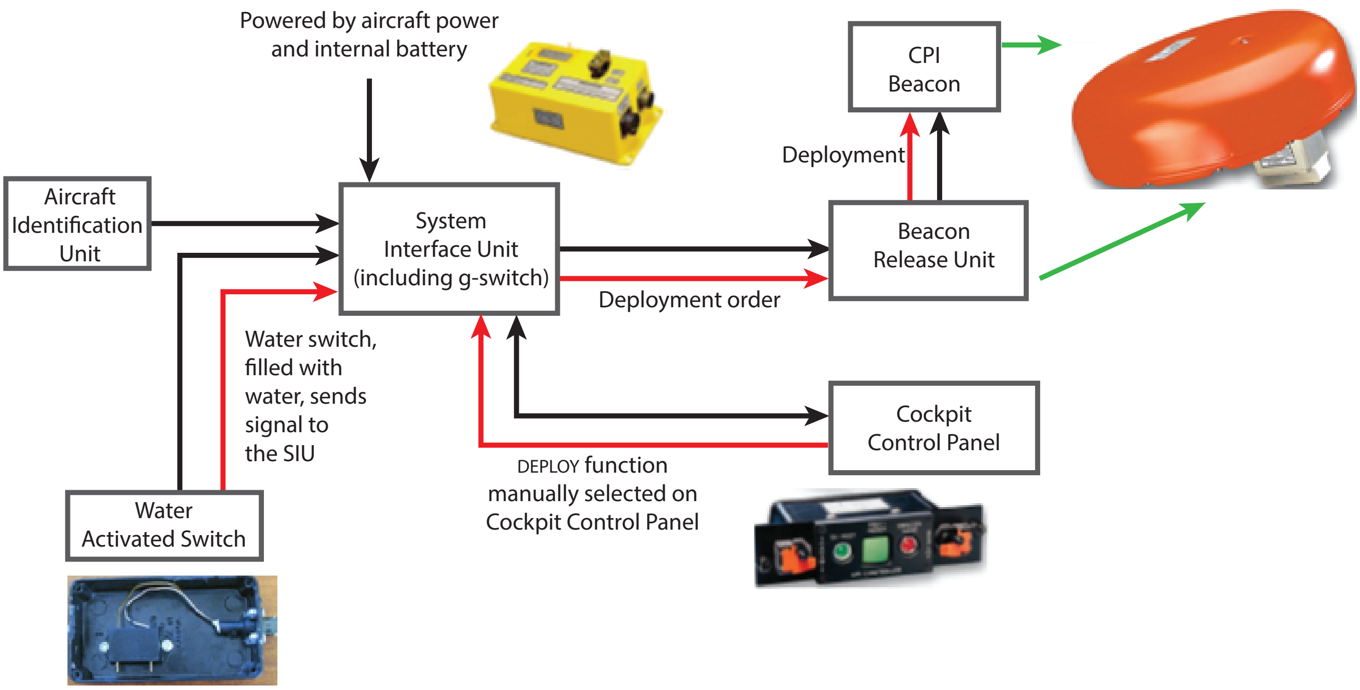


Figure 3

Schematic of Crash Position Indicator system not specifically protected against water ingress. The electrical connectors in the CPI system however conform to an industry standard specification[1] which ensures good performance when submerged in water at shallow depths.

The CPI system can receive power from the helicopter or from an internal battery within the system interface unit, which allows activation of the system for up to two hours after helicopter power is lost.

Deployment of the CPI is achieved by any one of the following:

(1) A g-switch detecting an acceleration of more than 6 g in any direction

(2) Manual operation of the DEPLOY switch on the cockpit control panel

(3) Immersion of the water activated switch

Regardless of the deployment method, automatic transmission of the beacon commences once the system has been triggered. The beacon release unit uses a small actuator and compressed spring to project the CPI away from the helicopter. The CPI is designed to then float and transmit on 406.025 MHz and 121.5 MHz.

The water activated switch is mounted in a box containing two exposed electrical contacts, a capacitor and a relay. Two holes in the bottom of the box allow water to enter when it is immersed; this allows the contacts to complete an electrical circuit to the beacon release unit. After a short delay, typically 5 to 10 seconds, for the capacitor to charge and operate the relay, the beacon release unit functions and deploys the CPI. If the connection between the contacts is interrupted during this period, due to fluctuations in the water level, the delay period resets. On both G-REDW and G-CHCN the water activated switch was mounted just above cabin floor level behind the cabin trim, and slightly aft of the left main cabin door aperture.

The CPI may be manually switched to a TRANSMIT function (without deployment) by the crew, via the cockpit control panel. Once selected to TRANSMIT, the CPI will not automatically deploy either by means of the g-switch or the water activated switch, unless a system reset, by pressing the TEST / RESET button on the cockpit control panel, has first been performed. The helicopter manufacturer was unaware of this feature of the CPI operation and as such no relevant information was included in the EC225 LP Flight Manual. Nor was this information included in the Type 15-503 CPI Operating Manual published by the CPI manufacturer.

Once activated, the CPI beacon transmits coded identification signals on 406.025 MHz, which are detected by the international Cosmicheskaya Sistyema Poiska Avariynich Sudov / Search and Rescue Satellite (COSPAS/SARSAT) distress alerting system. The transmitted signal from the CPI beacon takes the form of short pulses spaced at approximately 50 second intervals.

The system uses geostationary (GEO) satellites to detect the initial emergency transmission, whilst low earth orbit (LEO) satellites receive a signal and enable the approximate position of the point of origin of that signal to be established. A period of time is required since at least two LEO satellites need to be in receipt of an unobstructed signal for triangulation to take place. Although the satellites are capable of receiving and relaying a GPS position message, neither the G-REDW nor G-CHCN CPIs were GPS-enabled.

Footnote

1 Military Specification Mil-C-26482, Electrical Connectors.

The EC225 LP CPI system met the requirement in JAR-OPS 3.820[2], Automatic Emergency Locator Transmitter, paragraph (b), which was valid at the time of certification of the EC225 LP and which states:

> *'An operator shall not operate a helicopter in Performance Class 1 or 2 on a flight over water in a hostile environment as defined in JAR-OPS 3.480(a)(12)(ii)(A) at a distance from land corresponding to more than 10 minutes flying time at normal cruising speed, on a flight in support of or in connection with the offshore exploitation of mineral resources (including gas), unless it is equipped with an Automatically Deployable Emergency Locator Transmitter (ELT(AD)).'*

G-REDW CPI

The CPI on G-REDW did not deploy and remained attached to the helicopter. Photographic evidence shows that the water level in the cabin whilst the helicopter was floating was above the level at which the water activated switch was mounted. The crew did not activate the CPI beacon, either by selecting TRANSMIT or DEPLOY on the cockpit control panel, prior to the emergency evacuation. As such, no distress signal was detected from the helicopter during the accident.

G-CHCN CPI

The CPI on G-CHCN was manually selected to TRANSMIT by the flight crew during the final preparations for the ditching. At 1424 hrs a 'Detect-only' alert was received by the Aeronautical Rescue Coordination Centre (ARCC) at Kinloss, from a GEO satellite signal. This alert did not provide any positional information, but did contain the 15-digit hexadecimal code unique to G-CHCN. At 1432 hrs an unresolved position alert was then received, and at 1453 hrs a further LEO satellite alert was received, which confirmed the position of G-CHCN. The CPI beacon remained attached to the helicopter and continued to transmit until it was recovered to land. Photographic evidence and water damage within the cabin indicated that the water level was above that of the water activated switch, while the helicopter was floating.

Tests and Research

A review of the G-REDW and G-CHCN Flight Data Recorder (FDR) data confirmed that the accelerations experienced during both ditching events were insufficient to trigger the g-switches.

The G-REDW CPI system components, with the exception of the cockpit control panel and the aircraft identification unit, were removed from the helicopter and taken to the CPI manufacturer for examination and testing; they were found to be fully functional. There was no evidence of water ingress in the system interface unit or the beacon release unit. The beacon release unit was found to be in an undeployed state and as such there was no activation code stored in the system memory.

Testing of the water activated switch from G-REDW by submersion in water resulted in activation of the beacon release unit and subsequent transmission of the distress signal. No defects were identified with the tested components, which would have prevented the CPI from deploying during the accident.

Although the G-CHCN CPI beacon correctly transmitted distress signals following the manual selection of the

Footnote

[2] JAR-OPS 3 has been superseded by EC Regulation (EU) No 965/2012 of 5 October 2012. Paragraph CAT.IDE.H.280 *Emergency Locator Transmitter,* specifically replaces JAR-OPS 3.820, however there is no substantial change to the wording in the new regulation.

TRANSMIT function, all of the CPI system components were removed for testing. The cockpit control unit contained seawater and had suffered extensive internal deterioration due to corrosion, which rendered it incapable of operating. All of the other components were installed on the test bench and functioned correctly, leading to successful operation of the beacon release unit and deployment of the CPI. A visual examination of the water activated switch showed minor corrosion on one of the contacts, but no evidence of salt water deposits which may have indicated complete immersion in sea water. However, the external electrical connector was corroded, indicating that the water had reached at least that level. The activation code stored in the CPI system memory confirmed the manual TRANSMIT selection of the CPI during the accident. It was therefore concluded that there were no defects with these components that would have prevented the automatic deployment of the CPI beacon, had a manual TRANSMIT not been selected.

The helicopter wiring for the CPI system installation on both helicopters was satisfactorily tested for continuity and insulation resistance.

Previous incidents

On 18 February 2009 an EC225 LP G-REDU struck the surface of the sea during a night visual approach to an oil and gas platform in the North Sea. The AAIB investigation, published in AAIB Report 1/2011, determined that the failure of the CPI to deploy contributed to the delay in locating and rescuing the survivors. The investigation further determined that the CPI on G-REDU should, under the circumstances of the accident, have released automatically and commenced broadcasting on the COSPAS/SARSAT frequency, together with the VHF distress/homing frequency of 121.5 MHz. The reason for the failure of the CPI to deploy on G-REDU was not fully determined, however a number of possibilities were considered in the report. As a result of the findings of the investigation, Safety Recommendation 2011-071 was made:

Safety Recommendation 2011-071

It is recommended that the European Aviation Safety Agency reviews the location and design of the components and installation features of Automatically Deployable Emergency Locator Transmitters and Crash Position Indicator units, when required to be fitted to offshore helicopters, to ensure the reliability of operation of such units during and after water impacts.

Safety actions

The EASA responded to Safety Recommendation 2011-071 as follows:

'A rulemaking task was initiated in May 2012 (Reference: RMT.0120 (former 27&29.008)), which aims to undertake a broad review of helicopter ditching, water impact events and subsequent occupant survivability. A determination will be made on how certification rules and guidance material can best be developed to further enhance helicopter safety. The installation and functioning of all types of Emergency Locator Transmitters following water impact events is an integral part of this task. Both future and retroactive certification requirement are being considered.'

EASA have formed a working group to support this rulemaking task; the first meeting took place in early 2013.

CPI system modification

The Type 15-503 CPI installation on G-REDW, G-REDU and G-CHCN included the 503-21 standard of beacon release unit. Following the G-REDU accident, a new standard of beacon release unit (503-21-1) was developed by the CPI manufacturer which incorporates an integral water activated switch, in addition to the cabin-mounted water activated switch. The integral water activated switch is independent of the aircraft wiring, and will act to automatically deploy the CPI if the beacon release unit, mounted behind the CPI, becomes submerged. Thus automatic deployment of the CPI may occur, even if TRANSMIT has previously been selected.

Beacon release unit 503-21-1 is compatible only with system interface unit 503-24 with modification state -3 and above. It is designed to ensure that the CPI Beacon will deploy without dependency on the system interface unit, for example if the system interface unit was damaged, or if none of the other system interface unit triggers had been activated. The beacon release unit will remain functional for up to 15 minutes after power is removed from the system interface unit, after which an automatic 'power down' switches the beacon release unit to OFF.

Discussion

The accidents to G-REDU, G-REDW and G-CHCN are among three survivable off-shore accidents, investigated by the AAIB since the provision of an Automatically Deployable Emergency Locator Transmitter (ADELT) has been a mandatory requirement. The fitment of the CPI on the EC225 LP was intended to satisfy that requirement.

The preliminary findings of the G-REDW and G-CHCN investigations, with respect to the CPI system, have therefore been reported in this Special Bulletin in order to support the current EASA rulemaking task on this subject, which was initiated, in part, in response to Safety Recommendation 2011-071 arising from the G-REDU investigation.

The CPI is a primary radio location aid, to alert search and rescue authorities, and assist location of the helicopter and survivors in the event of an aircraft distress situation, such as ditching.

The CPI on G-REDW did not release automatically; photographs show the water level in the cabin was above the level of the water activated switch. Whilst further work is required to support any final conclusions, issues relating to the continuity of the helicopter wiring when submerged, the design of the water activated switch and the location of the water activated switch relative to the water level following the ditching are being investigated as possible causes for the non-deployment of the CPI.

For G-CHCN, the CPI correctly transmitted the appropriate distress signals following manual selection of the TRANSMIT function by the crew. However, had the helicopter not remained upright, the CPI would have stayed attached to the helicopter, due to the system design which renders the water activated switch, and thus the beacon release unit, redundant, following a manual TRANSMIT selection. This would greatly reduce the possibility of successful detection of the beacon transmission by satellites. As no information relating to this feature of the CPI system operation was included in the EC225 LP Flight Manual, the operators of G-REDW and G-CHCN were not aware of this feature.

As a result of the findings of this investigation the manufacturer of the CPI system has 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.

In addition, Eurocopter has undertaken a safety action to amend the Flight Manual for all Eurocopter helicopters equipped with a Type 15-503 CPI system, to incorporate this information and issued an Information Notice 2567-S-25 to promulgate this information to operators.

The Type 15-503 CPI system is also fitted to several other aircraft types which are not addressed in the aforementioned safety actions. In addition, other ADELT devices may exhibit a similar inhibition of the automatic deployment function following a manual selection to transmit. Therefore, in order to ensure that the Flight Manuals of all other aircraft equipped with a Crash Position Indicator system, or similar ADELT, contain information about any features which could prevent full automatic functionality of the system, the following two Safety Recommendations are made:

Safety Recommendation 2013-006

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.

Safety Recommendation 2013-007

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.

Ongoing investigation into the failure of the bevel gear vertical shaft

Since the update published in AAIB Special Bulletin S7/2012 on 29 November 2012, the investigation has continued to review the material properties and the dynamic loads in the bevel gear vertical shaft.

The coupon testing undertaken by QinetiQ to confirm the material properties and the material's susceptibility to cracking is nearing completion. An independent review of the fracture mechanics to establish why the shafts failed during normal operations is also being carried out. In order to ensure that the dynamic flight loads acting on the shaft are consistent with the design assumptions, the aircraft manufacturer is running a shaft, equipped with 32 strain gauges, through a series of dynamic tests.

The results of this activity will be reported in subsequent bulletins.

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