ACCIDENT

Aircraft Type and Registration:	Eurocopter AS332L2 Super Puma, G-CHCG
No & Type of Engines:	2 Turbomeca Makila 1A2 turboshaft engines
Year of Manufacture:	2003
Date & Time (UTC):	3 March 2006 at 1503 hrs
Location:	104 nm north-east of Aberdeen VOR/DME
Type of Flight:	Commercial Air Transport
Persons on Board:	Crew - 2 Passengers -18
Injuries:	Crew - None Passengers - None
Nature of Damage:	Lightning strike damage to one main rotor blade, one tail rotor blade and other components including all three main rotor servo-actuators
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	Approximately 15,000 hours (of which about 2,500 hrs were on type) Last 90 days - 91 hours Last 28 days - 29 hours
Information Source:	AAIB Field Investigation

Synopsis

The helicopter was ferrying oil company personnel from an oil production platform to Aberdeen Airport when it suffered a lightning strike. There was no vibration or damage visible to the pilots but there was a temporary disruption of the flight instrument screens and navigation system, and indications of failures in the flight data recorders. Whilst approaching Aberdeen Airport in deteriorating weather conditions, the helicopter suffered a hydraulic system failure due to loss of fluid but it was landed safely.

The exterior damage to the helicopter visible on the ground was typical but a further safety hazard was the hidden damage to the interior portions of the main rotor hydraulic actuators which had caused an hydraulic leak, depleting one system. Some of this damage may have been inflicted by an earlier lightning strike and this damage was not detected although the appropriate post-lightning strike checks had been carried out.

New post lightning-strike inspection procedures to be issued by the helicopter's manufacturer and amendments to the operating company's QRH and Operations Manual have been devised.

History of the flight

The helicopter was ferrying oil company personnel between the Beryl 'B' oil production platform and Aberdeen Airport. The outbound flight from Aberdeen had landed on the Beryl 'A' platform, after which the aircraft operated a shuttle flight to the Beryl 'B' platform.

The commander and co-pilot had reported for duty at 1100 hrs for a scheduled departure at 1200 hrs, though this was subsequently revised to 1300 hrs. Pre-flight preparations were routine, with full weather information available to the crew via a computerised self-briefing facility. The weather forecast for Aberdeen was for scattered cumulo-nimbus cloud with snow showers and thunderstorms for the afternoon period, with associated reductions in visibility to as low as 500 m. The Beryl Field weather report for 1215 hrs indicated that shower activity was relatively light and that no lightning activity had been observed. As part of their pre-flight preparation, the crew had access to a Meteorological Information Self Briefing Terminal (MIST) and were able to view information about lightning strikes detected within the current hour and the previous hour. There was no significant lightning activity recorded over the North Sea generally, and none at all in the planned area of operation.

Due to the late arrival of the inbound aircraft a 'rotors running' crew change was made. The aircraft took off at 1330 hrs for an uneventful flight to the Beryl 'A' platform. The aircraft flew at 3,000 ft and, although showers were encountered, weather radar returns were weak and no deviations from track were necessary. The helicopter landed on the Beryl 'A' platform, refuelled and operated the shuttle to the Beryl 'B' as planned. With the co-pilot as handling pilot, the aircraft lifted off again at 1527 hrs with 18 passengers on board.

The initial part of the flight to Aberdeen was flown at 2,000 ft. Although the crew reported a noticeable increase in weather radar returns, there were no high intensity returns and again no track deviations were considered necessary. Thirty six minutes into the flight, the helicopter was flying near to the base of cloud and encountering light hail when a lightning strike occurred. The commander was aware only of a loud bang or crack, whilst the co-pilot, who was looking across the flight deck, was also aware of a flash forward of the aircraft. The passengers generally reported both a flash and a bang.

There were no obvious signs of damage, and no vibration. The helicopter's four Electronic Flight Instrumentation System (EFIS) screens went blank, but recovered automatically within seconds. All flight data indications on the screens appeared normal, with the exception of the route steering information. The navigation system had suffered a power interrupt and all sensors were showing invalid information, including the GPS which was the primary navigation sensor at that stage. Within about a minute, GPS signals became valid again and the system automatically re-entered its navigation mode, with all pilot-entered route data being retained in memory. The crew also noticed that discrete FDR and DFDAU[1] caution lights were illuminated on the Health and Usage Monitoring System (HUMS) control panel, and that the ELEC caution on the Central Warning Panel (CWP) was illuminated, though at a much lower intensity than normal. The ELEC caption could not be cancelled in the normal manner and so it remained illuminated at the reduced intensity for the remainder of the flight (the caption normally indicated that a discrete caution light had illuminated on the electrical panel, though none had in this case).

Footnote

[1] FDR – Flight Data Recorder. DFDAU – Digital Flight Data Acquisition Unit.

The helicopter was descended to 1,000 ft in order to remain clear of cloud and Aberdeen ATC was notified of the lightning strike and change of altitude. The crew did not declare an emergency. There were no QRH actions for a lightning strike, so the crew continued the route with the intention of assessing their landing options as they neared the coast.

The crew were using VHF 2 for ATC communications as was normal practice, and attempted to establish contact with their company on a discrete frequency on VHF 1 but were unsuccessful. The crew tried to contact other company aircraft with a view to having their message relayed (due to their low altitude), but were answered by Scottish Military who indicated that G-CHCG was transmitting on the 'guard' emergency frequency, 121.5 MHz. This was contrary to indications on the radio control panel. Further attempts to use VHF 1 had the same result so the crew regarded the radio as inoperative and ceased trying.

As the helicopter neared the coast, an increasing intensity and quantity of weather radar returns was received and some weather avoidance became necessary, with a line of snow showers stretching from Peterhead in the north towards Aberdeen Harbour. Runway 34 was in use at Aberdeen, but in view of the extra time it would take to fly an instrument approach to that runway, the crew elected to fly visually inbound to the Airport, along the coast at a reduced altitude if necessary. Consideration had been given to landing at Peterhead (Longside) heliport, 22 nm from Aberdeen Airport, but this option was rejected after ATC informed the crew that it was being affected by snow showers. The crew also rejected the possibility of an 'off site' landing due to the hazard that would be created by the recently fallen loose snow.

As the helicopter neared Aberdeen the crew carried out the initial approach checklist, which included lowering the landing gear. Although the gear lowering sequence was normal, and 'down and locked' indications were achieved, it was followed soon afterwards by abnormal hydraulic system indications. The HYD caption on the CWP illuminated, together with SERVO, AP HYD and LVL captions on the hydraulic panel, although the three panel lights appeared to be flashing at random. The co-pilot noticed the hydraulic pressure gauge fluctuate up to three times, each time dropping to near zero before recovering to normal system pressure. The crew discussed the possibility that the indications may be due to an electrical problem, but as they did so the caution lights illuminated steady, the pressure gauge dropped to zero, and the co-pilot felt 'pulses' through the cyclic control as the controls became stiffer, confirming that it was indeed an hydraulic problem.

At about this time the aircraft entered worsening weather conditions, forcing the crew to ask ATC for a climb and radar assistance for an instrument approach to Runway 34. However, as the aircraft was climbing towards 2,000 ft, it emerged from cloud and a clear area was seen to the right, in the direction of the airport. The commander instructed the co-pilot to fly towards the gap, and made a 'PAN' call to ATC stating his intention to revert to a visual approach, which was immediately approved.

The aircraft landed without further problem on Runway 34. Once the helicopter was on the ground, some vibration could be felt through the airframe. After taxi-in and shutdown it became evident that the helicopter had suffered significant lightning strike damage to the main and tail rotor assemblies, and that a major hydraulic leak had occurred, with fluid draining down the helicopter's right side from a region to the rear of the main gearbox.

Examination of the aircraft

The helicopter (Manufacturer's serial no 2592) was examined by AAIB Inspectors at Aberdeen on the day after the incident. By then, the main and tail rotor blades had been removed as had the three main rotor hydraulic actuators. Engineering personnel were checking the transmission and flying control components for the presence of residual magnetism caused by the lightning strike.

There was obvious lightning damage to one main and one tail rotor blade, the main blade exhibiting surface scorching at the tip and root, including an area where the sub-surface bonding braid near the leading edge root had evidently been melted or blasted out and was missing a section about 23 cm long. The bonding strap from the blade to the rotor head had also melted. Other surface effects on the carbon fibre skin were observed at several points along the span.

The tail rotor blade had lost two sections of the metal leading edge erosion strip which also serves as a conductive path for electrical current. The missing sections were at the point where the parallel section of the blade joins the tip and the junction of the erosion strip and the sub-surface conducting strip. The bonding strap from the blade to the rotor hub had also melted.

Other areas of localised overheat damage were found, principally on the pitch link spherical bearings but also on a bearing associated with the flying control circuit within the fuselage. Similar damage had also been found on the spherical bearings of the three main rotor hydraulic actuators and, significantly, on the external 'Fescolized'[2] portion of the ram of two of them (see Figure 1).

Figure 1

Outer rod showing externally visible arcing damage

This damage had the appearance of localised melting and erosion of the chromium plating and the surface of the steel underneath and was clearly the origin of the hydraulic leak from No 1 system. All three actuators were despatched for testing and laboratory examination by their manufacturer under AAIB supervision.

Residual magnetism checks on the main, intermediate and tail rotor gearboxes led to their rejection and removal for examination but it is understood that this did not reveal any internal damage. Signs of arcing on the tail rotor driveshafts and some tail rotor control components also led to their removal. The unserviceable VHF transceiver and DFDAU units were replaced.

Description and examination of the main rotor hydraulic actuators

The AS322 has dual hydraulic systems and, to achieve the necessary redundancy in the primary flying controls, the main rotor servo actuators have a tandem arrangement (see Figure 2) in which each hydraulic system supplies power to separate pistons, although the pistons are on a common shaft forming part of a single actuator. Either system can control the helicopter on

Footnote

2 Patented process for electroplating with cadmium, chromium or nickel.

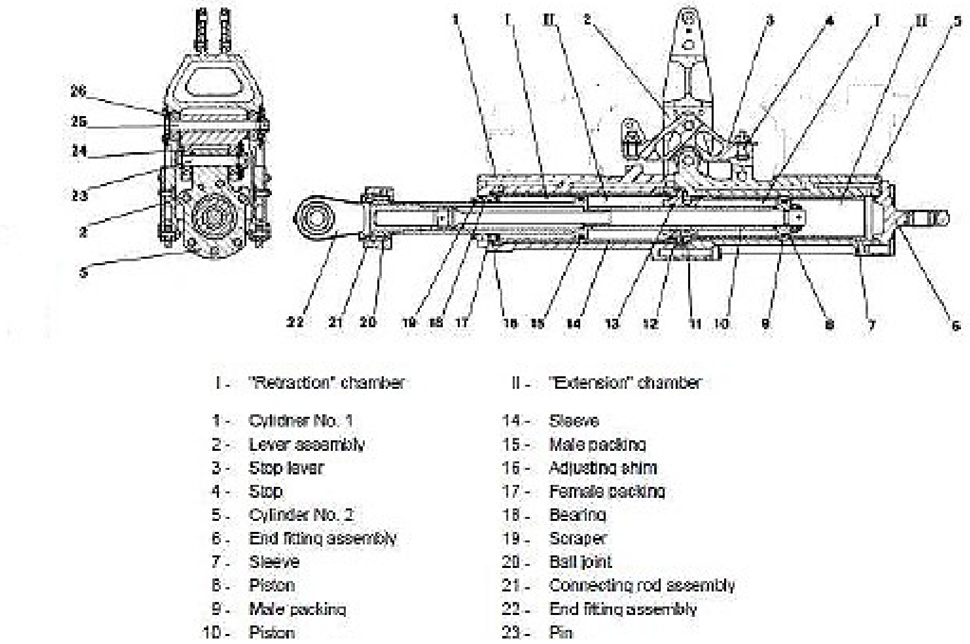

Figure 2

AS332L main rotor servo actuator

its own but, of course, they normally work together. It can be seen that the Fescolized portion of one piston extends out of the body of the actuator (No 1, or Left system) and is therefore visible externally, but the piston of the other system (No 2, or Right) remains completely hidden internally. A drain hole between the intermediate bearings of No 2 system should provide witness of any internal leakage past the Fescolized rod.

The examination commenced with a bench test of all three actuators. They were checked first at about 25 to 30 bar before full system working pressure of 175 bar was applied. The first actuator tested had visible evidence of metal erosion on the external portion of the Fescolized rod and, when tested at low pressure, a significant external leak was obvious such that it was decided not to continue to high pressure. Strip examination of this unit showed that the upper bearing seal had been perforated and it was concluded that this was responsible for the leak which had depleted No 1 system. Some erosion damage was noted on one of the spherical bearings but the internal rod was not marked and there was no leakage from System 2.

The next actuator tested showed some leakage from the centre bearing drain which disappeared at working pressure. There was slight leakage from System 1 at low pressure which again disappeared at the higher value but no leakage from System 2. The external portion of the rod also had visible erosion damage to the Fescolized portion and, when stripped, was found to have similar internal metal erosion damage. This would not have been visible without dismantling. Again, one spherical bearing had erosion damage and both the upper and central bearing seals were slightly damaged, accounting for the leak at low pressure.

The third actuator had no visible damage to the external Fescolized rod. It exhibited a slight leak from System 2 at the centre bearing which disappeared at high pressure but no leakage from System 1. However, when dismantled there was significant erosion damage to the internal rod and it was noted that the damage appeared to have two distinct areas, (see Figure 3), suggesting two separate events occurring with the piston in slightly different extensions; this possibility is discussed below. There was also evidence of electrical tracking on one of the spherical bearings.

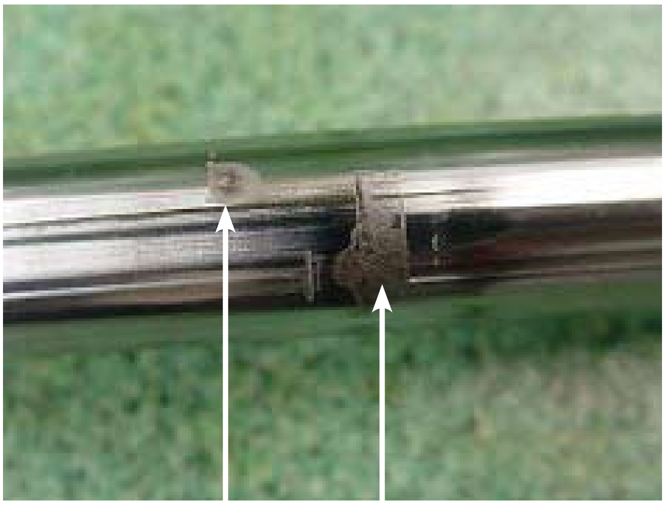

Figure 3
Damage to Fescolized portion of inner rod showing two distinct areas of arcing damage

Engineering analysis and conclusions

The hydraulic caution lights reported by the crew were to be expected from complete depletion of the No 1 system. The 'LH HYD LVL light illuminates when the reservoir level drops below 4 litres. At this point, a solenoid valve also closes to shut off the landing gear, tail rotor control actuator and autopilot from the main system, generating SERVO and AP HYD captions.

For the most part, the damage to the aircraft was typical of such events and, in particular, the damage to the rotor blades was not as severe as other recorded incidents which resulted in noticeable or severe vibration. Careful visual inspection revealed damaged components such as bearings and residual magnetism checks led to the rejection of otherwise apparently undamaged components. Although this operator was apparently unaware of previous instances of lightning damage to main rotor servo actuators, such damage has been experienced before and has been reproduced in testing for certification of later helicopter designs using similar actuators. When the AS332 was certified, there was no such testing required for these components.

Although there was no loss of hydraulic fluid from System 2, despite the damage to the pistons of two actuators which was revealed on strip examination, the damage to the actuators represented the most serious threat to airworthiness in this incident. The reason for the leak which led to depletion of the No 1 system appears to have been damage to the seal, either from the strike itself or from rubbing against the rough, eroded area of the rod. It is conceivable that, in the absence of seal damage, there will be no leakage when the actuator is moved such that the eroded area no longer impinges on the seal, but when the seal is damaged, leakage could occur at all actuator extensions. It was noted that any slight leakage, indicating seal damage, tended to be evident at low pressure only, suggesting that checking for leaks would be more rigorous at these pressures. However, low pressure testing is not normally required because the seals are optimised for a working pressure of 175 bars. According to the helicopter manufacturer, leakage at low pressure should not necessarily be considered as a malfunction because it would be difficult to define leakage criteria appropriate to low-pressure testing.

The fact that lightning damage to the actuators does not appear to be common is perhaps surprising given that any hydraulic component such as this, where there is no direct metal-metal contact between the cylinder and the ram, will have a propensity for a spark to jump across the non-metallic seals and cause localised melting of the steel. Of particular concern is the observation on the internal rod of one actuator that it had experienced two separate strikes. G-CHCG had suffered a lightning strike three days prior to this incident which resulted in a main rotor blade replacement. It is likely that one of the internal damage indications occurred as a result of this strike but it was not detected at the time.

Manufacturer's post lightning-strike check requirements

The Eurocopter Aircraft Maintenance Manual chapter 05-53-00-225 contains guidance on check requirements after a lightning strike**.** Paragraph 3.1.3.3 contained the only specific reference to checking the actuators as part of the main rotor head inspection. It stated:

> *……….perform a detailed check of all junction areas showing electrical discontinuity:*
>
> - *servocontrols (oscillating bearings, power rods and cylinders).*

The safety issue is that it is not possible to check visually for internal damage affecting No 2 system unless a leak is detected from the centre bearing. It is reassuring to note that all three actuators would have been removed even without the obvious damage to the Fescolized rods because of the damage to the spherical bearings (called 'oscillating bearings' in the manual extract quoted above). However, if it is accepted that this had caused one of the marks on the actuator which had apparent evidence of two separate strike events, such damage was not detected after the previous lightning strike.

Eurocopter have stated that they will be producing a Service Letter to operators which will include the following:

> *'To ensure that servo-controls damaged by a lightning strike do not remain in service, the EUROCOPTER documentation will be modified in order to specify the type of checks to be carried out following a lightning strike.*
>
> ***For main rotor servo control:***
>
> *a) Research of arcing mark on ball joint, power rod and body.*
> *b) Research any evidence of leakage.*
>
> *If any of these anomalies will lead (sic), the servo control must be sent to a repair station for detailed inspection and repair.*
>
> ***For tail rotor head servo control:***
>
> *If arcing mark on tail rotor blade or tail rotor head, remove the tail rotor servo control and send this equipment to a repair station for detailed inspections.*
>
> ***For main rotor and tail rotor head:***
>
> *a) Check the flight controls devices on servo control vicinity.*
>
> *b) Following a lightning strike revealed on a helicopter, a particular attention of the two hydraulic circuit's fluid level is to be performed during the next ten daily inspections.'*

Although this Service Letter will apply specifically to the AS332L, it is understood that similar instructions will be issued for other helicopter types manufactured by Eurocopter that have similar servo controls.

Meteorological information

General situation

An aftercast was obtained from the Met Office. At 1200 hrs on 3 March 2006 there was a slack area of low pressure in the North Sea with a line of instability lying just east of the coast of Scotland. The weather was cloudy or overcast with showers of rain and snow at the lower levels. Thunder was likely in some of the showers. The surface visibility would have been 15 to 25 km but reducing to about 2,000 m in snow showers. The base of the cumulus cloud would have been 2,000 to 2,500 ft, with stratus cloud beginning at 3,000 ft. The cloud base would have deteriorated in showers to between 1,000 and 1,500 ft beneath cumulo-nimbus clouds.

Lightning strike information

Information on the lightning strike was obtained from EA Technology, a UK company which has specialised in the monitoring of cloud-to-surface lightning strikes in the area of the British Isles for a number of years (see *Lightning detection systems* below for the method of strike detection). The strike was recorded as a single, isolated cloud-to-surface discharge at 1602:37 hrs, at position N58º 42' 24" W000º 12' 47", with a probable position tolerance of 1,500 m. The recorded position was within 2.5 nm of the estimated position of the strike. The strike had a strength of less than 40 kilo-amps and its polarity was positive. On the same day, between 0700 hrs and 1900 hrs, there were only two other lightning strikes in the North Sea area, each of which was in excess of 70 nm from the helicopter's position at the time of the strike.

Recorded information

Flight recorders

The aircraft was fitted with a combined Flight Data Recorder and Cockpit Voice Recorder (CVFDR) capable of recording a range of flight data parameters for a period of 8 hours and three audio tracks, each of 90-minutes duration, onto magnetic tape. The CVFDR was downloaded at the AAIB where data and audio recordings were recovered for the accident flight. Unfortunately, flight data from the CVFDR following the lightning strike was corrupted and unreliable, probably as a result of lightning damage to either the DFDAU or the data recording portion of the CVFDR, both of which sustained damage.

HUMS

Vibration data for the accident flight recorded for the operator's HUMS programme showed that there were no significant differences in vibration levels for the tail rotor and the main rotor before and after the lightning strike. However, these data were recorded at intervals of just under one hour and therefore do not give an immediate comparison pre- and post-strike.

Lightning physics

Lightning is essentially an electric discharge that occurs between one region of the atmosphere and another, or between one region of the atmosphere and the earth's surface. It occurs when the electric field exceeds a critical value, known as the 'breakdown potential'. The breakdown potential is high because air is a poor electrical conductor, so there needs to be a significant voltage potential if lightning is to occur. Such voltage potentials often occur in cumulo-nimbus clouds although the exact mechanism which causes them is not fully understood.

There are two types of lightning strike that can affect an aircraft in flight. The first is an 'intercepted' strike whereby the aircraft intercepts a naturally occurring lightning strike. The second is a 'triggered' strike which occurs when the conducting aircraft itself causes an intensification of the electric field in its vicinity. This intensification is sufficiently large to overcome the breakdown potential of the air and a lightning strike is triggered. It is thought that approximately 90% of all lightning strikes to aircraft are triggered by the aircraft itself, making it very difficult to forecast the strike.

Lightning detection systems

A number of ground-based 'Arrival Time Difference (ATD) systems world-wide are capable of detecting and recording lightning strikes. Such systems use a network of antennae, capable of detecting the extra low frequency radio signals (referred to as 'sferics') emitted by lightning. The time and location of a lightning strike can be calculated from the different times taken for the signals to reach the various receiver stations. The systems are able to discriminate between cloud-to-cloud strikes and cloud-to-surface strikes by the difference in the signals' polarisation, and normally only cloud-to-surface strikes are recorded and displayed, often within seconds of the discharge. The UK Met Office's own system provided the lightning strike data which was viewed by the flight crew on the MIST system as part of their pre-flight preparation.

The North Sea operators had jointly funded a system to display positions of lightning strikes on radar screens at Aberdeen ATC, using data supplied by the Met Office. However, the system used earlier technology and there was a delay of several minutes between a strike occurring and it being displayed, so its operational value was limited. At the time of writing this report, an updated system was being evaluated by National Air Traffic Services for possible future use at Aberdeen.

Airborne equipment is currently limited to weather radar and specialist systems which detect lighting sferics. Weather radar is able to detect areas of storm activity by means of radar returns from water droplets, but is unable to detect lightning itself. Systems which detect the electric signals from lightning are capable of displaying lightning strike data to the pilot on a dedicated display or as an integrated display with weather radar returns. Such systems can detect and display the early cloud-to-cloud discharges which often precede the more powerful cloud-to-surface discharges.

Neither of the two systems above is able to detect or warn of an increased risk of a lightning strike before it actually occurs, as they cannot detect the increase in atmospheric voltage potentials which precede an electrical discharge. Equipment is available which can measure such electrical energy fields, though whilst such devices (known as E-field meters) have been used in electrical field research, they have not been developed for operational airborne use.

Previous accident

On 19 January 1995 an AS332L Super Puma, registration G-TIGK, was lost over the North Sea after suffering a lightning strike which caused severe vibration and loss of tail rotor control. Whilst recognising that lightning discharge detection systems could not warn of the increased electrical fields that precede a discharge, the investigation decided that their required use could still afford helicopters a measure of protection from the lightning strike risk. The investigation made the following recommendation to the Civil Aviation Authority (CAA) on 7 December 1996:

> *"In order to provide helicopter commanders with the necessary 'real time' information to enable them to avoid flight into areas of actual thunderstorms or lightning activity in Public Transport helicopters which have composite rotor blades, the CAA and affected operators should jointly agree the fitment of lightning discharge mapping systems to such aircraft. The Authority should also inform other airworthiness authorities of the action taken in response to this recommendation." (Safety Recommendation 95-45)*

The recommendation addressees responded by insisting that further equipment trials were necessary before a decision could be made, and that the e-field sensing approach should be pursued as this potentially offered the most benefits. Earlier, and in response to the accident, initial development work on an e-field meter system for helicopters had been started by Lightning Technologies Inc. (LTI) of the USA, with the active support of the North Sea companies and the CAA. However, in November 1996 support for the e-field sensor development project was withdrawn, because the North Sea companies felt it to be too expensive. They took the view that, because the project was pure research only, it should be funded solely by LTI. Consequently, the e-field sensor approach was effectively terminated at this time, at least in terms of active support from the North Sea companies and the CAA.

In April 1997 the CAA issued the following response to the safety recommendation:

> *"Although the Authority would agree that an airborne lightning sensor mapping system may provide some benefit as a supplemental aid for North Sea helicopter operations and may lower the chances of a lightning strike attachment, there can never be any guarantee of this and it remains the case that adequate lightning protection provisions must be installed on the helicopter. The Authority would therefore have difficulty in justifying mandating the installation of lightning mapping systems for airworthiness certification purposes."*

Operational guidance

Part A of the operator's Operations Manual contained crew actions to be carried out after a known or suspected lightning strike. It had recently been revised to highlight the fact that there would likely be considerable damage to rotor blades, rotor heads and associated components. The manual stressed that damage may not be visible or detectable through vibration, and that the helicopter should be diverted and landed at the nearest suitable land base. Furthermore, in case of secondary indications of damage such as severe and increasing vibration, the aircraft should be landed immediately.

The pilots were aware that the aircraft's Quick Reference Handbook (QRH) contained no actions or advice in respect of a lightning strike, though with hindsight they both thought it should have done so. The QRH in use at the time was introduced by the operator's Norwegian sister company and had been adopted for use for reasons of commonality. A revised Operations Manual Part B and QRH were in preparation at the time of the accident, which addressed the lack of lightning strike guidance in the QRH. The new QRH contained the following text under the title "LIGHTNING STRIKE":

> 1. *LAND AS SOON AS POSSIBLE (Nearest land base recommended)*
>
> *If vibration increases significantly*
>
> 2. *LAND IMMEDIATELY*

The new Part B and QRH have been issued to training captains and to the AS332L2 simulator. Line pilots are being trained but printing difficulties have resulted in an effective date of January 2007 for widespread distribution of printed copies to line pilots and into helicopters.

Analysis

The lightning discharge which attached to the helicopter was the only cloud-to-surface strike recorded over a wide area of the North Sea during a 12 hour period. Although the ATD systems do not record inter or intra-cloud strikes, which could therefore have been present in the area, there was no other lightning activity reported by the helicopter's crew. Considering the proximity of the recorded strike to the helicopter's actual position, it is probable that the recorded discharge was the actual strike in question. The absence of other recorded or observed lightning activity would indicate that this was a triggered strike, induced by the presence of the helicopter itself.

The crew were aware that a general risk of lightning had been forecast for the day which, as usual, was associated with thunderstorms. However, the crew had not encountered a thunderstorm and weather radar returns did not suggest any active cloud formations, despite the forecast instability in the atmosphere. Nevertheless, given that the crew reported hail shortly before the lightning strike, it is probable that the helicopter was flying beneath an area of significant convective activity. There was no reliable forecasting of increases in atmospheric voltage potentials, and without the benefit of airborne e-sensing equipment, the crew had no way of knowing that they were entering an area of increased risk.

The crew were concerned by the absence of information in the QRH concerning lightning strikes, although they were aware of relevant advice in respect of the likelihood of damage to rotors blades and associated components within Part A of the Operations Manual. Given that the advice in the Part A that the helicopter should be landed "*as soon as possible*" or "*immediately*" depending on whether there were indications of damage, it is unusual that the QRH did not reflect what is clearly and rightly considered to be a serious situation. However, the operator had by that time taken steps to introduce lightning strike actions into the QRH as part of a full review of the Operations Manual.

Despite the absence of specific instructions in the QRH, the crew's actions were in accordance with their company's Operations Manual. Aberdeen Airport, although further away than alternative landing sites, was the closest suitable location for a safe landing in the prevailing weather conditions.

Conclusions and safety action

The flight crew took appropriate steps to manage the risk of a lightning strike but the very presence of their helicopter in the vicinity of a cumulonimbus cloud induced a lightning strike. They were unaware of any secondary damage to the helicopter's hydraulics until the landing gear was lowered and thereafter, they took measures to manage the attendant risk.

The visible exterior damage to the helicopter was typical and so were the associated electro-magnetic symptoms of the passage of high electrical currents through otherwise visibly undamaged components, leading to their replacement. What was less typical and a further safety hazard was the hidden damage to the interior portions of the main rotor hydraulic actuators. Some of this damage may have been inflicted by an earlier lightning strike and this damage was not detected although the appropriate post-lightning strike checks had been carried out.

New post lightning-strike inspection procedures to be issued by the helicopter's manufacturer have been devised and will be issued to prevent a similar recurrence of undetected lightning damage leading to a hydraulic failure. Also, amendments to the operating company's recurrent training and to its Operations Manual should ensure that appropriate action is considered by flight crews when consulting the QRH immediately after a lightning strike. Consequently, the AAIB did not make any formal safety recommendations.