AIRCRAFT ACCIDENT REPORT 3/85

Accidents Investigation Branch

Department of Transport

Report on the accident to SA 318B Alouette Astazou G-AWAP at Gat Sand, the Wash on 26 June 1983

LONDON
HER MAJESTY'S STATIONERY OFFICE

List of Aircraft Accident Reports issued by AIB in 1985

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5/84	Cessna Citation 500 G–UESS Isle of Lewis December 1983	February 1985
6/84	Pilatus PC–6/H2–B2 Turbo Porter G–BIZP Yarwell, Nr Peterborough December 1983	March 1985
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First published 1985

ISBN 0 11 550707 8

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Department of Transport
Accidents Investigation Branch
Royal Aircraft Establishment
Farnborough
Hants GU14 6TD

30 July 1985

The Rt Honourable Nicholas Ridley
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr D A Cooper, an Inspector of Accidents, on the circumstances of the accident to SA 318B Alouette Astazou G–AWAP, which occurred at Gat Sand, The Wash on 26 June 1983.

I have the honour to be
Sir
Your obedient Servant

G C WILKINSON
Chief Inspector of Accidents

Accidents Investigation Branch

Aircraft Accident Report No. 3/85
(EW/C 834)

Operator:	Helicopter Hire Ltd
Aircraft: Type:	SA 318B Alouette Astazou
Nationality:	United Kingdom
Registration:	G–AWAP
Place of Accident:	Gat Sand, The Wash Latitude 52° 55′ N Longitude 000° 12′ E
Date and Time:	26 June 1983 at 1320 hrs
	All times in this report are GMT

Synopsis

The accident was reported to the Accidents Investigation Branch (AIB) by the London Air Traffic Control Centre (LATCC) at 1516 hrs on the day of the accident and an investigation commenced the same day.

The helicopter was engaged in a survey of the seal population in the Wash. It took off from an operating site at Holbeach and flew to the area of the Gat Sand, where it was seen manoeuvring over a group of seals at a low height. A few minutes later it crashed on to the sand, all four occupants being killed.

The report concludes that the accident was caused by the disengagement of the main rotor head retention bolt, with consequent detachment of the rotor, due to corrosion of the engaging threads between it and the mast.

Contributory factors were the application of a different aeronautical grease from the one specified for use during assembly of the rotor head, the presence of a sulphate contaminant from an unknown source, the omission of a main rotor head inspection which had become due 207 operating hours prior to the accident, a low aircraft utilisation which resulted in relatively long periods of time between successive such inspections, and extension of the overhaul period of the main rotor mast assembly.

Following the accident the Civil Aviation Authority issued an Airworthiness Directive requiring inspection of other aircraft, and subsequently the manufacturer introduced an appropriate maintenance check.

1. Factual Information

1.1 History of the flight

On the day before the accident the helicopter had carried out an uneventful survey of the seal population in the area of the Wash, involving 3 hrs 25 min flying. During this period several seals had been tagged with a radio location device so that they could be identified later.

On the day of the accident the helicopter took off from a landing site at Holbeach at about 1300 hours, with the pilot and 3 observers from the Sea Mammal Research Unit on board, to conduct a visual and photographic survey. It flew to the Gat Sand where it was seen manoeuvring over a group of seals by some cockle fishermen. The fishermen paid no further attention to the helicoptor until their attention was drawn back to it by sounds they described as being like rifle fire. On looking up they saw the helicopter level at a height of about 50 feet and saw it fall to the ground, rolling to the right.

One of the fishermen transmitted a Mayday call to the Coastguard on his marine radio, and the others ran across the sand to the wreckage. On arrival it became obvious that all the occupants had died in the crash.

An RNLI lifeboat and a Royal Air Force Wessex search and rescue helicopter were soon on the scene, and the bodies of the four occupants were recovered. The Wessex crew took photographs of the wreckage and impact area. These showed that the aircraft had come to rest three quarters inverted with the main rotor complete but detached, lying with one blade resting on top of the rear fuselage.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	3	–
Serious	–	–	–
Minor/none	–	–	

1.3 Damage to aircraft

The helicopter was destroyed by impact damage.

1.4 Other damage

There was no other damage.

1.5 Personnel information

Commander:	Male, aged 57
Licence:	Airline Transport Pilot's Licence (Helicopters) valid until 8 November 1986, endorsed for the Alouette Astazou.

Medical Certificate:	Last medical on 13 June 1983, Class 1, no limitations
Total pilot hours:	9340
Total hours on Alouette:	3500
Total hours in last 28 days:	28
Total hours in last 24 hours:	3:25

1.6 **Aircraft information**

Manufacturer:	Aerospatiale, France
Aircraft type:	SA 318B Alouette Astazou
Date of manufacture:	1966
Manufacturer's serial number:	1966
Registered owner:	Helicopter Hire Ltd
Engine type:	Turbomeca Astazou II A2
Engine serial number:	474
Certificate of Airworthiness:	Transport Category (Passenger) valid until 23 August 1984
Certificate of Maintenance:	Signed on 28 May 1983 at 5104 airframe hours Period of validity: 100 hours/90 days
Aircraft hours at last take-off:	5144
Last check:	Check 22 on 17 June 1983, at 5129 airframe hours
Maximum weight authorised:	1588 kg
Estimated weight at time of accident:	1442 kg
Estimated centre of gravity (C of G) at time of accident:	2.887 metres aft of datum
C of G range:	2.72 to 3.15 metres aft of datum
Estimated fuel at time of accident:	232 kg

1.7 Meteorological information

From local weather reports the weather in the Wash area at the time of the accident was as follows:

Wind:	Northerly 7 kts or less
Temperature:	+ 12°C
Visibility:	Over 10 kilometres
No significant cloud	

1.8 Aids to navigation

Not relevant.

1.9 Communications

Not relevant.

1.10 Aerodrome and ground facilities

Not relevant.

1.11 Flight recorders

None fitted or required to be fitted.

1.12 Wreckage and impact information

1.12.1 General aspects

The helicopter crashed onto a sand bank at low water. Although a tide had washed over it before the first AIB examination the crew of the RAF Wessex, which was on site shortly after the accident, made observations and took photographs. The Wessex crew reported that they had looked for, and failed to find, any evidence of main rotor blade ground strikes other than the marks where the rotor lay. These marks exhibited no evidence of normal rotation. This evidence was supported by the photographs.

All wreckage found was in the close vicinity of the fuselage. The fuselage was essentially complete as it lay and was in a three quarters inverted position. The main rotor, complete but damaged, had separated from the mast and lay near the fuselage with one blade resting on top of the rear fuselage frame. The cabin and the structure behind it were heavily damaged. All the fuselage damage was consistent with a single ground impact with the helicopter in a nose-down, three quarters inverted, attitude. The main rotor gearbox and mast assembly were in place on the transmission platform. The engine lay alongside the fuselage virtually in its correct position, but with its mountings fractured.

The steel welded-tube tail boom was in place, and showed little indication of impact damage. The bottom longeron of the tail boom and a cross-brace tube had been broken. This damage was associated with paint smears on the green coded main rotor blade and had evidently been incurred when that blade, as part of the complete main rotor assembly, descended onto the tail

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boom which was then on the ground. The tail rotor and gearbox were still in place on the tail boom. Both blades of the tail rotor were bent, and the tail rotor guard frame had broken off and lay nearby. The swash plate assembly had separated from the main rotor mast and was connected to the head by one unbroken control rod.

The rotary scissors link was not recovered. The failures associated with its detachment were in overload with no evidence of pre-existing defect, and they were consistent with having been sustained during the detachment of the main rotor head.

Although a small amount of sand throw was evident in the photographs from the impacts of the main rotor hub and tailplane, the fuselage and separated main rotor had evidently not moved beyond their positions of first impact. All the damage suffered by the main rotor blades appeared to be entirely consistent with identified contacts with the airframe, and with ground impact. Given the impact attitude determined for the fuselage (nose-down, three quarters inverted) the observed rotor damage was such as to preclude the possibility of the rotor being in place on the mast at that moment.

Following consideration of this evidence with that obtained in a subsequent detailed examination of the wreckage, it was concluded that the accident was initiated when the main rotor detached whilst the helicopter was in normal flight, and that this had resulted from disengagement of the main rotor head retention bolt. The wreckage examination brought to light no evidence of any other failure or defect which could have contributed to the accident. The investigation therefore then centred on the reason for the disengagement of this bolt.

1.12.2 *Main rotor head*

Apart from the main rotor head retention components, described below in detail, the head assembly was found to be functionally intact. It had suffered some minor secondary damage. The droop stop ring had sustained three equally spaced dents, evidently caused by the stops hitting the ring heavily and probably coincidentally.

Although the head was found detached from the mast the head retention bolt was still in place in the head, retained by its locking cap. (see appendix 1 figs 1 and 2). The locking cap, retention bolt, and main rotor drive splines, were removed and examined in detail.

The locking cap showed no evidence of marked wear or distress. The bolt thread and part of the shank were covered with a fine paste-like deposit; this was a mixture of a rust brown and black colour in the threads, and black on the bolt shank. The deposit filled the thread, and when initially examined its surface had clear axial smear marks. The top three threads were virtually undamaged and retained their original form, but the rest were corroded and had suffered substantial loss of metal over a distance corresponding to the female thread length in the mast. Examination of micro-sections of the thread showed that there was a cadmium coating on the steel surface of the top three threads to a thickness of about 0.01 mm,

and in the roots of the damaged threads. The cadmium plating on the shank of the bolt was seen to be in good condition, although close examination did reveal local spots of deterioration. There was corrosion also on the seating face under the head of the bolt.

1.12.3 Mast head

The mast head, containing the mating thread for the bolt and the main rotor drive spline, was also examined. The thread appeared to be in a corroded and contaminated state similar to that of the bolt. Outside the area of the thread and its top annular face, the mast was relatively free from corrosion. The top face of the mast had an area of heavy contact and deformation, which was identified with matching marks on the lower face of the splined sleeve in the rotor head. From this and other evidence it was apparent that the rotor head had disengaged from the mast head spline, and had then descended again with massive impact onto the mast head due to negative blade angles being imparted through the flying control rods. The deformation of the mast top caused by this impact had formed a lip around part of the circumference, and further upward deformation had evidently been sustained during the final detachment of the rotor head and swash plate.

The mast splines were basically in sound condition. One section near the top end had been damaged due to the passage of the swash-plate assembly as the rotor head detached. The surfaces had patches of discolouration caused by light corrosion. Local areas of heavier corrosion were found in the roots of some splines near their top ends. Contact marks matching the form of the mating splines in the rotor head were seen on the spline side faces, most clearly on the normally loaded side. These marks at their most severe were sufficient to produce a slight step in the surface.

The female splines within the head were removed and examined. These splines are in two halves, top and bottom, retained in the head by clamp bolts. The top half of the spline assembly forms the cap which is held on the mast by the retention bolt. It had severe corrosion on the surface covered by the bolt head which matched corrosion on the bolt itself.

The assembly also had severe corrosion on its internal surfaces where they were in contact with the mast. In particular the normally loaded faces of the splines had worn to an extent that they were stepped by about 0.51mm, and there were heavy corrosion deposits on the splines and in their roots.

On one area of the spline assembly's internal surface, cadmium plating was still intact. Some patches of corrosion here had the appearance of having resulted from, or been deposited by, globules of liquid descending from an area of corrosion above. The evidence suggested the possibility that these patches may have resulted from the separation of a grease into its lower and higher viscosity constituents, the lower viscosity oils separating from the soap thickener and being centrifuged out. Another possibility was that, given the deterioration of the grease and the production of organic acids, these may have been leached out by water condensing in this area; it was noted that the mast formed a vent for the main rotor gearbox.

The lower half of the spline assembly was less seriously affected by corrosion, but had suffered the same degree of material loss on the spline loaded surfaces. At their extreme lower ends the splines had taken bruising damage in a rotational direction consistent with normal power application. This indicated that power was being transmitted to the head during its separation from the mast.

The surfaces on the outside of the splined liners, which normally are in contact with the head itself, were heavily fretted with corrosion discolouration.

The top five inches of the mast were cut off and sectioned for chemical and metallurgical examination (see fig 3).

Internally, corrosion damage to the mast was restricted to the retention thread; surface protection coatings were intact in other areas. The mast thread, as with the retention bolt, was filled with a brown/black deposit. The thread form indicated that there had been material loss principally from the loaded faces, so that the thread form had become truncated and in some areas had almost disappeared. Some smearing of the thread crowns was evident from the outward passage of the retention bolt. Where the unloaded face still existed its angle corresponded to the originally manufactured angle, and thus there was no suggestion that the thread had been deformed under overload.

1.12.4 *Chemical analysis*

Chemical analysis of the deposit found on the main rotor head retention bolt was carried out at the Royal Aircraft Establishment, Farnborough and the Materials Quality Assurance Directorate, Woolwich.

The analyses showed that the deposit was largely composed of the constituents of the base steel (mainly iron oxide) together with cadmium, presumed to have come from the original surface coating. There was no indication of molybdenum in the deposit, signifying that a molybdenum disulphide anti-scuffing paste had not been used during assembly as specified by the manufacturer (Maintenance Manual Chap 57.2, page 403, item B(4), "coat bolt ..... with Molykote G").

Constituents of the deposit were found which were indicative of the presence of a mineral grease with a calcium soap thickener. The expert advice obtained was that certain types of such grease, if they suffer chemical breakdown, can give rise to deterioration products (carboxyl acids) which are particularly damaging to cadmium plating although, usually, the base steel would not be affected. Such acids were identified in the deposit.

Ion chromatography revealed chloride, sulphate, formate, and acetate ions in significant concentrations in the deposit on the bolt. The formate and acetate ions were considered, from the above, to have been breakdown products of a grease used during assembly and, because of the sea immersion, no particular significance could be attached to the chloride result. The sulphate ion, which formed 4.8% of the deposit sample, would

have had a significant effect on the corrosion of the base steel. The quality of the chemical evidence was not good enough to allow the source of this contamination to be identified, but it is neither a constituent of the above grease nor a product of its decomposition.

The chemical evidence obtained from the corrosion deposit was also inadequate for a determination of the identity of the original grease, although it was clearly a mineral grease with a calcium soap thickener; and it was not possible to obtain an expert estimate, between reasonable tolerances, of the time involved in the corrosion process.

1.13 Medical and pathological information

Post-mortem examinations revealed no evidence that might have had a bearing on the accident. The helicopter's four occupants all died as a result of multiple injuries sustained in the impact. Tests for carbon monoxide, drugs, and alcohol proved negative.

1.14 Fire

There was no fire.

1.15 Survival aspects

The accident was not survivable. The fishermen were quickly on the scene after the crash, and their prompt distress call to the Coastguard evoked a swift response from the RNLI and the SAR helicopter.

1.16 Tests and research

None.

1.17 Additional information

1.17.1 The maintenance scheme

G–AWAP was maintained for Helicopter Hire Ltd (HHL) by an associated company, Helicopter Maintenance Ltd (HML). In April 1977 G–AWAP's scheme of scheduled maintenance was changed from the General Purpose Maintenance Schedule (1971) H to a CAA approved Progressive Maintenance Inspection Schedule (PMIS–HM12) which was based on the manufacturer's Maintenance Manual. The PMIS was re-approved by the CAA on 18 October 1982 as Issue 2.

The CAA approval of the PMIS was granted to HHL, as the operator; relevant extracts from the approval document are at appendix 2. In summary it required that, notwithstanding the contents of the PMIS, personnel were to maintain the aircraft in an airworthy condition at all times. It reiterated the requirements for compliance with the Air Navigation Order, and drew attention to certain other documents. It also set out the regulations for the extension of servicing periods.

The PMIS cycle covered 1600 hours of operation, broken into 25-hourly checks. Thus the cycle started with a check 1 at 25 hours and ended with a check 64 (the major check) at 1600 hours, the helicopter then commencing another cycle of 1600 hours. G–AWAP was on its second 1600 hour cycle at the time of the accident, the last inspection having been a check 22 which was completed on 17 June 1983 at 5129 airframe hours.

Additional requirements comprised an Annual Inspection; a Star Inspection for the renewal of the Certificate of Airworthiness (C of A) every third year; and Supplementary Inspections for items out of phase with the scheduled maintenance periods. The preamble to the master copy of the PMIS contained notes and conditions for the use of the schedule; these included the following statements:

(1) "Supplementary Inspections

Supplementary inspection pages to identify special instructions and other requirements peculiar to a particular model or its equipment and which are out of phase with scheduled maintanance periods for specific aircraft are, where applicable, inserted sequentially in this section of the Maintenance Schedule. Note: it is the responsibility of the operator to ensure that these records are accurate and current."

(2) "This schedule is approved for aircraft with annual utilisation not less than 600 hours flying. If the utilisation falls below 600 hours per annum the maintenance inspection frequency must be renegotiated with the Civil Aviation Authority."

The CAA has stated that the requirements in (1) above should have been met by means of the Supplementary Inspection Schedule (SIS). In the "Company Exposition" submitted to the CAA by HML in support of the application by HHL for approval of the PMIS the following statements were made:

"It is the responsiblity of the Chief Engineer or Chief Inspector to ensure components do not run over their respective overhaul times", and: "The Supplementary Inspection Sheet is raised each month (frequency to be increased at discretion of Chief Inspector) with all service bulletins, airworthiness directives, mandatory inspections etc. entered against each individual aircraft with total time or dates due."

From the master copy of the PMIS a book of worksheets had been made up by HML detailing each of the 64 checks in the 1600 hour cycle, with space for an aircraft maintenance engineer's signature against each item. The introduction to the book of worksheets was a modified version of the master copy. It did not contain the note on Supplementary Inspections, nor the limitation of a minimum 600 hour annual aircraft utilisation, but it included the following relevant statements:

"5 The Progressive Maintenance Inspection Schedule has a "Supplementary Inspection" section which includes all repetitive service bulletins, mandatory inspections, and advises the Engineer at which check they are accomplished."

"28 Nothing in the Schedule is to be construed as absolving maintenance engineers from maintaining the aircraft in a thoroughly serviceable condition."

"31 All Mandatory Inspections ..... must be carried out at the interval stated in the Supplementary Schedule. The 10% tolerance as stated in paragraph 12 of this section applies only to the Check in question and not the additional directives."

The following instructions appeared on the first page of each 25 hour check in the book:

"Draw up a list of defects reported and lodge in the applicable additional worksheet.

Refer to Supplementary Inspection Schedule for special inspections. Consult Component Status Sheet for components due."

The last of each set of sheets incorporated the certification forms necessary for routine maintenance, and there was also provision here for entering "Maintenance Due Between Checks".

The Chief Inspector of HML, the maintenance company for the whole of the relevant period, had also been its Technical Director for the two years prior to the accident. He stated that he had not been involved in drawing up the PMIS and SIS documents, but that both were in use at the time when the new type aircraft log book (CAP 398) was raised for G–AWAP in August 1978. Some time after this it was decided to discontinue the use of the SIS because it was found that the company was duplicating work, as the same information was required to be entered in Part C (pink pages) of CAP 398.

The CAA were not aware that the SIS was no longer in use. No example of a completed SIS was discovered during the accident investigation. Section C (pink pages) of CAP 398 contained provision for recording "modifications, SB's and AD's". The items recorded in that section of G–AWAP's Log Book were exclusively service letters, service bulletins, airworthiness directives, and one radio modification.

1.17.2 *The manufacturer's maintenance requirements*

The manufacturer's Maintenance Manual comprised functional engineering instructions for the maintenance of the SA 318B and, in Section 5, a schedule of the required maintenance.

Section 5.3.1 of the manual dealt with periodic maintenance related to airframe hours and calendar time. The information in this section was incorporated in the main part of the CAA approved PMIS, broken down into sixty four 25 hour inspections in a total cycle of 1600 operating hours. None of the inspections called for in Section 5.3.1 contained any specific requirement for the main rotor head retention bolt to be inspected, or any requirement for an action which would open the bolt to view.

Section 5.3.2 defined periodic inspections depending on engine and transmission system operating hours. These inspections were described as mandatory, but as they did not necessarily coincide with airframe maintenance cycles they could not therefore be listed in the 25 hour inspections. The CAA states that all these inspections were required to be listed in the Supplementary Inspection Schedule to the PMIS. Compliance with each was required to be entered in the Aircraft Log Book.

Section 5.3.2 specified two inspections of the main rotor head. One, at 400 hour intervals (Check ..... Rotor head assembly without disassembly, Chapter 57–2 IC–I) contained no action which would affect the head retention bolt. The second check, at 800 hour intervals (Check ..... Rotor in detail, Chapter 57–2 IC–2) required the removal of the rotor head and therefore the withdrawal of the head retention bolt. Although there was no specific instruction for the bolt to be examined there was a requirement for the bolt to be lubricated on re-assembly.

The required inspection of the main rotor mast at 800 hour intervals did not require removal of the head or inspection of the retention bolt. The bolt is formally a part of the main rotor shaft assembly.

The manual also contained advice on extra precautions to be taken following operation in a salt-laden atmosphere but none of the measures directly affected the retention bolt.

1.17.3 *Maintenance history*

On 12 August 1979 at 4137 hours a check 44 of the PMIS was completed. A note had been entered in the work sheet as follows:

> "Defect/Work Carried Out
>
> M/R M/R Head disconnected and inspected in detail IAW Manual Chapter 57–21C–2. M/R Head reconnected and re-torqued IAW M/Manual"

After a further 10 operating hours a Certificate of Compliance in the Technical Log was signed for the main rotor head being "inspected and torqued". Neither of these operations were recorded in the Aircraft Log Book.

Following the Check 44, an inspection "in detail" of the main rotor head became due, according to the manufacturer's Maintenance Schedule, at 4937 hours in November 1982. However it is not recorded in the "next compliance due" column of Part C of the Aircraft Log Book, or elswhere in that book, or in any work sheet. The Technical Director/Chief Inspector stated that he believed that during the period HML was not using the SIS this inspection was overlooked, not transcribed into part C of the Aircraft Log Book, and subsequently not picked up by himself or other personnel. He also pointed out that originally the main rotor head had a specified overhaul period of 1600 hours, and the "inspection in detail" at 800 hour intervals had been therefore regarded as a "half-life" inspection. It is apparent that the increase in overhaul life to 1800 hours introduced the need for a second "inspection in detail" during the service period of the head, because this period was not correspondingly increased to 900 hours.

Following the Check 44, there is no evidence that an inspection "in detail" of the main rotor head was carried out or that the main rotor head retention bolt was removed again up to the time of the accident. The main rotor and main gearbox were removed on two occasions, but this was reportedly done without removing the retention bolt and separating them. A Star inspection and a check 64 were completed in December 1981, apparently without the retention bolt being removed. Following the check 64 the main rotor mast and hub were listed as having been inspected; the nature of the inspection was not stated, but the Technical Director/Chief Inspector gave evidence that it was a visual inspection "in situ".

In a section of the check 64 work sheet entitled "Airframe – Rotor Hub and Blade Assemblies", item 14 stated "Remove main rotor blades and hub. On semi-articulated heads – balance and re-align". Against this item had been written "N/A". The Chief Inspector stated that he had not considered this item, requiring the removal of the head, as being applicable to the Alouette. (This helicopter has a fully articulated head and the blades are balanced at manufacture and tracked on the aircraft.)

The records show that the 25 hour inspection sequence laid down in the PMIS was followed up to the time of the accident. The current certificate of maintenance was completed following a check 21 on the 28 May 1983, and its period of validity reached beyond the time of the accident both in terms of calendar time and aircraft operating hours. The final 25 hour check (check 22) was carried out on 17 June 1983 at 5129 aircraft hours.

1.17.4 *Component lives and extensions authorised*

1.17.4.1 *Main rotor gearbox*

The main rotor gearbox(P.N 3160–62–00–000–15, S.N. S–10904) was fitted to the aircraft on 22 February 1977 at 3190 airframe hours. With an applicable overhaul period of 1800 hours it would have been scheduled for removal for overhaul at 4990 airframe hours. On 17 December 1982 the maintenance company (HML) extended the overhaul period by 10% under the authority delegated to it by the CAA. The main rotor gearbox then became due for removal for overhaul at 5170 airframe hours.

An entry in the aircraft's technical log on 17 December 1982 at 4987 airframe hours recorded that the gearbox had been inspected and evaluated in consideration of the overhaul period extension.

1.17.4.2 *Main rotor head*

The main rotor head assembly (P.N 3130–S–12–50–000–3, S.N. M625) was refitted to the aircraft after overhaul on the 20 September 1977 at 3360 airframe hours. With an applicable overhaul life of 1800 hours it would have been scheduled for removal at 5160 airframe hours.

1.17.4.3 *Main rotor mast assembly*

The main rotor head retention bolt (P.N. 3130–S–68–00–030) is part of the main rotor mast assembly. The main rotor mast assembly (serial number M1686) which was on the aircraft at the time of the accident was

fitted after overhaul on 17 January 1977 at 3145 airframe hours. The manufacturer's prescribed overhaul period for the mast assembly was initially 1600 hours. This was later extended, in an amendment to the manufacturer's Maintenance Manual, to 1800 hours for assemblies of a particular part number series of which M1686 was one (P.N. 3160–68–10–000–3). The head retention bolt was not cited as having a specific retirement life.

On 15 November 1982 the maintenance company extended the overhaul period for the mast assembly by 10%, the maximum allowable under the terms of its CAA approval.

On 13 May 1983 the maintenance company applied for, and received, direct CAA approval for a further extension of 1½% (25 hours). The basis for the application was that there were no lifed items, airworthiness directives, or service bulletins, applicable during the period of the proposed extension. No reason was given for the requested extension.

With the final extension applied the mast assembly would have been due for removal for overhaul at 5150 hours. Entries in the aircraft's technical log on 17 November 1982 at 4952 airframe hours, and on 11 May 1983 at 5096 airframe hours, recorded inspections for the proposed extensions. The first, recorded as "in detail", noted "nil defects, nil reports of vibration, no excess wear". For this inspection, probably conforming to section 40–1.1 IC–1 in the Maintenance Manual, the rotor head was not removed from the mast.

1.17.5 *Aircraft utilisation*

The records show that, between annual checks, the yearly utilisation for G–AWAP was as follows:

August 1978 to August 1979	449 hours
August 1979 to August 1980	253 hours
August 1980 to August 1981	148 hours
August 1981 to August 1982	340 hours
August 1982 to June 1983 (Accident)	264 hours

1.17.6 *Safety action*

The manufacturer and the CAA were asked if any previous occurrence of a similar type had been experienced. They reported that no record existed of any serious corrosion or failure of the main rotor head retention bolt. The CAA issued Airworthiness Directive AD 007–07–83 requiring inspection of the bolt and one example was returned for examination. However, only minor traces of corrosion were found and this was not in the bolt thread. On 8 June 1984 the manufacturer issued Service Letter 619–65–84 containing an appropriate maintenance check based on aircraft operating hours and calendar time.

1.18 **New investigation techniques**

None.

2. Analysis

2.1 Cause of the accident

The pilot was a well qualified and experienced helicopter commander who had carried out several seal survey flights on previous occasions. The weather conditions were ideal for the flight and the helicopter had been seen flying perfectly normally and safely until immediately before the crash. It was therefore clear that a catastrophic occurrence had taken place in the air. The investigation established that the rotor head had become detached from the mast because of the disengagement of its retention bolt, and this was the direct cause of the accident.

2.2 Corrosion of the bolt and mast

The process of corrosion of the main rotor head retention bolt and mast is not completely explained by the evidence available although several features have been identified as being significant. Firstly, at the time of the accident the bolt had been undisturbed for almost 4 years. Secondly, the specified assembly lubricant had not been used and the one which was used, though not precisely identified, was of a type which can produce carboxyl acid deterioration products which are known to damage cadmium plating – the protective coating on the surfaces of the retention bolt and mast. Thirdly, the main rotor mast formed a vent for the main rotor gearbox. Consequently, condensation could be expected to form inside the mast (which would be cooler than the gearbox) and produce an environment in which ferrous corrosion could develop in the area of the enclosed retention bolt should the local protective coating break down as occurred in this, apparently unique, case. Fourthly, the presence of the corrosive sulphate ion was detected in the corrosion product. Its source could not be identified and expert opinion was that although it was less significant than the carboxyl acids in the destruction of the cadmium plating, it would have been an accelerating factor in the corrosion of the bolt steel once the protective coating had broken down.

Understanding of the corrosion process was hampered by the deterioration with age of the original materials present, and by the sea water contamination suffered after the accident. In particular, any corrosion produced by operation in a salt-laden atmosphere was completely obscured by the sea water immersion.

The corroded areas were all loaded contact surfaces between the bolt and the mast, and they showed evidence of polishing and fretting as well as corrosion. It is likely that mechanical movement between the surfaces hastened the corrosion process. Although the records indicate that after the last assembly the torque of the bolt was re-checked and so was in all probability then correct, loss of metal with the first development of corrosion would have effectively reduced the pre-loading and allowed increasing movement in the bolt and splines. The corrosion therefore probably developed in an accelerating process associated with mechanical wear of these contact surfaces.

Whatever the detailed process of the corrosion, the length of time which transpired without the bolt being removed and inspected is considered to have been a factor in its being able to deteriorate to the stage where it finally disengaged. Although it could not be determined at what rate the corrosion had proceeded, it is considered that by the time the "Inspection in Detail" of the main rotor head became due in November 1982 at 4937 hours some deterioration of the bolt would have been evident.

Even if this were not the case the act of cleaning and re-lubricating the bolt would have inhibited the process of corrosion. The omission of this inspection, therefore, although it did not formally call for an examination of the retention bolt, was a major factor in the process of deterioration and ultimate disengagement of that bolt.

2.3 Maintenance aspects

The main rotor head retention bolt was not subject to any specific maintenance inspection between the overhauls of the main rotor mast assembly at 1800 hour intervals. However, at 800 hour intervals, in the manufacturer's Maintenance Schedule, the bolt would have had to be removed to allow inspection of the main rotor head "in detail". Although the inspection did not formally include the bolt it was required to be lubricated on re-assembly and any significant corrosion would then be evident. Moreover, the responsibility laid on the persons employed in implementing the maintenance requirements to ensure "that the aircraft is at all times maintained in an airworthy condition" (CAA approval for PMIS–HM12) required that the bolt was then seen to be suitable for further service. Unfortunately this opportunity was missed by the maintenance personnel involved because HML had allowed the Supplementary Inspection Schedule to fall into disuse, and the inspection due at 4937 airframe hours was not called up from the manufacturer's Maintenance Manual in any other manner.

As part of the principal load path in the helicopter's structure the retention bolt merits specific mention in the maintenance requirements when the relevant area is under inspection. Although, in this case, the corrosion would have been detectable had the manufacturer's Maintenance Schedule been fully adhered to, it does appear that to define the inspection periods of critical mechanical components simply in terms of operating hours is inadequate, in view of this accident, when allowing for operators with relatively low utilisation.

The preamble to the PMIS included the condition that if utilisation fell below 600 hours per annum the inspection frequency should be re-negotiated by the operator. Although G–AWAP did not achieve such utilisation in the five years before the accident this condition was not adhered to, nor was the anomaly noticed by the CAA when the aircraft's C of A was last renewed in August 1981. However mere alteration of the frequency of the PMIS 25 hour checks, including the Check 64 and the additional Annual and Star inspections, would not have altered the circumstances which led to the retention bolt's condition going undetected. It is

possible that the additional scrutiny involved would have prevented the gearbox and mast assemblies being allowed life extensions, but this can only be surmised and the default on the 600 hour utilisation criterion cannot be positively linked with the causative sequence leading to the accident.

2.4 Extension of scheduled maintenance periods

The Civil Aviation Authority's Approval document for the PMIS permitted the approved maintenance organisation, in certain circumstances, to extend the scheduled maintenance periods within specified limits.

The items to which this permission applied included maintenance inspections or actions and component overhaul periods, although it excluded life-limited components.

Overhaul period extension of 10% had been granted on the authority of the Chief Inspector on behalf of the maintenance company, as laid down in the PMIS approval, for the main rotor gearbox and the main rotor mast assembly. Approval for a further 1½% extension for the mast assembly was later obtained from the CAA. The main rotor head retention bolt was, of course, part of the mast assembly.

The endorsement in the CAA Approval which allows this procedure states that "Variation shall be permitted only when the periods prescribed . . . . . cannot be complied with, due to circumstances which could not reasonably have been foreseen . . . . . ". From the time of the maintenance company's authorised extension of the overhaul period of the main gearbox to the time of the accident, six months elapsed with an aircraft utilisation of only 157 hours. Given this, it would seem difficult to support a case of "circumstances which could not reasonably have been foreseen". No such circumstances were noted in the records for any of the three extensions, including the extension which was granted directly by the CAA. If, as seems likely from the records, these extensions were used merely to align the expiry times for the gearbox, mast, and head with the latest of the three assemblies to maximise usage of all three then this practice would not appear to conform to endoresement No 4 of the approval.

The aircraft was operating within the final extension period for the mast at the time of the accident.

3. Conclusions

(a) *Findings*

(i) The pilot held a valid licence and was experienced in the type of operation being flown.

(ii) The weather was not a factor in the accident.

(iii) The helicopter carried an adequate supply of fuel, and its weight and centre of gravity were within prescribed limits at all times.

(iv) Whilst the helicopter was flying normally and at a low height the main rotor detached.

(v) The detachment resulted from disengagement of the main rotor head retention bolt following wastage of the engaging threads between it and the mast as a result of corrosion.

(vi) The corrosion followed the destruction of the protective cadmium plating of these threads by the products of deterioration of a grease different from the type specified by the manufacturer for use during assembly of the rotor head, and was probably accelerated by a sulphate contaminant from an unknown source.

(vii) The manufacturer's Maintenance Schedule contained no specific requirement for the bolt to be inspected. However, a maintenance inspection which did contain operations which required the bolt to be extracted and greased before re-insertion, and which became due at 4937 hours and 7 months before the accident, had not been carried out.

(viii) The main rotor head inspection due at 4937 aircraft hours was not carried out because the Supplementary Inspection Schedule, part of the Progressive Maintenance Inspection Schedule, had fallen into disuse and the inspection was not called up from the manufacturer's Maintenance Schedule in any other manner.

(ix) The CAA approved the operator's Progressive Maintenance Inspection Schedule for an aircraft utilisation of more than 600 hours per annum. In the five years preceding the accident G–AWAP achieved an average of only 291 hours per annum, and never exceeded 450 hours per annum. Its operation did not, therefore, comply with that condition of the approval. The low utilisation was also one of the circumstances which led to the retention bolt not being examined for almost four years prior to the accident.

(x) The overhaul period extensions granted by the maintenance company in respect of the main rotor gearbox, and by the maintenance company and the CAA in respect of the main rotor mast assembly, did not conform to all the conditions of endorsement No 4 of the CAA approval of the PMIS.

(b) *Cause*

The accident was caused by the disengagement of the main rotor head retention bolt, with consequent detachment of the rotor, due to corrosion of the engaging threads between it and the mast.

Contributory factors were the application of a different aeronautical grease from that specified by the manufacturer during assembly of the rotor head, the presence of a sulphate contaminant from an unknown source, the omission of a main rotor head inspection which had become due at 207 operating hours prior to the accident, a low aircraft utilisation which resulted in relatively long periods of time between successive such inspections, and extension of the overhaul period of the main rotor mast assembly.

4. Safety Recommendations

None.

D A COOPER
Inspector of Accidents
Accidents Investigation Branch
Department of Transport

July 1985