Department of Trade

ACCIDENTS INVESTIGATION BRANCH

Bell 206 (Jet Ranger) G-BAYA report on the accident at Loch Avon, Inverness-shire, Scotland on 11 January 1977

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Department of Trade
Accidents Investigation Branch
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2 March 1978

The Rt Honourable Edmund Dell MP
Secretary of State for Trade

Sir,

I have the honour to submit the report to Mr P J Bardon an Inspector of Accidents, on the circumstances of the accident to a Bell 206 (Jet Ranger) G-BAYA which occurred at Loch Avon, Inverness-shire on 11 January 1977.

I have the honour to be
Sir
Your obedient Servant

W H Tench
Chief Inspector of Accidents

Accidents Investigation Branch
Aircraft Accident Report No. 1/78
(EW/C 586)

Operator:		P L M Helicopters Ltd, Dalcross Airport, Inverness, Scotland
Aircraft:	*Type:*	Bell 206 (Jet Ranger)
	Model:	B
	Nationality:	British
	Registration:	G-BAYA
Place of Accident:		Loch Avon, Inverness-shire, Scotland
		Latitude 57° 06′ 30″ N
		Longitude 03° 37′ 00″ W
Date and time:		11 January 1977 at about 1515 hrs
		All times in this report are GMT

Synopsis

The accident was notified by the Scottish Air Traffic Control Centre (SATCC) at 0915 hrs on 12 January 1977. The investigation was carried out by operations and engineering personnel of the Accidents Investigation Branch.

The helicopter was on a daytime photographic flight in visual meteorological conditions (VMC) over the frozen surface of Loch Avon carrying a pilot and a cameraman. It was in a slow acceleration at about 25 feet above the loch surface and at about 40 knots indicated airspeed (IAS) when suddenly a high rate of right yaw developed. After rotating through 1½ turns the helicopter crashed on to the loch. Both occupants survived and were rescued at 0115 hrs on 12 January by a Royal Air Force (RAF) helicopter after an air and ground search.

The report concludes that although a main rotor blade had severed the helicopter's tail rotor drive shaft at some time in the accident sequence it could not be shown that this was the cause of the loss of yaw control. The cause of the accident could not be determined.

1. Factual Information

1.1 History of the flight

G-BAYA had been chartered for photographic work involving several days flying in the Cairngorm Mountains. After operating in the area on 10 January the night of 10/11th was spent at the Coylumbridge Hotel, Aviemore, where the helicopter was parked on the hotel's helipad.

On 11 January an uneventful flight was made to Loch Avon departing Coylumbridge at 1405 hrs and returning at 1435 hrs. Loch Avon is 2,375 feet above mean sea level (amsl) and runs NE/SW, being 2,500 metres long and 250 metres wide. At 1145 hrs the helicopter took-off again with a cameraman seated adjacent to the rear starboard door space operating a side mounted movie camera.

After about 20 minutes flight time spent in transit to, and reconnaissance of, the Loch Avon area, the helicopter carried out two practice runs prior to starting filming.

The first photographic run commenced at about 1515 hrs with the helicopter in a hover at about 30 feet over flat, snow covered ground at the north-east edge of the loch, heading south-west. The pilot stated that once he was clear of slight recirculating surface snow caused by the rotor downwash he commenced a slow acceleration on a south-westerly heading making a gentle descent to approximately 20 feet. At an IAS of 15 knots, he continued the gentle acceleration but allowed the helicopter to climb as airspeed increased. At a speed believed to be about 40 knots IAS and at an estimated height of 25 feet he heard a bang from the rear of the aircraft. He immediately initiated a gentle climbing flare whilst he glanced at the instrument and warning panels for evidence of malfunction but saw nothing abnormal; neither did he hear any note from the engine and rotor speed aural warning system. On looking up he saw that the helicopter had already yawed through 45 degrees and was continuing to yaw at an increasing rate; also that a 20 degree bank to the right had developed and the angle was steadily increasing. He applied full left yaw pedal but a high rate of yaw to the right still continued to develop. The pilot stated that he then closed the throttle and used the collective pitch lever to make the best touch-down possible, which occurred, he thought, when the helicopter had yawed through 180°. The aircraft struck the frozen surface of the lake in a nose down attitude still yawing right and came to rest on its right side. The pilot heard the engine still running, so he shut it down and closed the fuel valve and switched off the battery master switch before leaving the helicopter. Meanwhile the cameraman had also got clear.

The cameraman, who was very experienced in helicopter camera work, said the flight had been uneventful until on the third run up the loch, he heard a muffled thump from behind the rear cabin bulkhead and he then heard the pilot say 'I have a problem'. He estimated the helicopter's speed at this time as 40 knots and its height as 80 to 100 feet. He noticed that immediately after hearing the noise the nose of the helicopter pitched first down, then up, and it started to yaw right. He held the camera firmly and it continued to run while the helicopter turned through 1½ revolutions descending until it struck the ice. After it came to rest he released his seat strap and crawled out. The cameraman also stated that he had flown several hundred hours in Bell 206 helicopters, and was familiar with the sound of the aural engine and rotor speed warning horn, but he did not hear it operate on this occasion.

1.2 Injuries to persons

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

1.3 Damage to aircraft

The aircraft was damaged beyond repair.

1.4 Other damage

There was no other damage.

1.5 Personnel information

Flight crew

The pilot was the sole flight crew member. Relevant details concerning him are:

Age	32 years
Licence	Airline Transport Pilot's Licence (Helicopters). The licence was endorsed for the Bell 206 and was valid.
Mandatory tests	The pilot's last Certificate of Test was on the Bell 206B and was dated 27 October 1976.
Flying experience	Total hours: 3,517 Total helicopter hours: 3,413 Total hours on Bell 206: 1,761 Total hours last 28 days: 18:15
Duty time	The pilot's duty time in the previous 7 days were within the prescribed limits.

1.6 Aircraft history

The helicopter, manufacturer's serial number 1035, was manufactured in 1973 and was brought on to the British register in July of the same year. The helicopter was purchased by P L M Helicopters in January 1976.

At the time of the accident the aircraft had a Certificate of Airworthiness (C of A) in the general purpose category valid until 17 July 1977. The maintenance records show that it had been maintained to an approved maintenance schedule and had a valid certificate of maintenance. All lifed components were within their life limitations and all service bulletins that might have been relevant to the circumstances of the accident had been satisfied with the exception of service bulletin 206-76-12 date 7 September 1976.

P L M Helicopters had scheduled this work to be carried out on 30 January 1977 so as to fall within the 90 day compliance period from date of receipt of the bulletin. This bulletin required the installation of tail rotor drive shaft bearings with provision for lubrication. This modification was raised following cases of bearing failure. The bulletin included a note that all bearing hangers must be installed with the spring clamp located on the left side of the tail boom.

The cyclic and collective flight control system incorporated irreversible hydraulic service actuators which prevent control force feedback. The yaw control system was a manual circuit the pedals being directly coupled by push-pull rods to the tail rotor pitch change slider. No stability augmentation system was fitted.

An Allison 250 C20 engine delivering 400 shaft horse power was fitted to the aircraft. It incorporated a hydro-mechanical control system which automatically governed main rotor speed. A warning horn mounted in the cabin gave aural warning of low main rotor speed or low engine speed. The helicopter was fitted with a compressor air bleed anti-icing system.

The power train system ran forward from the engine free wheel unit to the main rotor gearbox, and aft to the tail rotor by a tubular drive shaft in four sections running in self aligning sealed bearings along the top of the tail boom. The shaft was covered by a light alloy fairing.

Other relevant information is:

Total hours flown:	1,134
Hours since last C of A renewal:	536
Hours since last certificate of maintenance:	16:20
Total engine hours:	1,135
Maximum weight authorised:	3,200 lb
Estimated weight at last take-off:	2,960 lb
Estimated weight at time of accident:	2,860 lb
Centre of gravity range at accident weight:	Station 106.0 to Station 112.5
Centre of gravity at time of accident:	Station 109.0
Estimated fuel at time of accident:	240 lb
Rotor Limitations (Power On):	Maximum 100% (394 rpm)
	Minimum, below 8,000 feet, 95% (374 rpm)
Fuel type:	Jet A1 with approved anti-icing additive.

1.7 Meteorological information

An appreciation of the weather in the vicinity of Loch Avon between 1400 hrs and 1600 hrs on 11 January 1977 was prepared after the accident by the Meteorological Office. The following is an extract from that appreciation:

Wind:	Calm to 5 kts.
Temperature:	Approximately -4°C to -5°C.
Cloud:	Scattered cumulus, base 1,800 feet, tops 6,000 to 10,000 feet. Patches of stratus at 800 to 1,500 feet in showers. Scattered strato-cumulus, base 4,000 to 6,000 feet.
Visibility:	15 to 20 km but 3,000 m to 6 km in showers.
Weather:	Variable cloud with isolated snow showers.

The lake surface was frozen to a depth of 1 metre and was covered by a layer of powdered snow. The land around the loch was covered by approximately 30 cm of snow.

During the search and rescue period, the surface temperature in the area fell to -12°C. Moonrise was 2340 hrs.

The accident occurred in daylight.

1.8 Aids to navigation

Not relevant.

1.9 Communications

The pilot stated that one VHF set was tuned to the distress frequency of 121.5 MHz and he believed the other was on 133.20 MHz, the Scottish FIR frequency. Because of terrain screening no attempt was made to use the radio during the flight. Both radio sets were found tuned to 121.5 MHz on initial examination of the helicopter.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

None required and none fitted.

1.12 Wreckage and impact information

1.12.1 Examination of wreckage

The helicopter had come to rest on its right side, heading south. The right main skid had fractured and was found beneath the fuselage. (See Appendix A Photo 1). The tail boom had detached aft of the horizontal stabilizer and was lying some 2 metres from the main wreckage. Both main rotor blades were still attached to the rotor head and there is evidence of high rotational energy at the time of impact. One main rotor blade had fractured at its mid span position, and the outboard section was found 160 metres from the wreckage on the southern shore of the loch. The other blade was complete but bent upwards slightly at the tip. A section of tail rotor drive shaft 57 cm long, just forward of the tail rotor gearbox was missing and could not be found. The tail rotor assembly was undamaged and there is no evidence of rotation at impact. (Appendix A Photo 2). It was

apparent from examination that the helicopter had struck the ice in a tail down attitude whilst banked and rotating to the right.

1.12.2 Subsequent examination of the wreckage

The engine, the main rotor gearbox, the main rotor head, and the cyclic and collective flight control systems exhibited damage due to impact only and there is no evidence of pre-crash defect or failure. There was slight damage to the mast flapping stops which might have occurred before impact with the ice.

The tail rotor control system was found to be functional with the exception of two failures in the control push-pull rod system, which were the result of impact forces. The drive from the engine free-wheel unit through the tail rotor gearbox to the tail rotor was examined and it was found that the coupling between the aft short shaft and the long shaft had been disrupted when the tail boom buckled on impact. (See Appendix B).

The missing 57 cm of tail rotor drive shaft had left two fracture faces, one immediately forward of bearing 6, the other 10 cm forward of bearing 7. Bearing 6, which had supported the missing shaft, had been pulled out of its hanger.

Metallurgical examination of the fracture surfaces showed the mode of failure in both cases to be in torsion and bending. The torsional characteristics of the fractures were consistent with the normal torsional loading of the shaft. Metallurgical analysis of the shaft material confirmed that the shaft met the manufacturer's material specification and a dimensional check of the shaft proved satisfactory. The white main rotor blade tip had struck the tail boom fairing at a position coincident with the missing section of the tail rotor shaft. Though it seemed likely that both the shaft fractures occurred coincidentally with the main rotor blade strike, the possibility that one of the fractures occurred prior to this as a simple torsional failure was considered. Torsional failures of tail rotor drive shafts have occurred on other helicopters though Bell Helicopters Textron (BHT) say that the only type of failure experienced on the 206 tail rotor drive shaft had been due to seizure of a shaft support bearing. However the characteristics of the fracture surfaces were such that both these possibilities could be discounted.

The torsional characteristics of both failures showed that the shaft was being driven at the instant it was struck by the main rotor blade tip. The shaft failures were compared with those that resulted from a blade strike on a Bell 206A during an autorotative landing. (See Appendix C). The characteristics of the failures were found to be almost identical, indicating that both G-BAYA's fractures were caused when the shaft was struck by the white blade tip, and that there was no prior failure.

1.13 Medical and pathological examination

Not relevant.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Post crash action by survivors

The pilot was wearing a full harness and escaped unhurt. The cameraman wore a lap strap only and sustained minor injuries to his head and back. Both were able to get clear of the aircraft as soon as it came to rest. Both were warmly clad but the only survival equipment

available was the aircraft's first aid kit and one life jacket containing 3 day/night flares, a mini-flare pack of 8 flares, 4 small packs of barley sugar, a heliograph and some matches.

The pilot decided that he and the cameraman would march north to try to reach Glenmore Lodge or the Cairngorm ski lift approach road or at least a lower level clear of possible bad weather so that flares would be visible from a distance.

The snow was soft and about waist deep in places and they were only able to make slow progress.

They walked northwards down a valley until darkness when they sheltered in a rock crevice. Between 1630 and 1700 hrs, they fired two miniflares.

1.15.2 Overdue action

The helicopter was not in radio contact with any station during the flight but the flight details and ETA of 1530 hrs were known by the cameraman's assistant who remained at the Coylumbridge Hotel. At 1715 hrs he reported the aircraft overdue to P L M Helicopters at Inverness, and to the mountain rescue post at Glenmore Lodge. Just before this the Lodge had received a report of a red light thought to be a flare seen to the south-east of Cairngorm at about 1650 hrs. The police were contacted and the Rescue Co-ordination Centre (RCC) Edinburgh was alerted at 1757 hrs.

A ground rescue party was organised by the staff of Glenmore Lodge involving the Cairngorm and RAF Kinross mountain rescue teams. An RAF Shackleton was also sent to the area to assist in the search and a RAF Whirlwind helicopter was despatched to Glenmore Lodge to rendezvous with the mountain rescue teams.

1.15.3 The rescue

Ground parties set out from the local rescue co-ordination centre at Glenmore Lodge to establish radio links to provide communications in the bad reception area around Loch Avon, and a search party also made its way towards the point where the flare had been sighted. At 2105 hrs the searching Shackleton saw a flare, which had been fired by the helicopter pilot when he heard the aircraft overhead. The aircraft reported this position as being in a valley one mile north of Loch Avon.

Bad weather prevented the Whirlwind taking off until 0015 hrs on 12 January when the pilot decided to attempt a search in spite of very poor flying conditions due to darkness, low cloud and fog, and the terrain. This very determined and skilful rescue attempt by the helicopter crew was rewarded when about an hour later the two survivors were located on high ground 2,800 feet amsl and winched aboard.

1.16 Tests and research

None.

1.17 Additional information

A 35 mm movie camera was fixed in the right rear cabin doorway area on an anti-vibration mount and operated by the cameraman who was seated facing outwards. The camera had freedom about all three axes, its movement being controlled by the cameraman. The speed was 24 frames per second and the shutter speed 1/49th of a second. A colour film which had run from the helicopter's hover over the NE end of the loch until it was stopped by the cameraman after the accident, was recovered for analysis. It showed a view of the northside of the loch including mountains and skyline as the helicopter transitioned from the hover. It was apparent that the helicopter was well clear

of the loch surface throughout this transition. The picture seen was perfectly normal and clear until 12.5 seconds after the transition commenced when the start of bad frame blurring was the first indication of trouble seen on the film.

Because the camera was hand controlled the relationship between the camera and helicopter fuselage could not be accurately established. However on the assumption that the camera was held firmly enough for the relationship to be sensibly constant for the first two seconds after frame blurring commenced, certain observations can be made. The helicopter's pitch attitude was constant for the first 8/24 sec (ie 8 frames) when it then pitched nose down to reach - 20 degrees at 21/24 sec. It then pitched nose up to +5 degrees at the end of the 2 seconds period. In the same period the helicopter also rolled initially to the left during the first 9/24 second when it then rolled to the right, regaining an approximately level attitude after 1½ secs. The helicopter's behaviour in yaw could only be assessed from the film once yaw rates had become large.

However it was evident that within 2 seconds of the first blurred frame the helicopter was established in an accelerating right yaw and that this continued until it struck the ice after 1½ turns taking 9.35 seconds. During this rotation there were apparent large divergences in pitch and roll but these were corrected on each occasion until just before impact.

The main rotor disc is only seen on the film on five alternate frames (ie 1/12 sec intervals) between 5/24 and 13/24 sec from the datum. On these frames the rotor is in evidence and its movement indicates a disc motion first to the right and then reversing, and also a simultaneous rearward tilt. Though the main rotor speed could not be determined precisely from the film, it was established that it was certainly in excess of 360 rpm.

2. Analysis

It is apparent from the evidence that the accident occurred after the development of an uncontrollable yaw to the right. At the time the aircraft was accelerating slowly in straight flight, well above the surface of the loch and in clear weather.

The investigation was therefore directed in the main to determine the reason for the loss of yaw control, but none could be found. Initially, the severance of the tail rotor shaft appeared to provide the explanation, but detailed metallurgical examination of the fracture faces did not support this as it was concluded that the severance of the shaft was due solely to the main rotor blade strike and that this most probably occurred later in the accident sequence after the yaw had already developed. There is no evidence to support the possibility of a gross displacement of the main rotor disc leading to a blade strike as being the prime cause of the accident. The film evidence supports this conclusion as the initial change in attitude was nose down, whereas had the main rotor disc flapped back sufficiently to strike the tail cone a nose up pitch could have been expected.

There is also no evidence that the accident was due to any technical or mechanical malfunction or to pilot mishandling.

Though it was considered by the pilot that the survival equipment carried in the aircraft included all 'essential' items, it cannot be held that this equipment constituted a winter survival pack in the proper sense of the term, as it did not include any means of keeping survivors warm and dry. Fortunately a well organised and determined air and ground search and rescue operation carried out by the Royal Air Force, the Grampian Police and the Cairngorm Mountain Rescue Team located and picked up the two survivors at 0115 hrs on 12 January. The search and rescue operation would have been made easier and been more sure of success if the helicopter or its pilot had carried an electronic emergency locator beacon. At present Civil Aviation Authority Regulations do not require these beacons to be carried on flights of this type.

3. Conclusions

(a) Findings

(i) The pilot was properly licensed and he was competent to carry out the flight.

(ii) The documents of the helicopter were in order and it had been maintained in accordance with an approved schedule. There is no evidence to suggest that it was not fully serviceable at the start of the flight.

(iii) The helicopter was being operated in accordance with the company's operations manual with the exception that the required winter survival pack was not being carried.

(iv) While the helicopter was flying at low level over the frozen surface of Loch Avon it went out of control in a right hand yawing motion and crashed.

(v) The cause of the loss of control could not be established.

(vi) The occupants of the helicopter probably owe their survival to a rescue operation that was carried out with great determination and skill with excellent coordination between the various elements of the search.

(b) Cause

The cause of the accident could not be determined from the evidence available.

4. Safety Recommendations

4.1 It is recommended that the CAA consider a requirement that all aircraft operating into the remoter regions of the United Kingdom in the winter months be equipped to a modified Scale V as contained in Schedule 5 of the Air Navigation Order 1976.

P J BARDON
Inspector of Accidents

Accidents Investigation Branch
Department of Trade

March 1978

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