AIRCRAFT ACCIDENT REPORT 8/78

Department of Trade

ACCIDENTS INVESTIGATION BRANCH

Sikorsky S. 6 1N Helicopter G-BBHN Report on the accident in the North Sea, North East of Aberdeen on 1 October 1977

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Department of Trade
Accidents Investigation Branch
Kingsgate House
66-74 Victoria Street
London SW1E 6SJ

5 December 1978

The Rt Honourable John Smith MP
Secretary of State for Trade

Sir

I have the honour to submit the report by Mr G C Wilkinson, an Inspector of Accidents, on the circumstances of the accident to Sikorsky S.61N Helicopter G-BBHN which occurred in the North Sea, North East of Aberdeen on 1 October 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. 8/78
(EW/C606)

Registered Owner and Operator		Bristow Helicopters Ltd
Aircraft:	*Type*	Sikorsky S.61 helicopter
	Model	S.61N
	Nationality	United Kingdom
	Registration	G-BBHN
Place of Accident		In the North Sea, 48 nautical miles NE of Aberdeen Latitude 57° 38′ North, Longitude 01° 02′ West
Date and time		1 October 1977 at 1418 hrs All times in this report are GMT

Synopsis

The accident was reported to the Department of Trade Accidents Investigation Branch by the operator. The investigation comprised examination of the operational, engineering, search and rescue and survival aspects.

The accident occurred when the helicopter made an emergency landing in very rough seas and capsized almost immediately after touchdown. The liferaft could not be deployed, however all three occupants were rescued by another helicopter after 53 minutes immersion, uninjured but suffering from the effects of exposure. The floating wreckage was salvaged three days later.

It is concluded that this accident was caused by the helicopter alighting on open water in very rough seas which were beyond the seakeeping capabilities of the aircraft, because the commander believed that a major structural failure was imminent. It is probable that a main rotor blade pocket had become partially raised and disbonded causing very severe vibration.

1. Factual Information

1.1 History of the flight

The crew reported for duty two hours before the 0900 hrs planned departure time to enable the commander to brief the co-pilot on company procedures; this was the co-pilot's first offshore line operation following the completion of his type conversion on to the S.61N. The intended flight was from Aberdeen – Venture 2 oil platform – Odin drilling platform – Aberdeen. Venture 2 and Odin are about 142 nm ENE of Aberdeen.

Prior to engine start-up in Aberdeen and on two subsequent refuelling shutdowns, no obvious defects were apparent to the crew during their external inspections of the helicopter. After an uneventful outbound flight three passengers were off-loaded on Venture and a wooden crate containing 90 kg of freight was loaded in the passenger cabin and securely lashed down. After refuelling at Odin and whilst en route to Aberdeen instructions were received to return to Venture 2 and convey an injured workman to hospital in Aberdeen; before doing so it was necessary to refuel at Bredford Dolphin, about 110 nm from Aberdeen. The helicopter then returned to Venture 2 and picked up the casualty without stopping the engines. The casualty was placed in an aisle seat on the starboard side of the passenger cabin and was strapped in by the co-pilot who also provided him with a headset to reduce the noise. The passenger was not wearing a lifejacket but there were four readily to hand on the next seat. He was not given a specific safety briefing for the flight but he had already been instructed in S.61N safety and emergency procedures prior to leaving Aberdeen for the oil platform. Although he was in some pain with an injured foot it was not thought necessary for him to be accompanied whilst being taken to hospital.

The helicopter took off for Aberdeen at 1300 hrs and cruised at a height of 1,000 feet in visual meteorological conditions (VMC), at an indicated airspeed of 100 to 110 knots. A position check at 1400 hrs gave a ground speed of 78 knots, indicating a head wind component of about 32 knots.

At 1406 hrs, when 52 miles from Aberdeen, the commander informed Approach Control by VHF RTF that he had blade damage and was descending to 100 feet. The crew first became aware of a low amplitude flapping sound which later developed into a steadily increasing vibration that became worse when airspeed was reduced to about 70 knots. As it increased the vibration was accompanied by random feed-back to the cyclic pitch control. When the vibration commenced the commander tentatively identified it with blade-tip, blade tape, or blade pocket failure, all of which he had previously experienced on another type of helicopter. Before reducing speed he had made a visual check of the rotor tip-path plane which, at that time, showed an even straight line.

It was the commander's intention to continue the flight at low level but as the helicopter became progressively more difficult to control he decided it would be necessary to alight on the sea before control was completely lost; at this stage the degree of feed-back made the cyclic pitch control difficult to restrain and there was some restriction of control movements in the pitching plane. A 'Mayday' distress call was transmitted on the Aberdeen approach control frequency which was acknowledged. The distress call was also received by another helicopter, a Bell 212, call sign RJ, which made visual contact with HN four minutes later and remained in company. The pilot of RJ carried out a visual inspection of HN but could see no signs of damage or loose cowlings.

Between the 'Mayday' call and the ditching eight minutes later HN continued flying slowly towards land at a low height. During this period the commander evaluated the situation and considered alternative courses of action, but as time went by he was convinced that a catastrophic failure of the main rotor or a control jack was imminent and decided that he would have to put the helicopter down on the water notwithstanding the very rough conditions obtaining. He was influenced in his decision because the track to nearest land was cross-sea and cross-wind and in the event of control being lost he would be unable to turn the helicopter into wind and waves. He was also conscious of the presence of an injured passenger in the cabin who would have a better chance of survival if a landing was made with the helicopter still under control.

The commander ordered the co-pilot to read out the emergency drill checklist, which he did and instructed the passenger, over the public address system, to don his lifejacket. The co-pilot then put on his own lifejacket and took control whilst the commander donned his. During the time he was flying the helicopter the co-pilot experienced considerable difficulty with the cyclic control, he also observed that the rotor blade tip path was ragged as though a blade or blades were out of track, the accompanying vibration was one per rotor revolution. The commander resumed control and briefed the co-pilot to the effect that if it was necessary to stop the engines after touching down he would instruct him to do so and to apply the rotor brake.

At the time of the ditching the wind was assessed as being 30 to 40 knots with heavy seas and wave heights of 20 to 30 feet. As the commander brought the helicopter to the hover prior to alighting on the water the vibration intensified to a degree which dispelled any remaining thought of keeping the aircraft in the air. During the landing manoeuvre the helicopter brushed the crest of a passing wave, lifted off and touched down gently on the crest of the next wave and descended into the trough. The commander had considered keeping the rotors turning after touchdown but when he saw the 'wall of water' ahead he realized that the rotor would not survive. He ordered the co-pilot to shutdown both engines and apply the rotor brake. These actions were executed promptly and on the command 'go' the co-pilot undid his safety harness and moved out of his seat towards the cabin. The sea anchor was not deployed.

The commander attempted to maintain the helicopter laterally level and applied up-collective control as the rotor was slowing down. The helicopter climbed the face of the advancing wave, which was very steep, achieving a pitch angle of about 30° and on reaching the crest the bow lifted clear. According to eye witnesses in RJ the wave carried the machine backwards and it yawed about 30° to the left under the influence of wind and wave. As HN rolled to the left the slowly turning rotor blades dug into the water and it capsized almost immediately. The commander who had already unfastened his safety harness, was thrown heavily across the flight deck which was instantly flooded when the cockpit window broke as a result of water pressure. The passenger, who had seen both crew members release their harnesses, released his seat belt and was thrown sideways out of his seat. He subsequently picked himself up off the roof of the inverted cabin.

The three occupants evacuated the inverted and partially flooded aircraft with some difficulty but were unable to deploy the liferaft. The co-pilot, a strong swimmer, managed to reach and board an inflatable dinghy which had been dropped from RJ but was prevented by the wind and waves from picking up the commander and the passenger who remained by the aircraft. A civil SAR helicopter equipped with a winch eventually rescued the three survivors 53 minutes after the ditching.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal	–	–	–
Serious	–	–	–
Minor/None	2	1	–

1.3 **Damage to aircraft**

Substantial damage followed the capsize. The helicopter was salvaged three days after the accident, repaired and subsequently returned to service.

1.4 **Other damage**

None.

1.5 **Personnel information**

1.5.1.	*Commander:*	Male aged 36 years
	Licences:	United Kingdom Airline Transport Pilot's Licence (Helicopters) valid until 30.1.87. Also: Malaysian Airline Transport Pilot's Licence (Helicopters)
	Helicopter type ratings:	S.55; W.60; S.58T; S.61N
	Instrument rating:	Renewed 12.9.77
	Medical certificate:	Class 1 15.4.77
	Certificate of test:	S.61N 12.9.77
	Emergency and Survival drill:	10.11.76
	Wet dinghy drill:	23.11.76
	Flying experience:	Total all types: 3,985 hours Total helicopter: 3,735 hours Total S.61N: 570 hours Total last 30 days: 84 hours Total last 7 days: 27 hours
	Duty time:	Off duty 1700 hrs 30 September until 0700 hrs 1 October (14 hours) On duty 0700 hrs 1 October until 14.18 hrs 1 October (7 hrs 18 mins)
1.5.2	*Co Pilot:*	Male aged 34 years
	Licences:	United Kingdom Commercial Pilot's Licence (Helicopters) valid until 30.1.87. Also: United Kingdom Commercial Pilot's Licence and Instrument Rating (fixed wing). USA Airline Transport Rating (fixed wing) land and sea planes
	Helicopter type ratings:	Bell 47; S.61N
	Medical certificates:	Class 1 15.4.77
	Certificate of test:	S.61N 18.9.77 (initial on type)
	Emergency and Survival drill:	18.9.77
	Wet dinghy drill:	6.9.77

Flying experience:	Total all types: 7,600 hours Total helicopter: 112 hours Total S.61N: 11 hours
Duty time:	Off duty 38 hours 30 minutes prior to 0700 hrs 1 October On duty 0700 hrs 1 October until 14.18 hrs 1 October (7 hours 18 minutes)

1.6 Aircraft information

1.6.1 General information

(i)	Manufacturer:	Sikorsky Aircraft, USA
(ii)	Date of manufacture:	1973
(iii)	Constructors number:	61714
(iv)	Registered owner:	Bristow Helicopters Ltd registered 21.12.73
(v)	Certificate of Airworthiness:	United Kingdom Transport Category (Passenger) first issued 4.1.74, renewed 15.12.76 valid until 14.12.79
(vi)	Certificate of maintenance:	30.9.77 valid until 12.11.77 or 50 flying hours
(vii)	Total airframe hours:	4,213
(viii)	Hours since last check: (phase 3)	13
(ix)	Total Engine hours:	No. 1 – 1,525 No. 2 – 61
(x)	Engine hours since last inspected:	No. 1 – 13 No. 2 – 61
(xi)	Main rotor head:	Time since manufacture: 6,604 hours Overhaul life: 1,650 hours Time since overhaul: 1,026 hours
(xii)	Main rotor blades: Blade Life:	Type: P/N S6115-2051-041 9,400 hours

Blade No.	Hours since manufacture	Hours since overhaul/fit
1	4872	416
2	4646	416
3	3309	861
4	2303	861
5	3407	356

(xiii)	Main gearbox:	Hours since manufacture: 4,440 Hours since overhaul: 1,607
(xiv)	Weight of last take off:	7,615 kg

(xv)	Estimated weight at time of accident:	7,070 kg
(xvi)	Maximum weight authorised for ambient conditions:	9,299 kg
(xvii)	Estimated C of G at time of accident:	260.3 inches aft of datum
(xviii)	C of G range applicable:	255 to 278 inches aft of datum
(xix)	Fuel remaining at time of accident:	771 kg Jet A1

The main rotor blades were examined on 30.9.77 (the day before the accident) after a temporary chordwise repair tape had partially detached in flight resulting in a one per revolution vibration. The area of the blade affected was inspected and the tape replaced before the flight on which the accident occurred. No record was made in the aircraft technical log of the repair or of its location.

1.6.2 *Safety equipment*

The helicopter carried the following items of safety and survival equipment:

(i) *Inflatable liferaft*

One RFD 32 Man dinghy, Type 3OU 4D, with survival pack, was contained in a valise which was stowed vertically on the aft side of the wall, behind the flight deck, on the port side of the cabin aisle. The valise pack, which was intended to be launched through the cargo door, was secured to the wall with a web strap and quick release buckle which can also be remotely released from outside the hull. The survival pack contained, amongst other items, one pack of 6 Miniflares, 6 Day/Night distress flares and two tins of drinking water. The liferaft valise and its contents were last inspected on 22.10.76.

When the wreckage was recovered the liferaft was found to have deployed inside the cabin, the fabric was extensively torn and the inflation bottle had completely discharged.

(ii) *Lifejackets*

Crew: Two RFD type 50C Mk 2E pouch type inflatable life jackets were provided for the crew. The jacket worn by the commander failed to inflate using the CO_2 bottle due to a fault in the inflation head. Tests carried out by the manufacturer demonstrated that the failure to inflate was the result of damage to a non-return valve during assembly. To prevent a recurrence of this fault the torque loading of the valve during assembly has been reduced from 7-10 lb ins to 4-5 lb ins.

Passenger: Four RFD type 50C Mk 8 pouch type inflatable lifejackets were available for the passenger on the accident flight.

All the lifejackets were last serviced and inspected on 2.2.77.

(iii) *Personal locator beacons (PLB)*

Both crew lifejackets were equipped with SARBE Mk3 PLB for operation on 243 MHz. After the accident both PLB were tested and found to be in working order.

A tethered floating SARBE beacon, Type BE369, operating on 121.5 MHz, was contained in the liferaft valise. It was not recovered during salvage.

(iv) *Sea Anchor*

A G Q sea anchor in its pack was stowed under the co-pilot's seat. Although the sea anchor assembly permits rapid deployment once connected to the helicopter's towing cable it is not easy to extract from its stowage particularly if the aircraft is pitching heavily in a seaway. The sea anchor pack has to be connected to the externally mounted cable by a substantial snap hook, the hook being permanently fastened to the end of the sea anchor drogue strop. If the sea anchor is prepared for rapid deployment before landing, the heavy hook, the pack and 4.7 metres of static line are draped over the co-pilot's legs, thus presenting a potential hazard to the flight crew whilst carrying out the landing manoeuvre. Company pilots and the safety equipment officer differed in their views as to when and how the sea anchor should be connected preparatory to deployment and in this respect the Emergency Drill Check list was ambiguous. Since the accident the operator has re-positioned the sea anchor stowage at the front of the cabin from where it will be deployed through the cargo door by the co-pilot, who will under the revised Emergency Drill procedures move aft into the passenger cabin before touchdown.

1.7 Meteorological information

SYNOPTIC SITUATION

At 0100 hrs on 1 October, a low pressure area of 979 millibars, situated east of Iceland, was moving slowly south east and was expected to fill during the next 24 hours. A shipping forecast issued by the Meteorological Office at 0530 hrs on 1 October included a gale warning in all areas excepting Biscay, Finisterre and Sole. The area forecast for Viking and Forties gave the following information: Wind north westerly 6 to gale 8 but locally 5 in the east at times; showers, good visibility.

AREA FORECAST FOR THE NORTH SEA RIG AREAS

The airport meteorological office, Aberdeen, issued an area forecast at 0935 hrs on 1 October: this read in part:

> North Sea areas as defined, period 1100 to 1900Z. An unstable airstream covers the North Sea.
>
> Area Tango (the area of the ditching)
> Winds: 500 ft 290/30 temp. + 8° C
> 2,000 ft 300/40 temp. + 4° C
> Outlook for the next 6 hours: All areas no great change.

A routine observation at Aberdeen airport was made at 1420 hrs.

Surface wind:	270/18 knots variable 230 – 300° 10 to 28 knots;
Cloud:	one okta at 2,800 ft.
Weather:	Nil
Air temperature:	+11° C, dew point +4° C
QNH 998. QFE 989.6	

AFTERCAST

The Meteorological Office prepared the following aftercast for the area of the ditching for 1420 hrs.

Surface wind:	West to northwest 30 to 35 knots
1,000 ft wind:	300/40 to 45 knots
Cloud:	mostly broken cumulus and cumulonimbus base 1,500 ft to 2,000 ft but 600 ft to 1,000 ft in heavy showers
Visibility:	heavy squally showers
Air temperature:	+8° C
Sea temperature:	+11° C
Sea state:	very rough
Light condition:	good

According to the crew, G-BBHN flew through several heavy rain showers on the outward flight from Aberdeen to Venture 2.

1.8 Aids to navigation

(a) *On the ground*

Very High Frequency Omni Range (VOR)
Decca
Medium frequency non-directional beacon (NDB)

The rescue helicopter located the ditched aircraft using a known VOR radial and Decca coordinates. It was also given visual guidance by other helicopters already at the scene. No navigational problems were reported before or after the ditching and no post accident flight check of radio navigational aids were carried out.

(b) *In the air*

The aircraft was equipped with:

VOR, Automatic Direction Finder (ADF), and Decca.

The equipment listed was serviceable with the exception of a minor defect in the visual presentation of Decca which was not a factor in the accident.

1.9 Communications

Aircraft operating offshore from Aberdeen are controlled during their departure and arrival by Aberdeen Approach Control on 126.1 MHz. There is no control zone as such but there is a Special Rules Area within 10 nm of the airport. From Mondays to Fridays, outbound aircraft communicate with Aberdeen Approach until 35 miles offshore when they are transferred to company high frequency channel (HF) or Highland Radar on 134.1 MHz. RTF communication with oil rigs or platforms is on HF or VHF according to the allocated company frequency. On the day of the accident, outbound aircraft were transferred to company frequency at a range of about 60 miles and inbound aircraft called Aberdeen Approach at 60 miles to run.

In the case of the subject aircraft a routine inbound call was made to Aberdeen Approach at 1400 hrs when at a range of 60 miles.

Speech recording apparatus installed in Aberdeen ATC was serviceable at the time of the accident and the time injection on the RTF tape was accurate to within one second; the recorded RTF messages on 126.1 MHz were transcribed by the CAA Transcription Unit, NATS, Scotland.

1.10 Aerodrome information

Not relevant.

1.11 Flight recorders

None fitted; mandatory fitment of recorders in this type of aircraft is not required by UK Regulations.

1.12 Examination of the wreckage

The wreckage was towed into Peterhead harbour three days after the accident where an under water video survey was done before being lifted out of the water. All five main rotor blades had detached at the blade root ends immediately inboard of the root pockets, the rotor blades were not recovered but subsequent examination of the root ends showed that all five blades had failed in upward bending after several load reversals. Initial examination after salvage revealed that the fuselage was structurally intact with the exception of the tail boom which had separated in upward bending at a position immediately aft of the transport joint.

A subsequently detailed examination was concentrated on those areas where damage or malfunction could result in the heavy vibration and control feedback experienced by the crew; the main rotor assembly, its associated components, rotor control systems, the gear box and engine mountings and the engines. No defects were found in any of the assemblies except for corrosion of the engines' front casing and main gear box due to prolonged exposure to salt water.

1.13 Medical and pathological aspects

EFFECTS OF IMMERSION IN COLD WATER

Medical research into the effects of immersion in cold water has shown conclusively that without protective clothing a man of average body build will be helpless due to hypothermia after 30 minutes in water at 5^0 C or 120 minutes at 15^0 C. These times will be reduced if physical effort is expended. In water of less than 20^0 C, body heat is lost at a rate which exceeds its production and once body temperature has fallen from its normal value of 38^0 to below 35^0 C, heat production itself is reduced and a relatively rapid deterioration of physical and mental faculties then follows. If an unprotected human body is immersed in water of 10^0 C unconsciousness can occur after 60 minutes. The effects of reducing body temperature, and therefore life expectancy times without an anti-exposure suit, are illustrated in figure 1.

In the case under consideration the commander was semi-conscious when he was recovered from the water and he lapsed into unconsciousness shortly afterwards: his temperature had certainly fallen below 33^0 C and he displayed symptoms of moderate hypothermia. At this stage he would have been incapable of helping himself or others to board a liferaft and it is a considered medical opinion that if rescue had been delayed by even a few minutes he would have lost consciousness and, in the existing sea conditions, would have drowned.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Evacuation of the helicopter

Following the capsize the hull lay nose-down and, with the cabin filling rapidly, was settling lower in the water. When the co-pilot entered the inverted cabin he saw the passenger making his way towards him. The co-pilot released the buckle of the liferaft stowage but experienced difficulty in moving the valise towards the cargo door as, with the aircraft inverted the cabin floorboards had become detached and the baggage compartment doors were hanging down. With the water level rising and the airspace overhead diminishing rapidly, he concentrated on opening the cargo door, which was the exit through which the liferaft should be launched, but at first he was unable to open the door because of water pressure on the outside. The commander, who had meanwhile left the submerged flight deck via the starboard sliding window, made his way along the side of the upturned hull and tried to open the cargo door from the outside. Being unsuccessful he thought that the co-pilot might still be inside the flight deck area so he returned, looked into the flight deck under water through the side window and, having ascertained that the co-pilot was not there, returned to the cargo door where he, together with the co-pilot on the inside, succeeded in prizing it open sufficiently for the two occupants to squeeze through. Since there was no way of restraining the cargo door once it was open it kept sliding shut under the action of the waves and the pitching hull. Before they were able to leave the cabin the co-pilot and passenger were neck deep in water with little breathing space left overhead.

After the passenger left the cabin he was held by the commander against the side of the hull to prevent him from being swept away. The commander held on to the submerged cargo hook release cable with his arms around the passenger. Meanwhile, the co-pilot attempted to extract the liferaft from the cabin but as it was trapped against the inverted flooring by its natural buoyancy and the open luggage locker door, this proved to be beyond his capabilities since he had to restrain the cargo door with one hand whilst trying to dislodge the valise with the other. He was unable to exert sufficient downwards purchase on the pack because of its buoyancy and the hull's list to port. He also attempted, without success, to pull the liferaft pack out of the cabin by its retrieval lanyard. By the time that the wreckage was secured by the salvage vessel the liferaft had inflated inside the cabin. However it was not possible to establish if it had inflated as a result of the attempts to extract it from the cabin.

1.15.2 Post ditching events

Both pilots were dressed in uniform trousers and shirts, they were not wearing their uniform jackets or any kind of protective clothing although 'UVIC' thermal jackets were carried in the aircraft; it is understood that prior to the accident these were rarely, if ever, worn by aircrew. The crew had donned pouch style lifejackets which were equipped with SARBE PLB which could transmit emergency signals on 243 MHz.These beacons were not switched on by either pilot because their position was already known. The co-pilot's lifejacket inflated normally with its CO_2 bottle but the commander's failed to inflate when the CO_2 bottle was triggered. He later succeeded in partially inflating it orally. The passenger's lifejacket although correctly inflated kept slipping over his head when he became immersed by passing waves.

When the commander of RJ, which was hovering nearby, realised that the survivors could not deploy the liferaft from HN he instructed his passengers to release the 10-man liferaft from its stowage in RJ, he had difficulty in communicating with them because of engine noise; there was no Public Address (PA) system and he did not have a co-pilot. Before he could be prevented from doing so the liferaft pack was partly opened by a passenger, it was then pushed out of the starboard door at a position upwind of the ditched helicopter but unfortunately it was carried past the hull, missing the survivors by a distance of about 10 metres. The co-pilot of HN swam about 100 metres through heavy seas before reaching it. He then grasped the valise fabric and towed the pack to within about 3 metres of the wreck. Unfortunately the liferaft then spilled out of the pack and he could make no further progress because of the extra drag. He then attempted to gather the fabric into a manageable bundle but in the process the liferaft inadvertently inflated and was carried away rapidly downwind. He was by this time too exhausted to swim back to the other two survivors so he boarded the liferaft and attempted to paddle it but he could neither make headway against the high wind and rough sea, nor could he prevent it from drifting further downwind.

The commander decided to move the passenger from his position against the hull to a more secure location by the landing gear sponson. Using his legs, he wedged the passenger against the sponson struts whilst holding onto a fuel vent pipe protruding from the bottom of the hull. The wreck lay broadside to the waves and it was continuously rolling the survivors under water with each passing wave and swamping them in fuel contaminated water. The passenger was in some pain from his injured foot, the splint of which had broken. Also, because of two broken fingers on one hand he had to use his arms and elbows in order to hang on to the struts. When the rescue helicopter arrived the winchman saw that the commander, although in the last stages of exhaustion, was still holding the passenger's head above water with his free hand.

The passenger and then the commander were winched on board the rescue aircraft followed by the co-pilot who was retrieved from the liferaft which had by then drifted about half a mile downwind. The commander had no recollection of being winched on board the helicopter and he lapsed into periods of unconsciousness whilst being transported to hospital. All survivors were suffering from the effects of exposure but the commander was in a hypothermic state. His body temperature was 33° C when measured in hospital about one hour after his rescue. The co-pilot's temperature was 36.5° C and the passenger's 36° C. The passenger was dressed in shirt, denim slacks and a windproof coverall.

1.15.3 *Search and rescue operations*

The radio call indicating G-BBHN's rotor problem was heard by the pilot of RJ who then intercepted HN and stood by whilst it ditched, thereafter providing guidance to other helicopters who, in turn, were able to guide the rescue helicopter towards the upturned hull and the liferaft containing the co-pilot.

A British Airways S61N with an experienced winch man on board had just become airborne from Aberdeen on a revenue flight when the distress call was transmitted. It returned immediately to Aberdeen, loaded the winching gear, SAR equipment and a winch operator and was airborne again in 26 minutes.

The first helicopter on the scene, RJ, was able to keep the Aberdeen approach controller informed of events as they occurred. After dropping its liferaft it also dropped a floating emergency beacon near the wreck as a precaution against having to leave the scene before rescue was possible. A second passenger carrying helicopter, DE, arrived on the scene and dropped another liferaft; this attempt was also unsuccessful as the liferaft became inflated and blew away. RJ was then forced to leave the locality because of a low fuel state. A third passenger carrying helicopter, VB, then arrived and, hovering close to the survivors, its commander tried to convey by hand signs that they would be rescued in about five minutes. Meanwhile, DE, took station on the liferaft containing the co-pilot.

After tracking along the 058° Aberdeen VOR radial the rescue helicopter sighted the landing lights of VB who then guided it towards the upturned hull which was difficult to locate and keep in view because its light coloured paint scheme merged with the breaking seas.

The rescue helicopter arrived in the area 43 minutes after the distress call was transmitted. It reported that all the survivors had been picked up 10 minutes later. No particular problems were experienced by the rescue winchman during the recovery although two of the survivors were in no condition to help themselves.

Two of the vessels which responded to the relay distress message reached the reported crash position ten minutes after the survivors had been picked up. They started a search but could not locate the floating helicopter. Once the rescue helicopter had left the scene it took another helicopter 3½ hours to locate the wreck during the salvage search although its position had been accurately established beforehand. The emergency floating beacon which had been dropped by RJ was still transmitting on 121.5 MHz ten days after the accident.

None of the aircraft engaged in the rescue or salvage operations were equipped to home on the PLB or emergency flotation beacon transmissions on VHF or UHF.

1.16 Tests and research

None.

1.17 Additional information

1.17.1 Sikorsky S.61N operation

(i) Pertinent extracts from the S.61N approved Flight Manual part 2 Section V are as follows:

'Water operations

..... During high sea states, tail and main rotor clearances can be critical especially when moving into waves or parallel to them ..... In high sea states keep the nose of the aircraft at a 30° angle to the waves and maintain flying rotor rpm at all times.'

'Rotor shut-down

Rotor shut-downs have been demonstrated in wave heights of up to three feet.'

'Emergency Water Operation

If an emergency water landing is made the procedure to follow depends upon the condition of the aircraft after landing, power available, wind and sea conditions, and the proximity to shore or rescue boats, however, one of the following conditions should be applicable:

3. If the helicopter cannot become airborne and the sea conditions permit, the rotor system should be kept engaged to provide additional water stability. It may be possible to water taxi to an area where passenger evacuation and aircraft salvage may be possible. If taxying is not possible, the helicopter should be held with the bow angled 30° to 60° to the existing waves to provide maximum stability.

4. If necessary to shut down both engines, the sea anchor should be deployed and the landing gear lowered for maximum water stability prior to shut down.

5. If a water take-off cannot be accomplished and none of the previously mentioned methods will stabilise the helicopter in the water, and the helicopter is in danger of sinking or capsizing, it may be necessary to abandon the helicopter. Prior to overwater flights the pilot should assume the crew and passengers are briefed on the survival equipment and procedure of its use.'

(ii) *Company procedures*

(a) Emergency drill check list

The emergency drill check list carried in G-BBHN and used by the crew prior to ditching contained the drill detailed below:

'DITCHING DRILL Procedure No. 27

Considerations

..... It should be noted that the flotation characteristics of the S.61N rotors stopped are not good, and therefore, a safe method of transferring the passengers and freight must be established with the rotors still turning and remaining engine operating unless the sea state is such that it is unwise to carry it out.'

CO-PILOT	CAPTAIN
	1 MAYDAY
2 Hooks on sea anchor and deploys as soon as aircraft touches water.	
	3 Secures aircraft. Decision to stop rotors dependent on conditions.
4 Cabin lights on and cock-pit lights after touchdown.	
5 Closes window and leaves seat.	
6 Launches dinghy from cargo door.	
7 If attendant carried launches 10 man dinghy aft of air stair door.	
8 Evacuates passengers with assistance from attendant if rotors stopped and danger of capsize or on instruction of captain.	
	N.B. Captain orders Abandon a/c when safe if danger of capsize exists.

1.17.2 *Regulations*

SAFETY EQUIPMENT

Aircraft flying for the purpose of public transport are required by the Air Navigation Order (1976), Schedule 5, to carry safety and survival equipment of a scale which is considered appropriate to the type of aircraft, the area and type of operation. In the case of this type of aircraft flying over water and with more than 30 minutes flying time from an aerodrome where an emergency landing can be made, and for flights which involve manoeuvres on water, the scale of safety and survival equipment required to be carried shall include survival beacon radio transmitters. (Scales H, I & J). There is no requirement for any civil aircraft to carry radio apparatus capable of homing on to survival beacon transmission.

Survival clothing is only required to be carried when operating in areas where, in the event of an emergency landing, polar conditions are likely to be met (Scale V).

CABIN ATTENDANTS

The Air Navigation Order, Part IV section 18 reads in Part:

'(6) If it appears to be expedient to do so in the interests of safety, the Authority may direct any particular operator of any aircraft registered in the United Kingdom that the aircraft operated by him or any such aircraft shall not fly in such circumstances as the Authority may specify unless those aircraft carry in addition to the flight crew required to be carried therein by the foregoing provisions of this Article such additional persons as members of the flight crew as it may specify in the direction.

(7) (a) When an aircraft registered in the United Kingdom carries 20 or more passengers on a flight for the purposes of public transport, the crew of the aircraft shall include cabin attendants carried for the purpose of performing in the interests of the safety of passengers duties to be assigned by the operator or the person in command of the aircraft but who shall not act as members of the flight crew.

(b) The Authority may give a direction to the operator of any aircraft registered in the United Kingdom requiring him to include among the crew thereof whenever the aircraft is flying for the purposes of public transport at least one cabin attendant, notwithstanding that the aircraft may be carrying fewer than 20 passengers.'

The CAA had issued a dispensation to the operator permitting the carriages of 25 passengers in the S.61N without a cabin attendant.

1.17.3 *Search and Rescue*

1.17.3.1 Organisation

The United Kingdom is required to maintain an adequate and effective search and rescue (SAR) organisation for safety on and over the sea under the Convention on the High Seas and for the rescue of persons in distress at sea under the Convention of Safety of Life at Sea.

The Ministry of Defence (MOD) operating through the Maritime Headquarters/Rescue Co-ordinating Centres (MHQ/RCC) at Pitravie (near Edinburgh) and Plymouth have a primary responsibility for HM ships and military aircraft in distress and within available military SAR resources since 1947 have also been vested with the SAR responsibility for civil aircraft. They discharge therefore the UK's obligations to International Civil Aviation Organisation (ICAO) on behalf of Civil Aviation Authority (CAA).

The areas of responsibility for marine SAR covers the coasts of the United Kingdom and Northern Ireland and extends over an area which closely corresponds to that laid down by ICAO as the area assigned to UK for aircraft in distress (see fig 2). The responsibility for initiating and coordinating marine civil SAR operations rests with HM Coastguard (part of the Department of Trade (DOT) with rescue operations being primarily carried out through the agencies of MOD helicopters and Royal National Lifeboat Institution (RNLI) lifeboats. In October 1977 the Coastguard was organised into eleven divisions, but plans were well advanced to bring into effect a reorganisation into six regions, each with a Maritime Rescue Coordinating Centre (MRCC) in anticipation of the intentions of the Inter-

Governmental Maritime Consultative Organisation (IMCO) to institute a worldwide maritime SAR organisation patterned closely to that developed by ICAO. (The new UK organisation was introduced in September 1978.)

Within the organisation outlined above, however, no one person has the overall responsibility for all SAR services, policy and operations. The Report of the Committee to review the Marine SAR organisations of the United Kingdom, published in 1970, found that 'Although there are different shore based authorities for controlling and coordinating rescue operations when ships and aircraft are in distress at sea, the present arrangements which provide for close liaison between them, work satisfactorily and no change is recommended.' The overall lead responsibility has therefore to be split between the Marine SAR Committee and the MHQ/RCC's, depending on the type of SAR operations involved, with the other providing any necessary support. The UK Marine SAR Committee, set up in 1971, consists mainly of representatives of the MOD (Navy and Air), HM Coastguard, RNLI and the Post Office (PO), with other interested parties present, but the CAA were not included. The Marine SAR Committee meets two or three times a year under a chairman from the Marine Division of the Department of Trade.

At no time has any member of the Marine SAR Committee proposed that matters of aeronautical SAR should come within the purview of that Committee.

1.17.3.2 SAR facilities for civil aircraft in distress

Within the United Kingdom's area of responsibility and in the North Sea region in particular the following SAR facilities are provided:

(i) *Royal Air Force*

A Royal Air Force (RAF) Nimrod aircraft is maintained at a one hour's state of readiness by day and night to take off from either Kinloss (Morayshire) or from St Mawgan (Cornwall) according to availability. The Nimrod is the principal search unit for marine SAR; it has a high en route speed, a long range, is equipped with radar and can home on to PLB and emergency beacon transmissions on 243 MHz. Having located survivors it can drop survival equipment in the form of liferafts and survival packs.

RAF Wessex and Whirlwind helicopters are maintained on a 15 minute stand-by during daylight and one hour's availability by night at various locations around or near the coast: two locations are relevant to the North Sea region, Lossiemouth (on the Moray Firth 48 nm WNW from Aberdeen) and Leuchars (near Dundee, 54 nm SSW from Aberdeen). These helicopter types have nominal SAR radii of action of 95 and 85 nm respectively, transit speeds of 90 to 100 knots and an endurance of 2½ hours. Had it been necessary to activate these units in the case under consideration they would have needed refuelling at Aberdeen before proceeding to the scene, thus delaying their arrival until 1½ to 2 hours from the time of ditching. These helicopters are equipped to home on to emergency beacons transmitting on 243 MHz.

(ii) *Royal Navy*

The Royal Navy (RN) Sea King helicopters are based on the south coast of England and on the west coast of Scotland; they have a nominal SAR radius of action of 230 miles, a transit speed of 105 knots, a night search and location capability and are equipped to home on to emergency beacons transmitting on 121.5 and 243 MHz. It is intended to re-equip the RAF SAR units with this type of helicopter in 1978, thus increasing their effective radius of action from 100 nm to 230 nm.

In addition, RN surface vessels can be alerted for a visual search of the designated area.

(iii) An Aerospace Rescue and Recovery Squadron of the USA based at Woodbridge, Suffolk can provide an HH53 helicopter, when operational requirements permit, normally within an hour. These large helicopters have greater range and survivor carrying capacity than any British helicopters.

(iv) *Department of Trade*

At the time of the accident British Airways Helicopters had a contract with the Department of Trade to provide an S.61N helicopter for SAR duties. The aircraft was based at Aberdeen at one hours readiness and was required to be equipped with a rescue winch. No particular aircraft was dedicated to the SAR task. As and when it was necessary an available helicopter was fitted with a winch pack and manned by a crew which included a winch man and a winch operator. The radius of action of the S.61N in the SAR role is 150 nautical miles with a transit speed of 105 knots. The contract helicopter was not equipped with equipment to home onto emergency beacon transmissions either on 121.5 MHz or 243 MHz.

In the case of the subject accident the contract helicopter responded to the callout in the commendably short time of 26 minutes and carried out the rescue of the survivors from G-BBHN.

(v) *HM Coastguard*

Merchant shipping in the area and RNLI offshore lifeboats can be notified of the emergency situation and directed into the general area for a visual search for the survivors.

(vi) In addition to the military aircraft dedicated to the SAR role, non-specialist fixed wing aircraft may be available for search operations. Except in the case of a patrolling Nimrod, other aircraft would not be fitted with PLB homing equipment but would conduct an aural/tactical navigation search if emergency beacon transmissions were received.

(vii) *Self-help by Operators and Oil Companies*

Following the accident to G-BBHN, Bristow Helicopters Ltd and British Petroleum (BP) (a major customer) made provision for two winching units to be positioned on oil rigs in the Forties field with oil company personnel trained in their operation. Five of the Bristow helicopters which are contracted to BP have been modified to take winching gear. These arrangements were taken to guard against future mishaps in that area, in which event the nearest helicopter would divert to the most convenient oil platform with the winching gear and proceed directly to the scene of the accident.

1.17.3.3 SAR helicopter coverage and response times

Radii of action of existing helicopter types used by military and civil authorities for SAR duty within the North Sea region are illustrated in Figure 2. Included in this diagram is the extended coverage to be expected in the latter part of 1978 when Sea King helicopters will be based at Lossiemouth and Leuchars. It may be seen that although the new area covered will extend to the Shetlands, many oil platforms further north will still be well outside the direct range of UK based SAR helicopters and at the extremity of the range of Sea King SAR helicopters operated by the Norwegian authorities from the Stavanger area. Most of the Shetland oil fields installations lie to the east of Greenwich meridian which marks the eastern limit of the UK SAR area of responsibility in distress, but will be within the UK's area of responsibility for marine SAR, which from latitude 62° N runs down the UK/Norway meridan line to its junction with the Norway/Denmark meridian line. There is good liaison between RCC Pitravie, HM Coastguard Aberdeen and the Norwegian SAR authorities together with excellent communications links. The defined areas of responsibility present no operational or diplomatic problem. Sea King helicopters operating from Lossiemouth or Stavanger would have to refuel before being operationally effective in the outlying oil fields and anything up to 3 to 4 hours could elapse before survivors are picked up, especially when strong northerly winds prevail.

1.17.4 *Main rotor repairs*

On the day preceding the accident a one per revolution vibration was experienced during flight by G-BBHN and a precautionary landing was made to investigate. It was found that a blade tape, which had been used to mask a partially raised and disbonded trailing edge pocket, had lost adhesion and was flapping loosely. After cutting away the loose tape the helicopter was flown to Aberdeen where the blade was inspected and another temporary repair carried out. There was neither a record kept of the original repair nor was any entry made in the technical log concerning the blade tape replacement. Temporary repairs to blade pockets are permitted by the manufacturer and the airworthiness authority and no restriction is placed on the blade's continued operation after repair except for the over-riding requirement that 'a blade suspected of causing rotary wing vibration shall be replaced'.

Following the accident to G-BBHN the two British operators of S61N helicopters adopted the procedure of replacing the defective rotor blade or repairing the disbonded pocket to a more permanent standard. The Civil Aviation Authority (CAA) also issued advice on these lines.

1.17.5 *Main rotor vibration*

The helicopter manufacturer and the United States National Transportation Safety Board (NTSB) provided the following data on S.61 main rotor blade failure modes experienced previously.

	Failure mode	Effect
1.	The chordwise balance tip weights on a single blade become loose and displace outboard or chordwise.	Sudden increase in one per revolution vibration associated with possible feedback through cyclic control.
2.	A spanwise leading edge counter weight on a single blade dislodges and is ejected outboard due to centrifugal force.	Sudden violent increase in one per revolution vibration associated with feedback through cyclic controls.
3.	Separation of outboard section of main blade just inboard of the chordwise tip weight package.	Sudden violent one per revolution and associated feedback through cyclic controls.
4.	Trailing edge pocket(s) disbond-separates at spar backwall and peels back into air-flow.	Pocket lifting causes a tab effect with a resulting one per revolution vibration depending on extent and spanwise location of pocket, Can result in feed-back through cyclic controls.
5.	Loss of damping action on one blade.	Slight out of track and one per revolution vibration.
6.	Worn pitch control rod and bearings on one blade.	One per revolution vibration and possible feedback through cyclic controls.
7.	Chordwise temporary repair tape lifts and partially separates.	One per revolution vibration and possible feedback through cyclic controls.

1.17.6 *Helicopter sea stability*

The waterborne handling characteristics of the S.61N in high sea states have not been established but model (scale 1/8) tests were conducted in 1972 in order to determine its stability on water with the rotors stopped and the effectiveness of the sea anchor. From these trials it was found that in waves up to 30 m long with the sea anchor fully deployed the aircraft capsized when the wave steepness (height/wavelength ratio) was greater than 1:12. In waves between 30 m and 45 m long the aircraft was stable in waves of steepness ratio of 1:14 decreasing to 1:14.4 in waves up to 75 m long. The aircraft capsized more readily in waves approaching the length of the helicopter hull (20.66 m). It was apparent that, within limits, neither waveheight nor wavelength is a critical parameter with regard to the behaviour of the aircraft but that height/length ratio is. The effectiveness of the sea anchor is also affected by steepness ratio (as well as wind speed and wave face steepness). In steepness ratios greater than 1:11 the sea anchor is pushed back towards the hull by the advancing wave crest, thus permitting the aircraft's head to veer off until the drogue line became taut again. In steeper waves of 1:9 ratio the aircraft's behaviour is more seriously affected with the sea anchor being pushed back so far towards the helicopter that it is almost underneath when the craft reached the crest. In waveheights of 2.6 m and steepness ratios greater than 1:8 capsizes occurred in both breaking and non-breaking waves.

In open sea tests the model was pushed around and capsized in conditions equivalent to waves 3 m high and 18 m long and in waves 4.9 m high and 43 m long. The steepness ratio varied between 1:6 and 1:9.

The time taken to capsize to the fully inverted position varied between 1¼ and 8½ seconds. The time taken for the sea anchor to fully deploy from a crumpled state in the water ahead of the helicopter varied between 17 seconds in calm water to 10½ seconds in regular seas 2.2 m high and 29.6 m long.

Sikorsky SH-3 military helicopters are equipped with 787 kg displacement sponsons having auxiliary inflatable flotation bags mounted outboard. The derivative S.61N commercial helicopters are fitted with larger 1506 kg displacement floats, but are not equipped with the auxiliary flotation bags.

An analytical study was made in 1977 of the effects of adding 998 kg displacement inflatable flotation bags to the S.61N. As the aircraft is more hydrodynamically stable in pitch than in roll the enhancement in roll stability only was reviewed. A 'worst case' condition was assumed with the helicopter broadside to the waves and rotors stopped.

The S.61N has seven water-tight compartments in the fuselage below the cabin floor and eight water-tight compartments in each sponson. The fuselage provides a buoyancy of 13250 kg while each sponson adds 1506 kg to give a total available buoyancy of 16262 kg, or 175% of the aircraft's maximum gross weight of 9299 kg. Each auxiliary flotation bag has two water-tight compartments and displaces 998 kg increasing total available buoyancy to 18257 kg or 196% of the maximum gross weight.

Without flotation bags, the aircraft can sustain side winds up to 46 knots in calm seas or broadside waves up to 2.9 m in calm air. The bags improve this capability by 40%, to 65 kts or 4 m waves. A more realistic measure is the combination of wind and waves that can be sustained. Without bags, the aircraft is stable up to 26 knots/2.2 m seas; with bags it goes up to 31 knots/3.4 m seas. This means an improvement in the worst case condition from sea state 4.7 to 5.8. Aircraft sea state capability would be higher if the aircraft were heading into the waves and had a sea anchor deployed.

1.17.7 *Sea state at time of accident*

Photographs of G-BBHN prior to, during and after the landing confirm that the seas were steep and broken, however, it is difficult to determine the wave heights and lengths with any degree of accuracy. Using the overall length of the helicopter as a reference (22.2 m) the wavelengths appear to have been about 45 m. Wave height can only be deduced from the observations of the crew and eye witnesses and from the sea state (scale 8) assessed by those engaged on salvage and rescue operations. Using such data that exist applicable to the North Sea, wave heights between 4.5 m and 7.6 m are probable in sea state 8 conditions. Taking a wave height of 6 m as being reasonable but conservative, the steepness ratio of the waves at the time of the accident was probably between 1:10 and 1:6.

1.17.8 *Rotor survival in heavy seas*

No test data exist to assess this probability but the Flight Manual states that tail rotor clearance is critical in high sea states. Photographs taken during the tests described in 1.17.6 indicate that in wave steepness ratios of 1:9 in regular seas the tail would be at least partially submerged as the helicopter rode up over such a wave head-on since the front part of the hull would be clear of the water as far back as the trailing edges of the sponsons as it pitched up and over. The photographs also indicate that engine intakes would also be swamped as the aircraft rode into the crest, especially if the wave was breaking. Although no data exist to support the contention, it is difficult to see how tail rotor clearance could be maintained in steep breaking seas even when negotiated at a 30° angle, which is prescribed in the Flight Manual.

1.17.9 *Alert action*

On 21 October 1977 the Chief Inspector of Accidents wrote to the CAA listing twelve subjects which the investigation had highlighted. These were:

(i) Auxiliary flotation bags for S.61N helicopters.

(ii) Modified liferaft stowage for S61 helicopters.

(iii) Provision of exterior grab rails on helicopters.

(iv) Constant wear lifejackets for helicopter pilots.

(v) Anti-exposure clothing for helicopter passengers and crew.

(vi) S61 improved sea anchor installation.

(vii) Helicopter high visibility paint schemes.

(viii) Ability to lock cargo door open on S61 helicopters.

(ix) Security of floor coverings and access doors on helicopters.

(x) Communication system between crew and passengers on helicopters.

(xi) Review of helicopter ditching procedures.

(xii) Ability of SAR helicopters to home onto PLB transmissions.

2. Analysis

2.1 Engineering aspects

All of the blades were attached to the rotor head when the helicopter touched down and capsized but since they were subsequently lost the cause of the vibration can only be speculated upon from the symptoms described by the crew, the evidence of previous defects experienced on S.61N helicopters and known repairs carried out on one of the rotor blades.

According to the crew there was a barely perceptible flapping sound which developed over a period of minutes into heavy vibration at one per rotor revolution with cyclic pitch control feed-back, also, prior to touchdown the rotor tip-path appeared uneven. These symptoms are indicative of a main rotor blade defect. Examination of the main rotor head and its associated cyclic and collective control systems revealed no evidence of any failure which could have contributed to the conditions described. It is nonetheless possible to arrive at a probable cause for the vibration when the failure modes described by the manufacturer are considered. Failure modes 1, 2 and 3 (see 1.17.5) are sudden events, the onset of which are marked by a loud noise followed by heavy vibration. The suddeness of the event and the loud noise are not considered compatible with the subject case. Examination of the main rotor head eliminated failure modes 5 and 6. A chordwise temporary repair tape separation and/or trailing edge pocket disbond can cause a tab effect (failure modes 4 and 7) and this condition offers a most likely reason for the vibration. The severity of the vibration and control feed-back from either of these two failures is dependent on the extent of the separation and spanwise location of the pocket(s) concerned, and since the area of the pocket disbond and temporary repair coincided with an area of high blade loading it is concluded that the vibration was probably caused by separation of the blade tape repair and a partially disbonded pocket which probably resulted from an encounter with heavy rain showers when outbound from Aberdeen to Venture 2. There is no evidence to suggest that the temporary repairs were not properly carried out, but since the ensuing chain of events leading to the loss of the helicopter was probably thus set in motion, the wisdom of treating such a repair as other than a temporary, 'get you home' repair is questionable.

2.2 The emergency landing and capsize

The commander decided to land because he was convinced that a catastrophic failure of the main rotor or a control jack was impending. Whether or not this was in fact the case will never be known but since the Operations Manual contained no instruction or guidance specific to malfunctions of this kind, the commander's actions were of necessity based on his sense of airmanship and experience as a helicopter pilot. It would be wrong to criticise him for not keeping the helicopter airborne for as long as possible; his decision to land was not lightly taken and he was very much aware of the rough sea condition; the deciding factor was the injured passenger who would have stood little chance of surviving an uncontrolled emergency landing.

The landing itself was skilfully executed and the commander had intended to keep the rotors turning in order to maintain control whilst on the water, but when the helicopter sank into the wave trough he was convinced that the rotors would not survive in the high breaking seas. He therefore decided to shut down the engines and apply the rotor brake. The correctness of such a decision might be questioned and some professional opinion would advocate keeping the engines and rotors turning regardless of sea conditions because they are essential to remaining upright. On the other hand, it is doubtful, if any experience has been obtained in handling an S.61N in such conditions. The Operations and Approved Flight Manuals contain no advice on this matter except to say that the flotation characteristics of the S.61N with its rotors stopped 'are not good'. This implies that its chances of remaining upright in waves exceeding three feet cannot be guaranteed. Experience with naval Sea King helicopters (a similar type) which are fitted with flotation bags outboard of the sponsons, has shown that a capsize is inevitable when the rotors are stopped after landing in 3m waves. It is not known if engine and rotor integrity would survive in 9m seas or whether the helicopter would become unmanageable and be totally overwhelmed. In any event the rotor would need to be stopped before deployment of the liferaft and evacuation of the passengers and crew could take place.

There was some division of opinion within the company as to whether the sea anchor should be unstowed and connected to the towing cable before landing, or whether the whole operation should be deferred until the decision is made to stop engines. The events showed that there was no time to deploy the sea anchor because the co-pilot was otherwise occupied until the moment of the capsize; once it was decided to stop the engines, events moved with such rapidity that it is questionable if the sea anchor would have had time to become fully effective even if it had been prepared for deployment before landing. It is relevant to consider that a sea anchor deployment difficulty arose when another S.61N helicopter ditched in the North Sea in November 1970 (Civil Accident Report 11/71 refers). In view of the foregoing, a more suitable stowage and deployment technique for sea anchors should be devised for S.61N helicopters.

2.3 Evacuation and survival

The events which followed the capsize revealed shortcomings in the emergency ditching drill and survival equipment. The emergency procedure adopted by the operator made no provision for an immediate capsize which would rapidly follow rotor shut down after a landing in rough seas. Although passengers are given a comprehensive safety briefing before boarding the S.61N when outbound from Aberdeen, the emergency drill card used by the crew did not include precautionary measures such as briefing the passengers and positioning the liferaft for rapid launching. In an aircraft which requires two pilots for its safe operation, particularly in an emergency landing situation, when there is little time in hand, the co-pilot is liable to be fully employed on the flight deck in support of the commander. Without intelligent trained help in the cabin any worthwhile pre-ditching precautions would have to go by default. There is, therefore, an argument in favour of some form of passenger cabin supervision. The CAA, has however allowed the operator a dispensation from the ANO requirement to carry a cabin attendent when 20 or more passengers are carried. In the light of the evidence that has emerged in the course of the investigation into the subject accident and what might have transpired if HN had been full of passengers, a critical review of the necessity for the carriage of cabin attendants in North Sea helicopters would seem to be necessary.

The inability of the crew to extract the liferaft valise from the passenger cabin and deploy it normally highlighted the requirement for an urgent revision of the liferaft stowage in the S.61N. Ideally, two smaller liferafts stowed in such a manner that they could be deployed either from inside or outside the aircraft with the helicopter either erect or capsized would seem to provide an inherently higher chance of survival to crew and passengers in the event of a ditching.

The provision of some form of grab rail on the hull chine area so that survivors would have a convenient hand hold for use after leaving the aircraft and before boarding the liferaft is a necessity. The larger the passenger load the longer would be the delay in getting the survivors into the liferaft and therefore the greater the chance of them being swept away after evacuating the cabin. In addition some form of restraint is needed so that the main cargo door can be locked in the open position. This would ensure that a rapid evacuation is possible.

Without being able to launch the liferaft the occupants were most fortunate to survive 53 minutes of immersion and exposure to the elements. The commander was already in a moderate state of hypothermia and the passenger could do little to help himself when rescued; had the ditching not been observed by another helicopter it is difficult to imagine how all three survivors could have been recovered alive. Had they been able to get into the liferaft their survival without anti-exposure clothing would not necessarily have been assured particularly if the liferaft was damaged. The problems of survival in low sea temperatures have been the subject of considerable research and military aviation authorities have taken realistic steps to help their aircrew and passengers survive in this kind of environment. Knowing that such protection is available common sense would suggest that civil aircrew should not be required, or permitted, to operate in the North Sea environment without adequate protective clothing, however, a proportion of civil aircrew would probably oppose an attempt to make such a requirement obligatory in which case some realistic propaganda is called for by those responsible for flight safety. Experience in recent years shows that there has been one emergency ditching per year in the North Sea and this figure will probably double with the expansion of helicopter traffic in the Forties and Shetlands oil fields. Unless aircrew are properly insulated on entering the water, particularly during the winter and spring months, they would rapidly become incapable of helping their passengers to survive. In an emergency situation, such as a ditching, it is most undesirable for the two pilots to have to direct their attention away from their primary duties in order to don lifejackets. The provision and wearing of military style 'constant wear' lifejackets for helicopter pilots is essential.

2.4 SAR organisation

Since the Air Ministry (now MOD (Air)) were charged in 1947 with the SAR responsibility for civil aircraft from resources already established for military SAR requirements and the marine SAR Committee assumed responsibility for civil marine SAR in 1971 these two aspects of SAR have tended to have been treated as separate entities, there were however areas where the aspects overlapped and these until recently went unconsidered. Problems peculiar to the ditching of a civil passenger carrying aircraft were not discussed by the UK SAR Committee. This is perhaps understandable as the Committee's terms of reference were, briefly, to keep under review the general arrangements for marine SAR. Aircraft in distress were thought to be outside the SAR Committee limit at least until they had alighted on the water thereafter a ditched aircraft seems to have been considered to be little different from a vessel in distress. Ditching of an aircraft is however more critical than would often be the case when a vessel founders; passengers and crew would most probably have less warning before they find themselves in the water and would moreover have less opportunity to clothe and equip themselves, if such clothing and equipment was available to withstand the low temperatures obtaining in the North Sea. In the case of the subject accident none of the helicopters or rescue craft engaged in the operation were capable of homing on to PLB transmissions had it been necessary for the crew to use them and it is perhaps significant to note that when the contract was drawn up by the DoT for British Airways to provide a SAR helicopter in Aberdeen, there was no requirement for the helicopter to be able to home on to PLB and emergency beacon transmissions. However when the contract was drafted in 1971 there were few vessels that carried emergency radio beacons and the main purpose of the contract was to support such vessels in distress.

It is difficult to see how the survivors could have remained alive had their aircraft not been intercepted before ditching. Surface units arrived in the reported area about 63 minutes after the accident but were unable to find the drifting inverted hull; the DoT contract SAR helicopter was only able to home on to the wreck visually, thus, without homing equipment being available, location and rescue of the survivors could have been considerably delayed. An RAF 'Nimrod' might have arrived in about 1½ hours and homed on to PLB transmissions, but after this length of time in the water the survivors would not have been able to help themselves or use the equipment which could be dropped by the Nimrod. The RAF helicopters based at Lossiemouth and Leuchars might have arrived in the area 2 or 2½ hours after the ditching but their chances of finding anyone alive would have been minimal.

Whilst recognising that for North Sea operations relatively ineffective response times, paucity of SAR helicopter coverage and lack of suitable homing equipment have been revealed during this investigation, it should be fairly stated that the United Kingdom is better served with SAR facilities within its area of responsibility than many other ICAO signatories. Nonetheless, some important deficiences in the civil SAR organisations have been identified as existing at the time of this accident, which might have been recognised sooner had the CAA been involved in the deliberations of the Marine SAR Committee. This has now been remedied by the establishment of two specialist sub-committees; the one to consider general Civil Aviation SAR problems and the other to examine issues related to long range SAR helicopter cover in the Shetland area of North Sea oil activities.

The exclusion of the CAA as an active participant of the Marine SAR Committee probably resulted in a lack of understanding of civil aircraft SAR requirements and a lack of awareness of the magnitude and growth of North Sea oil industry traffic and its potential risks to helicopters.

3. Conclusions

(a) *Findings*

(i) The helicopter was correctly loaded, the crew were properly licenced and sufficiently experienced to carry out the flight.

(ii) The helicopter had been maintained in accordance with an approved maintenance schedule; an approved temporary repair to a disbonded main rotor pocket had been carried out the day before the accident but it had not been recorded.

(iii) Severe vibration and control feed-back led the commander to believe that a serious structural failure and total loss of control were imminent and he decided to land although sea conditions were severe.

(iv) The cause of the vibration could not be positively established but it is considered probable that it was due to the partially disbonded rotor pocket which had been temporarily repaired the previous day.

(v) After touchdown the engines were shut down, the rotor brake applied and the helicopter capsized within 30 seconds.

(vi) It is unlikely that the helicopter would have remained upright even if the rotors had been kept turning but in the sea conditions obtaining it is improbable that the engines and rotors would have been able to continue operating.

(vii) There was insufficient time to extract the sea anchor from its stowage and deploy it before the aircraft capsized. The effectiveness of the sea anchor in the sea and wind conditions that existed cannot be assessed.

(viii) The sea anchor stowage and the procedure for its deployment were unsatisfactory.

(ix) The liferaft could not be extracted from the flooded cabin because it was trapped against the inverted floor by its buoyancy. Its deployment was further hindered by the open under floor baggage doors which opened on capsizing.

(x) The cargo door could not be restrained in the open position, this hindered the evacuation of the cabin and subsequent attempts to deploy the liferaft.

(xi) The pre-ditching emergency drill adopted by the operator was carried out by the crew but the possibility of a rapid capsize had not been foreseen; in the circumstances therefore the drill was inadequate.

(xii) The rescue operation was well coordinated and skilfully executed by all the helicopter crews that responded to the 'mayday' call and great credit is due to them. However, the circumstances were entirely fortuitous. Had the distressed helicopter not been intercepted before it ditched it is doubtful if the upturned hull would have been found before the survivors had succumbed to the effects of hypothermia and drowned.

(xiii) The upturned hull was difficult to locate and keep in view because its light colouring blended with the breaking seas.

(xiv) The crew and passenger were not adequately dressed for survival in the existing sea and air temperatures.

(xv) Although personal locator beacons were available to the crew, none of the helicopters or surface vessels deployed was equipped to home on to their beacon transmissions, had a search operation been necessary.

(xvi) Present and intended SAR helicopter coverage and rescue response times in the North Sea region were inadequate to the needs of an emergency involving passenger carrying helicopters, especially in the Shetland oil fields.

(b) *Cause*

The accident was caused by the helicopter alighting on open water in very rough seas which were beyond the seakeeping capabilities of the aircraft, because the commander believed that a major structural failure was imminent. It is probable that a main rotor blade pocket became partially raised and disbonded causing very severe vibration.

4. Safety Recommendations

It is recommended that:

4.1 An SAR helicopter should be based in the Shetland Islands.

4.2 All helicopters assigned to the SAR role should have the capability of homing onto emergency beacon transmissions.

4.3 Ditching procedures for helicopters should be reviewed to take into account the probability of a capsize after touchdown.

4.4 The stowage of inflatable liferafts in helicopters should be designed so as to be deployable with the aircraft inverted.

4.5 Auxiliary flotation bags should be fitted to S.61N helicopters to increase the waterborne lateral stability.

4.6 Exterior hand-holds should be fitted to helicopters so that after a ditching survivors are not swept away prior to boarding the liferaft.

4.7 Both crews and passengers in helicopters operating over cold water should wear anti-exposure clothing.

4.8 Helicopter pilots, when operating over water, should be required to wear life jackets at all times.

4.9 The sea anchor installation in S.61N helicopters should be redesigned to ensure a more rapid deployment in the event of a ditching.

4.10 High visibility paint schemes should be applied to helicopters to facilitate location after ditching particularly if the aircraft is floating inverted.

4.11 The cargo door on S.61N helicopters should be modified so that it can be locked in the open position to facilitate an emergency evacuation.

4.12 The requirements for the carriage of cabin attendants in passenger carrying helicopters should be critically reviewed.

4.13 Under floor baggage locker doors, floor covering and panels should be positively secured to prevent their becoming detached after a capsize.

G C WILKINSON
Inspector of Accidents

Accidents Investigation Branch
Department of Trade

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