AIRCRAFT ACCIDENT REPORT 2/93

Air Accidents Investigation Branch

Department of Transport

Report on the accident to AS 332L Super Puma, G-TIGH near the Cormorant 'A' platform, East Shetland Basin, on 14 March 1992

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents) Regulations 1989

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Department of Transport
Air Accidents Investigation Branch
Defence Research Agency
Farnborough
Hampshire GU14 6TD

26 April 1993

The Right Honourable John MacGregor
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr R StJ Whidborne, an Inspector of Air Accidents, on the circumstances of the accident to AS 332L Super Puma helicopter, G-TIGH, that occurred near the Cormorant 'A' platform, East Shetland Basin, on 14 March 1992.

I have the honour to be
Sir
Your obedient servant

K P R Smart
Chief Inspector of Air Accidents

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GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	-	Air Accidents Investigation Branch
AAR	-	Aircraft Accident Report
ACARS	-	Automatic Communication and Recording System
ADELT	-	Automatically Deployed Emergency Location Transponder
AFISO	-	Aerodrome Flight Information Service Officer
amsl	-	above mean sea level
ANO	-	Air Navigation Order
ARB	-	Airworthiness Requirements Board
ASI	-	Airspeed Indicator
ATC	-	Air Traffic Control
AVAD	-	Automatic Voice Alerting Device
BCAR	-	British Civil Airworthiness Requirements
BHL	-	Bristow Helicopters Limited
BIH	-	British International Helicopters Limited
°C	-	Centigrade (Celsius)
CAA	-	Civil Aviation Authority
CAP	-	Civil Aviation Publication
CG	-	Centre of Gravity
CSS	-	Co-ordinator surface search
CVR	-	Cockpit Voice Recorder
CVFDR	-	Combined Voice and Flight Data Recorder
DAPU	-	Data Acquisition and Processing Unit
DGA	-	Director General Airworthiness
DGAC	-	Direction Generale Aviation Civile
DOT	-	Department of Transport
DRA	-	Defence Research Agency
EXIS	-	Emergency Exit Perimeter Lighting
FDM	-	Flight Deck Management
FDP	-	Flying Duty Period
FDR	-	Flight Data Recorder
FM	-	Flight Manual
FRC	-	Fast Rescue Craft
FT	-	Flight Time
g	-	normal acceleration
HARP	-	Helicopter Airworthiness Review Panel
HLO	-	Helicopter Landing Officer
HMLC	-	Helicopter Management Liaison Committee
HSC	-	Health and Safety Commission
HSE	-	Health and Safety Executive
HUMS	-	Health and Usage Monitoring System
IAM	-	Institute of Aviation Medicine (RAF)
IAS	-	Indicated Air Speed
IHUMS	-	Integrated Health and Usage Monitoring System
IMC	-	Instrument Meteorological Conditions
ISS	-	Injury Severity Score
JAR	-	Joint Airworthiness Requirements
LSJ	-	Life saving jacket
LWC	-	Liquid water content
mb	-	millibars
METAR	-	Meteorological Airfield Report
MHz	-	Mega Hertz
MOD	-	Ministry of Defence
MRCC	-	Maritime Rescue Co-ordination Centre
MSV	-	Multi-functional Support Vessel
MTOW	-	Maximum Take-off Weight
nm	-	nautical miles
OAT	-	Outside Air Temperature
OIM	-	Offshore Installation Manager
OM	-	Operations Manual
OSC	-	On Scene Commander
QNH	-	Corrected mean sea level pressure
RADALT	-	Radar Altimeter
RAF	-	Royal Air Force
RCC	-	Rescue Co-ordination Centre
ROV	-	Remotely Operated Vehicle
SAR	-	Search and Rescue
SBV	-	Stand By Vessel
TAF	-	Terminal Area Forecast
UK	-	United Kingdom
UTC	-	Co-ordinated Universal Time
VCF	-	Visual Contact Flight
VFR	-	Visual Flight Rules
VHF	-	Very High Frequency
VMC	-	Visual Meteorological Conditions

Air Accidents Investigation Branch
Aircraft Accident Report No: 2/93 (EW/C92/3/2)

Registered Owner and Operator:	Bristow Helicopters Limited
Aircraft Type:	Aerospatiale (Eurocopter (France) since 1 January 1992)
Model:	AS 332L Super Puma
Nationality:	British
Registration:	G-TIGH
Place of accident:	Approximately 500 metres east of the Cormorant 'A' oil production platform in the East Shetland Basin, Northern North Sea Latitude: North 61° 06' 19" Longitude: East 001° 05' 00" Height: Sea level
Date and time:	14 March 1992 at 1950 hrs

All times in this report are UTC

Synopsis

The accident was notified to the Air Accidents Investigation Branch (AAIB) by the operator and an investigation, which included representatives of the operator, oil company and Regional police, began as soon as the offshore site was reached.

The following Inspectors of Air Accidents participated in the investigation:

Mr R StJ Whidborne, Principal Inspector of Air Accidents (Operations) - Investigator in charge
Mr R D G Carter, Senior Inspector of Air Accidents (Engineering) - Engineering
Mr J Chappelow[1], Principal Psychologist, Institute of Aviation Medicine (IAM) - Human factors
Ms A Evans, Senior Inspector of Air Accidents (Engineering) - Flight recorders
Mr P N Giles, Senior Inspector of Air Accidents (Operations) - Rescue and survival
Mr R G Matthew, Senior Inspector of Air Accidents (Operations) - Operations
Mr C G Pollard, Senior Inspector of Air Accidents (Engineering) - Salvage and engineering

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[1] Appointed temporary Inspector of Air Accidents

The accident occurred at night during a shuttle of personnel from an oil production platform to a nearby accommodation 'Flotel'. The crew had been similarly engaged with other shuttle tasks since leaving Sumburgh nearly four hours earlier. Weather conditions were severe with winds gusting up to 55 kts, snow showers and very rough seas. However, the helicopter was being operated within its specified wind limits. Having embarked 15 passengers, the helicopter lifted from the platform helideck, transitioned forwards and almost immediately began a right turn towards the Flotel. Climbing to a height of 250 feet and whilst turning downwind, the handling pilot, who was also the aircraft commander, reduced power and raised the nose of the helicopter such that the airspeed reduced to zero and a rate of descent built up. Once he was aware of the descent, which was also advised by his co-pilot and the Automatic Voice Alerting Device (AVAD), he applied full power but the descent could not be arrested before the helicopter struck the sea. Down draughts and incipient Vortex Ring state may have exacerbated the situation.

The helicopter rolled onto its right side before inverting and sinking within a minute or two. All but five of the occupants managed to escape from the helicopter before it sank. Of the twelve survivors in the sea, only six were recovered alive; the others perished in the hostile sea environment, some of them having survived for a considerable time. The rescue operation, using ships and helicopters, began almost at once but was severely hampered by the conditions. The wreckage of the helicopter and its Combined Voice and Flight Data Recorder (CVFDR) were recovered some 30 hours later.

The following causal factors were identified:

(i) The handling pilot's failure to recognise the rapidly changing relationship between airspeed and ground speed which is a fundamental problem associated with turning downwind in significant wind strengths.

(ii) The commander, who was the handling pilot at the time, shortly after take-off inadvertently allowed the airspeed and then the height to decrease whilst turning away from a strong gusting wind.

(iii) Despite the application of maximum power, the helicopter was incapable of arresting its established descent within the height available. Incipient Vortex Ring state and down draughts may have contributed to this problem, as may the height of the wave crests.

(iv) Several human factors, including possibly some fatigue[2] and frustration, exacerbated by a demanding flying programme for which the commander was managerially responsible, may have degraded the crew's performance to an extent that the normal safeguards of two crew operation failed.

Eleven Safety Recommendations are made.

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[2] Throughout this report the term 'fatigue' is used as in common usage and not as in the more restricted sense implied in Civil Aviation Publication (CAP) 371. It is the result, in this case, of several hours of work, travelling and other activity

1 Factual Information

1.1 History of the flight

1.1.1 Background to the flight

The Super Puma helicopter, G-TIGH ('GH') was based at Sumburgh, Shetland on a long term charter to Shell UK Exploration and Production Limited (Shell UK Expro) and was used mainly to carry personnel and freight between Shetland and the oil installations, but was available to carry out whatever task was required by Shell UK Expro. It was normally fitted with 19 passenger seats.

On Saturday 14 March 1992, some accommodation Flotels, which are normally linked to the platforms by a gangway, had been moved away to their stand-off positions because of the severity of the winds and sea state in the oil field. Helicopters were therefore needed to carry out the morning and evening 'shuttles' of personnel between the Flotels and the platforms. The shuttle tasks in the Brent oil field would normally have been conducted by two Bell 212 helicopters which were based offshore on the Flotel 'Safe Gothia' but, on this occasion, the wind was stronger than that allowed for engaging their rotors.

The Shell UK Expro Air Transport Controller at Aberdeen contacted British International Helicopters Limited (BIH), requesting that one extra S-61N helicopter from Sumburgh should help their three S-61N crew change helicopters to carry out the morning shuttles. At the same time, about 0815 hrs, he asked Bristow Helicopters Limited (BHL) at Sumburgh if they could supply their Super Puma, 'GH', which, as well as having a higher wind limit for rotor engagement than the Bell 212s, was based on-shore in less adverse wind conditions. BHL told them that the helicopter was out of service awaiting an airtest but that it would probably be available when this had been carried out.

The BHL operations controller at Sumburgh then telephoned the Chief Pilot, who was spending the weekend off duty with his family in the Aberdeen area, seeking permission to accept the task. He also reminded him that the other Super Puma crew had, the previous evening, been scheduled to fly the airtest but would not be available before 1400 hrs. The Chief Pilot therefore said he would fly the airtest and the task himself. However, when he arrived at Aberdeen Airport to catch the ferry flight to Sumburgh, Shell UK Expro informed him that the helicopter was not now needed for the morning shuttles but it might well still be required for the evening ones. He therefore continued to Sumburgh, arriving there at 1030 hrs.

On arrival at Sumburgh, the Chief Pilot and the co-pilot, who were later to constitute the crew of the accident flight, carried out the airtest and landed at 1200 hrs. Learning that the helicopter was now serviceable, Shell UK Expro tasked 'GH' to take freight to the Brent 'A' platform, situated 112 nm north east of Sumburgh in the East Shetland Basin (see Appendix A), before starting the evening Brent oil field shuttles. It was also later requested that the helicopter should land at Unst, en route, to pick up a spare part for one of the two offshore Bell 212 helicopters.

1.1.2 The Brent oil field shuttle

The freight arrived at Sumburgh at about 1420 hrs and by 1525 hrs was loaded on 'GH'. Seat No 11, immediately aft of the port cabin door, was removed into the hold and the freight was lashed down in its place. Although the flight was ready to depart at this time, there was a heavy snowstorm passing through Sumburgh and, when it had passed, it was necessary to clean snow from the helicopter. 'GH' then departed at 1604 hrs, flying under Visual Flight Rules (VFR) at 1000 feet amsl and arrived at Unst at 1635 hrs, departing at 1646 hrs for the Brent oil field flying at 1000 feet in Visual Meteorological Conditions (VMC). Whilst en route, at 1704 hrs, 'Brent Logistics' radio gave the crew the details of their shuttle task, which, after unloading the freight at Brent 'A' and the spare part at 'Safe Gothia', was to comprise:

Brent 'D' → Brent 'B' → 'Safe Gothia' → Brent 'C' → Cormorant 'A' → 'Safe Supporter' → Cormorant 'A' → North Cormorant.

Having landed on the Brent 'A' at 1719 hrs, 'GH' lifted off at 1730 hrs and, at 1734 hrs, landed on the 'Safe Gothia' Flotel, where BHL helicopter engineers were situated. Whilst the helicopter was being refuelled, an attempt was made to re-fit seat No 11. Despite considerable efforts, the attempt was abandoned and the seat was replaced in the baggage hold, leaving 18 passenger seats available for use. The helicopter lifted from 'Safe Gothia' at 1801 hrs and landed on Brent 'D' at 1806 hrs, to begin the shuttles. The programme was:

Time (arr/dep)	Helideck	Passengers (pax) and remarks
1806/1816 hrs	Brent 'D'	Load 15, +1 extra pax added.
1820 hrs/ -	Brent 'B'	Load 2.
1827 hrs	(on deck)	Crew informed that requirement to pick up 6 pax at 'Safe Gothia' had changed to 5 and that the Cormorant 'A' to North Cormorant was cancelled.

Time (arr/dep)	Helideck	Passengers (pax) and remarks
1840 hrs	(on deck)	Again failed to re-fit seat No 11 and crew therefore decided to make a double shuttle from Brent 'B'.
- /1851 hrs		(lift-off)
1854/1904 hrs	'Safe Gothia'	Unload 18, Load 5.
1906/1907 hrs	Brent 'B'	Load 1.
1911/1924 hrs	Brent 'C'	Unload 6. Refuel. (Told of 3 lifts at Cormorant 'A').
1938 hrs	(en route)	Given the weather at Cormorant 'A' as: "Mostly 295°/40-45 kt but now 50-53 kt with snow showers".
1941/1948 hrs	Cormorant 'A'	Load 15 for 'Safe Supporter'.
1950 hrs		Accident.

The flight to the Cormorant 'A' was conducted under Visual Contact Flight (VCF) at 1000 feet amsl and, approaching the Cormorant 'A', despite the snow, the crew of 'GH' reported that they were in visual contact with the helideck.

At 1928 hrs, ATC 'Viking Approach' informed 'GH' that there was a snow shower and a cloud base of about 500 feet at Cormorant 'A'. Then, at 1938 hrs, they were informed that, although the wind had generally been 40-50 kt, it was now 295°/50-53 kt and that a snow shower was passing through with the wind "gusting a bit". A few seconds later 'Viking Approach' controller said "The direction's steady 295°".

At Brent 'C' and at Cormorant 'A' the crew stated that the wind made it extremely difficult to get out of the cockpit doors and so asked the respective Helicopter Landing Officers (HLOs) to do an external check of the helicopter and the loading for them.

1.1.3 The Cormorant 'A'/ 'Safe Supporter' shuttle

The task remaining for 'GH' required three shuttles between the Cormorant 'A' and its accommodation Flotel, 'Safe Supporter', which was anchored 200 metres away on a bearing of 075°M (see Appendix B). Thereafter, they would fly to the Tern platform to refuel before returning to Sumburgh.

Whilst checking the helicopter as requested, the Cormorant 'A' HLO noticed a small patch of granular rime ice, or impacted snow, on the front surface of the port wheel sponson. He states that it was firmly attached to the surface but that he did not see any more or make a comment on it to the flight crew.

Following a discussion in the cockpit concerning the likelihood of severe downwind turbulence off both the platform and the Flotel, the commander decided to fly the lift-off and to perform a right-hand circuit before handing the controls to the co-pilot on the final approach to the 'Safe Supporter'. Both pilots remarked that this would be a quicker way of getting there and, during this conversation, the commander mentioned twice that, once they had landed, he would be able visit a toilet on the 'Safe Supporter' in order to relieve himself.

At 1948 hrs, with deck clearance from the HLO, the helicopter was seen to hover above the helideck and then move forward to just beyond the deck edge heading about 300°M and virtually straight into wind, before entering a climbing turn to the right. From an observer's point of view the wind was causing the helicopter to drift rapidly to its right during this turn, such that it passed directly north of the platform, tracking in a north easterly direction (about 045°M) whilst still heading north. The helicopter continued to climb for another few seconds and then was seen to enter an increasingly steep descent until, at 1950 hrs, it struck the water some 500 metres east north east of the Cormorant 'A'.

The HLO on the 'Safe Supporter', seeing the helicopter begin to arc down towards the water, immediately ran to the edge of the helideck and, realising that 'GH' was in the water, transmitted a Mayday distress message. This was received by the Viking Approach Air Traffic Control Officer, who re-transmitted it and initiated the appropriate emergency procedures. Meanwhile, the HLO remained in position and provided initial identification of the lifejacket lights in the water.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	10	-
Serious	-	1	-
Minor/none	1	4	

1.3 Damage to aircraft

The helicopter sank to the sea bed and was damaged beyond repair.

1.4 Other damage

None.

1.5 Personnel information

1.5.1	Commander:	Male aged 29 years.
	Status:	North Sea Commander: Chief Pilot-Sumburgh
	Licence:	Airline Transport Pilot's Licence (Helicopters) Issued 22 August 1986 Re-issued 12 March 1992
	Aircraft ratings:	Aerospatiale AS 332L Super Puma; Bell 47
	Instrument Rating:	Valid until 9 January 1993
	Certificate of Test:	Valid, Day and Night, until 5 August 1992
	Base Check:	Valid until 31 August 1992
	Night Deck Landing:	Valid until 8 February 1993
	Line check:	Day: Valid until 30 August 1992 Night: Valid until 8 February 1993
	Emergency survival:	Valid until 5 August 1992
	Wet dinghy drill:	Valid until 11 August 1993
	Medical Certificate:	Class One. Valid until 30 June 1992
	Flying experience:	Total flying: 5,550 hours
		On type: 5,304 hours
		Last 90 days: 147 hours
		Last 28 days: 56 hours
		Last 24 hours: 4 hours
		Previous rest period: 44 hours

1.5.1.1 Operational experience

The commander joined BHL and was accepted for ab initio flying training, beginning on 29 March 1982. On 24 April 1984, he was offered a six month appointment as a First Officer and, having attained a Commercial Pilot's Licence (Helicopters), began flying for the company out of Aberdeen in the AS 332L Super Puma. In September 1985 he was promoted to Senior First Officer (Instrument Rated) and, in 1986, having attained his Airline Transport Pilot's Licence (Helicopters), was promoted to Captain Class 2. He then served a six month contract on Super Pumas in Djibouti, East Africa, before returning to Aberdeen. In April 1988, he was promoted to North Sea Commander on the Super Puma and at this time took on the additional responsibility of being a Ground and Airborne Navigation Instructor. In 1991 he applied for and was selected as the Chief Pilot of the BHL Sumburgh operation. He took up this post on 30 September 1991.

1.5.2 Co-pilot: Male, aged 40 years.

Status:	Senior First Officer	
Licence:	Airline Transport Pilot's Licence (Helicopters). Issued 27 December 1991	
Aircraft ratings:	Aerospatiale AS 332L Super Puma; Robinson R22	
Instrument Rating:	Valid until 9 August 1992	
Certificate of Test:	Valid, Day and Night, until 4 May 1992	
Base Check:	Valid until 9 August 1992	
Night Deck Landing:	Valid until 19 December 1992	
Line check:	Day: Valid until 19 May 1992 Night: Valid until 19 December 1992	
Emergency survival:	Valid until 10 August 1992	
Wet dinghy drill:	Valid until 17 May 1993	
Medical Certificate:	Class One. Valid until 31 July 1992	
Flying experience:	Total flying:	2,215 hours
	On type:	2,169 hours
	Last 90 days:	243 hours
	Last 28 days:	70 hours
	Last 24 hours:	4 hours
	Previous rest period:	44 hours

1.5.2.1 Operational experience

The co-pilot joined BHL on 2 May 1977 as an Operations Plotter at Sumburgh and was re-graded to an Operations Controller on 1 January 1979, remaining at Sumburgh until he was appointed as an Offshore Operations Controller on 8 December 1982. On 15 September 1986 he was posted to Unst as an Aerodrome Flight Information Service Officer, where he remained until 5 April 1988 when he was accepted by BHL for pilot training.

He completed the Super Puma conversion course as a co-pilot on 26 June 1989. On 22 September 1990 he passed the Civil Aviation Authority (CAA) initial Instrument Rating examination and was promoted to First Officer - Rated. He was posted to Sumburgh on 12 January 1991 and on 1 June 1991 was promoted to Senior First Officer on the Super Puma.

1.5.3 Duties and responsibilities of the Chief Pilot - Sumburgh

The BHL Chief Pilot at Sumburgh was the commander of 'GH' for the airtest, the freight flight and for the shuttle flights.

The BHL Sumburgh operation comprised two separate entities: the oil support charter operation, serviced by one Super Puma, and the HM Coastguard Search and Rescue (SAR) operation, using two SAR equipped S-61N helicopters.

Although the SAR operation had its own Pilot-in-Charge and was autonomous in operational matters, it remained administratively the responsibility of the Chief Pilot. In this case, the SAR Pilot-in-Charge was also the Deputy Chief Pilot. Neither operation was responsible to the quite separate one at Aberdeen. However, at upper management levels, the Sumburgh Chief Pilot was responsible to the BHL Operations Manager (Europe) and to the General Manager (Scotland) for commercial and administrative matters.

The responsibilities of the Chief Pilot, as laid out in the BHL Operations Manual (OM) Supplement Paragraph 1.4.1 'Flight Operations', include amongst many other matters:

> 'Liaison with the client (Shell UK Expro) for organisation of special requirements of the flying task.
> Organisation of the flying programme.
> Allocation of flight crews.
> Supervision of flight time limitations and rest period requirements.
> Liaison with the Chief Engineer for the programming of maintenance to meet the needs of the flying task.'

He was assisted in these matters by an experienced but non-executive Operations Controller.

1.5.4 Flight time limitations

The airtest and the flight to the Brent field were initially notified to the commander at about 0815 hrs and he travelled from his home to Aberdeen airport to catch the flight to Sumburgh. It departed for Sumburgh at 0930 hrs and, under OM provisions, this is the time at which the regulated Flying Duty Period (FDP) begins. Flying Time (FT) includes only the airborne operating time and the FDP therefore includes the following events:

0930 hrs	Boarding flight to Sumburgh	FDP: Start
1115 hrs	Starting airtest	
1130 hrs	Airborne time	
1200 hrs	Chock time[3]	FT: 30 minutes
1215 hrs	Off duty (15 minute debriefing)	
1535 hrs	End of Rest Period of 3 hours 15 minutes	(included in FDP)
1535 hrs	Half-hour briefing	(Start of Split duty)
1605 hrs	Lift-off for Unst and Brent field	
1950 hrs	Accident	FT: 3 hours 45 minutes

Total FT: 4 hours 15 minutes
Total FDP: 10 hours 20 minutes

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[3] Although the Technical Log records the flight as lasting only 15 minutes, it would appear that the commander did not include the hover and ground taxy phases of the airtest in the logged airborne time. The ATC transcript shows that the relevant chock-to-chock time was 30 minutes

The co-pilot's FDP began at 1015 hrs and was 45 minutes less than that of the commander. Both pilots had flown for 2 hours 40 minutes on 12 March 1992 in an FDP of 6 hours. Neither had worked on 13 March 1992.

For FDPs beginning between 0800 hrs and 1359 hrs, the OM Part 2, Section 9 permits a maximum FDP of 12 hours. However, if there is an intervening period during the FDP, free from all duties, of less than the full rest period demanded by the duty just carried out (reduced rest period), the task may be classed as a Split Duty and the 12 hours FDP may be increased by half that rest period.

A commander may also exercise his discretion to extend an FDP. The extension shall be calculated upon what actually happens, not on what was planned to happen. Moreover, this may be applied to an FDP which includes a reduced rest period, but only exceptionally and only then to allow for unforeseen circumstances which become apparent during the last sector. The maximum permitted FT, for the same period of duty, is 8 hours. This may only be extended in emergency circumstances arising once the flight has begun and must be reported afterwards.

The commander's FDP of 10 hours 20 minutes and the FT of 4 hours and 15 minutes extends only to the time of the accident, however, had the accident not happened the crew would have had to complete three rotations, a refuelling stop and the flight of a little over an hour back to Sumburgh. This would have added approximately another 2 hours 30 minutes to both the FDP and the FT.

CAP 371 The Avoidance of Fatigue in Aircrews - Guide to Requirements[4] contains at paragraph 23 'Limits on Helicopter Flying' and BHL OM uses these guidelines. Paragraph 23.2.3 states:

> 'After 3 hours shuttle operations between off-shore installations in conditions other than day VMC, a rest of 30 minutes free of all duty shall be allowed'. Paragraph 23.2.4.(b), dealing with survival suits, states: 'Schedules which involve continuous flying in excess of 4½ hours must include provisions for a break free of all duty of at least 30 minutes, not including a total of 30 minutes for immediate post-flight duties and pre-flight duties. The break must be scheduled prior to exceeding a total of 6 hours flying.'

The BHL OM, paragraph 9.11.6(d), states:

> 'On those single long range rotations where the total flying time is 4½ hours or greater, the thirty minute break must be taken prior to exceeding six hours flying.'

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[4] Effective 1 May 1990 - ISBN 0 86039 407 7

Paragraph 9.11.6 (e) states:

> 'Commanders may exercise their discretion to exceed the six hours flying prior to taking the thirty minute break in order to complete a long range rotation where it may be impractical or hazardous to shut down. In this case it shall be reported to the Operations Manager (Europe) on a Discretion Report Form in the format at paragraph 9.28. The company will submit this report to the Authority.'

1.6 Aircraft information

1.6.1 General information

1.6.1.1 Aircraft description

The Super Puma helicopter registered as G-TIGH was constructed by Aerospatiale Division Helicopteres (Helicopter Division) in July 1982 and carried the constructor's serial number 2034. The Helicopter Division of Aerospatiale has since been renamed Eurocopter (France). On 27 July 1982 'GH' was transferred to BHL, who had designated to their Super Pumas engaged in offshore oil work as 'Tiger'. The Super Puma has a conventional semi-monocoque fuselage and tail pylon and a retractable tricycle landing gear. There is a four bladed main rotor and a five bladed tail rotor. Power to the rotors is supplied by two Turbomeca Makila 1A turboshaft engines.

1.6.1.2 Cabin layout

The Super Puma is normally configured with two pilots' seats and 19 passenger seats, as shown in Appendix C - Seating Plan. At the time of the accident, the seating in 'GH' conformed to this except for seat No 11, which had been stowed in the baggage bay to allow space in the cabin for freight. Each seat in 'GH' was supplied with a headset for the use of the passenger and the headset electrical cord emerged from the top of each seatback: it was then attached to the headset by a quick release jack-plug.

All the windows in the passenger cabin of the BHL Super Pumas were modified to be 'escape' windows. These window transparencies are simply held in their apertures by rubber beading with a release tab attached inside and outside the cabin: when this tab is pulled, the beading is stripped away from the aperture and the transparency may be jettisoned into or away from the cabin.

Emergency lighting of the 'EXIS' type is provided around each aperture ('escape' windows, cabin doors and flight deck doors). A photograph of the 'escape' window installation is shown at Appendix C Figure C1. EXIS lights are required to have sufficient battery power to ensure at least 20 minutes of illumination but battery power may last for much longer.

Two 14 man liferafts were carried, manufactured by RFD Limited as the Type 14R Heliraft. On the right side of the cabin, the liferaft was packed in a valise mounted across the right-hand door frame, just inboard of the door but not attached to it: this liferaft could be released manually and deployed through the door aperture after the right door had been jettisoned. The other liferaft was stowed within a box structure underneath seats No 5 and No 6. To be deployed, this liferaft must be drawn from its stowage, its painter attached to the fuselage and it may then be deployed through the opened or jettisoned left door.

1.6.1.3 Emergency hull flotation

'GH' was equipped with emergency flotation equipment consisting of four separate inflatable bags. Two of these bags were mounted in a collar around the nose of the aircraft and one each on structural frames at the sponsons. In an emergency, inflation of the floats would be initiated electrically by the crew from the flight deck where the arming switch and a firing button were located on the centre console. An additional firing button was mounted on each pilot's collective stick. Standard operating procedures required the flotation gear to be ARMED whilst arriving at and departing from offshore helidecks.

1.6.1.4 Automatically Deployable Emergency Locator Transponder (ADELT)

The ADELT system fitted to 'GH' consisted of the beacon itself, a launching spring, a pyrotechnic squib and a lithium battery, all in a carrier mounted on the left-hand side of the rear fuselage. The launching system could be initiated by any one of three signals: a cockpit switch, a saline switch in the carrier or any one of three frangible 'crash' switches mounted in the airframe, close to the skin.

1.6.1.5 Maintenance records

Up to the time of the accident the aircraft had accumulated a total of 11,929:30 airframe flying hours. Due to reported high T4 readings (gas temperature at outlet of the gas generator turbine), an engine had been changed on 13 March 1992, replacing Makila 1A engine Serial Number 285 with engine Serial Number 233. The routine 15 minute test flight performed on the morning of 14 March 1992 followed this engine change and performance on the test flight was satisfactory.

The most recent inspections on 'GH' had been performed by BHL engineers at Sumburgh on 12 March 1992: these had been a '30/40 hour' inspection (a 30 flying hour inspection with additional '40 hour' items) and a '50 hour' 'out of phase' inspection, performed at 11,923:35 hours. The next check, due at 11,948 airframe hours, would have been another '30/40 hour' inspection. The BHL maintenance records indicated that 'GH' had been maintained in accordance with its approved maintenance schedule and there were no entries in the technical log relating to any defects which might have been relevant to the accident.

1.6.2 Weight and balance

The helicopter had been re-weighed on 2 September 1991 following an Integrated Health and Usage Monitoring System (IHUMS) modification. Assuming that 50 lb of fuel was consumed at flight idle power on the deck and that the crew assessment of the fuel gauge readings (3,700 lb) at landing on Cormorant 'A' was correct, the calculation of Take-Off Weight and Centre of Gravity (CG) show that, at the time of the accident the helicopter weighed 18,919 lb and the CG was 180.02 inches aft of datum. The Maximum Approved Take-off Weight (MTOW) was 18,960 lb and the longitudinal CG limit at MTOW was between 177.9 and 190.9 inches aft of the datum.

1.6.3 Limiting wind conditions

The BHL Operations Manual Part 5, Section 2.1 defines the following wind speed limitations for the Super Puma:

> 'Maximum gusting wind speed for rotor engagement: 55 kt'
> 'Maximum constant wind speed for departure: 75 kt'

Additionally, for reasons of personnel safety, the Shell UK Expro HLO Manual, paragraph 3.3 imposed a maximum wind speed across the helideck of 60 kt. The speed is measured by a hand held anemometer and it is usually several knots below the ambient wind speed.

Since this accident Shell UK Expro have included in their 'Company Adverse Weather Policy' a section on flying operations which gives guidelines to their managers on the viability of rescue from the sea in varying wind and sea states. One crucial aspect is that as the weather becomes more severe a progressively higher level of management must be involved in the decision making process. The policy is being further developed in order to apply a structured and consistent approach to the decision making by the production of an 'Expert system' lap-top computer programme.

1.7 Meteorological information

Prior to the flight, the crew of 'GH' obtained the meteorological airfield reports (METARS) and terminal area forecasts (TAFs) for both the mainland and offshore. These are detailed in Appendix D paragraph 2.

They also received various meteorological reports whilst en route and these are shown at Appendix D paragraph 3. The Aberdeen and Sumburgh METARs and TAFs were logged by the crew and discussed during the flight. The commander decided that these conditions did not preclude the night flight back to Sumburgh.

An aftercast, of the actual weather conditions was provided by the Meteorological Office at Bracknell. Relevant portions of this are:

> Synoptic situation: A complex area of low pressure to the north of Norway maintained a very strong unstable northerly airstream over the area with minor polar disturbances moving quickly southwards.
>
> Weather: Frequent moderate or heavy showers of hail or snow.
>
> Visibility: Around 10 kilometres falling rapidly to 300 metres in snow showers.
>
> Winds: Surface: 310°/35-40 kt, gusts 55-60 kt. 2,000 feet: 330°/60 kt.
>
> Cloud: Broken cumulus base around 1,500 feet tops 12,000 feet, occasional cumulo-nimbus base 550-800 feet tops 18,000 feet.
>
> Warnings: Severe turbulence and severe icing.

This situation is detailed more fully in Appendix D paragraph 4.

A Special Observation, taken at 1953 hrs by Oceanroutes UK Ltd[5] for the Cormorant 'A', following the accident, recorded:

> Wind: 300°/ 54-64 kt.
> Visibility: 4,000 metres in moderate snow, sky obscured.
> Vertical visibility: 1,200 feet.
> Temperature: -0°C; Dew point: -3°C.
> QNH: 989 mb.
> Freezing level at the surface.

The sea states are detailed in Appendix D paragraph 5.

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[5] Oceanroutes (UK) Ltd is a privately owned meteorological forecasting organisation for shipping

1.8 Aids to navigation

Not relevant.

1.9 Communications

Communications between the helicopter, ATC and 'Brent Logistics' radio station were satisfactory throughout and were recorded. Those between 'GH' and the HLOs were also recorded and in the majority were satisfactory but on occasion they were degraded by wind interference acting on the HLO's microphone.

During the final shuttle sector, the message from the 'Safe Supporter' HLO to the helicopter crew, concerning the pitch and roll of their helideck (see Paragraph 1.10), was considerably distorted by wind noise in the microphone. It required 30 seconds of repetitions and the aid of Viking Approach ATC, but, from comments made on the CVR, it is clear that neither crew member heard it. The message passed during the last seconds of the flight stated that the deck was pitching 4°, rolling 5° and heaving up to 4 metres. Further investigation revealed that the reported pitch and roll figures referred to total movement of the helideck ie 4° of pitch was 2° either side of the vertical and 5° of roll was 2.5° either side of the vertical.

1.10 Aerodrome information

1.10.1 Helideck details

The two relevant landing areas were the Cormorant 'A' helideck and the Flotel 'Safe Supporter'.

Cormorant 'A':

A fixed platform located at North 61°06.2'; East 001° 04.4'. The helideck measures 22.6 x 27.17 metres and is 183 feet amsl. It is orientated such that the helideck is at the north north west edge of the platform, which has a maximum installation height of 439 feet with the flare boom pointing south east. Gas was being flared at the time of the accident. The obstacle free sector is oriented about 346°M.

'Safe Supporter':

A mobile accommodation Flotel, normally moored alongside the Cormorant 'A'. Because of the sea state and the weather at the time, it was positioned such that its helideck was exactly 206 metres away from that of Cormorant 'A' on a bearing of

075°M (see Appendix B). The helideck measures 27.2 x 22.6 metres, is 84 feet amsl and was also at the north north west end of the Flotel, which has a maximum installation height of 238 feet. The obstacle free sector was from the north east, centred about 031°M. The helideck was classed as unstable.

It was noted by the crew of 'GH' that downwind of both of these structures there would be an area of considerable turbulence. To avoid flying through this area required a right turn after lift-off, followed by a right-hand circuit to make an approach to the 'Safe Supporter', into wind, on a heading of about 300°M.

1.10.2 Operations to unstable helidecks

The company OM Part 2, Section 1, paragraph 1.27, sets out limitations of helideck movement for Super Puma operations:

> 'Maximum helideck pitch or roll........3° Either side of the vertical.'

Miscellaneous operational standards are set out in Chapter 5 of CAA publication CAP 437 entitled 'Offshore helicopter landing areas: guidance on standards.' Paragraph 3 - Vessel Movement states:

> 'Although landing areas located amidships are less liable to the extreme vessel movement angles experienced at bow or stern locations, a Civil Aviation Authority clearance will be related to the aircraft operator's Operations Manual limitations regarding the vessel's movement in pitch, roll, yaw, heave and heading. It is necessary for details of these motions to be recorded on the vessel prior to, and during, all helicopter movements in a similar manner to that required for Department of Energy 'installations' in regulation 20(2) of Statutory Instrument 1019/ 76.'[6]

1.11 Flight recorders

1.11.1 Recovery and replay of the Flight Recorder

The Flight Recorder fitted was a Penny and Giles Model 900/D51506 CVFDR which records the most recent five hours of flight data onto five tracks and the most recent hour of audio data from captain, co-pilot and area microphone onto the remaining three tracks of an eight track continuous loop of magnetic tape. A satisfactory replay of all tracks was obtained and an edited transcript of the final part of the flight is at Appendix E.

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[6] Apart from the provisions of the first sentence, 'Safe Supporter', as a semi-submersible vessel, has the same characteristics

1.11.2 Cockpit Voice Recorder

The audio tracks contained data from the commander's microphone (Track 1) and co-pilot's microphone (Track 2) and the area microphone (Track 8). The audio levels on all three tracks were high, causing saturation of the signal but this did not preclude a satisfactory replay being obtained.

From a transcript of the recording a study of the cockpit work-load was carried out and this divided the tasks performed into three categories. The results were analysed in percentage terms of the overall duration of the recording, and cover both the commander and co-pilot tasks. The results are presented for the overall duration of the recording and then divided into those portions when the flight was airborne and those when it was on a helideck:

a. Logistics: 32.0% overall; comprising 11.7% airborne and 47% on deck.

This included changes in the tasking, load planning, filling out of the flight log, communications on the logistics with ATC and HLO, and the loading of passengers.

b. Flight planning: 27.5% overall; comprising 20.4% airborne and 33.8% on deck.

Tasks included planning of the flight, fuel, diversions and weather, and communications on these matters with ATC.

c. Flight operations: 33.3% overall; comprising 54.8% airborne and 16.7% on deck.

This included all tasks and communications necessary to conduct the flight, including check lists, flight and safety briefings, and ATC and HLO clearances.

1.11.3 Flight Data

The CVFDR formed part of an IHUMS which was intended to perform gearbox vibration analysis, rotor system track and balance monitoring, engine usage and exceedance monitoring and trending, maintenance and flight manual exceedance monitoring, operational usage monitoring, airframe vibration monitoring and flight data acquisition. On 'GH' only the flight data acquisition system in IHUMS was operational. The flight recorder system had been checked by BHL on 2 September 1991, and the parameters were within the tolerances given in the test schedule.

There were a number of areas of bad data due to deposits on the tape caused by the leakage of sea water into the crash protected enclosure during the immersion in water, bit recovery techniques were used to recover all this data except for one second during the flight which could not be recovered.

The recorded IAS had been checked on 2 September 1991 against the pilots' instruments and was within tolerance.

The OAT recorded on the flight recorder was about -1°C at lift-off decreasing to about -2.5°C by the end of the recording.

A Leigh Ice Detector sensed the Liquid Water Content (LWC) of the atmosphere and the output was displayed to the crew and the value was recorded on the flight recorder. Throughout the accident flight the value of LWC was very low, about 0.01 grammes per cubic metre and, although there were some momentary peaks to higher values, these were not consistent with the method of operation of the Leigh Ice Detector.

1.11.4 Interpretation of the Flight Data

Appendix F Figures F1 and F2 show the final take-off and flight from the Cormorant 'A' until the information ended at impact with the water. The helicopter lifted off at minus 50 seconds: the timing of events is related in seconds to the accident time which is also the end of the data. The heading was 300°M, which was into wind, and the helicopter hovered approximately 15 feet above the deck level for 10 seconds. The collective pitch recorded was just over 13° which was confirmed by the co-pilot's observation recorded on the CVR. The airspeed was over 50 kts which reflected the high wind speed with the helicopter heading into wind. At minus 40 seconds the collective was then increased to slightly more than 14° as the helicopter climbed, the pitch attitude went to about 6° nose down as the helicopter moved forward and began a turn to the right with a roll attitude of about 15°. At minus 30.5 seconds the helicopter passed over the edge of the deck as indicated by the sudden increase in Radio Altitude (deck height 183 feet amsl).

The helicopter climbed slightly to just above 200 feet Radio Altitude at minus 29 seconds, before descending slightly to 185 feet. This activated the AVAD warning to sound chimes and then "CHECK HEIGHT", the bug had previously been set to 200 feet as indicated from the audio data. The audio data also indicated that the crew then reset the bug to 100 feet.

The pitch attitude increased to a maximum of about 13° nose-up, then remained steady at about 10° nose-up. The helicopter then climbed again, at minus 25 seconds as the helicopter reached 250 feet the airspeed began to decrease from above 70 kt. The helicopter then levelled at about 250 feet Radio Altitude at minus 20 seconds, this was accompanied by the lowering of the collective to around 11.5°.

At minus 13 seconds with the collective at 11.5° the altitude began to decrease initially at a rate of about 6 feet/second. At 220 feet Radio Altitude, at minus 11 seconds, the collective pitch began to increase from about 11° at a rate initially of about 1°/second. The airspeed at this time had fallen to under 20 kt, below the operating range of the digital air data computer system. The rise in collective pitch lever was accompanied by an increase in torque on both engines and this varied in proportion with the changing rate of collective pitch application (see Appendix F Figure F1).

The AVAD sounded chimes and a "ONE HUNDRED FEET" warning as the helicopter descended, three seconds before the end of data; this occurred simultaneously with the warnings shouted by the co-pilot.

There was an increase in normal acceleration (g) in the final second of data; the final value recorded is 1.45 g. The final value recorded on the collective pitch was 18°, and the engines indicated 52% and 49.5% torque on No 1 and No 2 respectively, showing full power had been demanded through the collective position and was being produced by the engines. The indicated airspeed increased to about 38 kt at the end of the data. The final value of pitch attitude recorded was 4.1° nose-up, and roll attitude 0.3° left. The rate of descent at impact was 25 feet/second.

1.11.5 Helicopter track

Appendix F Figure F3 shows the ground track of the helicopter from the Cormorant 'A' derived from the three axis accelerometer and magnetic heading corrected for a 6°W variation, and shows the position of the 'Safe Supporter' (206 metres from Cormorant 'A' on a bearing of 075°). Helicopter magnetic heading, recorded by the flight recorder is indicated at the appropriate position on the track. The helicopter lifted off on a heading of 300°M and the final recorded heading was 098°M. Also shown is an arc of 134° which, according to data supplied by the manufacturer to the FAA as part of the type certification requirements, is the furthest extent of the right seat pilot's view to his right, although by adopting an extreme and contorted position it may have been possible to see a little further round. The track plot and arc of vision suggest that the handling pilot could see the 'Safe Supporter' initially but, once he had turned through a heading of about 350°, he would have had great difficulty in seeing it.

Whether on not he actually saw it in the latter stages of the flight is uncertain and the commander thinks that he was able to see it. The co-pilot would certainly not have been able to see it.

The final position was calculated to be 215 metres to the north and 532 metres to the east of the Cormorant 'A'. This position is accurate to ±60 metres along the north/south axis, with negligible errors in the east/west axis.

The final position recorded by the Decca R-Nav 1 was 359 metres north and 586 metres east of the rig and was corrected for the datum error on Cormorant 'A'. The resolution of the recorded R Nav data equates to a distance of 190 metres along the north/south axis and 95 metres along the east/west axis. This recorded position confirmed the final position calculated from the accelerometer data allowing for inaccuracy arising from the resolution of the recorded R Nav position.

Appendix F Figure F4 shows a three dimensional trajectory for the final flight path with the relevant comments from the CVR.

The ground speed calculated from the accelerometer is shown in Appendix F Figure F5, also shown is the recorded ground speed which is taken from the Decca R-Nav 1 system, and a ground speed calculated from the airspeed assuming the following winds (see Appendix D for meteorological data):

Surface to 60 feet	300°	42.0 kt
60 ft to 150 feet	300°	48.5 kt
150 feet and above	305°	52.5 kt

The values of recorded airspeed towards the end of the data may be high because of the large descent rate during this period, this is reflected in higher values of derived ground speed from this source. The final calculated ground speed from the three axis accelerometer was 43 kt. Appendix F Figure F5 shows the calculated value of IAS using the derived ground speed and the winds (as above). This decreased to about 5 kts at 5 seconds before impact and then increased to about 10 kts at impact.

1.11.6 Vertical flight profile

Appendix F Figure F6 shows the vertical flight profile, the Radio Altitude has been corrected for the height of the deck and is plotted with the pressure altitude (corrected from 1013 mb for the mean sea level pressure) and height derived from the integration of the three axis accelerometer recordings.

Appendix F Figure F7 shows vertical speed derived from the accelerometer data and rate of change of Radio Altitude, also shown are the recorded values of Altitude Rate from the DIGITAS system. The height started to decrease at around minus 17 seconds with a rate of descent initially of around 6 feet/second (360 feet/minute), this gradually increased from minus 8 seconds to a maximum rate of 30 feet/second (1800 feet/minute) at minus 0.5 seconds. There was a small decrease in the rate of descent to a value of 25 feet/second (1500 feet/minute) at the end of the data and this may indicate the start of a recovery.

1.11.7 Computer modelling of helicopter flight path

Flight data from the CVFDR were sent to Eurocopter (France), to compare the flight measurements (including some derived information) with the simulation results using their S80 flight mechanics model. This model is not a performance model, but is a theoretical flight mechanics model which allows the simulation of varying wind conditions, and has been validated from flight test data. The flight data were also given to the Defence Research Agency (DRA), Farnborough who used a blade element analysis technique to reproduce the final flight path of the helicopter. The pilot control inputs were simulated by a control routine, using a series of subroutines based on aircraft data supplied by Eurocopter (France). Extracts from these reports are reproduced at Appendix G.

1.12 Wreckage and impact information

1.12.1 Location and recovery

The helicopter was recovered from the sea bed at a depth of about 150 metres (500 ft) with the assistance of saturation divers from the MSV 'Stadive'. MSV 'Stadive', which was made available by Shell UK Expro, was also equipped with two remotely operated submersible vehicles (ROVs) fitted with video and still cameras and hydrophones to detect signals from the helicopter's Dukane beacon.

The MSV 'Stadive' was positioned at the reported co-ordinates of the ditching position at about 1330 hrs on 15 March 1992. The main fuselage section of the helicopter was located and, using the ROV cameras and at about 1815 hrs, the tail boom together with the pylon and majority of the tail rotor was located. The five bodies found in or near the wreckage were recovered by about 2300 hrs.

The fuselage was raised to the deck of MSV 'Stadive' and the wreckage was then transported by a supply vessel to Aberdeen.

1.12.2 Impact information

The crushing damage to the underside of the fuselage was most pronounced forward and to the right. However, the final FDR records show the helicopter as being slightly nose-up and banked very slightly to the left just before impact: together, this indicates that the initial impact with the sea was into a wave on the right of the nose area. The damage to the helicopter's tail boom indicates that it also failed structurally at impact, pivoting forward and to the right.

After recovery, it was found that the emergency jettison mechanism for the right cabin door had not been used and that the door had come off of its own accord in the impact with the sea (see Appendix C Figure C2). Damage to the attachment points which normally hold this door in place indicate that this was from a combination of the inertia of the door and deformation of the attachment points when the fuselage flexed in the impact (see Appendix C Figure C3). There is no mechanical connection between this right door and the liferaft mounted immediately inboard. Examination of the mountings and the release mechanism for this liferaft indicated that it had not been released by deflection or by inertia. The indication was, therefore, that it had been released manually by one of the passengers pulling one of the two release handles located on the top of its mounting bar.

The cabin door release mechanisms showed that there had been no attempt by the passengers to open the cabin doors. It was noted that the design of the emergency release mechanism for these doors relies on gravity to release a portion of the sliding door track. The British Civil Airworthiness Requirements (BCAR) Section G - Rotorcraft used for United Kingdom (UK) certification of the AS 332L deal extensively with the requirements for emergency exits in helicopters, including the number and type of exits for different sizes of helicopters and their arrangement, marking and access. Neither BCAR Section G, nor BCAR 29 (which succeeded Section G), define any range of aircraft attitudes in which emergency release mechanisms should be operable. This had been noted previously by AAIB in an Aircraft Accident Report (AAR 2/89) on an accident involving an AS 332L, G-BKZH, 35 miles east north east of Unst, Shetland on 20 May 1987. Recommendation 4.4 of that report was:

> 'The lack of a facility to jettison the cabin doors on an AS 332 in an inverted position should be reviewed.'

The CAA reply was given in Follow-up Action on Accident Reports (FACTAR F2/89) which was published coincident with the AAIB report. The response to Recommendation 4.4 was:

> 'The AS 332 is certificated on the basis that, in the event of a ditching, it will remain upright long enough to permit the doors to be jettisoned and an orderly evacuation to be carried out in all but the most severe sea conditions. The requirements also address crash conditions and these have to be taken into consideration during the certification process to maximise the chances of post-impact survival.
>
> In the case of the AS 332, the need to jettison the doors in an inverted position presupposes a capsize following a crash, as opposed to a ditching within the certification limits. In these circumstances, an attempt to jettison doors or other large surfaces subject to differential pressure may not be the most suitable escape method. The CAA has therefore required helicopters operating over the North Sea to be modified so that all suitable openings are readily usable for underwater escape and their access and location highlighted. The attention of all occupants is drawn to the location and operation of these exits during the pre-flight briefing. However, the CAA will review this aspect of the aircraft's certification.'

The cabin doors of AS 332L helicopters can not be relied upon to jettison without the effect of gravity acting upon the release mechanism in a normal (ie virtually upright) attitude.

1.12.3 Subsequent examination

1.12 3.1 Rotor head

The rotor head had remained substantially as a unit but had suffered considerable damage in specific locations. All hinges (feathering, flapping and drag) could still operate but the attachments of two of the four rotor blade frequency adapters (drag hinge dampers) were broken.

1.12.3.2 Main rotor mast

When the rotor mast assembly was separated from the main transmission, at the conical casing joint, it was found that the rotor mast itself was fractured. The failure had occurred just above the splined lower end of the mast which engages in the transmission output from the upper planet carrier. Metallurgical examination of this failure showed that it was the result of a torsional shear overload with no pre-existing defects. The sense of the failure was consistent with the rotor being impeded whilst power was being applied through the transmission to the mast.

The position of the torsion failure on the mast was at a point of deliberate weakness. This weakness had been designed to act as a mechanical fuse within the transmission system as close to the rotor as possible. The intent was to allow the rotor's inertia to shear the mast in the event of a sudden seizure within the gear train, thereby leaving the rotor free to rotate.

Both the lift bearing and the conical casing had suffered considerable damage. The casing itself had split through the bearing retention housing and some balls had broken free from the two bearing races. There was no evidence on either of these components to suggest that the damage had occurred whilst the rotor shaft was turning.

1.12.3.3 Main transmission

The main transmission had extensive corrosion of the magnesium alloy casing due to salt water immersion. This corrosion was equally advanced on both the inside and the outside of the casing. There was no evidence of pre-corrosion casing distress. Although the corrosion products had caused complete binding of the mechanism, after dismantling the transmission, it was established that there was no evidence of a pre-existing failure or malfunction within it.

1.12.4 Emergency hull flotation

When 'GH' was surveyed by ROVs and divers from MSV 'Stadive', it was observed that two of the inflatable bags (right forward and right aft) had come out of stowage and the other two (left forward and left aft) were still correctly packed. There was no evidence of the bags having inflated and, when they were examined at the surface, all the inflation bottles were found still to be fully charged. On the flight deck the arming switch on the centre console was found in the ARMED position but neither of the firing buttons, mounted on the collective levers, had been pushed. There was no facility for automatic inflation of the flotation gear. The electrical initiation circuits and relays for the flotation system were later checked at Farnborough and found still to be functional. This indicates that, at the time of the accident, the hull flotation system was armed and available.

1.12.5 Flight instruments

Several flight instruments were removed and taken to their respective overhaul agencies to be examined in detail, to determine their serviceability at the time of the accident.

1.12.5.1 Artificial horizons (Attitude Direction Indicators)

The damage to both pilots' Attitude Direction Indicators was similar and was entirely attributable to salt water ingress after the accident. This had, for instance, seized up the inertial rotors in their housings but the mechanical linkages were intact and the bearings in good condition. The electrical continuity was found to be complete, either on initial check or after light cleaning of commutator brushes to remove corrosion deposits. On both instruments the caging mechanism was found to be in the 'fully retracted' (ie uncaged) position. The erection cutoff switches were in the 'locked' position, indicating that the aircraft and gyros had passed beyond the 'erectable' range (± 11° from vertical) when the gyros stopped.

1.12.5.2 Airspeed indicators (ASIs)

The type of ASIs installed in 'GH' displayed a conventional pointer, driven mechanically by a pitot/static aneroid capsule. Both ASIs had suffered minor damage to the mechanical linkage due to excessive barostatic pressure on the pitot side of the aneroid capsule but the linkage was otherwise intact.

1.12.5.3 Barometric altimeters

The barometric altimeters in 'GH' were of the mechanical type, with 28V DC electrical power for instrument lighting and vibration. Although barostatic pressure had collapsed the balanced aneroid capsules in both instruments, the mechanical linkages had remained intact and in place. Air leak checks were performed on the aircraft pitot and static systems and were found to be within the permitted tolerances.

1.12.5.4 Radio altimeters (Radalt)

The Radalt system in 'GH' consisted of a transceiver unit and the two pilots' indicators in the cockpit. The electronics had suffered too much damage from the salt water immersion to be tested but the mechanical linkages were intact.

1.12.6 Engines

The two engines were subjected to strip examination at an engine overhaul facility in Aberdeen with the participation of representatives from AAIB, Bureau Enquêtes-Accidents, Turbomeca and BHL. Both engines showed ample evidence of their exposure to the sea water, particularly the engine oil tanks, which were made of a magnesium alloy. Apart from the substantial corrosion products evident in the oil system from this chemical reaction, both engines were mechanically sound, with no evidence of any overheating within the engines or damage to the bearings. There were only small amounts of leading edge erosion on the compressor blades and no significant debris in any of the oil filters or magnetic chip detectors.

1.12.7 Automatically Deployable Emergency Locator Transponder

The ADELT beacon had been successfully deployed in the accident. The pyrotechnic deployment squib in the fuselage-mounted ADELT carrier had fired, the aircraft ADELT wiring was intact and the saline switch was functional. The glass bowls of the two forward 'frangible' switches were intact, despite deformation around the right-hand switch but the rear 'frangible' switch had been fractured in the impact by displacement of the aircraft skin. Thus it appeared the rear 'frangible' switch had initiated the deployment of the beacon and that, if this had not occurred, the saline switch would have done so shortly afterwards.

Examination of the ELT beacon itself showed the unit to be fully serviceable and, when activated, still to give a satisfactory signal.

1.12.8 Emergency exit perimeter lighting (EXIS)

This design of emergency lighting is common to a number of helicopter types operating in the North Sea and is placed around the designated emergency escape apertures. In the case of the passenger windows, which are of the push-out 'escape window' type, the escape exit is delineated by four corner lights (Appendix C Figure C1). The lights are activated by a saline switch and power is supplied by a small battery. Both items are close to the window and mounted approximately half-way up the cabin wall.

When the helicopter was recovered onto the deck of the MSV 'Stadive', a number of the EXIS lights were still operating and later examination showed them to be serviceable. However, most of the survivors had not noticed the EXIS lights around the cabin exits.

1.12.9 Liferafts

Two RFD Heliraft Type 14R Mark 1 liferafts were carried on board 'GH'. One, which was recovered with the helicopter, was stowed under seats No 5 and No 6 was removed by the AAIB at Farnborough and inflated. It functioned normally and there was no evidence to suggest that it would not have done so had it been deployed at the time of the accident.

The liferaft which was normally stowed in a valise beside the cabin right door had been deployed. It was examined at the manufacturer's facility, under AAIB supervision. It had suffered severe and extensive damage, especially to the buoyancy chambers and floor. Several areas of damage were identified which showed clear evidence of cutting, puncturing and snagging of the fabric by an external agent. In the case of the floor particularly, the damage had been substantially extended beyond the initial areas, probably by the force of the sea water. A number of sewn attachment joints had failed, probably due to loadings which, in direction and magnitude, were outside their design criteria.

The gas bottle had discharged and the inflation mechanism appeared to have functioned satisfactorily. The canopy arch / fender had suffered severe damage caused by the penetration of a sharp object. Both main buoyancy chambers had suffered severe damage but at least one of them must have been inflated and remained so until after the survivors clinging to it had been rescued. Although survivor reports indicated that the liferaft had suffered a considerable amount of damage during the initial deployment, particularly to the floor area, it is evident that there had been subsequent damage by the elements and during the recovery.

The strobe beacon and its associated switch and battery were examined. The switch is magnetically activated, the magnet strip being held on the switch unit by a Velcro fastening. When the chamber, on which it is situated, inflates it causes the magnet strip to pull from the switch unit; this closes the circuit from battery to light. The magnet strip was found to be still partially attached to the switch unit but it was on the wrong side of the switch stowage securing tie; if it is assumed to have been correctly fitted this implied that it had at some stage been separated from the switch but had later become re-bonded. The battery was found to be in the fully discharged state. Although, when connected to a fresh battery, the capacitor could be heard charging and discharging, the light unit did not function.

1.13 Medical and pathological information

Both crew members were fit to fly and neither showed any evidence of a medical condition that would have influenced the accident.

Autopsy examination of the fatalities revealed that in all cases death was as a result of drowning. In some cases drowning occurred after the onset of hypothermia from cold water immersion.

Appendix H lists the Injury Severity Score (ISS) for each occupant. The ISS is a method of indicating the severity of injuries and it has been used in recent AAIB investigations of public transport accidents. Injury details for the deceased were coded from autopsy records. Injury details for the survivors were coded from medical records supplied by the Gilbert Bain Hospital, Lerwick, Shetland. All the injuries, both for survivors and the deceased, were superficial and slight to the extent that they should not have affected the ability of an individual to escape from the helicopter.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 General

After impact, the helicopter rapidly adopted a right side down attitude and then became fully inverted before it sank. It was not possible to determine a precise time for this but it is thought to have taken only a minute or two. The flight deck and cabin suffered relatively minor disruption in the impact with the sea but all of the escape windows on the right side of the cabin were ejected and the right cabin door suffered distortion which caused it to detach. The escape windows and the cabin door on the left side remained in position. The impact came without warning and there was no evidence to suggest that all the occupants were other than in their seats with their harnesses properly fastened.

1.15.2 Evacuation

The commander escaped from the aircraft via the right flight deck door window and came to the surface to see the co-pilot close by; it was not possible to determine how the latter had escaped. Water ingress to the cabin was rapid and, although the survivors who had been seated to the rear reported that they had time to take a deep breath of air, those at the front did not. Passenger S3[7] escaped through the right front escape window; S1 and S5 exited through the escape window apertures nearest their seats; S2 removed the front left escape window and exited through it and S4 removed and exited through the escape window next to his seat on the left side. NS2 was seen by S5 to leave through the escape window aperture just behind his seat. Positive identification of the escape route of the other four NS passengers was not possible and so it has not been possible to indicate either their seat numbers or escape routes in Appendix C.

Five occupants did not escape from the cabin and were later recovered from the sea bed. One, NE 5 who had probably been in seat No 5, was found with the cord of an acoustical headset wrapped tightly around his neck. The quick release jack-plug had failed to separate because it had been jammed into the seatback by the seat headrest support. At what stage this entanglement had occurred could not be determined.

The liferaft in the right cabin door was released from its stowage, probably by a passenger, shortly after the door had opened on impact; it started to inflate almost immediately, the inflation probably being initiated by the short painter. It suffered major damage, particularly to the floor, as a result of contact with parts of the helicopter. It did however inflate at least partially and provided support for some of the survivors. Both crew members and passengers S1, S3, S5 and NS6 were known to have been at, or in the vicinity of, this liferaft. At an early stage S1 attempted to assist NS6 into the liferaft; the attempt was unsuccessful and NS6 drifted away from the area. Because it was so badly damaged, the liferaft was extremely unstable in the water and overturned on several occasions. On one of these, S3 was thrown into the sea and was unable to swim back to it; the cord which retained the liferaft survival pack had wrapped around his leg and consequently became detached from the liferaft and drifted away with him.

Shortly after escaping on the left side S4 found that he was very close to two other passengers in the water; one, apparently dead. He later identified him as NS4 and he linked himself with the other, NS3. He could see the liferaft inflated on the far side of the helicopter but was unable to get to it.

The liferaft stowed under seats No 5 and No 6 adjacent to the left cabin door was not deployed and those who escaped from the left side were unable to get to the other liferaft mainly because of the prevailing weather conditions and the fact that the fuselage was, initially, between them and it.

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[7] For clarity passengers have been described throughout this report as; S = Survivor; NS = Non Survivor (escaped, but did not survive); NE = Non Escaper

1.15.3 SAR policy

As a Contracting State under the Convention on International Civil Aviation, the UK is committed to providing SAR services for international civil aviation throughout defined areas on a 24 hour basis.[8]

Responsibility for SAR for civil aircraft within the UK Search and Rescue Region (SRR) rests jointly with the Ministry of Defence (MOD) and the Department of Transport (DOT), advised by the CAA. The DOT is also responsible for SAR policy for civil aviation.

MOD is responsible for the implementation of SAR services for civil aviation throughout the UK SRR and this responsibility is discharged through two military Rescue Co-ordination Centres (RCCs), RCC Edinburgh and RCC Plymouth. Air assets, both helicopters and maritime patrol aircraft, are provided by the military for civilian SAR under the operational control of an RCC and are tasked by HM Coastguard when engaged in maritime incidents. Additionally, DOT contracted SAR helicopters are located at three sites in the UK (including Sumburgh) under the operational control of HM Coastguard.

On occasions, aviation distress incidents are first reported to and initial action is taken by HM Coastguard. However, the responsibility for initiating and co-ordinating civil aeronautical search and rescue north of latitude N52°30', in the United Kingdom, rests with the RCC at Pitreavie, near Edinburgh. The RCC and its resources are provided by the MOD. Where there is a marine involvement the RCC is supported by the appropriate Maritime Rescue Co-ordination Centre (MRCC), in this case at Aberdeen.

1.15.4 Search and rescue

Once it was known that 'GH' had crashed into the sea, the SAR operation was controlled by RCC Edinburgh with Aberdeen MRCC maintaining close liaison throughout.

Where the incident is directly related to an offshore installation, the Offshore Installation Manager (OIM) will normally be designated the On Scene Commander (OSC) and will control the detail of the search and rescue effort. In this case the OIM of Cormorant 'A' was designated OSC. A suitable surface vessel is normally appointed Co-ordinator Surface Search (CSS); the supply vessel 'Edda Fram' was designated CSS.

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[8] Full details are published in UK Aronautical Information Publication (AIP) Volume 2; SAR

The Offshore Installations (Emergency Procedures) Regulations 1976 require that a Standby Vessel (SBV) be present within 5 nm of every offshore installation when it is manned. The purpose of this vessel is to give assistance in the event of an emergency on or near the installation. The OIM would normally inform the vessel when a helicopter was about to take-off from a platform; the vessel would then move to a position close by that platform. On this occasion the vessel was standing off by about 1.5 nm and was unaware of the helicopter movement.

A detailed account of the search and rescue operation is given in Appendix I.

1.15.5 Life Saving Jackets (LSJ) and survival suits

The LSJ used by the crew and passengers was the Beaufort Mk 28 Series 1 and Series 4 respectively. None of the survivors reported any problem with its operation although it was noted that it tended to ride up the body, even when it had been correctly fitted. All the survivors reported difficulty deploying the spray screen. There was only one reported case of the light not working. Both crew members' lifejackets appear to have functioned normally.

Of the five passengers who escaped but did not survive, NS4 and NS3 appeared to be floating normally with their lifejackets inflated; NS5 was floating face down with his LSJ deflated due to a tear in the buoyancy chamber, and NS1 and NS2 were floating upright with the inflated LSJ having ridden up to such a degree that their faces were under the water. Of those who failed to escape none had inflated their lifejackets.

The crew wore Multifabs Type 411 Crew survival suits which appeared to have performed satisfactorily. The co-pilot's suit was outside its servicing date but there was no evidence to suggest that this in any way contributed to his non survival but inadequate clothing worn under the suit may have contributed to the eventual onset of hypothermia.

The Multifabs Passenger survival suit was worn by all the passengers. The majority appear to have been correctly fitted, with the central zip up to at least 3 inches from the top. Evidence suggested that a majority also had the hood up when the accident occurred.

None of the survivors reported feeling particularly cold nor did any report difficulties with water entering the suit. None managed to extract and put on the gloves and, although some managed to fit it, the strobe light kept falling off its Velcro attachment on top of the hood.

The suit worn by NS2 was the only one which was positively identified as having taken in a significant amount of water; the suit was partially unzipped but it was not possible to determine if it had been like this at the time of impact.

The recovered survival suits and LSJs were examined on behalf of AAIB at RAF IAM. The Institute also conducted some tests using a live subject and mannequin to determine leak rates of the suits with varying degrees of zip position in relation to survival times. Performance of the LSJ was also evaluated. A copy of the IAM report is at Appendix J. It should be noted that tests of similar survival suits by the Robens Institute has estimated survival times considerably in excess of those quoted in the Appendix.

1.16 Tests and research

1.16.1 Flight data analysis

Comparisons of recorded flight data with computer simulation models were performed for AAIB by Eurocopter (France) and DRA Farnborough as described in paragraph 1.11.7 and Appendix G.

1.17 Additional information

1.17.1 Visual Contact Flight (VCF) at night

The BHL OM Part 2, Section 10, paragraph 10.3.1.3 and 10.3.1.4 (ii) set out the requirements for VCF meteorological conditions:

> 'Night overwater sectors of less than 10 nm
>
> Latest information available should indicate that actual weather conditions likely to be met.......are such as to allow flights to take place below and clear of cloud at a height of at least 500 feet above the surface, or 100 feet above the destination......whichever is the higher. The associated visibility should be 5 km, or such that the destination or intermediate structure shall be continuously visible from the point of departure.
>
> Night overwater sectors 10 - 30 nm
>
> Latest information available should indicate that the actual weather conditions likely to be met over the route to the destination and alternate are not less than:- cloud base 1200 feet, visibility 5 km.
>
> Night overwater sectors greater than 30 nm
>
> VCF by night over water may be continued only if the helicopter can be flown below and clear of cloud at a height of not less than 1000 feet with a visibility of 5 km and helicopter attitude can be assessed by reference to a clearly distinguishable external horizon.'

Paragraph 10.11 lists the standard practice for setting Radalt bugs during various phases of flight. At night the non-handling pilot's Radalt bug is to be set at 300 feet for take-off and also whilst en route for a VCF shuttle. Note 4 to the paragraph states:

> 'The Commander should always determine the minimum safe setting, depending on weather conditions. If a "CHECK HEIGHT" warning is given by the SPWS[9],then the commander will call out his observed height and intentions.'

1.17.2 Icing conditions

When Aerospatiale (later Eurocopter (France)) originally issued the Flight Manual (FM) for the Super Puma, flight in icing conditions was prohibited for this helicopter. However, after trials had been carried out, in December 1989 the CAA issued Change Sheet No 5, adding to the stated Operating Limitations in the FM, for British certificated Super Pumas. This states:

> 'Flight in icing conditions is permitted provided that appropriate modifications are embodied and in accordance with the terms of the relevant approval.'
>
> Supplement (10.54).
>
> 'Icing conditions must be assumed to exist when in cloud or when the visibility is reduced to 1000 metres or less in visible moisture with a true air temperature of 0°C or less.
>
> Flight in freezing rain or freezing drizzle, regardless of the visibility, is prohibited.'

Irrespective of the above, icing conditions must be assumed to exist whenever there are visible signs of ice or slush build up on any part of the helicopter.

The helicopter commander has stated that no portion of the flight was conducted in icing conditions and icing was neither indicated nor observed. Nevertheless, the HLO on the Cormorant 'A' did see a small deposit of crystalline ice or impacted snow on the frontal portion of the helicopter's left sponson. He saw no need to report this to the crew and he was under no obligation to do so.

There are no FM limitations in relation to flight in falling snow.

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[9] Surface Proximity Warning System; in this case the AVAD

1.17.3 FM Supplement 10.54

In the Supplement, referring to flight in limited icing conditions by the Super Puma not fitted with rotor icing protection, paragraph 2.3 (a) 'Flight envelope authorised for intermittent icing conditions', it specifies the following limitations:

> 'Maximum pressure altitude: 8000 feet
> Minimum outside air temperature: minus 10° C
> Maximum severity: 0.8 grammes / cubic metre
> Maximum duration: 5 minutes.'

And paragraph 2.6, 'Limitations for flight to a non-icing zone', states:

> 'When any one of the imposed limitations is reached, the flight time to the non-icing zone must not exceed five minutes.
>
> Above the surface, or above the minimum altitude allowed by the operating rules, whichever is the greater, there shall be at least a 500 feet height band of positive temperature air available and into which the helicopter can descend within five minutes.'

1.17.4 Administrative and operational workload

The nature of shuttle or short inter-rig flights in the offshore environment inevitably gives rise to a considerable amount of paperwork and record keeping. This has to be dealt with by the crew as the flight progresses. The essential part of this work is to satisfy the crew that for each sector the helicopter is flown within the correct regulated weight for the prevailing conditions, taking account of limiting factors such as deck size, obstructions or turbulence sectors. Also, they must constantly re-evaluate their fuel state in the light of departure to the final destination with any necessary diversions. Administratively, the crew must know the up to date situation concerning different numbers of passengers, their baggage and freight to be loaded and unloaded on various helidecks together with the associated paper work of manifests, load sheets and any dangerous goods certificates. An accurate record of landing and take-off times must be maintained. This is a considerable administrative burden on crews engaged in multi-sector operations, especially when the load is altered at a moment's notice, which requires a complete revision of every element of the remaining sectors' paperwork.

For many years it has been appreciated that the normally required amount of paperwork could, on multi-sector flights, be sufficiently onerous to the flight crews that it might have the potential to detract from their attention to the safe conduct of the flights.

Certain measures have been adopted to try and alleviate this load. The absolute requirement for load sheets has been exempted when either an electromagnetic recording or manual record held on the installation of passenger numbers, baggage and freight weight, and fuel remaining can be made for subsequent transcription to documents used to audit the conduct of the flight. In some cases computerised personnel logging on and off installations by means of 'swipe' cards has been implemented and this could be incorporated into the system used for passenger manifests.

In 1984, the CAA commissioned a consultant to research this situation and the results of this were published in 1989 but, although the report highlighted the problems, it did not appear to provide any viable solutions. The CAA then consulted helicopter operators to define the problem more accurately, to improve operating procedures and to refine the existing Exemptions from Regulations.

The CAA continued to examine the problem and proposed a feasibility study for the use of telemetry, similar to that established in the fixed-wing Public Transport sector, known as Automatic Communication and Recording System (ACARs). Such a system may have the potential to reduce crew workload, by automating the tasks of both calculation and recording. Within the CAA a research project relating to cockpit paperwork has been identified and it is expected that a feasibility study will be authorised in the financial year 1993/94.

1.17.5 Controlled flight into the sea for no apparent airworthiness cause

The Safety Regulation Group (SRG) of the CAA has maintained a data base of civil accidents and incidents since January 1976. Some foreign accidents involving non UK registered aircraft and some military accidents have also been recorded where details have been available. Data has been extracted for those accidents and incidents involving helicopters that had crashed into the sea due to apparent loss of control or disorientation with no apparent airworthiness cause and are shown in Appendix K. While some reports are lacking detail, several instances involved poor weather conditions which bore a similarity to the circumstances of the accident involving 'GH'.

1.17.6 Helicopter Airworthiness Review Panel

In December 1982 the CAA asked the Airworthiness Requirements Board (ARB) to review existing requirements for public transport helicopters and to make recommendations for improved safety standards. The Technical Committee of ARB set up an appropriate panel of experts and their report, the Helicopter Airworthiness Review Panel (HARP) report was published as CAP 491 in June 1984. The panel's findings and recommendations represented a milestone in the search for improved helicopter safety. Shortly after its publication, CAA announced that £1.5 million would be made available for the various research projects recommended by the panel. A further £1.6 million was made available during the six years following the report.

Whilst most of HARP's 15 recommendations are concerned with matters of airworthiness, Recommendations 1, 9, 10 and 15 have direct relevance to this accident and are therefore discussed in some detail.

HARP recommendations were included in the CAA research programme and a further response was to establish a Helicopter Management Liaison Committee (HMLC). Under the chairmanship of the Head of Design and Manufacturing Standards Division of SRG, the Committee meets regularly to 'provide a forum for the exchange of information and advice on airworthiness and operational matters between the CAA SRG and the United Kingdom Offshore Helicopter Operators'.

1.17.6.1 Human factors

HARP made the following recommendation:

> 'RECOMMENDATION 1. That the CAA initiate a special study into the detail causes of the significant number of helicopter accidents attributed to 'human error' to see where technology might contribute to useful improvement.'

The Director General Airworthiness (DGA) of the CAA established a Working Group to evaluate the extent to which incidents and accidents to helicopters were due wholly or in part to human factor causes, and to suggest what steps might be taken, within the limits of current technology, to minimise or eliminate those causes. The Working Group were to report to DGA by December 1985 and in July 1987 CAA Paper 87007 was published. The paper contained some 29 recommendations of which 18 related to airworthiness standards, five related to operational standards and six were of a more general nature. A Human Factors Steering Group, which included representatives of the SRG, the aviation industry as well as IAM and AAIB, had been formed under the auspices of the Civil Aviation Research and Development Board. When, in 1991, the Authority's Chief Scientist Division was divided between National Air Traffic Services and the SRG, it was agreed to dissolve the Human Factors Steering Group and the SRG formed another Human Factors Working Group whose terms of reference were 'to encourage awareness of human factor issues in SRG line activities.' This Working Group covers both research and some wider aspects. It is noteworthy that the original Working Group had recognised the problem of 'In flight paperwork' and recommended:

> 'Some means of relieving the crew of the burden of in flight paperwork should be sought, and necessary changes to requirements introduced.' (see paragraph 1.17.4).

1.17.6.2 Ditching

Survivability after ditching is predicated on the case of a emergency alighting on the water. The case of the survivable accident resulting from controlled or uncontrolled flight into the sea may be considered more catastrophic but nevertheless the functioning of survival aids, evacuation by survivors and their subsequent rescue can be considered only in the same light as ditching. These considerations were addressed in the HARP report. The panel reported in paragraph 8.4 thus:

> '<u>Ditching</u>. Ditching is really part of Crashworthiness but better considered as a separate case, and one of particular concern to the British helicopter industry operating as it does for long distances near the sea. We believe it will be a long time before extensive scheduled passenger services are flown for long periods over water. Those who fly out to North Sea platforms wear sophisticated survival suits and are instructed in their use; we cannot believe this would be acceptable to the normal fare paying passengers.
>
> The frequency of forced landings (and hence in overwater operations of ditching) is such that a high probability of survival of all occupants is essential. To achieve this, the helicopter must have adequate buoyancy, stability, practicable means of escape and effective liferaft equipment.
>
> Buoyancy needs to be assured in order to provide the pilot with ditching as an acceptable option, and there are strong arguments in favour of deployment of flotation bags before contact with the water. Reserve buoyancy may be desirable in the event of survivable damage. The need for stability is emphasised by the very limited practicability of escape from a capsized helicopter. The conditions on which the stability of the helicopter should be demonstrated must take account of realistic wind speeds accompanying severe sea states. Special consideration needs to be given to conditions in the very inhospitable areas such as the Northern North Sea.
>
> There are a number of aspects of life raft deployment and operation that need review. Draft requirement papers are in an advanced stage and we would advocate early publication and application.

> Thus we make the following recommendations:-
>
> RECOMMENDATION 9. We propose draft requirements covering ditching be published at an early date to encourage technical consideration.
>
> RECOMMENDATION 10. We propose that resolution of the problems of stability of a ditched helicopter be urgently pursued.'

A number of developments in the area of survivability followed these recommendations including improved survival suits with a spray hood, 'escape' windows, EXIS lighting, ADELT, Heliraft reversible liferafts and hull flotation gear. The main action in respect of HARP Recommendation 9 was to initiate a joint research programme involving CAA, the UK Offshore Operators' Association, the DOT, the Health and Safety Executive (HSE) and, on 7 October 1985, the CAA published Paper G779, which in turn amended Section G of BCARs. The Paper G 779 contained a number of significant changes to the BCAR and may be summarised thus:

> It is required that, after ditching, the helicopter should float in a stable position for not less than five minutes. This is to allow time for the deployment of liferafts and for passengers to board them 'in severe seas'. The design of the helicopter and its buoyancy aids must have demonstrated its ability to comply with a set of criteria which are set out in an Appendix or, where compliance is not possible, a limitation should be published in the FM[10]. The flotation and trim characteristics were required to be investigated in up to sea state 6, which was defined as Very Rough sea with significant wave heights of 4 to 6 metres but with a maximum wave height of 9.15 metres.

1.17.6.3 Civil /military exchange of information

Recognising the generic link between civil and military helicopters, HARP noted that there was no formal contact or procedure at a policy level where new needs could be discussed and views exchanged. The Panel felt that there was a balance to be drawn between common sense consideration of likely benefit by discussion of the needs of the two types of user (civil and military) and the interference in the autonomy of those responsible for defence development and expenditure. The following recommendation was therefore made:

> 'RECOMMENDATION 15. The CAA should discuss with the Ministry of Defence the setting up of some sort of formal collaboration on

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[10] Type certification of the AS 332L pre-dated this revision to the requirements. Tank testing of representative models had shown an ability to meet the original requirement and, since it was also established that the helicopter met the revised requirements, no limitations in this respect were placed in the the FM

> helicopter matters. This should include consideration of development of safety requirements and the exchange of appropriate in-service information '

1.17.7 Deployment of emergency hull flotation

The AS 332L helicopters operating in the North Sea area are equipped with emergency flotation equipment consisting of four separate inflatable bags. Two of these bags are mounted in a collar placed around the nose of the aircraft and one each on structural frames at the sponsons. In an emergency, inflation of the floats is initiated electrically from the flight deck, where the arming switch and a firing button are located on the centre console and an additional firing button is mounted on each pilot's collective stick. In North Sea operations the system would, typically, be ARMED for the approach, landing and take-off phases at offshore helidecks.

The Royal Navy operates a number of helicopter types (Westland Wasp, Wessex, Lynx and Sea King) with hull emergency flotation which may be automatically activated by saline immersion switches and the EH 101(Merlin) is designed with a similar system. For the Sea King, the use of the boat hull dictates that this switch is mounted in the controls compartment, about mid-way up the helicopter so that it would only be activated in the case of a capsize. There are a number of naval helicopter types which, in addition to pilot initiated inflation of the emergency flotation, allow for automatic inflation when the hull is immersed. Although there are some differences between types, the system typically comprises DC electrical initiation of the flotation system either from the flight deck or from any one of a number of immersion switches or submersible actuators, with an arming switch mounted on the flight deck. In contrast, the United States Navy helicopters, such as the Sikorsky SH-60B Seahawk and SH-3, do not carry automatic systems.

Similar automatic systems have also been fitted to a number of civil helicopters, generally by later modification. For example, Puma SA 330J helicopters operated by Bristow Australia are to be fitted with automatic systems as have been Bell 212 and Bell 214ST helicopters. BHL had requested an automatic inflation system for the AS 332L at initial purchase. The prime certificating authority, (DGAC) had resisted this proposal on the ground that the risk of inadvertent deployment during cruise flight constituted an unacceptable hazard. In view of this no request was made to the CAA for such a modification.

A number[11] of accidents involving UK registered helicopters operating on the North Sea feature the helicopter hitting the sea with the hull flotation armed but

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[11] S-61N G-BDES in November 1988 (Aircraft Accident Report 1/90)
S-61N G-BDII in October 1988 (Aircraft Accident Report 3/89)
S-61N G-BEWL in July 1990 (Aircraft Accident Report 2/91)

the pilots were unable to initiate inflation. Other instances have occurred in which the crew were able to initiate inflation when this was performed before a controlled ditching or where an intentional ditching was made into a calm sea.

1.17.7.1 Royal Navy experience

At the request of the AAIB the Royal Navy Flight Safety Centre reviewed their record of hull flotation deployments on RN helicopters, covering the years 1986 to 1992. Within this period there were a total of 15 inadvertent inflations, of which six occurred in flight, four while the helicopter was on the ground or deck and five during maintenance or servicing operations.

Of the six inflations in flight, two were attributed to helicopter operations close to powerful radars in ships of the US Navy and two to inadvertent manual selection; the cause of the other two was unknown. In none of the inflations was there any evidence that the saline immersion switches had been the initiating cause.

Within the scope of this review, therefore, it was apparent that the provision of the 'automatic flotation' feature in these RN helicopters had not materially altered the reliability of the flotation system. This was despite the 'automatic flotation' mode being a simplex system, needing only a single switch to be activated. The review, which covered Sea King, Lynx, Wasp and Wessex helicopters, further showed that in none of the cases had the inflation of the floats caused difficulty to the pilots in handling the aircraft.

1.17.8 Offshore safety

> The Hon Lord Cullen's report on the Public Inquiry into the Piper Alpha Disaster[12] was studied with particular reference to helicopters. In the context of the Piper Alpha disaster, helicopters and their availability were seen mainly in their rescue role and the report called for a '.......flight following system for determining at short notice the availability and capacity of helicopters in the event of an emergency.' (Recommendation 77)

The report recommended that:

> 'There should be a single regulatory body for offshore safety.'
> (Recommendation 23)

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[12] London: HMSO November 1990 Cm1310 (two volumes)

but acknowledged that:

> 'The other body which has a specific responsibility in regard to installations is the CAA which is responsible for safety in commercial helicopter operations.' (paragraph 16.31).

Since then the Offshore Safety Division of the HSE has assumed regulatory responsibility for every aspect affecting an installation including the design and maintenance of helideck facilities and the management of helideck operations. The CAA remains responsible for the regulation of normal flights to, from and between the installations.

The first 13 recommendations of the Cullen Report called for oil companies to submit to the regulatory body a Safety Case in respect of each of its installations. These recommendations have been implemented by the Offshore Installations (Safety Case) Regulations 1992, which require a duty holder to demonstrate in his Safety Case that:

> 'his management system is adequate to ensure that the relevant statutory provisions will (in respect of matters within his control) be complied with in relation to the installation and any activity on or in connection with it;
>
> he has established adequate arrangements for audit and for the making of reports thereof;
>
> all hazards with potential to cause a major accident have been identified; and
>
> risks have been evaluated and measures have been, or will be, taken to reduce the risks to persons affected by those hazards to the lowest level that is reasonably practicable.'

The definition of a major accident includes the collision of a helicopter with the installation. In practical terms this means for example that the Safety Case should assess the adequacy of the organisation and arrangements for helideck operations and for any foreseeable risks of helicopter operations in the light, for example, of adverse weather conditions which might inhibit SAR activities.

Other recommendations of the Cullen Report called for the reform of existing legislation. HSE is developing proposals for four sets of regulations, including one on Management and Emergency Response, in consultation with industry and trade unions.

1.18 New investigation techniques

1.18.1 Flight data recorder

CVRs have been fitted to public transport helicopters having a maximum total weight authorised exceeding 2,730 kg since 1984 and their usefulness in accident investigation is well proven. Following an accident to a Bell 212 in the North Sea in September 1982[13], AAIB recommended that 'Flight data recorders be fitted to as wide a range of helicopters as is practicable.' Since 1 February 1991 UK registered helicopters in the Transport Category (Passenger or Cargo) having a maximum total weight authorised exceeding 2,730 kg have been required to carry either separate or combined CVR and FDR, (ANO Schedule 4 Scale SS refers.) This investigation was the first involving a civil helicopter fitted with an FDR and the information extracted from the recorder proved invaluable. The reconstruction and analysis of the final flight path would not have been possible without such information.

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[13] Aircraft Accident Report 2/84

2 Analysis

2.1 General

The accident occurred during severe weather conditions but they were not beyond the capabilities of the helicopter and its crew. The tasks accepted by the aircraft commander were both demanding and high in workload.

Helicopter operations over the North Sea are acknowledged to be conducted in some of the most extreme conditions encountered anywhere. In particular, winter weather can combine the hazards of strong and gusting winds, rough seas, severe turbulence and icing at low level with poor visibility in precipitation. The development of successful passenger and freight charter operations in such conditions is a tribute to the design of the helicopters and the crews' method of operating them. This accident was the first North Sea accident involving collision with the sea by a Super Puma helicopter since its introduction in 1983 and after some 370,000 hours of operation. Its safety record, despite a number of technical failures, is good. For the record, since 1976, accidents involving controlled flight into the sea indicate that such a hazard is ever present in offshore operations. The type of helicopter involved is less significant than the conditions in which it is most likely to occur which are darkness and poor visibility.

This analysis examines the operational background to the accident flight including those decisions leading up to the flying programme conducted by 'GH' on the day of the accident. The relevant weather conditions are examined in the light of aircraft and operational limitations. The accident flight itself is then examined in the light of flight data recordings and the problems of visual contact flight by night at low level in strong winds. Human factor aspects of a failure in human performance are then discussed. With the fortunate survival of the commander, who was also the handling pilot, it has been possible to corroborate much of his evidence with that obtained from the CVR and other sources. Nevertheless, the commander himself is unable to explain the circumstances of the accident and it is not surprising that, in the aftermath of such a traumatic event, his total recollection is uncertain. In attempting to explain the accident, part of this analysis must ascribe to the commander certain attitudes and perceptions which he may not necessarily recall.

The question of passenger safety and the need for some assessment of survivable sea conditions in the event of a mishap is addressed. Certain matters of airworthiness are discussed, in particular those relevant areas of the HARP report and the need for an integrated systems approach to offshore helicopter survivability.

The survival of six occupants, including the helicopter commander, indicates a degree of good fortune, the benefits of training for emergency situations, the successful function of survival equipment, and the dedication of those responsible for the search and rescue of survivors. The deaths of eleven of the occupants show that survival in these circumstances is dependent on the ability to evacuate a small and cramped cabin and the vital necessity for the correct functioning of survival aids.

2.2 Airworthiness

Detailed examination of the helicopter and its systems after recovery indicated that there was no malfunction that could have contributed to the accident. Flight recorder information confirmed that the helicopter was performing normally up to the time of impact. The main cabin structure showed commendable integrity in the face of considerable impact forces and this must have assisted the survival potential of the occupants.

The damage to and within the conical casing of the main rotor gearbox was consistent with a large lateral load having been applied to the rotor mast top when the mast was not rotating and was unrestrained at its lower end. This was consistent with the loading imposed on the rotor mast when the main helicopter wreck was being raised from the sea bed with the splined end of the rotor mast already fractured following its shear failure as a result of impact forces.

2.3 Operational considerations

2.3.1 Operational control

Super Puma 'GH' had been detached to Sumburgh from the helicopter operator's main base at Aberdeen. Apart from the company Sikorsky S-61Ns, on contract to HM Coastguard, it was a single aircraft deployment under the management of the commander, who had been appointed by his company as Chief Pilot, Sumburgh. The commander of HM Coastguard S-61Ns, also based at Sumburgh, was his deputy.

When the crew departed from Sumburgh at 1604 hrs they knew that, having completed their delivery of freight to the Brent 'A' platform, there would probably be a requirement to complete some shuttle flights within Brent Field and also at Cormorant 'A'. The acceptance or otherwise of these tasks was left to the commander without reference to any superior authority. In any case, as the appointed Chief Pilot, he was effectively his own superior. It is therefore pertinent to consider the planning factors that demanded the commander's attention. Weather conditions had considerably curtailed routine flying operations and the client, Shell UK Expro, had therefore to implement an 'ad hoc' arrangement of helicopter support for offshore operations. Thus it was not surprising that 'GH', which was on contract to the client anyway, should be used to the maximum.

The limiting factors to this would be the availability of 'GH's crew within their permitted flying and duty period, and the availability of any relief crew. However, other important planning factors needed to be considered. The extended operating hours of Sumburgh airport and those of possible diversion aerodromes had to be established. It was clear that the severe weather conditions had already closed down offshore based helicopter operations. The extreme wind and sea conditions meant that unstable helidecks, such as the 'Safe Supporter', might have been pitching and rolling outside the permitted limits for Super Puma landings. The short term weather forecast offshore and at base was an important factor, as was the advent of night. The fact that icing conditions were likely to affect at least the outbound and inbound transit flights also needed consideration. All these factors had to be assessed by whoever was to agree the client's requested flying programme, which included the shuttling task.

In the event it was the commander of 'GH' who agreed to the task and, whereas there is some evidence of his consideration of TAFs and actual weather conditions, it is apparent from re-examination of the meteorological data, particularly the 1500 hrs en route forecast winds and temperatures, that he failed to appreciate the crucial fact that the return flight would be at night in conditions in which it may not have been possible to avoid icing conditions in accordance with the requirements of the FM Supplement (see paragraph 1.17.3). The flight was not required under an emergency situation and the maintenance of a safe public transport standard was paramount, even at the expense of perceived commercial necessity.

2.3.2 Flight time limitations

For a duty period starting after 0800 hrs the maximum permitted flying time for a two pilot operation was 8 hours, in a duty period of 12 hours (see paragraph 1.5.4 and CAP 371 paragraph 23.1). The period between the end of the airtest and the eventual departure from Sumburgh could be counted as a rest period and, since one sector had already been flown (the airtest), a Split Duty was permissible. Half of the rest period could be added to the FDP thus extending the maximum allowed duty period to 13 hours and 37 minutes.

The commander had originally decided, at that time quite reasonably, that he should carry out both the airtest and the shuttles. However, the task was then extended, first by the addition of a freight delivery to Brent 'A', then by a sector to Unst to collect a spare part. The start of the flight was then delayed by the need to clear snow off the aircraft. By about 1500 hrs, an hour before his departure on the first leg to Unst, the commander had already been on duty for five and a half hours. In his planning the commander might reasonably have calculated that his own FDP would not have been exceeded provided that he went off duty by 2307 hrs. Allowing for post flight administration, the flight should have been expected, at the time of departure from Unst, to be terminated by about 2230 hrs and, had it not been for the accident, this was most likely to have been the case. Nevertheless, a working day that started when he left home at 0830 hrs and was not due to end before 2300 hrs is long by any standards. Even the three hour rest period would have done little to assuage the effects of fatigue on any normal pilot.

Although 'GH' was not shuttling in the strict definition of the term (average rate of 10 or more landings per hour), the task on which the crew were engaged in the prevailing conditions was tiring. Four inter-rig sectors had been flown in the Brent Field and the accident happened on the first sector of the Cormorant 'A' rotations after a 19 mile transit flight from Brent. The crew had been flying continuously for 3 hours and 45 minutes up to the accident and a further 2 hours and 30 minutes flying was to be expected before landing at Sumburgh. A scheduled break was required by the BHL approved FDP scheme after 6 hours continuous flying had been completed but, in conditions where it was impractical or hazardous to shut down, the commander was authorised to exceed the 6 hour period and would then have been required to submit an appropriate report. The conditions on the evening of the accident would have justified the commander's decision to continue beyond 6 hours of continuous flying. Although the flight was within the guideline limits set out in CAP 371 the circumstances of the long working day, the weather and the in-field changes to the programme combined into an abnormally fatiguing schedule for the crew of 'GH'.

2.3.3 In flight administration

The final hour of the flight was available for analysis of workload through the 60 minute record of the CVR. Although this represents just over a quarter of the total flight time leading up to the accident, it is typical of a multi-sector shuttle operation. The analysis shows that at least 32% of the time was taken up with 'administrative' matters (see paragraph 1.11.2). Even if much of this work may be regarded as routine, it creates for the crew an important distraction from the main task, which is the safe conduct of the flight, in that less attention and mental effort is available for safety aspects.

In addition to the data already electronically recorded, the IHUMS recording facility could further reduce the burden if pertinent details may be typed into the on board computer, which will then both perform calculations and maintain a record for subsequent downloading at base. Experience will show whether this will result in any noticeable improvement on cockpit workload.

The evidence of this accident points to an pressing need to reduce crew's cockpit workload. It is therefore recommended that the current study within the CAA on the subject of cockpit workload should be given a high priority with a view to reducing the workload, in particular administrative matters, of flight crews whilst airborne or engaged in the shuttling task. Meanwhile, standard operating procedures should ensure that flight administration and flight planning must be completed, so far as is practical, before each movement takes place. [Recommendation 4.1].

2.4 Weather conditions and limits

2.4.1 Wind limits

The wind at no time precluded flight, but it did provide particular problems. The prime one, which the commander appeared not to have considered, was the effect of turning downwind whilst flying visually solely by external references, a potentially hazardous manoeuvre that is emphasised in basic flying training.

Although the helicopter can hover at zero airspeed, it requires much more power to do so than it does to maintain level flight with forward velocity. A power setting required to maintain forward level flight will, therefore, be inadequate to maintain hovering flight and any loss of airspeed will cause the helicopter to descend if not checked. Such a reduction in airspeed is the likely outcome of turning away from a substantial headwind whilst visually maintaining a constant ground speed. This appears to be exactly what occurred as 'GH' lifted from the Cormorant 'A' and immediately entered a 180° climbing turn: whilst the perceived ground speed remained fairly constant, the airspeed decreased to zero and an inevitable descent ensued.

2.4.2 Deck limits

On this occasion the helideck pitch and roll figures were being radioed to the crew only during the final few seconds of the flight. Information about the helideck movement was of vital interest to the crew and affected their imminent decision on the feasibility of landing on 'Safe Supporter'. Difficulty in deciphering the figures may have caused some distraction and it would have been wiser to have obtained the information before departing the Cormorant 'A' helideck.

The pitch and roll figures of 4° and 5° respectively which were reported by 'Safe Supporter' referred to the total movement of the deck. This represents twice the 'deviation from the vertical' ie 2° either side in pitch and 2.5° either side in roll. It is with reference to deviation from the vertical axis of the deck that the OM defines the limits (pitch and roll 3° either side of the vertical). The reported figures therefore placed the deck movement within the limits for landing by a Super Puma (see paragraph 1.10.2).

It appears that there has been no standardisation of the exact manner in which this crucial information is passed. Although, on this occasion, the (undefined) numbers passed referred to total pitch and roll, this is not always so. It is therefore highly desirable that the information should be passed in a way which is most easily assimilated by the flight crew: ie is one which is directly comparable with their known OM limitations, which refer to deviation from the vertical axis of the deck.

It is therefore recommended that the CAA should publish an amendment to CAP 437 Chapter 5.3 - Vessel Movement, that stipulates an agreed and unambiguous method of reporting pitch and roll. [Recommendation 4.2].

2.4.3 Icing clearance

Another factor to be considered both at the planning stage and during the subsequent flights was the correlation between the advent of night and the permitted circumstances of flight in icing conditions. There was little possibility of the return flight to Sumburgh being carried out in accordance with the OM and this was quite evident from both the local weather and the Sumburgh METARs and TAFs which the crew had obtained. Nevertheless, the commander appears to have been unaware of the constraints on this flight made by the unavoidable need to fly in icing conditions without there being a 500 feet layer of warm air above the surface in which to shed any accrued ice.

2.5 Human factors

2.5.1 General

It is generally acknowledged that a high proportion of all air accidents involve human factors to a greater or lesser extent. Where there is clear evidence to rule out mechanical failure or airworthiness causes (as in this accident), the investigation must necessarily concentrate on explanations for possible failures in human performance. This is a difficult area in which to make other than subjective assessments, but it can be assisted by flight skills experts and experienced behavioural psychologists. It is not the purpose to be unduly critical of the flight crew, but rather to examine the reasons for their failure in order to recommend measures designed to prevent a recurrence.

The investigation was greatly assisted by having available the immediate evidence of the CVFDR. The recorded data indicated that a major factor in the accident was a hasty and ill considered flight manoeuvre performed by an experienced and competent pilot. In order to examine this performance, a Principal Psychologist from the Institute of Aviation Medicine was co-opted onto the investigating team as a temporary Inspector of Air Accidents. He worked closely with the operational group of the investigation and has validated the parts of this analysis that deal with human factors. Interview of the surviving pilot and detailed examination of the CVR suggested several factors influenced the performance of the crew at the time of the accident: these include the short notice of the flight, the commander's position of responsibility within the company, the worsening weather conditions, the unavailability of other crews, the last minute amendments to the flight plan and the operational difficulties experienced throughout. The most important personal factor was fatigue, which may have adversely affected resource management, decision making and even handling technique. Throughout this report the term 'fatigue' is used as in common usage and not as in the more restricted sense implied in CAP 371. It is defined in the Oxford English Dictionary as 'weariness resulting from bodily or mental exertion'. It is the result, in this case, of several hours of work, travelling and other activity both mental and physical. Collateral evidence is provided by the recording of crew conversation during the last hour of the flight, in that comments, apparently untypical of this crew, suggest a degree of frustration and temporary confusion which could well be indicative of fatigue.

2.5.2 Crew resource management

2.5.2.1 The commander

The commander frequently flew with this co-pilot whom he liked and respected. Although not himself a flying instructor, he took pleasure in fulfilling the normal aircraft commander role of passing on his experience to one less experienced. The commander elected to perform the first part of a right-hand circuit himself, so that the downwind turbulence on the left side of the two structures could be avoided, and in the discussion of this decision to fly a right-hand circuit, the words, "quickest", and "save a big long loop around" were used. It therefore seems possible that the idea of a speedily accomplished circuit to position the helicopter for the co-pilot's final approach (cf. an instructor's "I'll just (quickly) put you on finals" to his student) may have overshadowed consideration of the consequences of so doing.

Virtually all of the commander's considerable experience had been gained in the North Sea environment and it can hardly be imagined that he had not encountered similar meteorological conditions before, albeit with the benefit of flying a powerful helicopter aided by a sophisticated auto pilot. It might be considered, perhaps, that a more beneficial experience of this severe headwind/tailwind effect might have been gained in light helicopters, which demonstrate more clearly the potentially hazardous effects of turning downwind. However, the commander's only experience of light helicopter flying was during his initial training, some ten years previously. It is possible, therefore, that the commander's experience was lacking a broader experience based on several different helicopter types and operating environments which, had he benefited from such experience, might have prompted him to consider this particular effect whilst planning his 'quick' circuit. Nevertheless, regardless of the commander's reason for doing so, the imprudent haste to begin the turn away from the into wind lift-off heading certainly influenced the remainder of the flight and, without it, this accident would not have occurred.

2.5.2.2 The co-pilot

It might be considered that the co-pilot, as non-handling pilot, was tasked with monitoring the flight instruments and should have drawn attention to the rapidly worsening flight profile. However, during the 30 second build up to this situation, he was almost certainly engaged in trying to decipher a radio message concerning the pitch, roll and heave of the 'Safe Supporter' helideck and, no doubt, the presence of these messages in the pilots' headsets would have discouraged any verbal communication between the pilots.

The first clue that all was not well was available from the indicated airspeed which decayed from 70 kt at minus 27 seconds, to zero knots at minus 10 seconds. Significant height loss occurred at minus 15 seconds and the commander had begun to apply collective pitch by minus 12 seconds. Thus the earliest time that the co-pilot could have noticed a worsening airspeed situation was at minus 27 seconds, but the consequent reduction in height would not have become significant to him until about minus 14 seconds, only two seconds before the commander did apply corrective action.

When the descent became very steep, as the AVAD sounded "ONE HUNDRED FEET", the co-pilot did alert the commander with five increasingly urgent calls of "WATCH THE HEIGHT". Even if he had detected the worsening situation earlier, it is difficult to see what effective action he could have taken in the brief time available to him. Although he did give repeated verbal warnings, his ability to have assisted with or taken over the flying controls must be seriously in doubt, particularly since he had full confidence in the commander's ability.

2.5.3 The flight profile

The FDR record shows that the right turn after lift-off was initiated abnormally early and that the initial turn was made a full 20 seconds before achieving the speed for the best rate of climb (V_Y =70 kt), which is stipulated in OM Part 5 Section 1.3.2 as the end of the necessary acceleration phase. In fact, the turn was entered before stabilisation at any speed or height had been established and, by the time the helicopter did achieve 70 kt indicated airspeed, it had already been banked 17° to the right, which was then reduced to 13°, and it had changed heading by 30°. This lack of basic airmanship may well have been due to the onset of some tiredness arising from the commander's long workday (nearly 12 hours since leaving his home).

Another possibility is that his stated desire to relieve himself dictated a rushed circuit onto the 'Safe Supporter', particularly as he mentioned it twice immediately prior to lift-off. Common experience tends to confirm the degradation in performance that can result from such nagging physiological needs.

Having started the turn, the commander cannot recall whether he ever actually saw the 'Safe Supporter' but the ground track plot derived from the FDR together with the likely arc of vision from the right-hand seat suggests that he would have lost sight of it once he had turned through a heading of about 350°(see paragraph 1.11.5). This being the case it is most likely that his attention was concentrated on looking hard over his right shoulder for sight of his destination. At 70 kt IAS the commander lowered the collective pitch lever and the helicopter descended slightly, as shown by the first significant dip in the radio altimeter trace, and this reduction of power would have been perfectly rational, provided that he was monitoring his airspeed and height.

The commander was certainly aware of the close proximity of the 'Safe Supporter' to the Cormorant 'A' and was probably aware of the rate at which he was passing by it. Therefore, as he would be anxious not to approach it too quickly, he may have, intentionally or instinctively, reduced power and raised the helicopter's nose in order to reduce the apparent speed. However, it can be seen from the FDR that only the ground speed was high, as a result of the aircraft turning downwind out of a strong headwind, whilst the airspeed was rapidly decaying.

The fact that the commander was unaware of this loss of airspeed, suggests that his attention was directed solely towards visual acquisition or retention of the 'Safe Supporter', at the expense of an occasional flight instrument scan to monitor the flight profile. It could be that he was also distracted from the task by trying to understand the poor quality radio transmissions concerning the 'Safe Supporter's' helideck pitch and roll movements.

By the time that the collective pitch lever had been lowered from 14°, at what may have been planned as the maximum transit height, to 11°, presumably in order to level off, the helicopter had already lost all forward airspeed and it then had insufficient power to sustain level flight. The consequent descent, although clearly indicated on the flight instruments, initially passed unnoticed by both the commander and the co-pilot. However, ten seconds later, when the commander did notice it, and began to raise the collective lever, the rate at which he did so suggests that he was still unaware of the rapid rate of descent which had built up.

By 1800 hrs it was dark. This added an extra dimension to the difficulty of operating in VCF. Visual cues were less obvious and greater attention was required to maintain safe horizontal and vertical separation from obstacles and the surface respectively.

2.5.4 Human factors summary

A number of factors contributed to the accident flight being more difficult and demanding than normal. It was delayed on departure from Sumburgh due to the late arrival of freight and the need to clear snow from the helicopter. The original task was subject to several amendments and the inability to re-fit seat No 11 reduced the maximum passenger load so that the shuttle programme had to be re-organised. Throughout the flight the severe weather made passenger handling on the helidecks slow and difficult. The strong wind made it difficult to operate the cockpit doors, thus preventing the crew from leaving the helicopter other than through the cabin which was cluttered by boarding and disembarking passengers. Helideck communications were garbled, it was dark and the cockpit was poorly illuminated and was, in general, a difficult place in which to work. The commander himself eventually needed to relieve a full bladder.

Taken together these factors must have given rise to a certain degree of frustration. This most likely contributed to the several errors of judgement made by an experienced and well qualified North Sea Commander. The combination of frustration and fatigue demanded too much of his decision making capabilities and management of resources.

2.6 The lack of response to corrective control inputs

As the collective pitch lever was raised, there is evidence of some aircraft pitch, roll and, to a lesser extent, yaw, all consistent with entry into the Vortex Ring state[14], as is the slight and momentary flattening of the otherwise increasing

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[14] Vortex Ring state: The flow condition existing on the main rotor in a vertical descent, when the rate of descent is approximately equal to the downwards air velocity which generates the lift (provided by the rotor)

torque curve. The performance study carried out by Eurocopter (France), showed that, by the time the collective lever had reached the top of its travel (maximum power applied), the helicopter should have arrested its descent and climbed away. A similar study by DRA Farnborough, but using a different model, showed the same result. It is considered unlikely that any ice accretion could have been sufficiently rapid or severe to have affected the rotor blades which, only seconds earlier, had demonstrated normal torque required to hover over the deck at near maximum weight. It is also unlikely that any accrued salt deposit would have suddenly eroded the aerodynamic performance of the blades.

Thus the actual flight, as recorded by the FDR, is at variance with the two independent mathematical models using the same recorded data in that both of the latter require some additional explanation for the crash into the sea. In the one case a satisfactory explanation is obtained when vertical air movements (both up and down) are applied. In the other case an assessment is made that incipient Vortex Ring must have been present. It is therefore most likely that the apparent lack of effect of the applied power, in arresting the rate of descent in time to prevent collision with the sea, was due a combination of incipient Vortex Ring state and a down draught, both of these conditions occurring in the final few seconds of the flight. Although both mathematical models assumed a smooth surface, the rough sea state with wave heights of up to 11 metres most likely prejudiced the chances of the helicopter flying away.

2.7 AVAD fixed and variable height warnings

As the helicopter climbed above the 200 feet (set on the co-pilot's Radalt bug) and then shortly descended below it, an AVAD warning of 'CHECK HEIGHT' was sounded. The co-pilot's bug should, according to the OM, have been set to 300 feet and, had it been so, the 'CHECK HEIGHT' warning would have played no part in the sequence since the helicopter never achieved that height. However, the crew reaction to this warning was to reset the lower of the two Radalt bugs to 100 feet (co-incident with an already scheduled 'ONE HUNDRED FEET' warning), thereby removing the nuisance of what they believed to be an unnecessary 'CHECK HEIGHT' warning.

The more significant warning of 'ONE HUNDRED FEET' occurred when the accident sequence was already established and the helicopter was descending through 100 feet, some four seconds before impact. Although not directly applicable to this accident, if this pre-scheduled warning height had been set at 150 feet, another four seconds would have been gained.

The original reason for scheduling the fixed height warning at 100 feet no longer applies to UK offshore operations. When AVAD was introduced, flights in Instrument Meteorological Conditions (IMC) permitted a minimum descent height for an offshore radar approach of 150 feet, and the AVAD warning was therefore set appropriately below this. However, as the daytime minimum for such approaches has now been elevated to 200 feet, a more appropriate scheduled warning would perhaps be set at 150 feet.

It is therefore recommended that the CAA should discuss with helicopter operators the safety benefit of raising the AVAD fixed height warning to a more appropriate height for existing minimum descent heights. [Recommendation 4.3].

2.8 Human factors training and research

2.8.1 Flight Deck Management training

Prevention of the human factor type accident is a major air safety goal. In recent years flight crew training has been extended to include Flight Deck Management (FDM), embracing Line-Oriented Flight Training and Crew Resource Management. The ground syllabus for flight crew licence examinations includes some study of human performance limitations. In this accident neither crew member had benefited from these programmes and it can only be surmised as to whether a greater awareness of the insidious effects of growing fatigue and frustration might have prompted a more cautious approach to the task. FDM training is a small but welcome step in tackling the human factor problem but full effectiveness will be reached only with universal application and it is encouraging to see helicopter operators moving steadily in this direction.

2.8.2 Research

Human factor research and discussion takes place in a number of disparate forums but there appears to be no effective co-ordination of this work. It is a popular topic for air safety seminars and other discussion groups as well as being the theme of many safety related magazine articles. This largely academic approach contributes much analysis of the problem but little in the way of solutions. Because of the difficult nature of the subject few practical measures, apart from those mentioned earlier, are proposed. While technology has assisted flight crews with enhanced communications, navigation aids, autopilots and engine control and monitoring devices, the basic handling and decision making skills required remain almost as critical as they were at the inception of helicopter flight. Good training, crew procedures and self discipline form the basic defence against failure in human performance.

The human factor in relation to helicopter flight seems to defy either progress or better safeguarding from the known pitfalls attributable to human error. HARP's first recommendation was:

> 'That the CAA initiate a special study into the detail causes of the significant number of helicopter accidents attributed to 'human error' to see where technology might contribute to useful improvement.'

In response to this HARP recommendation the CAA set up a Human Factors Working Group which identified several areas for improvement in human factor aspects of helicopter operations. The group's findings were reported in CAA Paper 87007 which was published in July 1987 and the group then disbanded. The high cockpit workload associated with administrative paperwork was acknowledged and a partial reduction achieved through the permitted use of tape recorded or written records made by installation radio operators of departure messages including load and fuel states. The possible technological solution in the form of a hand held computer has not materialised and the benefit of using the IHUMS equipment for such purposes remains to be seen. This example is typical of slow progress being achieved over the problems identified in CAA Paper 87007. Six years later the CAA project remains as a possible feasibility study subject to funding being made available.

In 1992 the CAA Chief Scientist's responsibility for safety research management was devolved to the SRG. It was decided to dissolve the Human Factors Steering Group and a new Working Group has been formed to promote these matters within SRG.

It is highly desirable that this important aspect of safety research has some national point of focus to which all those working in this field can direct their attention. This role in respect of safety related research falls to the CAA/SRG and they have the capability to identify and initiate suitable programmes. It is therefore recommended that, in further pursuance of the HARP Recommendation No 1, the CAA should commission a study into 'human error' helicopter accidents. The study should include recommendations for programmes of research and co-ordination of the industry's effort. The possibility of international collaboration should also be examined. [Recommendation 4.4].

2.9 Survival aspects

2.9.1 General

The accident occurred, without warning, in extreme weather conditions for both survival and subsequent rescue. The analysis in this section of the report is made with this in mind and acknowledges that both survivors and rescuers, and their equipment, were operating near the limiting conditions for both survival and subsequent rescue.

Although none of the passengers recalled seeing the EXIS lights around each door or window, this does not necessarily mean that they had failed to illuminate or even that they did not assist in the location of exits. A possible reason for survivors not recalling the EXIS lighting is that the lighting strips were obscured by the foaming inrush of water and other debris as the helicopter began to invert. Another explanation may be that some survivors had already escaped from the helicopter before the EXIS lights had been activated by their saline switches which may not have become immersed in sea water until some time after the crash. Whatever the reason there is clear evidence from survivors that the EXIS lighting had not aided their escape. Similar experience, in which the EXIS lights around the exits and escape windows did not appear to have assisted the passengers in their escape, was also reported by survivors of the accident to S-61N, G-BEWL, in July 1990 (AAR 2/91). The purpose and function of EXIS lighting should be part of the re-assessment of offshore helicopter passenger safety and survivability called for in Recommendation 4.9 (see paragraph 2.9.7).

2.9.2 Aircraft flotation equipment

The hull emergency flotation bags had not been deployed because the crew did not have time to activate them. Although they are primarily designed to provide flotation following an intentional ditching, they must also be useful as additional buoyancy following a collision with the sea. According to witnesses, 'GH' remained at the surface for one or two minutes, generally inverted and awash. Inflated hull flotation bags would have extended this time and, perhaps more significantly, have caused the hull to float higher in the water thus aiding the escape by occupants. Escape is only feasible within a few metres of the surface and therefore any delay in the sinking of the cabin is bound to be beneficial. In an accident scenario it is unreasonable to rely on flight crew initiation of the emergency floats and therefore an automatic system is highly desirable. The manufacturers remain concerned at the possible hazard of inadvertent deployment and would wish to incorporate adequate safeguards. Since the present manual system is only ARMED during landing and take-off, the risk of inadvertent deployment during the cruising phase of flight must be minimal. It is therefore recommended that the CAA should consider amending certification requirements for public transport helicopters operating over the sea to include a suitable system for manual and automatic inflation of emergency hull flotation equipment and that this requirement should also apply to helicopter types currently in service. [Recommendation 4.5].

2.9.3 Cabin door jettison

The examination of the wreckage and the evidence of the surviving passengers indicates that there was no attempt to perform an emergency jettison of either cabin door. The fact that the right-hand door came off in the impact with the sea was, therefore, fortuitous. It is possible that the dinghy in the aperture for the right-hand door was actuated by one of the two passengers seated in the adjacent seats but, since they did not survive, this cannot be ascertained.

The fact that the cabin doors of an AS 332L will not necessarily jettison in an emergency (see paragraph 1.12.2) if the helicopter is on its side or inverted is a reflection of the 'controlled ditching' philosophy and cannot be viewed as acceptable for a wider range of impacts, where the helicopter is likely to remain erect for a very short period. The fact that the windows mounted in the cabin doors are of the push-out 'escape window' variety is a bonus but is not a substitute for a properly jettisonable door. This is particularly true with the prospect of attempting to deploy a liferaft through that door aperture which was the case for 'GH'. This latter point makes the facility to jettison the cabin door under all circumstances paramount and it is noteworthy that the manufacturer favours, for this reason, the location of liferafts externally in the sponsons. Furthermore, to ignore the potential benefit of an escape aperture some 1.35 metres square and to accept substitution of much smaller 'escape' push out windows cannot be seen to maximise the overall system for cabin evacuation under all conditions.

It should be noted that the current Airworthiness Requirements do not require that emergency release mechanisms should be operable through any particular range of aircraft attitudes (see paragraph 1.12.2). Thus the existing jettison mechanism of the AS 332L cabin doors, which may not function with the aircraft inverted, appears to conform to the current airworthiness code. A long term solution would be for the airworthiness code for future type certifications (BCAR 29 and JARs 29 and 27) to specify that emergency release mechanisms should be operable in all aircraft attitudes; this might then be applied to existing helicopter types. In the shorter term, it is recommended that The CAA should re-examine their response to the AAIB recommendation made in Aircraft Accident Report 9/88 with a view to the urgent modification of AS 332L cabin doors so that they can be jettisoned when the helicopter is not upright. [Recommendation 4.6].

2.9.4 Sea survival

Both the commander and the co-pilot were clinging to the liferaft and the former was rescued from it after approximately an hour. The co-pilot was known to have survived for a considerable time, during which he was reported to have made every effort to maintain the morale of his fellow survivors. He eventually drifted away from the liferaft; it is probable that he had succumbed to hypothermia and subsequently drowned.

The five passengers who survived were in the water for between 40 minutes and 1 hour 25 minutes. Their survival equipment must be considered, in general terms, to have functioned effectively for them to have remained alive and conscious in the prevailing conditions. One of the major problems experienced by the survivors, and no doubt by those who did not survive, was being swamped by waves breaking over their heads. The effectiveness of the LSJ spray hood in alleviating the problem cannot be assessed as none of the survivors managed to deploy it.

The right-hand liferaft was deployed, albeit fortuitously and in a damaged state (see paragraphs 1.12.9 and 1.15.2), and was of assistance to the occupants who had escaped from the helicopter serving as a focal point for those who were able to reach it and thus probably helping to maintain the morale and will to survive of the individual members. However, the left-hand liferaft remained in its secured stowage underneath the left-hand seats and it cannot, in this accident, be considered as having been accessible.

This sort of liferaft stowage, away from the aperture through which it will be deployed, is not unique to the AS 332L and is consistent with the philosophy whereby survival equipment is predicated on the 'controlled ditching' case. Nevertheless those accidents in which the impact is unanticipated, at night or into a rough sea demand an equal ability to use all the available liferafts as basic aids to survival. These are the very conditions, remote from the 'controlled ditching' philosophy, which are most likely to militate against successful deployment of liferafts.

Whether liferafts should be mounted internally or externally on helicopters may be argued with equal merit. The current requirements allow for both cases. However, it is yet again apparent that the requirements are predicated on the 'controlled ditching' case and the most effective mounting in the crash into the sea case is not addressed.

The passenger survival suit, having a relatively smooth surface, has nothing on which a firm grip can be obtained and anyone attempting to assist a survivor can only use the fabric of the LSJ. One of the two non survivors, who were found floating with their lifejackets around their heads, was NS1[15]; it is possible that the attempts which were made to pull him onto the liferaft could have started the process which eventually loosened it to the point where it would no longer effectively support him above the water. The only non survivor whose LSJ was damaged and had deflated was NS5. It is probable that he was the passenger who had been snatched from the hands of the crew members of the 'Seaboard Support' when they attempted to rescue him.

The reason why NS2's survival suit was unzipped and his LSJ was around his head could not be determined. NS3 was probably still alive when S4 was rescued; it is possible that the exertion of attempting to grab lines thrown to him and to get nearer the 'Edda Fram' weakened him to such an extent that he was unable to stop himself being swamped by the waves and drowned before he could be rescued. S4 reported that NS4 appeared to be dead very soon after the impact. It is possible that the injuries he had sustained had weakened him sufficiently to reduce his chances of survival.

At present there is no CAA specification for passenger survival suits (unlike flight crew suits) but there is for LSJs. This has resulted in many different types of suit resulting from co-operation between the suit manufacturers, oil companies and helicopter operators. There is a clear need for standardisation which can only be achieved through regulatory action. Furthermore, without suits and LSJs both being subject to a co-ordinated specification an unsatisfactory combination could unwittingly exist. This is a typical example of the need to adopt an integrated escape and survival system in which the inter-relationship of all the survival assets would be considered (see paragraph 2.9.7 and Safety Recommendation 4.9).

2.9.5 Search and rescue

The search and rescue phase was conducted in a sea state which made it extremely difficult for both the surface and air resources to operate. It is a tribute to the standard of the personal survival equipment and the emergency training, together with the skill, dedication and courage of those involved in the search and rescue phase, that six people survived and were rescued. Location of the survivors and escapees did not appear to have been a problem as the scene was close to the installations. The LSJ strobe lights on the survival equipment were clearly visible, although survivors reported difficulty in attaching the light to the hood of their survival suits. It was the recovery of the survivors which proved the most demanding, even to the specialised rescue SBVs and SAR helicopters.

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[15] Identified as S = Survivor; NS = Non Survivor (Escaped but did not survive); NE = Non Escaper

The HLO was required to inform the SBV when helicopter operations are to take place from a platform[16]. The vessel should then move to a position close by that platform. The definition of 'close by' is not specified. For unknown reasons, perhaps an oversight or perhaps in view of the sea state, the SBV, 'Seaboard Support', was not informed of the helicopter movement on this occasion and the vessel was standing off about 1½ nm away. The weather was such that it would have been imprudent to launch the Fast Rescue Craft (FRC) and consequently the vessel itself had to navigate to the area and effect the rescue. Sea conditions and not location were the dominant factors affecting the rescue effort. It is quite impossible for the master of an SBV to anticipate where, in the 'close standby' radius of an installation, a ditching might occur.

Apart from the 'Grampian Monarch' and the 'Seaboard Support', the surface vessels which arrived on the scene in the early stage were supply vessels with high freeboard and without specially dedicated recovery areas; their ability to recover survivors from the water was even more severely limited than that of the SBV.

Helicopters were the more suitable craft for rescue operations in the conditions even though the high seas made winching operations extremely difficult. Two survivors and four bodies were recovered by surface vessels and four survivors and two bodies were recovered by helicopters. One of the rescue helicopter winchmen was incapacitated when he was struck on the head by the gas inflation bottle of the Heliraft from 'GH'. Fortunately another qualified winchman was available in the helicopter. The winchmen are reluctant to wear protective helmets, unlike their counterparts in the Royal Navy and Royal Air Force. They state that such equipment makes it more difficult communicate with survivors. Whilst recognising this limitation it is recommended that the CAA should issue guidance to SAR operators on the need for suitable head protection to be worn by winchmen engaged in SAR operations. [Recommendation 4.7].

2.9.6 SAR co-ordination

In this accident the co-ordination of the search and rescue operation was vested in the RCC because the casualty was an aircraft (see paragraph 1.15.3). However, the environment in which the accident occurred was maritime. Aberdeen MRCC personnel are more intimately involved in many aspects of the offshore operation. They maintain a close liaison with helicopter, shipping and offshore operators and provide regular SAR training courses and exercises for offshore personnel. In an emergency situation positions overlooking the MRCC operations room are dedicated to these agencies. The communications and recording systems are

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[16] The Offshore Installations (Operational Safety, Health and Welfare) Regulations 1976 [SI No 1019/1976] and CAP 437 Chapter 4 paragraph 3.1

comprehensive and up to date, including a Ship Earth Station for satellite communication and a direct link to RCC Stavanger to facilitate the mobilisation of Norwegian air assets. Under normal circumstances most of the search and rescue resources used would be under the control of MRCC; this includes the air resources. No criticism of the RCC is implied but it is considered that the appropriate MRCC would be a more effective co-ordinating agency in the maritime environment even when the accident involves an aircraft. It is recommended that the Department of Transport should consult with CAA and Ministry of Defence on the most appropriate co-ordinating agency for search and rescue operations associated with accidents at sea. [Recommendation 4.8].

2.9.7 Survival summary

This accident has demonstrated that, even in the case where a helicopter strikes the water without warning, the margin between escaping or not and subsequently surviving or not can be very small. Considerable progress has been made in passenger safety in offshore helicopter transportation during the past two decades and it is a tribute to that effort that the margin is so small even in such adverse conditions. The CAA, with regulatory responsibility, sets minimum standards which are published in a manner that allows the industry to determine its own manner of compliance. The CAA welcome the adoption of higher standards than the agreed minimum when the industry decides to do this. It is recognised that the industry has played an active role in the development of survival equipment but it is also recognised that such individual efforts can lead to a fragmented approach with a confusing variety of standards and specifications. A clear lead is required from those with regulatory responsibility and the CAA see their role as 'guide and mentor' to the industry.

Safety deficiencies have been identified in the following areas: LSJs, survival suits, the attachment of strobe lights, possible snagging by passenger headset cords, the visibility of EXIS lighting, cabin door jettisoning whilst inverted, location of Helirafts, and automatic inflation of hull flotation gear. Some, but not all of these aspects are subject to CAA regulation and in many cases a re-appraisal of the requirements is called for. It is however fundamental that the whole question of survival must be assessed in the light of a complete system. For example predicted survival times based on the performance of a survival suit must take into account the ability to escape from an inverted helicopter cabin, the availability of liferafts and the performance of hull flotation gear. Unilateral remedies such as brighter EXIS lighting or cordless passenger headsets could have some unforeseen effect on the whole survival package. In the case of a crash into the sea there would appear to be an overwhelming case for externally mounted liferafts. Conversely, a controlled ditching would almost certainly benefit from internally available liferafts. Rather than prescribe for a worst case scenario or on balance of probabilities, a new and significant methodology is called for by those responsible for safety regulation.

The experience of the offshore industry (already available through such groupings as the UK Offshore Operators Association, British Helicopter Advisory Board and CAA HMLC) together with safety oriented bodies such as Robert Gordon's University and the HSE must be allowed to play an active part in the safety policy. The HSE in particular can provide experience in promoting strategic approaches to the management of risk, one example of which is the safety case regime which has been introduced to offshore operations. It is therefore recommended that the CAA, in consultation with the offshore oil industry and other appropriate bodies such as the HSE, should re-assess offshore helicopter passenger safety and survivability in normal operating conditions using the concept of an integrated escape and survival system in order to promulgate such regulations as are necessary to achieve it; such an assessment should be made against both a controlled ditching and an uncontrolled crash into the sea where the helicopter inverts and sinks almost immediately. [Recommendation 4.9].

2.10 Passenger safety

The sea state was a major limiting factor on survivability. Twelve occupants escaped from the helicopter and all were able to inflate their lifejackets. In more favourable weather conditions, it is possible that all twelve who escaped would have survived and could have been rescued by the SBV and its FRC alone. Under existing regulations the feasibility of carrying out a prompt and effective search and rescue operation, should an accident or precautionary ditching occur, is not a flight planning consideration. In this accident, the difficulties which the rescue resources would experience were predictable and the odds were weighed heavily against a totally successful operation.

It was recognised by HARP that helicopter operations carried a greater risk of ditching in comparison with similar operations by medium size turboprop aeroplanes. Few if any emergency procedures call for the immediate landing of fixed wing aircraft whilst at least five such emergencies require this action in the Super Puma emergency check list. Other offshore helicopter types have similar emergency provisions.

Accepting the greater exposure to the risk of helicopter ditching, some assessment should be made of those conditions which would preclude successful SAR operations following a crash into the sea or an intentional ditching. The FM or OM criteria relate solely to aircraft operations and not to post accident search and rescue. Regulations governing the offshore oil industry and the safety of its personnel do not appear to have addressed this problem. Oil companies themselves might reasonably consider such implications for installation emergencies including the shuttling of personnel by helicopter. Normal transit flying to and from the shore may also be in jeopardy to non survivable ditching conditions but this falls outside the immediate environment of an installation. The initiative taken by Shell UK Expro with the addition of a section dealing with flying operations to the Company Adverse Weather Policy (see paragraph 1.6.3) is welcome in addressing this problem. Whilst the policy does not affect the obligations of the helicopter operator and its commanders it nevertheless focuses on weather conditions which are judged by the client to be suitable or otherwise for the search and rescue of oil workers who might suffer a helicopter ditching. Ideally such a policy should take account of the overall helicopter transport operation in order for example not to jeopardise routine operations by concentrated flying after a suspension due to adverse weather. The policy and its development should be carefully studied by the industry and its regulators.

Whereas oil companies have a duty of care for their employees' safety, so too does the helicopter operator in respect of public transport over water operations. Personnel working offshore are both employees and passengers. Since the transport of passengers offshore is in the nature of a charter operation it is logical that the charterer (ie the oil companies) should concern themselves with safety standards required by them of the helicopter operators. In many cases this aspect is already an important factor in the awarding of contracts to helicopter operators. Ultimately the employer (oil industry) is best placed to determine a tolerable risk for the total air transport operation. In the light of Lord Cullen's recommendations (see paragraph 1.17.8) for a single regulatory body for offshore safety, these matters appear appropriate ones for the attention of the Health and Safety Commission in conjunction with the CAA who are required to ensure, by regulation, the safety of public transport by aeroplane and helicopter. The Offshore Safety Division of the HSE is currently reviewing existing regulations[17] with a view to bringing forward new regulations on evacuation, escape and rescue, as recommended by Lord Cullen. It is recommended that the Health and Safety Commission should address in its current review of offshore safety legislation the need for operators of offshore installations to take account of the effects of weather conditions on the likely effectiveness of search and rescue facilities. [Recommendation 4.10].

2.11 The HARP report

The HARP report focused attention on several safety aspects of public transport helicopters (see paragraph 1.17.6). Indeed, the necessity for HARP arose from a number of helicopter accidents in UK waters. To date the most evident development arising from the HARP report has been that of Health and Usage

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[17] Offshore Installations (Emergency Procedures) Regulations (SI 1976/1542)

Monitoring Systems (HUMS). The availability of the CVFDR, so useful in the investigation of this accident, was a direct result of the recent requirement for public transport helicopters to be fitted with FDRs; some helicopter operators have chosen to install an FDR as part of an Integrated HUMS.

The HARP report was a milestone in identifying a number of difficulties facing the civil helicopter industry in the early and mid 1980s. Many of its recommendations called for research and development which, by definition, were long-term items. Unfortunately the passage of time can blunt the urgency of these well intended and welcome recommendations such that some renewed impetus is desirable. In relation to the HARP recommendations mentioned here, the accident to 'GH' has shown that technology has so far contributed little improvement in avoidance of human error type accidents.

Although this accident was a crash, the survivability aspects were the same as those of a ditching. HARP itself said that ditching was a part of crashworthiness but better considered as a separate case. In airworthiness terms this may be appropriate but in survivability terms there can be little difference in the manner in which survivors find themselves in the water; either as the result of a crash or after an intentional landing. The CAA, following the HARP recommendations, have concentrated on the ditching case which is predicated on the requirement for the helicopter to float upright for five minutes whilst allowing an orderly evacuation and boarding of liferafts. It must be acknowledged that recent collisions with the water by helicopters have shown that survival by some of the passengers is both possible and likely. Therefore post crash survival is an important aspect which the circumstances of this accident tend to confirm. The continued existence of such long standing problems should renew the impetus towards a speedy resolution.

Recommendation 4.4 made earlier in this report embodies the spirit of HARP Recommendation 1 which deals with human factors and recognises the need for more research in these areas.

The benefits of shared experience between civil and military authorities was recognised by HARP in their Recommendation 15. For many years there has been some official collaboration between the CAA and the MOD on helicopter matters but it is felt that much day to day experience is excluded from this channel. For example the Royal Navy have considerable experience of automatically deployed hull flotation gear and yet civil helicopters appear to lag behind in this respect. Military pilots can contribute many useful ideas on the problems of night operations with limited or confusing visual cues and yet civilian helicopter operators seem content to absorb such experience through the small number of Service trained pilots entering civil aviation, rather than through more formal consultation. It is therefore recommended that the CAA should consider inviting Ministry of Defence helicopter specialists to join an appropriate group, such as the Helicopter Management Liaison Committee, with a view to further the exchange of operating experience. [Recommendation 4.11].

3 Conclusions

(a) Findings

(i) The crew members were properly licensed, medically fit and adequately rested to operate the flight.

(ii) Neither crew member had benefited from Flight Deck Management training. At the time of their training for professional licences study of human performance limitations was not in the syllabus.

(iii) The commander was well experienced in North Sea operations and in particular on the Super Puma. He had little experience of any other type of helicopter or environment. The co-pilot was experienced in North Sea operations but had less experience as a pilot.

(iv) At the time of the accident the commander had been on duty for 10 hours and 20 minutes and had been flying continuously for 3 hours and 45 minutes since leaving Sumburgh. The co-pilot's duty period was some 45 minutes less. The approved Flight Time and Duty Period limitations set out in BHL OM, which are based on CAP 371, had not been exceeded.

(v) The helicopter had been correctly maintained and was airworthy at the time of the accident. It had been loaded within its permitted limits and carried sufficient fuel for its task.

(vi) Weather conditions, including the sea state, at the time of the accident were severe but were not outside the permitted operating envelope of the helicopter.

(vii) There were neither regulations nor published criteria of sea states relating to the viability of search and rescue operations following a helicopter crash or ditching.

(viii) The handling pilot, who was also the commander, performed a rushed and hazardous flight manoeuvre which resulted in the crash into the sea. A number of factors, including possibly some frustration and fatigue, may have led him to rush the manoeuvre.

(ix) During the final hour of the flight operation, about one third of the crew's workload consisted of administrative matters connected with the flight thus reducing the amount of mental effort available for operational considerations and flight planning.

(x) Performance analysis indicated that salt accretion or icing of the blades and the airframe did not contribute to the accident. Although some ice or snow accretion was noted on the helicopter's sponson by the HLO, normal hover power for the conditions of wind was indicated at take-off from Cormorant 'A'.

(xi) The absence of a 500 feet height band of positive temperature air into which the helicopter could descend meant that there was little possibility of the planned return flight to Sumburgh being accomplished within the regulations.

(xii) The degrees of pitch and roll reported by the 'Safe Supporter' immediately before the accident placed the helideck within the limits for a Super Puma but the usual manner in which this information is passed can be ambiguous. The crew, who had been unable to hear the HLO's radio report, were still trying to verify this fact when the accident occurred.

(xiii) The visual cues available at night and in snow showers were insufficient alone without frequent reference to flight instruments and in particular the airspeed indicator. Whilst turning downwind in a strong gusting wind, close attention to the maintenance of airspeed was required if it was not to become dangerously low.

(xiv) The handling pilot was distracted from his flight instrument scan by his visual search for the 'Safe Supporter' and, for speed and attitude reference, he relied solely on the rapidly changing visual cues. During the right turn the commander most likely lost sight of the 'Safe Supporter'. The co-pilot, who should have been monitoring the flight instruments, was concentrating on garbled radio transmissions which also hampered communication between the two pilots. The sequence of events left little time for the co-pilot to recognise the worsening situation and to intervene on the flying controls.

(xv) The AVAD height warning at 100 feet occurred too late to alert the crew since by then the pilot had already made corrective control inputs in an effort to avoid the crash. A warning at 150 feet, which is more relevant to current operating limits, would have gained 4 seconds but still would not have averted the crash.

(xvi) Two independent mathematical models using the recorded flight data showed that the helicopter should have climbed away without striking the sea given the corrective actions applied by the commander. The fact that it did not is explained by the presence of vertical air currents, incipient Vortex Ring state and possibly the wave crests of the rough sea.

(xvii) None of the occupants was impeded from escape by impact forces alone. One of the fatalities appeared to have been restrained within the cabin by his headset cord because the quick release jack-plug had become jammed in the seatback.

(xviii) Once the helicopter was in the water the hull flotation gear was not deployed by the crew. Manual activation was the only option available and, given the nature of impact, this was impractical; automatic inflation would have been more effective and the helicopter would probably have remained afloat for longer.

(xix) Most of the survivors did not notice the EXIS lighting. This may have been because they escaped before it had been automatically activated or because the strip lights were obscured.

(xx) Survival times are greatly influenced by the performance of immersion suits and typically a leak of 500 ml reduces immersed insulation by 30%. There are no CAA regulations for passenger survival suits and hence no performance specifications. However, Shell UK Expro ensure that suits worn by passengers on their charter flights meets the same specification as aircrew suits (Specification 19).

(xxi) Some LSJs had slipped up the body. Tests showed that an LSJ that remained in the correct position contributed greatly to breathing ability and gave an added sense of security. In some cases the length of exposure in the rough sea and rescue attempts may have caused the displacement of the LSJ.

(xxii) Only one of the two Helirafts carried inside the helicopter was deployed, probably by an occupant, and this suffered damage from some part of the helicopter's structure such that it was much less effective than its design allowed for.

(xxiii) Co-ordination of the rescue operation was good between RCC and MRCC. Whilst RCC have prime responsibility for aircraft search and rescue, MRCC are better placed to control offshore accidents.

(xxiv) Other than aircraft operating limitations there are no regulations concerning public transport helicopter operations in adverse weather. Since the accident Shell UK Expro have introduced an adverse weather policy which gives their management guidelines on the viability of rescue from the sea in adverse weather. This does not affect the helicopter operators' and aircraft commanders' normal responsibilities.

(b) Causes

The following causal factors were identified:

(i) The handling pilot's failure to recognise the rapidly changing relationship between airspeed and ground speed which is a fundamental problem associated with turning downwind in significant wind strengths.

(ii) The commander, who was the handling pilot at the time, shortly after take-off inadvertently allowed the airspeed and then the height to decrease whilst turning away from a strong gusting wind.

(iii) Despite the application of maximum power, the helicopter was incapable of arresting its established descent within the height available. Incipient Vortex Ring state and down draughts may have contributed to this problem, as may the height of the wave crests.

(iv) Several human factors, including possibly some fatigue and frustration, exacerbated by a demanding flying programme for which the commander was managerially responsible, may have degraded the crew's performance to an extent that the normal safeguards of two crew operation failed.

4 Safety Recommendations

It is recommended that:

4.1 The current study within the CAA on the subject of cockpit workload should be given a high priority with a view to reducing the workload, in particular administrative matters, of flight crews whilst airborne or engaged in the shuttling task. Meanwhile, standard operating procedures should ensure that flight administration and flight planning must be completed, so far as is practical, before each movement takes place.
[Safety Recommendation 93-22]

4.2 The CAA should publish an amendment to CAP 437 Chapter 5.3 - Vessel Movement, that stipulates an agreed and unambiguous method of reporting pitch and roll.
[Safety Recommendation 93-23]

4.3 The CAA should discuss with helicopter operators the safety benefit of raising the AVAD fixed height warning to a more appropriate height for existing minimum descent heights.
[Safety Recommendation 93-24]

4.4 In further pursuance of the HARP Recommendation No 1, the CAA should commission a study into 'human error' helicopter accidents. The study should include recommendations for programmes of research and co-ordination of the industry's effort. The possibility of international collaboration should also be examined.
[Safety Recommendation 93-25]

4.5 The CAA should consider amending certification requirements for public transport helicopters operating over the sea to include a suitable system for manual and automatic inflation of emergency hull flotation equipment and that this requirement should also apply to helicopter types currently in service. [Safety-Recommendation 93-26]

4.6 The CAA should re-examine their response to the AAIB recommendation made in Aircraft Accident Report 9/88 with a view to the urgent modification of AS 332L cabin doors so that they can be jettisoned when the helicopter is not upright. [Safety Recommendation 93-27]

4.7 The CAA should issue guidance to SAR operators on the need for suitable head protection to be worn by winchmen engaged in SAR operations.
[Safety Recommendation 93-28]

4.8 The Department of Transport should consult with CAA and Ministry of Defence on the most appropriate co-ordinating agency for search and rescue operations associated with accidents at sea.
[Safety Recommendation 93-29]

4.9 The CAA, in consultation with the offshore oil industry and other appropriate bodies such as the HSE, should re-assess offshore helicopter passenger safety and survivability in normal operating conditions using the concept of an integrated escape and survival system in order to promulgate such regulations as are necessary to achieve it; such an assessment should be made against both a controlled ditching and an uncontrolled crash into the sea where the helicopter inverts and sinks almost immediately.
[Safety Recommendation 93-30]

4.10 The Health and Safety Commission should address in its current review of offshore safety legislation the need for operators of offshore installations to take account of the effects of weather conditions on the likely effectiveness of search and rescue facilities.
[Safety Recommendation 93-31]

4.11 The CAA should consider inviting Ministry of Defence helicopter specialists to join an appropriate group, such as the Helicopter Management Liaison Committee, with a view to further the exchange of operating experience.
[Safety Recommendation 93-32]

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