AIRCRAFT ACCIDENT REPORT 2/91

Air Accidents Investigation Branch

Department of Transport

Report on the accident to Sikorsky S-61N, G-BEWL at Brent Spar, East Shetland Basin on 25 July 1990

This investigation was carried out in accordance with

The Civil Aviation(Investigation of Accidents) Regulations 1989

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

10 September 1991

The Right Honourable Malcolm Rifkind
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 British International Helicopters Limited Sikorsky S-61N helicopter, G-BEWL, that occurred at Brent Spar , East Shetland Basin on 25 July 1990.

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
AC	-	alternating current
ADELT	-	Automatically Deployable Emergency Locator Transmitter
AFCS	-	Automatic Flight Control System
ANO	-	Air Navigation Order
AOC	-	Air Operator's Certificate
ATC	-	Air Traffic Control
AVAD	-	Automatic Voice Alert Device
B APP	-	Brent Approach
BCAR	-	British Civil Airworthiness Requirements
BIHL	-	British International Helicopters Limited
°C	-	Centigrade (Celsius)
CAA	-	Civil Aviation Authority
CAM	-	Cockpit Area Microphone
CVR	-	Cockpit Voice Recorder
DC	-	direct current
DEn	-	Department of Energy
DFDR	-	Digital Flight Data Recorder
DH	-	Decision Height
EXIS	-	Emergency exit perimeter lighting
FAA	-	Federal Aviation Administration
FAR	-	Federal Aviation Regulation
FLIR	-	Forward Looking Infra-Red
FRC	-	Fast Rescue Craft
g	-	normal acceleration
HLO	-	Helicopter Landing Officer
HORG	-	Helicopter Offshore Route Guide
HSE	-	Health and Safety Executive
ISS	-	Injury Severity Score
JAA	-	Joint Airworthiness Authority
JAR	-	Joint Airworthiness Requirement
LDP	-	Landing Decision Point
LSJ	-	Life Saving Jacket
mb	-	millibars
MHz	-	Mega Hertz
MRCC	-	Maritime Rescue Co-ordination Centre

GLOSSARY(cont)

MRGB	-	Main Rotor Gearbox
MSV	-	Multi-Functional Service Vessel
MTOW	-	Maximum Take-off Weight
NDB	-	non-directional radio beacon
NPRM	-	Notice of Proposed Rule-Making
Ng	-	Gas generator rpm
NPRM	-	Notice of Proposed Rule-Making
Nr	-	Main Rotor rpm
NTSB	-	National Transportation Safety Board (USA)
OM	-	Operations Manual
QNH	-	Corrected mean sea level pressure
RADALT	-	Radar Altimeter
ROV	-	Remotely Operated Vehicle
rpm	-	revolutions per minute
SAR	-	Search and Rescue
SSL(s)	-	Speed Select Lever(s)
UTC	-	Coordinated Universal Time
UHF	-	ultra high frequency
VHF	-	very high frequency

Brent Spar at approximately 0950 hrs. on 25 July 1990.

Brent Spar at approximately 0950 hrs. on 25 July 1990.

Air Accidents Investigation Branch

Aircraft Accident Report No 2/91

(EW/C1172)

Registered Owner and Operator:	British International Helicopters Limited
Aircraft Type:	Sikorsky S-61N
Nationality:	British
Registration:	G-BEWL
Place of accident:	Brent Spar, East Shetland Basin
	Latitude: 61° 03' N Longitude: 001° 40' E Elevation: 105 feet
Date and Time:	25 July 1990 at 0944 hrs

All times in this report are UTC

Synopsis

The accident was notified to the Air Accidents Investigation Branch (AAIB) by the operator, the charterer and the Department of Energy (DEn) shortly after 1125 hrs on the day of the accident. A team of AAIB inspectors began the investigation the same day, based on Multi Functional Service Vessel (MSV) 'Stadive' and in Aberdeen.

The following AAIB personnel participated in the investigation:-

Mr R StJ Whidborne, Principal Inspector (Operations)	Investigator in Charge
Mr R D G Carter, Senior Inspector (Engineering)	Structures (cabin and seats)
Mr P N Giles, Senior Inspector (Operations)	Survival and Human factors
Mr S W Moss, Senior Inspector (Engineering)	Examination of wreckage and airworthiness aspects.
Mr R J Vance, Senior Inspector (Engineering)	Cockpit Voice Recorder

Specialists of the Royal Air Force Institute of Aviation Medicine assisted as follows:-

Wing Commander D J Anton RAF Head of Biomechanics	Survivability
Mr R Green, Head of Psychology Division	Attentional and perceptual factors

The accident occurred whilst the helicopter was manoeuvering to land on the Brent Spar, a permanently moored semi-submersible offshore storage and tanker loading unit. After the helicopter had approached to a hovering position adjacent to the helideck, several witnesses realised that it was positioned dangerously close to a part of the installation's crane structure. The tail rotor blade tips contacted a handrail surrounding the anemometer mast which was attached to the crane 'A' frame after which the helicopter crashed onto the helideck and almost immediately fell over the side of the deck and into the sea. Seven survivors were rescued from the sea having made their escape from the sinking helicopter. Six occupants including the crew perished.

The report concludes that the accident happened when the handling pilot allowed the helicopter's tail rotor to contact a hand rail surrounding the 'A' frame of the Brent Spar crane which resulted in the helicopter crashing onto the helideck before falling into the sea and sinking.

The following causal factors were identified:

(i) Negligible wind offered freedom of choice in the direction of approach but required careful handling of the power available and consideration of any rejected landing profile. An indeterminate horizon made attitude control of the helicopter more difficult.

(ii) Although all the operating restrictions imposed on the Brent Spar helideck by the CAA were observed, a combination of subtle differences relating to this particular landing, as opposed to any other, may have led to the erosion of a safety margin that had already been reduced by the intrusion of the crane structure into the obstacle limited sector.

(iii) The commander's choice of approach was inexplicable given the number of more favourable options open to him but it may have been influenced by his previous experiences of approaching Brent Spar in strong wind conditions.

(iv) Orientation of the rotating helideck when a vessel was moored to Brent Spar meant that the major obstacle would often be positioned behind a helicopter which was landing into wind. Pilots were therefore not unused to this situation and the commander may have accepted the constraint it placed upon the direction of approach.

Ten Safety Recommendations were made during the course of the investigation.

1 Factual Information

1.1 History of the flight

1.1.1 Outbound flight

G-BEWL, ('WL') left Sumburgh Airport, Shetland at 0819 hrs as Shell Flight 1 for the Brent Field which is located some 112 miles north east of Sumburgh (see map at Appendix A). On board were five passengers for the 'Polycastle' accommodation vessel which was located alongside Brent Alpha and 11 for the Brent Spar (see AERAD plate at Appendix A). In order to preserve sufficient fuel for an onshore diversion, the flight plan was amended so that the first landing was to be made on the 'Polycastle', where fuel was available, before making the short transit to the Brent Spar. It arrived at the 'Polycastle' at 0925 hrs, landing on a heading of about 060°. Passengers and freight were off loaded and fuel to the quantity of 323 litres (500 lb on the fuel gauges) was uplifted for the continued flight, which was planned to go to Brent Spar and Brent Alpha Platforms before returning to Sumburgh. The commander had obtained approval from Brent Approach for the final in field landing to be on the Brent Alpha since he preferred to operate from this deck rather than the 'Polycastle' at the projected take-off weight for the return sector to Sumburgh.

1.1.2 Approach to Brent Spar

The helicopter lifted off from the 'Polycastle' at 0940 hrs and established radio contact with Brent Spar on the Brent Approach frequency (122.25Mhz). The Helicopter Landing Officer (HLO) gave landing clearance to the crew. The nine outbound passengers from Brent Spar were assembled by the stairs on the opposite side to the crane cabin and below the level of the helideck. The HLO was at eye level with the deck and he, his assistant and the Offshore Installation Manager saw the helicopter approaching from the direction of Brent Alpha. 'WL' flew a right hand turn passing behind a tanker, MV 'Drupa', that was moored to the Spar with the ship's axis displaced to the south west of the installation centreline. The tanker's heading had been recorded as 132°(T) at 1100 hrs (16 minutes after the accident). Her engines were going slowly astern to maintain a slight pull on the mooring hawser and at 1100 hrs she was experiencing a tidal current of 0.4 knots from the south west.

'WL' flew along the port side of the tanker in what appeared to be a normal manner and became established in a hover adjacent to and about 50 feet above the level of the helideck. It then moved to the right, crossing the edge of the deck and appeared to drift slightly rearwards while yawing to the left. Some of the passengers on board the helicopter became concerned at its position in relation to the installation, feeling that they were abnormally close to the crane and misplaced from the normal landing position. Some of them reported the tail of the helicopter swinging to the right just before impact and it became apparent to eye witnesses on the Spar that there was an imminent danger of the tail of the helicopter striking part of the crane structure. The HLO also observed the helicopter's hazardous position but before he was able to radio a warning to the crew, there was the sound of tail rotor blades striking part of the crane structure. The helicopter thereafter yawed to the right through about 150° and crashed on to the deck whilst still yawing. Meanwhile, the personnel on the Spar had taken shelter beneath the helideck in order to avoid a considerable amount of falling debris. The helicopter momentarily came to rest on the edge of the helideck, partially supported by the personnel safety netting, however, before the passengers and crew could escape, it fell over the edge of the deck and plunged into the sea. Most of the occupants were still strapped into their seats on impact with the sea. Brent Spar personnel quickly launched the installation lifeboat with three crew members in it with the intention of recovering survivors.

1.2 Injuries to persons

	Crew	Passengers	Others
Fatal	2	4	-
Serious	-	4	-
Minor / None	-	3	

1.3 Damage to aircraft

The helicopter was destroyed.

1.4 Other damage

The anemometer mast, including a protective handrail, was struck by the helicopter. The helideck and its anti slip netting was extensively damaged when the helicopter crashed onto it and a portion of the deck edge safety netting collapsed as the helicopter rested on it momentarily before plunging into the sea.

1.5 Personnel information

1.5.1 *Commander*: Male, aged 46 years

Licence:	Airline Transport Pilot's Licence (Helicopters) valid until 29 May 1998
Aircraft ratings:	Westland S55 Series 3, Sikorsky S-61N
Certificate of test:	14 December 1989
Instrument Rating:	Renewed 18 July 1990
Medical examination:	Last examination 8 June 1990, Class one
Flying experience:	Total flying: 9125 hours

	On type: 5450 hours approximately
	Annual: 720 hours
	Last 28 days: 20 hours
	Last 7 days: 18 hours
Previous rest period:	Off duty 1900 hrs 24 July 1990
	On duty 0800 hrs 25 July 1990

1.5.2 *Operational experience*

The commander had learned to fly with the Royal Air Force in 1964 and served as a helicopter pilot until October 1978 when he joined British Airways Helicopters Limited and, later, its successor company, British International Helicopters Limited (BIHL). He achieved command on S–61N helicopters in June 1980. He was appointed a Supervisory Captain[1] by his company on 27 March 1990.

1.5.3 *Landings on Brent Spar in previous two years*

Date	Wind	Vessel moored
21 September 1988	120° /18 gusting 21	No
14 December 1988	170° /21 gusting 24	Yes
14 June 1989	170° /29 gusting 35	No
13 June 1990	010° /22 gusting 28	Yes

1.5.4 *Co-pilot* Male, aged 23 years

Licence:	Commercial Pilot's Licence (Helicopters) issued 23 February 1990 and restricted to day flying only until 31 October 1990. Valid until 22 February 2000
Aircraft ratings:	Hughes 269, S-61N
Certificate of test:	20 May 1990
Instrument check:	25 May 1990
Medical examination:	Last examination 4 January 1990, Class one
Flying experience:	Total flying: 430 hours approximately
	On type: 180 hours
	Annual: 180 hours (North Sea operations)
	Last 28 days: 66 hours
	Last 7 days: 20 hours
Previous rest period:	Off duty 1900 hrs 24 July 1990
	On duty 0800 hrs 25 July 1990

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1 This is the first stage of additional responsibility given to a Line Captain.

1.5.5 *Operational experience*

The co-pilot started his flying training with the Royal Navy before completing it with CSE, Oxford where he obtained a Commercial Pilot's Licence (Helicopters). He joined BIHL on 26 February 1990 and, after type conversion to the Sikorsky S-61N, he began line training from the company's base at Sumburgh in May 1990 and completed his final line check on 23 June 1990.

1.5.6 *Experience requirements - Offshore operations*

General requirements for commanders and co-pilots undertaking day and night operations to offshore helidecks were contained in BIHL Operations Manual Volume 1, Section 4. For commanders operating to a 'Restricted' deck it was required for them "to have been present on the flight deck under the Command of a suitably experienced Captain during Landing and Take-off on the helideck". Co-pilots' initial experience required four landings and four take-offs, with engine failure practice on both approach and take-off phases. Recency for both crew members required one landing and take-off in the previous 60 days. Both pilots were so qualified.

1.6 Aircraft information

1.6.1 *General information*

Manufacturer:	Sikorsky Aircraft, Division of United Technologies Corporation
Registration:	G-BEWL
Type:	S-61N
Engines:	Two General Electric CT58-140-1
Serial number:	61769
Date of manufacture:	1977
Registered owner:	British International Helicopters Limited
Total airframe hours:	15,312 hours
Certificate of Airworthiness:	Current until 10 August 1990. Public Transport Category.

1.6.2 *Aircraft weight and centre of gravity*

Basic weight (as at 10 August 1988):	13,736 lb
Crew (2):	374 lb
Passengers (11):	2,057 lb
Baggage and Freight (forward hold):	170 lb
Fuel (centre tank empty):	2,000 lb
Take-off weight from 'Polycastle':	18,337 lb

Estimated weight at time of accident:	18,277 lb
Restricted landing weight at Brent Spar:	19,000 lb
Maximum authorised take-off weight:	20,500 lb

The Centre of Gravity (CG) datum was 267.4 inches forward of the rotor centroid. At an operating weight of 18,337 lb, the permitted CG range was between 257 and 277 inches aft of datum. At the time of the accident the helicopter was loaded with the CG 265.6 inches aft of datum.

1.6.3 *General description*

'WL' was a Sikorsky S-61N twin-engined helicopter of conventional semi-monocoque aluminium alloy construction with five bladed main and tail rotors (see Appendix B), configured with two pilot's seats and 19 passenger seats (see Appendix C).

1.6.3.1 *Flying controls*

Pilot inputs from the cyclic and collective control levers are transmitted to the main rotor assembly via a system of rods and bellcranks. Mounted on the Main Rotor Gearbox (MRGB) are three simplex hydraulic servo jacks which assist movement of the swash plate using the main hydraulic system pressure of 1500 psi. In the event of failure of the supply pressure these jacks effectively become rigid links which transmit motion from the input rods but provide no power assistance.

To achieve the required redundancy, a second (auxiliary) source of hydraulic power assistance is provided between the pilot's controls and the primary jacks operating on 1500 psi pressure. A unit, referred to as the auxiliary servocylinder and located on the bulkhead behind the Captain's seat, provides hydraulic boost for the flight controls in the event of failure of the primary hydraulic system. In normal operation, both systems work in tandem but either can be de-selected in emergency such as a runaway servo.

The auxiliary servocylinder comprises four banks of servo-mechanisms, three of which actuate the lateral, fore-and-aft and collective controls as do the primary system. A fourth mechanism provides hydraulic boost for the yaw pedals[2]. The lateral, fore-and-aft and yaw servocylinders also incorporate electro-hydraulic servovalves which are driven by signals from the Automatic Flight Control System (AFCS). Two further solenoid valves are installed on the lateral and fore-and-aft servos to respond to signals from the pilot's 'beeper trim' switch which allows small adjustments to be made in these axes. In the event of auxiliary hydraulic power

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2 There was no primary hydraulic boost for the yaw pedals. In the event of auxiliary power failure the pedals could be moved manually but with much higher pedal forces.

failure or de-selection the auxiliary servocylinder reverts to transmitting pilot inputs to the primary servos without hydraulic assistance and without AFCS or 'beeper trim' facilities.

1.6.4 *Maintenance*

The maintenance records indicated that the helicopter had been maintained in accordance with an approved maintenance schedule. The Certificate of Maintenance Review had been renewed on 19 July 1990. The last scheduled inspection had been a 150-hour 'P3' check at 15,302 airframe hours and the next inspection would have been a 50-hour 'P1' check at 15,332 airframe hours. Examination of the helicopter's Technical Log did not reveal any history of defects of relevance to this accident.

1.6.5 *Seats*

At the time of the accident, 'WL' was configured for a total of 21 occupants: that is, two pilots and 19 passengers (see Appendix C). The two pilots' seats were of a military type, model number 762R10000 manufactured by Aircraft Mechanics Incorporated, Colorado Springs, Colorado, and attached at their bases to runners mounted on the cockpit floor.

The passenger seating comprised seven single-seat units and six double-seat units, all Model 650 seats, manufactured by the Burns Aero Seat Company, Burbank, California in the period 1965-69. This model of seat is of a type which may readily be folded away when the helicopter is re-configured for carrying cargo. Looking forward from the rear of the helicopter, the single seats were arranged along the left-hand side of the passenger cabin and five of the double seats were arranged along the right-hand side; the remaining double seat was a bench type seat mounted centrally at the rear of the cabin. All of the passenger seats faced forwards, except for one rearward-facing double seat (Row 8R) mounted just aft of the airstair door. All of the passenger seats, except the rear bench seat (Row 11), were mounted at their outboard end to fittings in the cabin wall and at their inboard end the vertical seat legs were attached to fittings set into the cabin floor.

1.6.6 *Escape windows*

In October 1985 the CAA issued a Direction specifying, for helicopters chartered for off-shore oil and gas exploration, the installation of additional equipment. This included that :

> "(c) All openings in passenger compartments agreed by the Authority as suitable for the purpose of underwater escape shall be so equipped as to be openable in an emergency".

Guidance on interpretation was provided in an Airworthiness Information Leaflet (AD/IL/0124/1-4) issued in December 1987. The Leaflet specified both the requirements for escape window lighting and the minimum acceptable size of window aperture (17" x 14").

In the case of the S-61N helicopter, the three Class 7 Licence North Sea operators co-operated on a common design of escape window as all the passenger windows in the S-61N are above the minimum acceptable size. At the time of the accident, the state of modification of 'WL' was that all the passenger windows had been converted to escape windows, with the exception of the window farthest aft on the left-hand side and the three windows farthest aft on the right-hand side. Although these windows were not specified as escape windows by the CAA, BIHL had begun a programme of converting them as well to escape window specification shortly before the accident.

1.6.7 *Automatic Voice Alert Device (AVAD)*

The helicopter was fitted with an AVAD which was interfaced with the Radar Altimeter (RADALT) and the intercommunication system to give audio warnings at 100 feet and at a preset height using the RADALT bugs. The BIHL Operations Manual, Volume 9: 'Flight Management', described its operation as follows:-

"Operation

A. A 'Check Height' message is heard when the helicopter descends through the lower of the Rad Alt DH[3] bug settings at a rate of less than 5000 ft/minute. This message is repeated after 4.5 seconds.

NOTE:- If Rad Alt bugs are set to the same height the 'Check Height' message is activated at that height

B. During the descent a 'one hundred feet' message is heard when the helicopter altitude is at, or passes through 100 ft, if the rate of descent is less than 5000 ft/minute. This message cannot be inhibited.

CAUTION:-
BECAUSE 'ONE HUNDRED FEET' AND 'CHECK HEIGHT' MESSAGES HAVE THE SAME PRIORITY, A 'CHECK HEIGHT' WARNING IN PROGRESS WILL DELAY THE 'ONE HUNDRED

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3 DH=Decision Height

FEET' WARNING. THIS CAN RESULT IN THE 'ONE HUNDRED FEET' WARNING BEING HEARD AT HEIGHTS SIGNIFICANTLY BELOW ONE HUNDRED FEET.

C. Use of Suspend facility.

1. If the suspend facility is used, the "suspend button" on the collective must be depressed prior to reaching the Decision Height for the 'Check Height' message to be suspended. This suspends operation for 3 minutes. Depressing the 'suspend button' during an active suspend period resets the 3 minute suspend period.

2. If the helicopter is below the DH at the end of the suspend period, the 'Check Height' message will not be heard. activation will only occur when the helicopter climbs above and then descends through DH as described in B.

NOTES:- The 'one hundred feet' message is unaffected by the suspend facility.

The suspend mode may be cancelled at anytime by holding the TEST / RESET switch momentarily to RESET."

From examination of the wreckage it was found that the commander's RADALT (right hand side) bug was set at 50 feet.

1.6.8 *Tail take-off system*

The helicopter's main gearbox was fitted with a through shaft which permitted the No 1 engine to drive the accessory section of the main gearbox in the event of the normal drive system failure. If this should occur the accessory section would be driven at a lower rpm. A frequency sensor would detect the change in frequency of the AC essential bus caused by the lower operating rpm of the AC generators and illuminate a light marked TAIL TAKE-OFF which was located on the central warning panel. Since the AC system lacked frequency protection whilst airborne, the warning light could also be activated when the normal drive system was operating at less than 100% Nr (203 rotor rpm). The sensor would detect an under frequency when Nr was about 97% or 98% and the associated warning caption would be displayed.

1.7 Meteorological information

1.7.1 Synoptic situation and general weather

A ridge of high pressure extended southwards across the North Sea from an anticyclone centered in the Norwegian Sea. Surface wind was variable at 5 knots or less. The sea surface temperature was +13°C. Visibility was probably between 2000 and 3000 metres and the weather was intermittent drizzle. Cloud consisted of a broken or overcast layer of Stratus based at 600 feet with tops at 1700 feet. In local drizzle there was a distinct possibility of patches of Stratus at or around 100 to 200 feet. Sea level pressure was 1023 mb.

1.7.2 Actual observation at Dunlin Alpha (10 miles north of Spar) at 0950 hrs:

Wind: calm.
Visibility: 400 metres in fog.
Cloud: 6 oktas of Stratus at 100 feet with 8 oktas of Stratus at 800 feet.
Temperature: +13°C, Dew point temperature: +13°C.
QNH 1022 mb.

1.8 Aids to navigation

Not relevant.

1.9 Communications

1.9.1 Air Traffic Control (ATC)

All communication between 'WL' and ATC agencies during the flight from Sumburgh were routine and in accordance with normal practise. Once in the Brent Field the flight was under the control of Brent Approach on frequency 122.25 MHz. A relevant extract from the transcript is reproduced at Appendix D.

1.10 Aerodrome information

1.10.1 Brent Spar helideck

The helideck, including the crane, is part of a rotating structure which is mounted on castors on top of the permanently moored semi-submersible offshore storage and tanker loading unit. The structure can be rotated through 360° about the Spar by mechanical means controlled from the installation (see Appendix E). With a tanker moored but not loading, the structure will be rotated under the influence of the vessel and during loading operations the mechanical means is used to rotate the structure to ensure that no undue load comes on the product hoses.

1.10.2 CAA Restriction

In common with all landing areas located on the UK continental shelf, Brent Spar helideck was constructed and inspected to conform to standards set out by the Department of Energy (DEn) in agreement with the CAA. Surveys to check compliance with these standards were carried out by Lloyd's Register of Shipping in its capacity as a Certifying Authority for offshore installations appointed by the Secretary of State for Energy. Lloyd's Register of Shipping issued a Certificate of Fitness (LR GBI 00319/85) in respect of Brent Spar valid, "subject to annual and additional surveys in accordance with the Regulations"[4] until 17 September 1990. The DEn last inspected the installation in January 1990 when no comment concerning the helideck was made. The CAA were not required to make routine inspections of offshore landing areas.

Notes on 'Offshore helicopter landing areas: guidance on standards' are at Appendix F which includes notes on landing area markings, inspection and the responsibility of the operator. These guidelines detailed acceptable obstacle environments and landing area characteristics. They also contained the recommended dimensions of landing areas which were to accommodate various types of helicopter operating in UK offshore waters and this was based on the helicopter type's overall length including rotors. In the case of the S-61N an area of minimum diameter of 22.2 metres was specified. However, where helidecks were of insufficient size to provide the required landing area or where the obstacle environment did not meet the specified criteria, operational restrictions were advised by the CAA. Since Brent Spar landing area could accommodate a maximum diameter of 19.8 metres[5] the CAA imposed certain restrictions that were to be observed by S-61N helicopters operating to and from the Brent Spar. These were:

a. Maximum operating weight to be 19,000 lbs;
b. Maximum permitted pitch and roll 1°[6];
c. Crane to be positioned to the satisfaction of the helicopter captain.

Additionally, to ensure greater security for the tail rotor, a segment of the aiming circle directly opposite equipment located close to the dividing line between the

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4 Regulation 9(1) of the Offshore Installations (Construction and Survey) Regulations 1974.

5 The CAA advised DEn of a 'D' value of 19.8 metres in their letter dated 2 December 1982 and this value was actually painted on the helideck. The subsequent Certificate of Fitness, dated 17 January 1983, contained a typographical error which showed the 'D' value to be 19.18 metres and this was carried over to subsequent Certificates of Fitness. The diference (0.62 metres) did not affect the distance of the nearest obstacle from the centre of the deck.

6 Normal limits for S-61N operations to mobile structures is 3° pitch and roll.

obstacle free and obstacle sector, and over an arc of at least 45°, is to be red and yellow hatched to indicate headings on which landings are prohibited.

1.11 Flight recorders

1.11.1 Cockpit Voice Recorder

'WL' was fitted with a 30 minute duration Fairchild A100A Cockpit Voice Recorder (CVR) and a Fairchild A152 Cockpit Area Microphone (CAM). The channel allocation was as follows:-

Channel 1:	Cabin Address and Nr Signal
Channel 2:	Co-pilots 'hot microphone'
Channel 3:	Pilots 'hot microphone'
Channel 4:	CAM

Specification No 11 (issue 3) was published by the CAA Airworthiness Division on 13 August 1983 and detailed operation of the CVR as follows:

> " 3.5.2 Where the recorder is electrically powered such that it might continue to operate after a crash or ditching, then an automatic means shall be provided to simultaneously stop the recorder and prevent each erasure feature from functioning, within 10 minutes after impact.
>
> NOTE: An acceptable means of compliance would be to install a device which would interrupt the electrical supply to the recorder when the inertial force on the aeroplane exceeds 3g forwards or, for helicopters, 3g along the axis 45 degrees below the horizontal forward axis. In addition, for helicopters equipped in compliance with the Air Navigation Order for flights over water, a device should be installed so as to interrupt the electrical supply to the recorder following an enforced ditching."

The CVR was powered by the DC Essential Bus Bar and provision for a power interrupt in the event of a heavy landing or ditching was provided by a g switch and float switch respectively.

The 30 minute recording started at about 0913 hrs when the commander was arranging his change of flight plan to land firstly on the 'Polycastle' and then the Brent Spar. Following normal checks and briefing, an uneventful en-route descent and rig NDB / Radar approach was completed. Two minutes before landing on the 'Polycastle' the crew discussed the best approach path and the more suitable handling pilot. The commander stated that, in the event of an emergency, the 'overshoot' would be to the right but nevertheless he would remain as handling pilot. He also observed that the wind was easterly but that if the wind had been more northerly then there would have been 'more of a problem'.

At 0938 hrs, when unloading and re-fuelling on the 'Polycastle' had been completed, the commander arranged with Brent Approach to go to Brent Alpha after the Brent Spar, as it would be preferable to take-off from the Alpha deck for the return flight to Sumburgh. He realised that his helicopter would be operating close to MTOW and the obstacle environment on the Alpha was better than that on the 'Polycastle' under the prevailing conditions. The commander briefed his co–pilot that he intended to take-off to the left and then make a sharp left turn in order to keep in visual contact with the Spar. A transcript of the last two and a half minutes of the CVR recording has been superimposed on the ATC transcript at Appendix D.

It is apparent from the recording that the commander was handling the helicopter throughout the approach and landing. His comment about the "crane" is considered to have been most likely in the context of the approach although the actual word is indistinct. Sixteen seconds before the end of the recording, the commander announced his intention of "going across" i.e. moving to the right in order to position the helicopter over the landing area. Four seconds before the end of the recording the AVAD system initiated a 'CHECK HEIGHT' call. It should have been repeated 4.5 seconds later and could not have been suspended by the crew therefore it must be concluded that the second warning would have occurred after the end of the recording (see paragraph 1.6.7).

A time history of recorded Nr and of the frequency signature of the first stage of the Gas Generator (Ng) was plotted (see Appendix D). The recording stopped at 0943:29 hrs. This was most likely due to power to the recorder being interrupted as the g switch activated when it sensed accelerations resulting from the tail rotor strike.

The CVR record showed that the only unusual feature of the flight was the low recorded Nr signal as the helicopter prepared to land on the Brent Spar. The recorded Nr signal was compared to the Nr signal extracted from the CAM channel and from this it was determined that the Nr immediately prior to cessation of recording was approximately 97%.

1.11.2 *Digital Flight Data Recorder*

Under regulations existing at the time of the accident the helicopter was not required to be fitted with a Digital Flight Data Recorder (DFDR) but such equipment is required to be fitted to this class of helicopter operating in these circumstances of flight by 1992. If 'WL' had been fitted with a DFDR it would have assisted in the investigation of the accident.

1.12 Wreckage and impact information

1.12.1 Location and recovery

Immediately after the accident a small amount of wreckage was recovered from the surface of the water. This included the right-hand landing gear sponson, the left mainwheels, the tailwheel and the Automatically Deployable Emergency Locator Transmitter (ADELT).

A Remotely Operated Vehicle (ROV) from the 'Rockwater Smit Semi 2' located the helicopter which could be seen lying on the seabed on its right-hand side at a depth of 139 metres. Underwater survey showed that the helicopter, whilst basically intact, was severely disrupted at the forward fuselage/cockpit area and that the tail boom had folded forwards and was lying on the left-hand (uppermost) side of the fuselage. This section was attached only by the control cables running aft to the tail rotor. The badly damaged left-hand sponson also lay on this side of the fuselage attached only by its bracing strut. Only some 0.5 metres of each main rotor blade remained attached to the rotor head. Other blade debris was located in the vicinity of the main wreckage either as large, almost complete, sections or as small fragments. Recovery of the wreckage was undertaken by the MSV 'Stadive', a larger semi-submersible multi-purpose service vessel. At about 0300 hrs on 26 July the main wreckage was raised to the deck of the 'Stadive' using a strop which had been wound round the main rotor mast. During the lift the partially attached left sponson broke away and was recovered following a series of dives to recover loose debris from the seabed.

Shortly after the helicopter was secured on deck, the bodies of the six victims were removed. The CVR was also removed and taken to the AAIB at Farnborough for analysis.

1.12.2 Examination of the Brent Spar installation

The helideck of the Brent Spar had suffered considerable damage during the accident. It could not be inspected in its immediate post-accident condition due to the requirement to clear loose debris from the deck before further helicopter landings were attempted. In particular, the damaged anti-slip netting was removed and some portions of the friction surface had to be lifted where it had been damaged by the impact. All helicopter debris from the helideck level had been collected. This debris consisted almost entirely of pieces of the main and tail rotors, whilst the lower deck levels also contained many pieces of main rotor trailing edge.

The damage to the helideck itself comprised a segment of the deck edge netting which had collapsed downwards at 90° to its normal orientation (see Appendix G). The adjacent segment had also been folded downwards over roughly one third of its length. White-coloured scrape marks could be seen on the deck surface just within the aiming circle over an arc of approximately 120°. Several deep dents in the steel deck were associated with these scrape marks. A number of main rotor strike marks could also be discerned on the deck. Damage to the crane structure was confined to the handrail at the top of the 'A' frame and the associated mast supporting the anemometer. The former had at least 11 clearly defined strike marks on its upper surface whilst the latter had been crushed almost flat at its mid-point and the signal generator box had been knocked-off onto the deck below (see Appendix I). The damaged section of rail and the anemometer mast were later cut from the structure and despatched to the AAIB at Farnborough. Damage had also occurred to the deck edge lighting system in the area where the helicopter had collapsed the deck edge netting.

1.12.3 *On-site examination of the wreckage*

On completion of the salvage operation it was possible to determine that all of the helicopter had been recovered with the exception of two almost complete main rotor blades and sections of some others. Fragments of the tail rotor blades and fuselage/sponson structure and some other items such as window transparencies were also missing.

The tail rotor hub contained remnants of four blades whilst the fifth blade had broken off close to its flapping hinge and was recovered from the sea bed. Three of the attached blades had substantial damage to their tips which had resulted in loss of variously 9 to 23 cm of tip structure. The fourth had broken off some 25 cm from its root (see Appendix H) and the remainder was not recovered. The fifth (detached) blade had also lost about 10 cm from its tip but was also badly bent and twisted and had lost most of its trailing edge structure. Much of this was identified amongst the debris collected from Brent Spar. The tail rotor drive shaft had fractured mid-way between the intermediate and tail rotor gearboxes and bore evidence of impact by some aerofoil shaped object. There was also another separation of the shaft associated with the severed tail boom.

The engines appeared superficially undamaged apart from a fractured starter 'bullet' on the right-hand unit. This was recovered from the vicinity of the main wreckage on the seabed. There were no signs of abnormalities within the Main Rotor Gear Box (MRGB).

It was noted that, upon recovery, the sliding baggage compartment door on the right-hand side had detached due to structural disruption in that area, the right-hand cabin emergency escape hatch was missing (later recovered from the sea bed) and the left-hand cabin emergency escape hatch had been pushed inwards and was found inside the cabin. All other doors and escape hatches were found in the closed and locked condition with the exception of the various push-out windows, most of which were broken or missing. The life raft associated with the rear emergency door had fallen out of its stowage and was lying uninflated on the cabin floor. Several passenger seats were found to have dislocated or collapsed and a considerable number of interior furnishing panels had detached and were loose inside the cabin.

1.12.4 *Subsequent examination of wreckage*

1.12.4.1 *General*

The wreckage was transported by sea to the operator's main base where the engines were removed under AAIB supervision to enable it to be transported by road to the AAIB at Farnborough. The engineering investigation centred on the following aspects:

a. To establish from analysis of the wreckage and the witness marks on Brent Spar the orientation of the helicopter at the moment of impact with the crane and its subsequent behaviour.

b. Whether any evidence of pre-impact structural, electrical or mechanical failure existed which could account for a loss of control or difficulties in handling the helicopter.

c. The performance of the helicopter's structure, seats and furnishings in relation to survivability of the occupants.

1.12.4.2 *Examination of impact marks and damage*

The nature of the witness marks on the handrail section of the 'A' frame comprised 11 clearly defined strikes on the upper surface of the circular section rail. As illustrated in Appendix I these marks were linear in nature and formed a series of parallel lines at an angle of approximately 65° to the axis of the rail. At no point had these strikes managed to penetrate the heavy gauge material of the rail. The anemometer mast, of thinner gauge material, had received two distinct heavy vertical swipes from above to below which had crushed and deformed the tube. The plastic case of the anemometer signal generator mounted below the marks had been detached by these impacts.

On the helicopter itself, it was possible to discern white paint deposits on the left-hand fuselage side and corresponding dark blue scrapes on the left sponson showing that the sponson had, at some stage, ridden-up and impacted the side of the fuselage in the vicinity of the emergency exit. The left-hand landing gear fescalized ram had broken in bending from left to right but the diagonal sponson support, which has an inbuilt telescoping feature to absorb the energy of a very heavy landing, had not been compressed. This would indicate that the impact with the helideck had not been severe in the vertical sense but the landing-gear had been subjected to considerable sideways translation, causing its failure. The right-hand sponson had detached from the fuselage in a predominantly rearwards direction with the landing gear intact, major damage being restricted to the nose of the sponson and suggesting an impact with the water. Further information on damage to the helicopter's structure relating to survivability considerations are included in paragraphs 1.12.5 and 1.12.6 below.

1.12.4.3 *Examination of the flying control systems*

Despite the damage to the helicopter, it was possible to ascertain that there had been no pre-impact disconnection of the rods controlling main rotor cyclic and collective pitch or the rods and cables controlling the tail rotor. The tail rotor blade drive shaft failures also clearly resulted from impact forces.

It proved possible to connect an hydraulic rig to the manifold supplying the primary servo jacks on the MRGB. Following the application of hydraulic power, the jacks could be actuated easily and smoothly by manually moving the input linkages and exhibited no tendency to jam or 'run away'.

The components of the main rotor assembly, including the pitch control rods had suffered heavy damage due to the main rotor strikes. All failures were consistent with such an event.

The auxiliary servocylinder appeared mechanically undamaged, so this was removed and taken to an overhaul facility where it was subjected to a full function check under AAIB supervision. It was found that the unit performed correctly with respect to hydraulic function but ingress of seawater had impaired the operation of the AFCS electro-hydraulic servovalves, which could therefore not be tested.

The position of the switches as found in the cockpit controlling the hydraulic and flying control functions were all consistent with normal operation.

1.12.4.4 *Examination of engines and engine controls*

The engines were examined without dismantling and with advice from a representative of the manufacturer. Apart from the detached starter motor on the right-hand engine, both units appeared to be mechanically undamaged. The external accessories showed no abnormalities and examination of the intake and exhaust revealed the rotating assemblies to be in good condition. In fact, their condition was such that it appeared that neither engine could have been developing any significant power at the time they entered the water, there being complete absence of any distortion normally seen when an engine under power ingests large quantities of a dense medium such as water.

Examination of the engine controls could not conclusively prove the pre-impact selection on the Speed Select Levers (SSLs). As found, the right SSL was in the GROUND IDLE detent but the left had received a sideways blow which had deformed the mechanism such that the detent latch no longer operated and it could therefore move freely over the entire range from SHUT OFF to 100% SPEED. Given the absence of witness marks, it was not possible to say for certain where the SSLs were at impact with the deck and, subsequently, the sea, since structural disruption could have pulled the control cables and moved the levers and/or the mechanism on the engine fuel control unit.

It was, however clear that the left emergency fuel shut off valve was closed. This valve was activated either by a switch on the pilot's fuel control panel or by pulling the fire emergency fuel shut-off selector 'T' handle on the overhead console. This handle (which is also associated with arming of the engine fire extinguishers) was found to be pulled in the case of the left engine whilst both switches on the fuel panel were selected OPEN. Since valve actuation is by electrical motor, it is beyond doubt that a crew member had pulled the left 'T' handle whilst electrical power was still available. They had not, however, done so in the case of the right-hand handle nor had any fire extinguisher bottles been fired. This latter action required a separate selection.

1.12.4.5 Examination of transmission components

The main and tail rotor gearboxes were strip-examined. Despite the inevitable heavy corrosion due to salt water immersion it was possible to determine that there were no apparent defects in any of the main gears or accessory drives.

1.12.5 Structural damage

The structural damage to the airframe supported the description of the impact sequence given by the eyewitnesses and the survivors. It was apparent from the damage to the left-hand sponson and its fuselage attachments that the initial fuselage impact on the helideck was on the left-hand side of the helicopter and the impact of the left-hand sponson caused sufficient fuselage disruption to allow the left-hand emergency escape hatch to enter the passenger cabin. Otherwise the fuselage was substantially intact, and the seats undamaged, before the helicopter suffered its impact with the water.

Three major airframe failures occurred on initial water impact. Firstly, the right-hand sponson became completely detached. Secondly, the fuselage suffered a failure from approximately station 120 to station 170 (that is, from close to the cockpit bulkhead to just aft of the cargo door). Thirdly, the tail boom of the helicopter failed and folded to the left.

Of the windows in the passenger compartment, the transparency remained intact in two windows, both on the left-hand side. The other escape window transparencies had all separated cleanly from the helicopter. The four windows which had not been modified, in the rear of the helicopter, had all been broken but shards of the fractured transparency had remained in the window apertures.

1.12.5.1 *Impact parameters*

The pattern of damage to the skin of the lower fuselage and the right-hand sponson indicated that, at impact with the surface of the sea, the helicopter was at a pitch angle of some 5° to 10° below the horizon and at a roll angle of approximately 10° to the right of horizontal.

The vertical distance between the helideck of the Brent Spar platform and the sea is 105 feet. Of this distance, approximately 95 feet would have been covered in free-fall, giving an impact velocity of about 75 feet per second (approximately 50 mph) at the surface of the sea.

The damage to the airframe and the seats confirmed that the major impact, that with the water, was mainly vertical but with longitudinal and lateral components. It also showed both that the impact was less severe in the rear of the cabin than in the forward section and that the longitudinal component of the deceleration was more severe in the forward section than in the rear section.

A conservative calculation of the deceleration loads indicated that the velocity change of between 70 and 80 feet per second gave a peak load factor in the range of 20 to 25g at the cabin floor.

1.12.6 *Seating*

1.12.6.1 *Flight deck crew seats*

Both crew-members' seats had remained in place in the cockpit and did not appear to have suffered any major structural collapse as a result of the inertial loads in either impact. However, both the pilot's seat and co-pilot's seat had sustained forward bending distortion of the upper seatback. This appeared to have been due to the intrusion of the structural bulkhead immediately aft of the seats during the structural collapse of this part of the fuselage at impact with the water. Both the pilot's and the co-pilot's four-point harnesses were intact but on the co-pilot's side the restraining bar mounted on top of the seatback had separated.

1.12.6.2 Passenger seats

Of the 13 sets of passenger seating in the cabin, ten were occupied at the time of the accident: six of the seven left-side single seats, three of the right-side double seats (Row 9R having two occupants) and the Row 11 'bench' seat. All the occupied seats showed some degree of damage, ranging from slight deformation to complete separation of the seat. In all cases the deformation was within the structure of the seat itself and the associated wall attachment: the floor attachments, in contrast, had remained entirely in place.

The single seat at Row 2L had separated from the floor. Both the forward and aft seat legs had collapsed completely, predominantly in a vertical sense, and the side fittings had pulled out of their wall attachments. This seat demonstrated the features seen to differing degrees in the other occupied left-hand seats: these included collapse of the rear vertical seat legs, downward motion of the seat base and separation of the wall attachments. Other common features were that the armrests on all the occupied left-hand seats had been deformed to the right, into the aisle, and that the seat lap-belts had remained intact.

The structural damage to seat 3L showed that it had been occupied at the time of the water impact whereas the corresponding lack of damage to seat 4L showed that it was not occupied in the impact. On seat 3L the rear vertical leg had fractured under compressive and bending loads and the forward vertical leg had then buckled. The aft wall attachment had remained in place but the forward wall attachment had separated and the seat base had rotated towards the rear.

The structure of seat 5L (see Appendix C) collapsed in a similar way to seat 3L, with a complete bending fracture of the rear vertical leg although in this case the forward vertical leg remained intact. Both wall attachment points had become displaced from their fittings, the frame of the seat base had suffered bending and the seat had collapsed downwards and to the rear. Of the remaining single seats, 6L and 7L had both sustained damage but had remained attached and upright whereas 8L had collapsed rearwards.

Seat 9R (see Appendix C) was the only seat with two occupants and was the only double seat to have suffered structural collapse: both vertical legs of the seat gave way, as did the forward wall attachment, and the seat rotated to the rear. Double seats 4R and 8R were unoccupied and showed no deformation. Double seats 5R and 6R, both with one occupant, showed deformation of the seat frame but had not collapsed.

1.12.7 *Emergency exit perimeter lighting (EXIS)*

Emergency exit lighting was described in the operator's S-61N Technical Study Guide (Volume 5) as follows:

> "Modification 061/33-50-010 introduces a comprehensive system of lighting to delineate all S61 emergency exits. The lighting elements are in the form of 15" lighting bars or small 2" x 2" corner pieces, manufactured by 'EXIS'.
>
> Class 1 Exis lighting is delineated by 15" lighting bars which are positioned at the top and both sides of the cargo, airstair, and port emergency doors, and on all four sides of the over sponson emergency windows. These lights have three methods of illumination:-
>
> a) By means of a pilot operated switch in the cockpit overhead console, just aft of the right hand pilot's wander light.
>
> b) Through immersion of the CVR float switch (STBD side of the hull just forward of the tail wheel).
>
> c) By immersion of the saline switch which is integral with the individual battery which powers the lights for each exit.
>
> Class 2 Exis Lighting on the push-out windows and any other supplementary escape exits is delineated by four corner pieces. Their sole method of illumination is via the saline switch in each exit's individual battery cell.
>
> Cockpit windows are delineated by 15 inch lighting bars positioned on all four sides of each exit. The lights are not triggered by either the CVR float switch or the cockpit switch, as their illumination prior to or during touch down at night, would affect the pilot's night vision during a critical phase.
>
> The sole method of illumination for each cockpit window is the saline switch on the base of its individual battery cell. The two cells are positioned on the bulkhead behind the respective pilot's seat, at a height of approximately two feet above the cockpit floor.
>
> The individual battery cells in the 'EXIS' system will provide steady lighting for some 20 minutes[7] , and the Class 1 cabin lights should only be switched on from the cockpit immediately prior to a ditching or forced landing. Battery

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[7] This is a guaranteed battery duration. In fact sufficient power to illuminate the lighting could be available over a much longer period.

life will be rapidly shortened by switching procedures, and the system is presently installed on a 'hands-off' basis. The engineering department will carry out a periodic functional check of the lights on the maintenance schedule. All emergency exits and escape windows were marked by EXIS strip lighting. Each EXIS is powered by an independent battery and can be triggered by a dedicated saline switch."

When the helicopter was recovered onto MSV 'Stadive' it was noted that most of the EXIS lighting was still operating and later testing of each system revealed it to be fully serviceable.

1.13 Medical and pathological information

1.13.1 Injuries

At Appendix C, the seating diagram for the helicopter shows in which seats the occupants died and the Injury Severity Score (ISS) for all seat occupants. The ISS is the sum of the squares of the three most serious regional injuries. This method of scoring was adopted in the 1989 accident to Boeing 737-400 G–OBME at Kegworth (AAR 4/90). It is a method of scoring injury severity in a way that can be correlated with aircraft damage and, in the absence of secondary factors such as drowning or fire, provides an estimate of the likelihood of death or serious permanent incapacitation (ISS of 16 equating to a 10% probability of death). Injury details for the deceased were coded from autopsy records. Only significant injuries were coded. Injury details for the survivors were supplied by the Aberdeen Royal Infirmary.

1.13.2 Fatal injuries

Post mortem examination of the crew members revealed no pre-existing medical condition which was considered to have contributed to the accident.

There were considerable differences in the injuries sustained by the two pilots. This is reflected in the differences in the ISS (commander 41, co-pilot 12). The injuries to the commander, his position partially out of the helicopter, and the fact that his harness was undone, perhaps immediately following impact with the helideck, strongly suggests that he was not restrained at the time of the impact with the water. The nature of his injuries were such that he would have been immediately incapacitated and unable to escape.

The co-pilot's injuries were less severe. He suffered a fixed dislocation of his right shoulder which would have prevented him from using his right hand to operate the quick release fastener of his harness. A minor head injury may have further incapacitated him. The type of shoulder dislocation indicated that his right arm was extended prior to the impact which caused it (this could have been either the impact with the deck or the impact with the water).

The most serious injuries were to the occupant of the single seat in Row 2 (ISS 75). These injuries occurred principally as a consequence of the seat collapse. The injuries to the occupant of Row 3 (left) were much less (ISS 14). The damage to this seat shows that he was displaced to the right on impact. The injury to his left ankle is a typical impact injury. He clearly survived the impact and freed himself from the seat but failed to exit the helicopter.

The passenger in the single seat in Row 5 suffered serious injuries, although his ISS did not fully reflect their severity (ISS 22). His head injury was incapacitating. The damage to his face suggested impact with the back of an armrest. Photographs show that, on recovery, this passenger was displaced to the right and thus may have hit his head on the back of the armrest of either the seat in front or the double seat to the right of him. His injuries may have been related to the intrusion of the airframe and emergency exit adjacent to his seat. The damage to his seat suggests that, during the principal impact, he would have been moving forward and to the right. The injuries to his face were similar in character, although greater in extent to the injuries suffered by the passengers in the single seats in Rows 7 and 8. It is likely that all of these injuries share a similar injury mechanism, that is flailing around the lap belt, with facial impact on the back of the armrest of one of the seats in front.

Both occupants of the double seat in Row 9 suffered slight injuries (ISS 1) which would not have been incapacitating. The seat collapsed and the passenger seated in the outboard side effected his own escape. The other occupant had not released his harness and had drowned.

1.13.3 Survivor injuries

The passenger in the single seat in Row 6 suffered facial lacerations and a compound comminuted fracture of the right tibia and fibula that was almost certainly related to the collapse of the seat in front of him. The passenger in the single seat in Row 7 fractured two right ribs. The armrest of his seat was displaced to the right as was the armrest of the seat in front of him. The single seat in Row 8 collapsed, but the passenger sustained only minor injury (ISS 1) and made a successful escape. Three other passengers sustained only minor or trivial impact injury. One passenger was uninjured.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Evacuation

The flight deck and the front portion of the passenger compartment were severely disrupted by the impact with the sea and the majority of the cabin windows were either broken or ejected by the distortion of the airframe or the force of the water. The fuselage sank almost immediately but survivors were seen in the water shortly afterwards. They described how water ingress was rapid. Two passengers escaped through the right hand emergency window aperture, one through a broken fixed window on the right side and one through a push-out window aperture next to his seat on the left side. The occupant of the rearmost seat escaped through the rear left fixed window which was broken. One passenger could not recall how he escaped; the window next to his seat was one of two push-out windows still in position when the wreckage was recovered. Another passenger on the left side was uncertain about his egress, however, it is likely that both escaped through apertures on the right hand side which would have been above them at the time. All seven survivors came to the surface in the same area, relatively close to the installation, and three of them managed to swim to one of the helicopter sponsons which was floating nearby.

1.15.2 Rescue

At 0945 hrs an emergency message was broadcast from Brent Spar, the installation was put on RED ALERT and the lifeboat was launched. The standby vessels in the immediate area were 'Seaboard Support' and 'Seaboard Sentry'; 'Support' was positioned between the Brent Alpha and Bravo platforms, about one mile from the Brent Spar; 'Sentry' was about 400 metres to the west north west of the Brent Spar. Both standby vessels launched a Fast Rescue Craft (FRC) and proceeded to the search area. Brent Bravo was instructed to release supply vessel 'Far Sleipner'. A request was passed to the Maritime Rescue Co–ordination Centre at Aberdeen to scramble HM Coastguard Search and Rescue (SAR) helicopter from Sumburgh. The accommodation semi-submersible 'Safe Gothia' was instructed to scramble its Bell 212 SAR helicopter. Meanwhile, another BIHL S-61N which had been waiting on Brent Bravo flew at once to the scene of the accident and the co-pilot photographed the immediate scene. The Multifunction Service Vessel (MSV) 'Stadive' was positioned five miles west of Brent Alpha and the MSV 'Rockwater Smit Semi 2' about two miles away. Both vessels called their divers to the diving bell and set course for the search area.

The 'Spar' lifeboat went to the aid of a survivor who was lying face down about 40 metres from the installation. His life saving jacket (LSJ) was not inflated and his immersion suit had taken in water. One of the lifeboat crew jumped into the water and the semi-conscious person was manhandled aboard at about 0947 hrs.

By 0950 the MV 'Drupa's' lifeboats had been brought to standby and the 'Sentry' FRC had arrived in the area. The first person picked up by the 'Sentry' FRC was bleeding from a head wound and appeared to have a broken leg; the second appeared to be uninjured but was drifting away from the scene; three more, one of whom had sustained a back injury, were recovered from the detached and floating sponson from 'WL'. The FRC then set course for the 'Sentry 'and at 0951 hrs five survivors were transferred before the FRC returned to the search area.

A Bell 212 from 'Safe Gothia' arrived in the search area at 0955 hrs whilst the HM Coastguard S-61N, departed Sumburgh. The 'Support ' FRC arrived at 0956 hrs and picked up a survivor who was floating freely some distance from the others. It was noted that he had a cut on the head. Seeing no other survivors in the immediate area, the FRC set course for the 'Support'. By 1005 hrs it had been determined that all the personnel based on Brent Spar had been accounted for but six occupants of the helicopter were still missing.

At 1010 hrs a survivor was transferred from the FRC to the 'Support'. Brent Spar lifeboat had moored alongside but, due to the heavy swell, the crew were unable to transfer their survivor to the standby vessel. This was later effected via the FRC.

At 1022 hrs a Bell 212 lifted from the 'Safe Gothia' to begin Forward Looking Infra Red (FLIR) operations. To facilitate this the standby vessels were instructed to move to the north of the area. A Royal Air Force Nimrod maritime patrol aircraft was diverted from its training task to assist in the search and was expected to arrive at 1050 hrs.

The survivors were given first aid on the standby vessels. At 1030 hrs a doctor was winched onto 'Sentry' and the transfer of survivors, by helicopter, to the 'Safe Gothia' accommodation platform began; the first arrived at 1035 hrs. The transfer of survivors to the 'Safe Gothia' was completed by 1147 hrs. On the vessel they were given medical treatment and, at 1344 hrs, all seven survivors were flown directly to the Aberdeen Royal Infirmary.

At 1047 hrs, the 'Rockwater Smit Semi 2' launched a ROV, which located the main wreckage at 1122 hrs. 'Stadive' moved over the area and began a survey. 'Stadive' launched its ROV at 1406 hrs and by 1517 hrs, it was confirmed that the six occupants still unaccounted for were in the wreckage which lay on the seabed. At 1520 hrs the search for survivors was officially ended.

1.15.3 *Life Saving Jackets (LSJ)*

The passengers wore the RFD LSJ 102 Mk2BA. The jacket was contained in a pouch which was worn at waist level and was secured by tapes that were passed round the body, and fastened with a double bow. To don the LSJ, the pouch was unfastened, the jacket extracted and then fitted over the head. It was inflated by pulling a toggle on the side. Ideally the RFD LSJ 102 Mk3BA should be donned prior to the ditching, but as there was no warning, this had to be accomplished in the water and these actions were all performed after evacuation. A majority of the survivors, even those with relatively minor injuries, experienced significant difficulties.

The ingress of water to the cabin was rapid and at least one survivor experienced some initial difficulty finding his seatbelt buckle. There was a strong possibility that the LSJ pouch may have impeded his access to it.

Once in the water, a majority of the survivors found the LSJ difficult to unpack and fit, this was especially a problem for those with injuries. One survivor never did manage to fit or inflate his LSJ properly. This, combined with the fact that his immersion suit had taken in water, left him floating face-down. Fortunately, he was very close to the Spar but there is little doubt that he would not have survived had it not been for his timely rescue and first aid treatment by the Spar lifeboat crew.

1.15.4 *Liferafts*

Following recovery it was noted that the forward Heliraft (RFD 14R Mk1) had been dislodged from its mounting but not inflated. The rear Heliraft had also become dislodged from its stowage on the inboard wall of the rear emergency exit. On recovery the life raft was found punctured and deflated although the inflation bottle had been discharged.

1.15.5 *Automatically Deployable Emergency Locator Transmitter (ADELT)*

The helicopter was fitted with an ADELT which was mounted on the right of the tail boom just aft of the airstair door. Once deployed, the beacon was intended to transmit simultaneously on both VHF and UHF emergency frequencies and also to respond to any radar interrogation. Design battery life was for 48 hours of continuous operation. The ADELT had been armed by the crew prior to lift off from the 'Polycastle' in accordance with standard operating procedures. Automatic deployment of the beacon would be achieved when any one of three fuselage mounted frangible switches or the salt water submersion actuator energised the helicopter DC power supply or deployment battery respectively, whereupon an electrically detonated squib initiated ejection of the beacon by means of powerful springs.

Following the accident, the ADELT was quickly recovered by one of the vessels in the area. It appeared to have deployed normally but, would have been operating for only a short period before it was switched off. Some six weeks after the accident, the beacon was examined by the manufacturer who found that the radio transmitter battery was so low that transmissions would have been weak, however, power to the radar transponder was just sufficient for it to have operated normally.

1.16 Tests and research

Nil.

1.17 Additional information

1.17.1 Crew duties and responsibilities

The duties of the commander (C), handling pilot (H) and non handling pilot (NH) were listed in Section 2 of the BIHL Operations Manual as follows:

> "Duties of C
> Nominate H/NH
> Brief or designate briefing of passengers
> Nominate who is to make radio calls
> Sign the Tech Log and Load Sheet
> Brief P2 on the operation of engine controls
> Monitor ATC calls
>
> Duties of H
> Initiate drills
> Keep hands and feet on the flying controls at all times in flight except in the cruise with HDG hold engaged, when feet may be off the yaw pedals.
>
> Duties of NH
> Tune and identify Nav aids as specified by C
> Maintain Nav and Flight Log
> Prepare Load Sheets
> Do Power Assurance Checks
> Operate SSLs and U/C Controls (see below)
> Write down and read back ATC clearances
> Record, and Monitor compliance with, ATC instructions
> Supervise Loading/Unloading"

Normal RPM Control Levers (Speed Select Levers) are used to select a desired power turbine speed that is thereafter automatically maintained by the fuel control units. SSLs are connected directly to the stopcocks and indirectly to the fuel metering valves in the fuel control units. Movement of the lever changes the power turbine speed influence upon fuel metering and causes the fuel control to change its amount of metered fuel which, in turn, changes the gas generator output. Prior to take-off, NH will select SSLs forward to set Nr not above 106% with matched torques. Once safely established in the climb, power is reduced and Nr maintained at the normal operating speed of 100%. During a normal offshore approach and landing, NH maintains Nr between 100% and 106%. This generally requires some forward movement of SSLs as power is increased to bring the helicopter to hovering flight.

1.17.2 *Take-off and Landing technique - offshore*

At the time of the accident, guidance to S-61N crews on the technique to be used when landing on offshore platforms was contained in the BIHL Operations Manual (OM) Volume 9 'Flight Management' Section 2 'Crew duties and procedures' dated 1 July 1987 :

"B. Twin Engine Approach and Landing

Normal approach to approximately 300 ft from the platform.
Gradually decelerate to a hover approx 100 ft from platform
Manoeuvre to hover over landing pad."

In Section 8 (Performance) the Landing Decision Point (LDP) was described as: "In hover alongside platform". The technique was described thus:

"1. Approach to hover alongside platform, wheels down.
2. Manoeuvre to position in hover over landing pad."

After the accident the operator revised Section 2 of the OM thus:

"B - Twin Engine Approach and Landing

Carry out a normal approach to approximately 300 ft from the helideck edge. Gradually decelerate to achieve a Landing Decision Point approx 100 ft from the deck edge, with wheels approx 30 ft above the deck height. This LDP will vary with ambient conditions, but represents the point in space through which the helicopter will pass which is the latest point from which a safe go-around may be initiated either in normal operations or in the event of a malfunction.

Having reached the point where the handling pilot (H) decides that in the event of any malfunction he is committed to the landing and cannot safely fly away, (i.e. after flying through the LDP), he is to call "COMMITTED", and the non-handling pilot (NH) is to acknowledge this call.

Manoeuvre carefully from the LDP to position the helicopter in hover above the intended landing point. Avoid unnecessary large control movements and also avoid rearward movement if at all possible. Such positioning from LDP should be made smoothly and carefully, ensuring the correct landing point is not flown through, and obstacle clearances are not reduced. Land from a stabilised hover.

C - Approach Considerations

Due to the considerable number of variable factors, including but not limited to wind vectors, deck size, the obstacle free sector and other vessels and installations in the immediate vicinity, each approach is in real terms different, and the helicopter commander must decide and brief which is the optimum. However several principles apply.

As far as crosswind limitations allows, approaches should be completed with the landing point remaining within the view of both pilots.

The rate of closure with the aiming point, and the rate of descent as the helicopter crosses the deck edge are critical in ensuring that the helicopter can be brought to a hover over the landing point without eroding obstacle clearances and without large power changes. Therefore, if at the LDP the helicopter is not in a stabilised approach, or the landing manoeuvre will involve large control inputs or power changes at a late stage, the approach should be discontinued.

On multi-sector flights, each individual approach must be considered carefully. Crews must be aware of possible changes in wind direction, the location and orientation of cranes, movement of other vessels, or even changes of movement of the helideck itself between approaches, where helidecks are located on floating or semi-submersible vessels or structures."

1.17.3 *Significance and orientation of the 'H'*

During the investigation a small and random survey of experienced North Sea pilots revealed an almost complete unawareness that the orientation of the 'H' was designed to assist in location of the obstacle sector, although originally this had not been the case. It was also revealed that pilots could sense something wrong when the 'H' was incorrectly orientated.

1.17.4 *Helicopter Landing Officer (HLO)*

Chapter 4 of CAP 437[8] "Offshore helicopter landing areas: guidance on standards" sets out the duties of the HLO as follows:

> "It shall be the duty of the Helicopter Landing Officer of an offshore installation to ensure, before any helicopter lands on or takes-off from the installation, that:
>
> (a) the helicopter landing area is clear of obstructions, including:
>
> (i) any ice, snow, heavy spray or seas on deck;
> (ii) loose tools, machinery or other articles; and
> (iii) oil, gas or other flammable substances;
>
> (b) any cranes in the immediate vicinity of the helicopter landing area have ceased to operate;
>
> (c) no persons other than persons whose presence is necessary for safe helicopter operations are in the vicinity of the helicopter landing area;
>
> (d) the fire fighting equipment for the helicopter landing area is manned by adequately trained persons;
>
> (e) any vessel standing by to render assistance to the installation has been informed that helicopter operations are to take place; and
>
> (f) any safety nets on or around the helicopter landing area are properly secured and in good condition."

1.17.5 *Previous collisions*

A digest of occurrences involving helicopter collisions with offshore installations is given at Appendix J. Of the fourteen accidents listed, three involved the tail rotor striking part of the structure, one involved the tail wheel striking the helideck safety rail and one involved the main rotor striking the crane jib. The list is based on records that have been maintained by the CAA since 1976 and, whilst not complete,

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8 Extracted from Statutory Instrument No. 1019/1976 The Offshore Installations (Operational Safety,Health and Welfare) Regulations 1976.

covers the most intensive period of helicopter support for North Sea gas and oil exploration and production. The digest also includes a number of foreign occurrences.

1.17.6 *Current seat requirements*

UK certification of the S-61N in 1964 was based on a comparison of US Civil Air Regulations Part 7 and the relevant BCARs. The pertinent issue of BCAR Section G (Rotorcraft) was Issue 2, dated 1 February 1963 and chapter G3-8 ('Crash landing conditions') detailed the strength requirements for seats. This required that all combinations of.inertia forces up to a maximum of 6g should be considered, using components, relative to the rotorcraft, of:

> 6g downwards to 3g upwards
> 4g forwards to 3g backwards
> Zero to 3g sideways. These load factors are applicable to the weight of the seat and a 170 lb occupant.

In November 1975 the CAA published Issue 5 of BCAR Section G. This included a requirement that a factor of 1.33 should be applied to the strength requirements for seat and harness 'local attachments' but did not alter the deceleration load factors.

In December 1986 BCAR 29 replaced BCAR Section G as the basis for new certification of rotorcraft in the UK. BCAR 29 (Emergency landing conditions - General) carried forward the same load factors as chapter G3-8 of BCARs. BCAR 29 (Seats, Safety Belts and Harnesses) specified the same additional factor of 1.33 for attachment points for seats and harnesses.

1.17.7 *Changes in seat requirements in the United States*

Historically, the static load factors required by the Federal Aviation Administration (FAA) for "Emergency landing conditions" have been lower than those specified by the CAA: FAR 29.561 and FAR 27.561 specified, until 1989, static load factors for seats of:

> 4g downwards to 1.5g upwards
> 4g forwards
> 2g sideways.

However, in the 1980s the FAA and the helicopter industry co-operated in studies to improve the crashworthiness of civil helicopters; this work stemmed, in large part, from work performed in the 1960s and 1970s by the US Army, consolidated in the publication of the US Army Aircraft Crash Survival Design Guide. The FAA's rotorcraft programmes were conducted in parallel with similar projects to improve the crashworthiness of Part 25 aircraft (Transport category aeroplanes) and Part 23 aircraft (General aviation aircraft).

In 1986 the Crashworthiness Project Group of the Rotorcraft Airworthiness Requirement Committee made recommendations to the FAA for energy-attenuating seats with shoulder harnesses. In response the FAA issued a Notice of Proposed Rule-Making (NPRM 87-4) in April 1987 and in November 1989 the FAA issued the final rules, as Amendments 27-25 (Normal category rotorcraft) and 29-29 (Transport category rotorcraft).

Both amendments closely matched the NPRM in:

1. prescribing a shoulder harness for each occupant;
2. revising upwards the static load factors to be considered in the design of seats and
3. the definition of 2 dynamic tests.

Static load factors - The static load factors applied to seats and other items of mass within the cabin were increased to:

Upward :	4.0g
Forward:	16.0g
Sideward:	8.0g
Downward:	20.0g (after any stroking of the attenuation system)

Dynamic Test Requirements - Two tests are defined, using instrumented 170 lbs anthropomorphic test dummies to simulate the occupants. To simulate the effects of cabin floor deformation, the parallel floor rails or fittings in both tests are misaligned by at least 10° in pitch and roll before the dynamic test.

<u>Test 1</u> approximates to a near-vertical impact, with some forward speed, applying a minimum of 30g deceleration from a minimum velocity of 30 feet/second, canted aft 30° from the vertical axis of the seat.

<u>Test 2</u> approximates a horizontal impact with some yaw, applying a minimum of 18.4g deceleration from a minimum of 42 feet/second, the seat yawed 10° from the direction of deceleration.

Although these rules took effect in December 1989, they apply only to new transport category aircraft types and do not apply to existing aircraft types, or to their derivatives. A further NPRM (89-32) has been issued to cover the proposed installation of shoulder harnesses in all newly manufactured rotorcraft, even if they have a Type Certificate preceding December 1989.

1.17.7.1 *Accident to Sikorsky S-61L, N618PA, at Newark, New Jersey, USA on 18 April 1979*

The investigation of this accident was conducted by the National Transportation Safety Board (NTSB). Their report (AAR 79-14) concluded that the accident occurred when one of the five tail rotor blades separated from the helicopter and the resulting vibrations caused the tail rotor and its gearbox to separate from their mountings. The helicopter entered a rapid nose down right turn at about 150 feet and the ground impact was on a grassy area next to the runway. There was no fire and the fuselage, substantially intact, came to rest on its left side.

Of the 18 persons on board, three passengers were killed, 10 passengers and the three crew members sustained serious injuries and two passengers sustained minor injuries.

The passenger seats in N618PA were, as in 'WL', a mixture of single and double Model 650 seats manufactured by the Burns Aero Seat Company. Only 3 of the occupied passenger seats remained intact and the damage reported to the seats was similar to that in 'WL', with structural failures at both floor and wall attachments. Among the report's conclusions was that "the failure of the seat support and tiedown structure contributed to the number of fatalities and serious injuries".

1.17.7.2 *Accident to S-61N, G-BEON, near the Isles of Scilly on 16 July 1983*

This accident occurred when the helicopter flew into the water in a gentle descent. Of the 26 occupants, 20 were killed. The AIB report (AAR 8/84) noted that six of the double passenger seats had separated as a result the impact, with separations occurring both at the wall and the floor attachment points.

A number of the floor attachment separations had occurred where there was a simple sliding collar holding the moving tongue in engagement with the floor fitting, without positive locking. In the case of the S-61N, the UK operators and the CAA acted to remove this problem and in November 1987 this action was consolidated for all aircraft types by the CAA issuing Appendix 37 to Airworthiness Notice 12. This required that this type of seat attachment fitting be replaced with a style of fitting requiring positive manual action to release it.

The AIB report also noted that the BCARs (chapter G3-8) required that helicopter passenger seats be able to withstand the loads generated by a longitudinal deceleration of 4g, whereas deceleration tests on sample seats indicated that the actual deceleration in the G-BEON accident was considerably higher than this. The recommendation was, therefore, made that:

"The requirements concerning the strength of helicopter passenger and cabin attendant seats be reviewed". (Recommendation 4.8, AAR 8/84).

Following the recommended review, the CAA have stated that it is Joint Airworthiness Authority (JAA) policy to include the FAA amendments in JAR 27 and 29 certification codes. Furthermore, the review of structural requirements intended to maintain a survivable volume within the airframe is being considered as a next stage in the continuing development process.

1.18 New investigation techniques

Nil.

2 Analysis

2.1 General

The flight from Sumburgh to the 'Polycastle' was made without incident and the commander's decision to change the flight routeing so that he could re-fuel on the 'Polycastle' as soon as he was safely in the Brent Field was prudent. The en-route descent and alternative procedure NDB/Radar approach were competently flown, with the commander pointing out to his co-pilot some of the planning aspects involved. Having discussed the most appropriate handling pilot for the landing, the commander, occupying the right hand seat, decided to complete the landing on the 'Polycastle' himself. The final heading of about 060° being into what slight wind there was at the time.

The accident occurred following an approach that was made somewhat difficult considering the prevailing weather conditions, lack of significant wind and chosen approach. Possible reasons for the commander's choice of positioning and the resulting handling difficulties that he may have encountered are analysed. The landing manoeuvre is assessed both in the light of witness accounts and the performance of the AVAD. An examination of helideck certification, inspection and markings is made in conjunction with a psychologist's analysis of attentional and perceptual factors (see Appendix K).

Detailed examination of the wreckage did not indicate any technical malfunction that could have contributed to the accident. There is no doubt that loss of control of the helicopter followed the loss of tail rotor effect after it had collided with the anemometer mast, whereupon the main rotor torque caused the fuselage to rotate before it hit the helideck.

Several factors contributed to the survival of seven passengers, notably their training in survival techniques, the favourable weather and proximity of rescue vessels. This analysis discusses whether the collapse of several seats contributed to the inability of four passengers to escape.

2.2 Approach to the Brent Spar

With the 'Polycastle' passengers disembarked and re-fuelling completed, the turn round checks were carried out and the commander informed the co-pilot that he would turn sharp left after take off in order to remain in visual contact with the Spar. From eyewitness evidence it is clear that 'WL' then flew past the south side of the Spar before turning right to fly round the stern of the tanker MV 'Drupa'. During this approach the Spar landing area was on the commander's right-hand side and, given the conditions of negligible wind, an approach from this direction was feasible.

However, in view of the short time taken to transit the 1.6 miles from 'Polycastle' the commander may have judged such an approach to be too hasty. In fact, the commander elected to approach the landing area on a heading that was roughly aligned with that of the tanker. Again, in terms of wind considerations this was feasible but now the only significant obstacle, the crane assembly, was positioned to the right and rear of the helicopter. Indeed, given the design of Brent Spar helideck, it would always assume this orientation when under the influence of a moored vessel which would lie facing into wind and subject to any modification by tidal currents. The commander would have needed to look over his right shoulder in order to keep the landing area in view and the co-pilot could probably see nothing of it at all.

In view of the commander's more recent experiences of landing on the Spar (see paragraph 1.5.3), when in every case there was a strong wind blowing and in two cases a vessel was moored in such a way as to provide a good indication of the wind direction, the positioning of the MV 'Drupa' on the day of the accident may have prompted the commander to fly the approach in the way that he did. Furthermore, he was probably content to fly almost right round the landing area and its attendant obstacles whilst he planned his approach.

The co-pilot appears to have performed his duties of monitoring and managing the engine power parameters satisfactorily, although the rotor rpm was allowed to droop to 97% as the helicopter came into hovering flight. This differed from the preceding landing on the 'Polycastle' when rotor rpm (Nr) was maintained above 100% as a result of the co-pilot's handling of the SSLs (see paragraph 1.17.1).

It was noted that, in contrast to the previous landing on the 'Polycastle', there was hardly any exchange of instructions or reports between the crew members. This may be partly explained by the fact that the landing on Brent Spar was occurring so shortly after the one on the 'Polycastle' and the previous briefing was still held to be valid. It may also indicate that the commander was fully occupied with his approach and landing to the exclusion of any involvement by the co-pilot. The latter was in no position to assist or advise the commander.

From the time history of recorded Nr and of the frequency signature of the first stage of the Gas Generator (Ng) (see Appendix D) it can be seen that Ng and Nr increased prior to take off from 'Polycastle' as the co-pilot advanced the SSLs. The helicopter lifted into the hover, checks including indicated torque were completed and the helicopter continued towards the Brent Spar. One minute and 18 seconds after lift off the Ng and Nr decreased. Although no comment was made on the CVR, this was as a result of the the SSLs being adjusted. During the next one minute and 14 seconds both Ng and Nr remained relatively constant until the helicopter began turning around the MV 'Drupa', when Nr began to reduce slowly and Ng increased. This is consistent with the application of increased collective pitch as the helicopter slowed down into hovering flight. Nr reduced below 97% and it is possible that this low Nr, with the consequent reduction in the aircraft 400hz AC electrical supply, triggered the TAIL TAKE-OFF warning caption on the central warning panel and the Master Caution caption.

The CVR record indicates that the handling pilot did not call attention to this low value of rotor rpm. Also at 97% there was a slight possibility of the AC power supply being interrupted with the consequent loss of Automatic Flight Control System (AFCS). In the unlikely event that this had occurred, the commander could have been distracted at a crucial stage of the approach, although there was no evidence of such distraction from the CVR. Furthermore, the commander did not call for the SSLs to be placed 'fully forward', which would have been an obvious remedy to his perception of a low rotor rpm. His audible detection of this condition was less likely as it occurred gradually rather than suddenly and during a period of high workload. It must be concluded that although the rotor rpm was low, possibly as a result of the co-pilot's distraction or inattention, it did not significantly affect control of the helicopter.

Consideration was given to the possibility that the helideck had moved unexpectedly, perhaps under the influence of the tanker, during the landing manoeuvre. There is no doubt that in conditions of rough seas and strong winds the whole of Brent Spar can move rapidly and unpredictably. It is for these reasons that the much reduced limits for pitch and roll have been applied since the helideck can move laterally over a considerable distance. It is, however, noteworthy that this limitation currently applies only to S-61N helicopters. On the day of the accident conditions were such as to make this highly unlikely. However, the influence of the tanker MV 'Drupa' with propulsion slowly astern and being subjected to tidal drift, caused the helideck to rotate during the morning. Witnesses on Brent Spar do not recall any movement of the deck at the time of the accident. In the time scale of 16 seconds from the commander's stated intention of "going across now" to impact, any movement of the deck was considered insignificant.

2.3 The AVAD alert

Four seconds before the end of the CVR recording a single 'CHECK HEIGHT' message was heard (see paragraph 1.11.1 and Appendix D). The equipment appears to have functioned normally and as might have been expected with the lowest RADALT bug set at 50 feet (see paragraph 1.6.7). Obviously the helicopter was higher than 50 feet above sea level as it came to hovering flight alongside the landing area. As it moved to its right and over the structure, the RADALT would have sensed a reduction in height to less than 50 feet but, since the rate of closure would have been greater than 5000 feet per minute, the warning should have been inhibited.

However, if the helicopter was at a height greater than 50 feet above the landing area as it moved to the right, the warning would have been activated as the helicopter descended to below 50 feet above the deck. This is considered to have been the more likely scenario, particularly since it fits most closely with the time interval between the AVAD warning and tail rotor impact.

2.4 The manoeuvre to land

The approach terminated with the helicopter hovering adjacent to the landing area in the manner recommended in the performance section of the Operations Manual. It must be recognised that every offshore landing will have its own peculiarities, particularly in relation to the wind direction, obstacles and deck layout, together with safe approach and go-around paths. The handling pilot must exercise his discretion in the light of all these factors at the relevant time of landing. In this case the commander did not take the opportunity to approach with the obstacle clearly in his view but chose an approach which he may have thought was facing into whatever slight wind may have been blowing. This is an important consideration for a heavily laden S-61N but, since the landing was to be on a restricted deck, 'WL' was being operated at a weight some 2160 lbs below MTOW. Nevertheless, it was noted by the co-pilot that 65%-75% torque was required to hover alongside the installation. This was a normal power requirement under the circumstances but considerably more than half of the available twin torque, which meant that the helicopter would have been incapable of hovering with one engine inoperative. It thus illustrates the need for careful management of the power available when hovering in negligible wind conditions.

At the time of the accident there was no published recommended height at which to hover but, from S-61N training and performance for hover in ground effect considerations, it was accepted that about 30 feet above the deck was ideal. Analysis of the AVAD warning and the manner in which the 'A' frame handrail was struck suggest that the helicopter was at least 50 feet above the deck prior to impact. This would have a significant effect on the amount of structure visible to the pilot: the higher he was the less he could see. In order to retain sufficient visual reference it is likely that the handling pilot inadvertently moved rearwards as he descended and thus unwittingly towards the obstacle. It is clear from eyewitness evidence that the helicopter was under control as it moved to its right and slightly rearwards. The handling pilot had poor visual cues, such as there were being confined to the helideck immediately below and to his right. Maintenance of a steady hover over the deck would have required good attitude reference but, in the absence of much structure within the pilot's field of view, the relatively smooth surface of the sea, which in turn merged with an indistinct horizon, would have been a poor substitute. These factors may also explain the inadvertent rearwards movement of the helicopter.

As soon as the tail rotor struck the crane 'A' frame it lost its effectiveness in counteracting the main transmission torque and the helicopter would have started to revolve about its vertical axis at an increasing rate. To cope with such an emergency in the hover requires immediate removal of the torque by stopcocking both engines and simultaneously reducing collective pitch to a minimum. The commander certainly lowered the collective lever which resulted in the helicopter landing heavily on the edge of the helideck. Evidence of the engines being shut down is inconclusive and it is possible that at least one SSL was retarded (see paragraph 1.12.4.4). Nevertheless the torque effect was cancelled as soon as the helicopter was in contact with the deck. Under the circumstances, this was the best that the crew could hope to achieve.

The handling pilot would have been aiming to position the cockpit area immediately over a suitable segment of the yellow aiming circle and, in accordance with normal practice, at a wheel height of about 10 feet. Indicators of the obstacle sector which would have been visible to the handling pilot were the prohibited landing sector and the white painted 'H'. This latter item, although the significance of its orientation is described in CAP 437, may not have been known by the commander. The small and random survey of experienced North Sea pilots referred to in paragraph 1.17.3 indicated an almost complete lack of awareness that the 'H' was designed to assist in location of the obstacle sector, although originally this had not been the case. Nevertheless, it was also apparent that pilots could sense something wrong when the 'H' was incorrectly orientated which would suggest a familiarity with its usual orientation. It is unlikely that the commander was other than typical in his appreciation of this and therefore his primary aid for a safe landing was the aiming circle. It has therefore been recommended that the attention of all offshore operators be drawn to the significance of helideck markings, in particular the 'H' and its orientation in relation to the obstacle free sector.

2.5 Landing area characteristics

2.5.1 Certification and inspection

At the time of the accident responsibility for the certification and inspection of offshore landing areas rested with several different agencies. Primary responsibility for design and construction was with DEn who in turn delegated the responsibility for survey to a Certifying Authority, which, in the case of Brent Spar, was Lloyd's Register of Shipping. This procedure was probably adequate in terms of monitoring compliance with the regulations by the operators of the installation. However, it could not cover actual helicopter operations, which would require assessment by a specialist with adequate background training and which was not available to either DEn or the Certifying Authority. Concerning the operation of helicopters to and from the installation, the CAA was available to advise DEn and the Certifying Authority of any operational restrictions to be imposed on decks that could not meet the agreed criteria. Brent Spar, by virtue of the fact that its 'D' value was 11% smaller than that prescribed for S-61N helicopters, required that such helicopters were operated at a reduced weight, in order to give a greater performance margin. Further restrictions were placed on the amount of deck pitch and roll permitted and the positioning of the crane during helicopter operations.

The CAA had also identified a possible hazard from the crane structure, in that it was close to the boundary of the 150° obstacle sector and in fact infringed upon the sector in which obstacles were limited to no more than 1.11 metres in height. Hence a prohibited landing sector had been imposed, which was marked by red hatching marks on the aiming circle. It is important to realise that this sector was designed to prevent helicopters landing with their tail orientated towards the obstacle: it did not preclude helicopters manoeuvering in such a manner that the cockpit area infringed the sector prior to touch down. In this situation the distinction between 'approaching' and 'landing' and at what point the one becomes the other is unclear. If the helicopter adopted a heading within the prohibited landing sector at any height below the crane structure (30 feet) then its tail would be hazarded. It would thus be helpful to define the parameters of any prohibited landing sector more clearly and this should be included in the recommended revision of helideck markings (see paragraph 2.5.3 below).

These operational constraints had been devised by the CAA as a result of careful scrutiny of the helideck drawings and dimensions. The significance of the rotating helideck, such that a moored vessel would generally orientate the only significant obstacle (the crane 'A' frame) into a position behind a helicopter that was landing into wind, was presumably apparent to the original author of the operational restrictions. Furthermore, there was ample opportunity for feedback of any special operating problems from the Authority's own Flight Operations Inspectors who maintained close contact with the operators. Indeed operators themselves have the responsibility given in ANO Article 28 to satisfy themselves that intended landing areas are "suitable for the purpose".

Although S-61N operations had been completed successfully to Brent Spar over a period of several years and, apart from the incident in September 1977, involving a Bell 212 helicopter which struck the crane jib cable (see Appendix J), there was nothing to suggest that the Spar deck was unduly hazardous. Operational advice had been obtained from the CAA. In order to provide such advice, physical inspection by trained aviation specialists is considered essential. Arrangements for such inspection will need to take account of the 'Cullen Report' into the Piper Alpha disaster. This report recommended that there should be one regulatory body for offshore safety (recommendation 23) and that it should be located within the Health and Safety Executive (HSE) (recommendation 25). It is therefore recommended that CAA considers with HSE the best arrangements for inspection of at least all restricted helidecks, and ideally all helidecks, which are regularly used by UK registered helicopters.

Operational information about Brent Spar helideck was available to the crew in their company OM supplement and the AERAD 'plate'. It is not known whether the crew referred to these publications on the day of the accident and it may be surmised that the commander had relied on his knowledge of Brent Spar gained on previous occasions. However, if he had chosen to refer to the publications, perhaps to educate the co-pilot, the information presented was inaccurate in that the helideck markings were neither drawn to scale on the 'plate' nor correctly positioned in relation to the general helideck layout and the prohibited landing sector was not shown. The plate notes that "S-61N may operate subject to CAA operating restrictions" but these restrictions are not listed and must be sought elsewhere. They are listed in the company OM but the statement "Crane to be positioned to the satisfaction of the helicopter captain" is ambiguous and may, in this instance, refer to the crane jib in elevation or azimuth or the whole crane including the rotating deck. The second note on the AERAD plate is also ambiguous and would be more correct if it stated that "the helideck was rotatable through 360° when NO tanker loading was taking place." With a tanker moored, the helideck could only be rotated within the confines permitted by the tanker's position in relation to wind and tide.

The aviation industry has long been well served by AERAD publications. The service in relation to North Sea installations differs from that relating to licensed aerodromes and their associated instrument approaches and departures in that it is a simple guide to landing areas, their location, communications and physical characteristics. In view of the number and different types of landing areas , including those that are migratory in nature, the task of maintaining up to date information is not underestimated but it has the merit of providing information to a common standard. There is no formal method whereby this information is promulgated unlike, for example, the UK Air Pilot which includes an officially sponsored directory of aerodromes. It has been recommended that information that is carried on the flight deck includes all the relevant information and that AERAD landing area plates, or their equivalent, are drawn to scale with all markings shown. It is also recommended that official sponsorship of such publications be considered.

2.5.2 *Attentional and perceptual factors*

In November 1990 during the investigation of this accident, a series of approaches were flown in an S-61N to Brent Spar and these were observed by the Head of Psychology Division, RAF Institute of Aviation Medicine. Part of his report is at Appendix K and gives some consideration of the factors that may have led to the commander's mishandling or misjudgement.

While it is impossible to ascribe any weighting to the factors mentioned in the report, they do suggest that a combination of subtle differences relating to this particular landing, as opposed to any other, may have led to the erosion of a safety margin that had already been reduced by the intrusion of the crane structure into the obstacle sector.

2.5.3 *Assistance to pilots*

Following several helicopter ditchings during the past 15 years the question of mandatory carriage of crew members in addition to the flight crew has been raised. Under current regulations, cabin attendants are not required to be carried whenever the number of passengers is less than 20 and this reflects the norm in present day North Sea helicopter operations. In the context of the accident to 'WL' it is pertinent to consider whether an additional crew member might have prevented the landing accident. Troop carrying helicopters of the Royal Air Force employ a crewman whose duties include assisting the pilot by reporting obstacles and helicopter positioning during manoeuvres close to the ground but any such assistance would be limited in the context of helideck landings, where there is generally less freedom of choice in respect of landing direction. Additionally, since a crewman could observe from only one side of the helicopter (in the case of the S-61N it would be from the forward cargo door on the right side) there would be many occasions when the crewman would be totally unsighted in relation to the landing area. So far as ditching is concerned, a crewman or cabin attendant would be unlikely to have any significant effect on the outcome of an unpremeditated ditching or crash into the sea such as occurred to 'WL'. For these reasons no recommendation concerning the provision of additional crew members is made.

The HLO realised that the helicopter was dangerously positioned prior to the impact. Given that four seconds before the impact the helicopter was at least 50 feet above the helideck and therefore its presentation in a hazardous position from the HLO's point of view probably occurred within this time frame, there was hardly any time for him to radio a warning to the crew. In any case such a method of communication could not be relied upon since other transmissions could not be excluded. His duties (see paragraph 1.17.4) did not include the giving of any landing guidance to helicopter pilots. Commonsense would dictate a radio warning about any hazardous situation but in no circumstances should an HLO be made responsible for helicopter landing manoeuvres.

It is axiomatic of all operations by single main rotor helicopters that the tail rotor is vulnerable to collision with obstructions or the ground. This is exacerbated by the fact that pilots cannot see the tail and is supported by the fact that several of the accidents listed at Appendix J involved the tail of the helicopter. Some form of protection, in addition to good airmanship and prudent handling, is highly desirable.

It is recommended that methods of ensuring greater security for the tail rotor whether by revised helideck markings, visual position indicators or proximity warning devices be examined.

2.6 Airworthiness aspects affecting survivability

2.6.1 Seat collapse

The successful escape of seven occupants with relatively minor injuries shows that the accident was, in the main, survivable. The principle damage to the helicopter was to the front and to the left, this matched the more serious injuries. The collapse of passenger seats undoubtedly complicated escape, contributed to injury and may have lead directly to fatality. The injuries to the passenger in Row 2 were typical of those seen when seats collapse and the occupant is subject to secondary collisions with other items of aircraft structure. Had this occupant been adequately restrained, and had his seat not collapsed, he might have survived the impact and escaped.

The structural damage to the cockpit of the helicopter was severe and would have made escape extremely difficult. It is clear from the overall damage to the helicopter that there was a considerable mismatch between the available structural strength in the airframe and the modest strength of the seats. This led to the seats collapsing before the airframe.

Evidence of the surviving passengers indicated that, following the impact with the sea, the passenger cabin rapidly filled with water and the survivors escaped through the nearest window to their seat. It was to aid rapid evacuations of this type that the CAA specified escape windows for this category of helicopter operations. The evidence from this accident confirms the benefit of the provision of escape windows throughout the passenger compartment.

The injury and evacuation information in this accident shows that all the fatalities occurred due to drowning rather than impact injury and that at least two of the victims drowned with injury scores which make it extremely unlikely that they became unconscious in the impact (see paragraph 1.13). All of the passenger fatalities were in seats which collapsed upon impact with the sea surface although the supporting floor structure under all the passenger seats, except seat 2L, remained intact. Thus the survivability in this accident would have been increased by the provision of improved seats (see paragraph 1.17.7) which would have attenuated the impact loads and provided effective upper torso restraint. This would both have reduced the level of injury due to impact loads and put the occupant in a better position to make a rapid evacuation.

2.6.2 *Restraint System*

The passengers were secured by lap belts. Two of the fatalities, the passengers in the single seats in Rows 3 and 5, showed evidence of having flailed on impact and struck their heads on seats or items of structure in front of them. In the case of the Row 5 fatality, the impact was incapacitating and directly contributed to the passenger's death. Four of the survivors also showed evidence of injury from poor restraint. One other passenger (Row 11) survived the impact despite apparently having released himself from his seat belt prior to impacting the water.

The finding that improved seating would both have reduced impact injury and increased the likelihood of successful evacuation also applies to the 1984 accident to S-61N, G-BEON, near the Scilly Isles, in which 20 of the 26 occupants died, all from drowning (see paragraph 1.17.7.2). The CAA response to the safety recommendation arising from that accident was to require the removal of single action floor fittings. This was helpful in itself but, since the safety recomendation had not specified it, the wider issues of seat strength, energy attenuation, and shoulder harnesses were not addressed.

Comparison of the estimated deceleration in impact of 'WL' with the water (paragraph 1.12.5.1), and the static strength requirements under which the seats were approved (paragraph 1.17.6), shows that the impact loads were considerably in excess of the both the CAA and FAA requirements at the time of the certification of the S-61N. The impact velocity of 70-80 feet/second was also higher than the 30 feet/second and 42 feet/second specified in the new dynamic test requirements of FAA Amendments 27-25 and 29-29 (paragraph 1.17.7). The dynamics analysis and the comparative lack of damage to those double seats with only a single occupant (seats 5R and 6R), however, indicate that the actual impact loads in the cabin of 'WL' were not substantially above the 30g and 18.4g levels specified in the FAA Amendments. Furthermore, the lack of damage to the floor structure of 'WL' demonstrates that the floor would be compatible with this type of seating. It is recommended, therefore, that the CAA should amend BCAR 29 to include static and dynamic test requirements to at least the standards of FAA Amendments 27-25 and 29-29. Furthermore, these standards should be incorporated into the corresponding Joint Airworthiness Requirement.

Amending the Airworthiness Requirements is, however, only applicable to new helicopters presented for type approval; it does not address the existing fleet or continuing production of existing designs. The evidence from this accident, and from research both by the US Army and the FAA, demonstrates that the provision of shoulder harnesses significantly reduces injuries in helicopter accidents, even with seats designed to the lower static requirements. It is recommended, therefore, that the

CAA should require that newly manufactured helicopters of UK registration should have an effective upper torso restraint installed at every seat position which should also exploit the available strength of the airframe. It is also recommended that this provision should apply to existing helicopters within the next five years.

During the investigation it was noted that the individual weights of the six fatalities were all above 170 lb and the average was 186.2 lbs. The provisions of ANO 1989 Section 3: The Air Navigation (General) Regulations 1981 compensate for this where "the appropriate weight for male passengers over 12 years shall be 83 kg" (182.6 lb) This regulation applies to the calculation of an offshore helicopter's operating weight but the same figure has not been used for seat strength determination. It is recommended that the passenger weight specified in ANO 1989 Section 3: The Air Navigation (General) Regulations 1981 be taken into account when determining the seating requirements for specific roles such as oil and gas exploration.

2.7 Search and Rescue / Survivability

The rescue operation was initiated and completed with commendable efficiency. Location of the survivors and the wreckage was not a problem in the reasonable sea conditions. Rescue agencies were conveniently placed near the scene of the ditching. In fact the ditching was a secondary event following an impact with the landing area and a virtual free fall into the sea. It was thus unpremeditated and the occupants had little or no time to prepare themselves. A degree of incapacitation occurred at impact with the sea and that, together with the collapse of some seats, must account for the inability of four passengers to make their escape.

The passengers had been equipped with pouch type life jackets which would be donned but not inflated in the case of a premeditated ditching. In this case the survivors had to don and inflate the LSJ once they were in the water and this proved to be extremely difficult. The LSJs, once fitted and inflated, functioned normally and there was no evidence to suggest that they contributed to the fatalities. However, had this type of accident occurred in less favourable conditions, or if the injured passenger had not been rescued so promptly, the fact that the LSJ needed to be unpacked and donned in the water could have significantly reduced the chances of survival. It is therefore recommended that the provision and wearing of a single action LSJ should be mandatory for all passengers on North Sea helicopter flights.

The ADELT beacon appears to have deployed normally under the initiation of the saline switch, however, given the circumstances of the accident, in which the ditched helicopter was located immediately, the ADELT had little or no part to play in the SAR phase. When the beacon was examined by the manufacturer it was found to operate correctly, both in respect of the radio homing signals and in response to radar interrogation. Battery power was found to be lower than expected and this would have affected the radio signal strength. The radar response was at full strength, due to lower voltage requirements. Examination of the battery revealed no defect and it was unclear why its capacity was low. At the time of the accident, the battery had consumed some 70% of its service life and, depending on the frequency and duration of in service checks, may have been approaching replacement. Also, even when not activated, storage in the vertical or near vertical position would cause some current drain due to latching of the attitude sensing circuitry. This may have been the case before installation or in the period following recovery.

3 Conclusions

(a) Findings

(i) The crew were properly licenced, medically fit and sufficiently rested to operate the flight.

(ii) The commander was adequately experienced to land on a restricted deck. The co-pilot, although inexperienced, was not involved in the final handling manoeuvre, apart from his management of the Speed Select Levers.

(iii) The helicopter had been properly maintained, correctly loaded and was airworthy at the time of the accident.

(iv) Weather conditions at the time were adequate for visual contact flying but the horizon was indistinct and there was hardly any wind.

(v) Brent Spar helideck was too small to accommodate the recommended landing area for an S-61N but operational restrictions had been imposed by the CAA under which S-61N operations were permitted and these had been observed by the commander of 'WL'.

(vi) Information about the landing area which was available on the flight deck was incomplete and the aiming circle was not drawn to scale. Operating restrictions relating to S-61N were ambiguous.

(vii) Although the prohibited landing sector most clearly indicated the presence of a hazard, the white painted 'H' in the centre of the aiming circle was also orientated so that its horizontal bar was on the bisector of the obstacle free sector. This may not have been known by the crew and was not the most conspicuous way of marking the obstacle sector.

(viii) The helideck was not routinely inspected by aviation specialists.

(ix) Visual cues used routinely by the handling pilot may have led him to position the helicopter closer to the main obstruction before he transferred his attention to the aiming circle, which was displaced from the centre of the deck in order to ensure sufficient clearance. In order to retain sufficient visual reference it is likely that the handling pilot inadvertently moved rearwards as he descended and thus unwittingly towards the obstacle.

(x) Although the rotor rpm was low prior to moving across the helideck, possibly as a result of the co-pilot's distraction or inattention, it did not significantly affect control of the helicopter but it could have distracted the handling pilot. However, its gradual onset made audible detection less likely.

(xi) The helicopter was seen to move obliquely across the deck until the tail rotor struck the crane 'A' frame. Some passengers and observers became aware that it was in a hazardous position prior to the strike.

(xii) The CVR almost certainly stopped as soon as power to it was interrupted under the influence of the g switch when the initial tail rotor strike was sensed.

(xiii) The AVAD warning suggests that the helicopter was probably at a height greater than 50 feet above the helideck as it moved to its right and it then moved downwards and backwards until the tail rotor struck the crane 'A' frame.

(xiv) Carriage of a crewman or cabin attendant was unlikely to have prevented the accident.

(xv) The HLO, although momentarily aware of the helicopter's hazardous positioning, had hardly any time in which to radio a warning to the crew.

(xvi) Seven passengers escaped from the sinking helicopter through window apertures, some of which were jettisonable, and the right hand emergency hatch.

(xvii) The passenger seats installed in the helicopter were to a structural strength requirement that was less than that of the airframe. This led to seat collapse and a consequent reduction in passenger survivability.

(xviii) The search and rescue phase was conducted with commendable speed and efficiency.

(xiv) The ADELT beacon, if it had been required by rescue agencies, was unlikely to have provided assistance for any length of time or over any great distance due to its depleted internal batteries.

(b) Causes

The accident happened when the handling pilot allowed the helicopter's tail rotor to contact a hand rail surrounding the 'A' frame of the Brent Spar crane which resulted in the helicopter crashing onto the helideck before falling into the sea and sinking.

The following causal factors were identified:

(i) Negligible wind offered freedom of choice in the direction of approach but required careful handling of the power available and consideration of any rejected landing profile. An indeterminate horizon made attitude control of the helicopter more difficult whilst it was hovering higher than the normal 10 foot wheel height above a relatively small structure.

(ii) Although all the operating restrictions imposed on the Brent Spar helideck by CAA were observed, a combination of subtle differences relating to this particular landing, as opposed to any other, may have led to the erosion of a safety margin that had already been reduced by the intrusion of the crane structure into the obstacle limited sector.

(iii) The commander's choice of approach was inexplicable given the number of more favourable options open to him but it may have been influenced by his previous experiences of approaching Brent Spar in strong wind conditions.

(iv) Orientation of the rotating helideck when a vessel was moored to Brent Spar meant that the major obstacle would often be positioned behind a helicopter which was landing into wind. Pilots were therefore not unused to this situation and the commander may have accepted the constraint it placed upon the direction of approach.

4 Safety Recommendations

It is recommended that :

4.1 The attention of all off-shore operators be drawn to the significance of helideck markings, in particular the 'H' and its orientation in relation to the obstacle free sector. (forwarded 6 September 1990).

4.2 The CAA considers with HSE the best arrangements for inspection of at least all restricted helidecks, and ideally all helidecks, which are regularly used by UK registered helicopters.

4.3 Information carried on the flight deck includes all the relevant information and that AERAD landing area plates, or their equivalent, are drawn to scale with all markings shown. (forwarded 6 September 1990). It is also recommended that official sponsorship of such publications be considered.

4.4 The attention of operators is drawn to the significance of any prohibited landing area, especially if the intention is to provide added security for the tail rotor. It should be made clear that, although there is no reason why the tail of the helicopter should not occupy this sector, any infringement by the cockpit will hazard the tail rotor. (similar wording forwarded 6 September 1990).

4.5 Methods of ensuring greater security for the tail rotor whether by revised helideck markings, visual position indicators or proximity warning devices be examined.

4.6 BCAR 29 be amended to include static and dynamic test requirements to at least the standards of FAA Amendments 27-25 and 29-29. Furthermore, these standards should be incorporated into the corresponding Joint Airworthiness Requirement.

4.7 Newly manufactured helicopters of UK registration should have an effective upper torso restraint installed at every seat position which should also exploit the available strength of the airframe.

4.8 The provisions of recommendation 4.7 should apply to existing helicopters within the next five years.

4.9 The passenger weights specified in ANO 1989 Section 3: The Air Navigation (General) Regulations 1981 be taken into account when determining the seating requirements for specific roles such as oil and gas exploration.

4.10 The provision of a single action LSJ should be mandatory for all passengers on North Sea helicopter flights. (forwarded 3 August 1990).

R StJ Whidborne
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1 August 1991

The Civil Aviation Authority's response to these Safety Recommendtions is contained in CAA Follow-up Action on Accident Reports (FACTAR) No 2/91, to be published coincident with this report.