AIRCRAFT INCIDENT REPORT 5/95

Air Accidents Investigation Branch

Department of Transport

Report on the incident to Bell 214ST, G-BKJD near the Petrojarl 1, East Shetland Basin on 6 December 1994

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

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

28 September 1995

The Right Honourable Sir George Young
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr M M Charles, an Inspector of Air Accidents, on the circumstances of the incident to Bell 214ST, G-BKJD, near the Petrojarl 1, East Shetland Basin on 6 December 1994.

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
AARS	attitude/altitude retention system
ADI	attitude director indicators
AEO	all engines operating
AGL	above ground level
ANO	Air Navigation Order
ATC	Air Traffic Control
°C, M, T	Celsius, magnetic, true
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication
Cb	cumulo-nimbus cloud
CDP	critical decision point
CDT	critical decision time
CRM	Cockpit Resource Management
CVFDR	Cockpit Voice and Flight Data Recorder
DRA	Defence Research Agency
FBW	fly-by-wire
FDR	Flight Data Recorder
g	normal acceleration
HAPS	Helicopter Airfield Performance Simulation
HP	handling pilot
hrs	hours
IFR	Instrument Flight Rules
IGE	inside ground effect
IMC	Instrument Meteorological Conditions
KIAS	knots indicated airspeed
kt	knot(s)
km	kilometre(s)
LAM	Limited Area Model
lb	pound(s)
mb	millibar(s)
MGT	measured gas temperature
Ng	gas generator RPM
NHP	non-handling pilot
QNH	corrected mean sea level
RPM	revolutions per minute
RT	Radio Telephony
SAR	Search and Rescue
SCAS	Stability and Control Augmentation System
TDP	take-off decision point
TQ	torque
T's & P's	Temperatures & Pressures
UTC	Universal Time Co-ordinated
UTIAS	University of Toronto Institute for Aerospace Studies
VHF	very high frequency
VMC	Visual Meteorological Conditions
V_{MIN} IMC	minimum indicated airspeed in IMC
V_{TOSS}	take-off safety speed
V_Y	normal climb speed

Air Accidents Investigation Branch

Aircraft Incident Report No: 5/95 (EW/C94/12/2)

Registered Owner:	Caledonian Helicopters Ltd
Operator:	Bristow Helicopters Ltd
Aircraft Type:	Bell 214ST
Nationality:	British
Registration:	G-BKJD
Place of incident:	Near the Petrojarl 1 - A floating storage vessel in the East Shetland Basin Latitude: 61°15.65' North Longitude: 000°42.55' East
Date and Time:	6 December 1994 at 1755 hrs All times in this report are UTC

Synopsis

The incident was notified to the Air Accidents Investigation Branch (AAIB) by the operator on 7 December and an investigation began that day. The following Inspectors of Air Accidents participated in the investigation:

Mr M M Charles - Investigator in charge
Mr J J Barnett - Operations
Mr J W Chappelow - Principal Psychologist, DRA Centre for Human Sciences
Mr R J Vance - Flight Data Recorders and aircraft performance

The incident occurred at night during an attempt to land 15 passengers on the helideck of the Petrojarl 1 but the severity of the deck movements and air turbulence were such that the commander decided to abandon the landing and return to the mainland. During the go-around manoeuvre and initial climb in significant turbulence the aircraft lost forward airspeed and, under the influence of a strong headwind component, it drifted backwards towards the vessel. At a position close to the vessel's overhead at about 600 feet above sea level the commander, who was handling the aircraft, believed that it was no longer responding normally to control inputs and he diagnosed an incipient vortex ring condition. Both pilots became involved in the recovery from this condition and the aircraft entered a steeper than intended dive from which it recovered at very low altitude.

The investigation identified the following causal factors:

(i) There were severe levels of turbulence close to the Petrojarl 1 brought about by the general weather situation combined with microburst activity generated by an adjacent cumulo-nimbus cloud.

(ii) The information available to the crew did not alert them to the potential influence of the cumulo-nimbus adjacent to the Petrojarl 1.

(iii) The commander lacked recent experience in operations by night to platforms in difficult weather conditions.

(iv) The crew did not maintain an accelerative pitch attitude in the severe turbulence experienced during the transition to climbing flight.

(v) The procedures for transition from the hover outside ground effect into climbing forward flight by sole reference to the flight instruments were inadequately defined.

(vi) The procedures for recovery, on instruments, from circumstances involving an unintentional loss of airspeed were not fully documented.

Five safety recommendations were made during the course of the investigation.

1 Factual Information

1.1 History of the flight

1.1.1 Background to the incident flight

The flight crew and the helicopter were based at Aberdeen. On the day before the incident both pilots were on standby at their homes but neither was required for duty. On the morning of 6 December both were contacted at home by telephone at about 0830 hrs and asked to report for duty. Their task was to fly to Sumburgh Airport (near the southern tip of the Shetland Isles), where they were to collect 15 passengers and take them to the Petrojarl 1, a floating storage vessel. From the Petrojarl 1, the task was to take 12 passengers to Sumburgh and then to return without passengers to Aberdeen. The unplanned tasks had arisen because the passengers were normally conveyed to the Petrojarl 1 by a Sikorsky S61 helicopter but the sea state was such that the movement of the vessel's helideck was outside the limits for the S61 but within the limits for the Bell 214ST.

Both pilots arrived at their operating base at about 0900 hrs and began preparations for the day's flying. At just after 1000 hrs they boarded G-BKJD (hereafter referred to as 'JD') and discovered that the aircraft was unserviceable because of a fuel gauging error. They returned to the engineering line office where they were offered G-BKFP (hereafter referred to as 'FP') the operator's only other available Bell 214. However, this aircraft had undergone recent rectification and required an air test before it could be released for a revenue flight. The crew boarded 'FP' and started an engine whereupon they received a low oil pressure warning relating to a tail rotor gearbox and so the aircraft had to be shut down. With both Bell 214 helicopters unserviceable, a decision was taken to concentrate resources on rectifying 'FP'. The oil pressure transducer was changed and a further attempt to start up had to be abandoned when the warning returned. More oil was added to the gearbox but this failed to cure the fault and the third attempt to start was abandoned. More components were changed and on the fourth engine start, the low oil pressure warning extinguished. At about 1250 hrs the crew carried out a brief air test which was satisfactory and they then shut down the aircraft, completed the necessary post air test paperwork and prepared for the forthcoming flight to Sumburgh.

They took off from Aberdeen at 1324 hrs bound for Sumburgh but at 1348 hrs and 46 miles from Aberdeen, the tail rotor gearbox warning light illuminated again. The crew immediately commenced a diversion to the nearest suitable heliport but after about 2 minutes, the warning light extinguished. Consequently, they decided to return to Aberdeen on a route which took them close to suitable landing sites so that they would be able to land without delay if the warning returned. It did not return and the crew landed at Aberdeen and shut down 'FP' at 1424 hrs.

By this time 'JD', the other Bell 214, had been partially rectified and engineering resources were concentrated on finishing this work. An unserviceable fuel tank probe had been replaced and to check its proper function, the fuel tanks had to be completely filled. This was more fuel than the crew wanted for the flight to Sumburgh and so after refuelling and testing the new probe, the aircraft had to be partially defuelled. Whilst this work was carried out the flight crew completed the technical paperwork and incident report for the unsuccessful flight in 'FP'. After that, they prepared once again for the forthcoming flights and departed Aberdeen at about 1530 hrs.

The flight to Sumburgh was uneventful. It was carried out in daylight and in pleasant weather conditions. In the cruise the flight crew were able to verify that the wind computed by their navigation equipment was 250°/30 kt which was consistent with the forecast wind. Near Sumburgh they encountered scattered cumulus clouds with bases between 1,500 and 2,000 feet and they landed at about 1645 hrs. On the ground they embarked 15 passengers, their baggage and a small quantity of fuel which brought the aircraft's all-up weight close to the maximum allowable take-off weight.

1.1.2 The incident flight

The aircraft departed Sumburgh in darkness at 1700 hrs and joined Helicopter Main Route 'Hotel' (shown at Appendix A) which terminated at Gate 'Hotel' on the boundary of the East Shetland Basin communication sector. They cruised in generally good visual meteorological conditions but under Instrument Flight Rules at 2,000 feet altitude with the co-pilot in the left-hand pilot's seat acting as the handling pilot. They navigated using the Global GNS500 radio navigation system; it was computing a wind at 2,000 feet of westerly at 40 kt and their computed route and turning points were superimposed on the weather radar display. On the radar display they noticed several small but intense returns which were about one mile in diameter; they were slightly larger than a typical platform return and they had a thin yellow band surrounding the red core area; they did not see any lightning or St Elmo's fire.

As they got nearer to the Petrojarl 1 and identified the vessel on radar, they noticed one bright red return close to the vessel. The commander recalled that this weather return was just to the north of the vessel by about half a mile and he thought the yellow band around the red core mingled in slightly with the Petrojarl's return. The co-pilot, on the other hand, thought that the return was between one and two miles to the north west of the vessel and that there was a definite space between the vessel's radar return and the yellow band surrounding the red centre of the weather return. He associated his recollection of this radar display with actioning the approach checklist some four or five miles from the vessel. At this point the landing light was switched on and both pilots remembered seeing drops of rain or flakes of snow in the light beam but the precipitation was short-lived and there was no requirement for the windscreen wipers. Later, on final approach to the vessel, the radar was switched to standby and it remained on standby throughout the subsequent manoeuvres.

At about 1740 hrs the helicopter crew contacted the Petrojarl 1 by VHF radio. They were told that the vessel was maintaining a heading of 258° and were given details of the weather and deck movement. The vessel had passed a wind direction of 300° but as the aircraft approached the ship, the wind appeared to the flight crew to be more in line with the vessel's heading and so the co-pilot retained control for the final approach. As they came alongside the vessel on its starboard side, abeam the central derrick they noticed an increase in air turbulence. At about this stage it also became clear that the wind direction was more from their right than they had at first thought, which would make it difficult for the co-pilot to execute the landing. Without coming to the hover, the co-pilot abandoned the approach and climbed the helicopter ahead to about 800 feet altitude using, he thought, about 90% torque and 80 kt airspeed. He felt slightly uncomfortable during this manoeuvre because of the air turbulence, which also affected the aircraft's pitch attitude stability.

Control was exchanged between the pilots on the downwind leg of a left-hand visual circuit. The commander flew a long, gently curving final approach leg which brought the aircraft alongside the vessel's port side. During the early part of this approach he felt that the turbulence was only moderate and he was able to control the aircraft in pitch and roll using chiefly the cyclic 'beep' trimmer switch. As the aircraft approached the helideck, the commander noted from the vessel's windsleeve that the wind direction was from between 10° and 20° right of the bow. As he brought the aircraft to the hover about 50 feet above helideck level on its port side, the turbulence became very marked and he had difficulty in stabilising the hover because of the air turbulence and helideck motion. At the same time, the co-pilot, who as non-handling pilot was monitoring transmission torque, noticed the strong air turbulence and frequent torque fluctuations. He also observed that the sea state ahead of the ship was more agitated than beneath the aircraft. This "boiling" of the sea surface reminded him of flying beneath a tropical storm.

After assessing the ship's movement, the commander began to manoeuvre the aircraft towards the helideck whereupon the turbulence and aircraft movement became, in the co-pilot's opinion very violent. At this stage the commander decided that the combination of air turbulence and deck movement was too severe for a safe landing and he announced to the co-pilot that he was abandoning the approach. There were no lights ahead of the vessel and no natural horizon cues as the commander began the go-around manoeuvre. As they climbed away he felt that his control inputs had been positive but the rate of climb was lower than he had expected and the air turbulence increased in severity; both pilots felt uncomfortable in the turbulence. The co-pilot remembered monitoring the torque and both pilots were aware that the airspeed was lower than normal in the climb.

At some stage in the climb, he thought as they climbed through 700 to 800 feet altitude, the co-pilot noticed that the aircraft's pitch attitude was unusually nose high. He made a remark about the pitch attitude to the commander who, at this stage, was aware that he was having problems controlling the aircraft and was making unusually large control inputs. He noticed that the airspeed was low and reducing rapidly through 40 kt towards zero; the co-pilot also noticed a rapid reduction in airspeed. The commander then felt that the aircraft was sinking; he diagnosed a state of incipient vortex ring and informed the co-pilot of his diagnosis. To escape from this condition the commander pushed forward on the cyclic control but this did not seem to him to have the desired effect of increasing the airspeed. At the same time the co-pilot grasped the controls and both pilots then jointly made a further nose down cyclic input. As the aircraft entered an intentional dive, the commander reduced collective sufficiently to off-load the engines but not so far as to enter autorotation. The co-pilot briefly saw the wave tops illuminated by the landing light and noticed a great deal of black on his attitude indicator as he felt the collective being lowered. During the established dive both pilots were aware of each other holding the controls and the commander transmitted a brief 'MAYDAY' message on the VHF radio. Next he noticed the surface of the sea illuminated by the landing light and pulled back on the cyclic control to avoid impact with the sea. At this point the co-pilot was looking at the instruments and did not see the sea but as they climbed away once more, he maintained his grip on the flight controls. In the climb the commander heard an answer to his 'MAYDAY' transmission and, not wanting to have boats and people enter the rough sea unnecessarily, he cancelled the emergency. He then allowed the co-pilot to continue flying the aircraft whilst he contacted the Petrojarl 1 by radio, checked the state of the aircraft and reverted to his previous non-handling pilot's duties. Only two systems indicated faults: the Stability and Control Augmentation System (SCAS) pitch channel and one of the two elevator channels had disengaged and so he re-engaged them.

Both pilots discussed their options and it was decided that they would return to Sumburgh. They cleared the area of severe air turbulence within 2 minutes and set course for Sumburgh at 1,000 feet altitude. En route they discussed what had happened and how close they had come to the sea. They also noticed that the weather radar was off-line and initially it could not be restored to normal operation. Later the radar operation was restored but by this time the crew felt they had no need of it because they could see the lights of towns on the islands. By this time they were also receiving a radar service from Sumburgh radar.

The aircraft landed uneventfully at Sumburgh at 1854 hrs where the passengers were debriefed and reassured by the co-pilot. The aircraft was shut down at 1900 hrs, 65 minutes after the incident. When discussing the flight, the co-pilot remarked that the turbulence encountered near the Petrojarl 1 was the worst he had ever experienced. The commander remarked that it was almost as bad as the worst turbulence he had ever experienced some years before when the windspeed in the cruise was 90 kt.

1.1.3 Eyewitness recollections

The manoeuvres of the helicopter around the Petrojarl 1 were observed by at least five members of the vessel's crew and by the master of a support vessel (the Toisa Conqueror) stationed on the Petrojarl's port side. These witnesses had written reports of their observations shortly after the incident occurred.

The Petrojarl's crew saw the aircraft circle the vessel and then make a normal approach on its port side. As it neared the helideck, they noticed its pitch attitude becoming very unstable. When it was some 8 to 10 metres above the helideck it stopped hovering and moved initially upwards and then forwards. After a few seconds the aircraft stopped moving forwards relative to the vessel and, when it had climbed to a significant height, it started to come backwards, tail rotor first. When it was over the aft end of the helideck it swerved rapidly to the right and nose-dived towards the water. They heard the 'MAYDAY' call on the radio and saw the aircraft recover from the dive quite close to the sea surface. They then appreciated that the aircraft was back under control and watched it climb away.

The master of the Toisa Conqueror saw the helicopter circle widely at altitude and then approach the Petrojarl's helideck from its stern passing to the port side of the top third of the derrick. To him it appeared to hover over the bridge before moving forward slightly towards the helideck. It then accelerated forwards and upwards very quickly. When it was well above and ahead of the Petrojarl 1, it hovered at a height much greater than the height of the derrick. Next, with its heading the same as the Petrojarl's, it moved backwards towards the vessel. When it was slightly astern of the helideck he saw it enter a nose-dive. He heard the word 'MAYDAY' on the radio repeated twice and saw the helicopter disappear behind the Petrojarl 1. At that point he stopped watching it and prepared to launch a rescue boat and crew. However, the boat's crew, who were watching events from a position above his, informed him that the helicopter had avoided the sea and was still flying. He heard the helicopter pilot say something about strong or extreme turbulence and then the helicopter departed for Sumburgh.

1.1.4 Passenger recollections

The passenger seated behind and between the pilots said that the air turbulence was very violent near the ship and he watched the pilot struggling to control the helicopter. He saw full power applied and then white waves all around the helicopter. There was more struggling with the controls and then they gained height and returned to Sumburgh. He did not notice the aircraft enter a steep dive.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal	-	-	-
Serious	-	-	-
Minor/None	2	15	

1.3 Damage to aircraft

The aircraft was apparently undamaged and returned to Aberdeen the next day where the flight data recorder was removed and replayed. Although at the time of the incident the crew were not aware of any exceedence of the transmission torque limits, the data indicated that the transmission had been significantly overtorqued.

1.4 Other damage

None.

1.5 Personnel information

1.5.1	Commander:	Male, aged 37 years
	Status:	Line Captain
	Licence:	Airline Transport Pilot's Licence (Helicopters) issued 9 September 1985
	Aircraft ratings:	Aerospatiale models 355F and 355N, Bell 214, Bell 222, Bell 206, Bell 47, Sikorsky S61, Boeing Vertol Chinook
	Instrument Rating:	Renewed 22 February 1994
	Base check:	15 August 1994
	Line check:	5 August 1994
	CRM course:	22 April 1994
	Medical certificate:	Class One renewed on 15 July 1994 with no waivers or conditions

Flying experience:

Total flying:	6,573 hours
On type:	2,895 hours
Last 90 days:	92 hours
Last 28 days:	
Flying:	32 hours
Instrument flying:	4 hours 5 minutes
Night flying:	3 hours 25 minutes
Last 24 hours:	3 hours 20 minutes

Previous rest period: 14 hours

Flying duty period at time of incident: 8 hours 55 minutes

1.5.1.1 Commander's operational experience

The commander began ab initio flying training in 1979. On completion of this training he obtained a Commercial Pilot's Licence (Helicopters) and flew the Sikorsky S61N for the oil industry. In 1983 he converted to the Bell 206 and Bell 47 but after a brief period flying these light helicopters, he converted to the Boeing Vertol 234 (Chinook) and flew both the S61 and Chinook on North Sea operations. In 1983 he also qualified for a Private Pilot's Licence (Aeroplanes Groups A & B). In 1985 he joined a different company flying the S61 on oil industry support tasks; during that year he also qualified for the initial issue of his instrument rating and he obtained his Airline Transport Pilot's Licence (Helicopters). In 1985 he converted to the Bell 214 and flew the type on oil industry support tasks from then until March 1990 when he converted to the AS355 and Bell 222. His flying duties were then split between the Bell 214 at Aberdeen and as a relief pilot for a police helicopter support unit in the south of England. Between August 1992 and February 1994 he was employed full time at the police air support unit. Between February 1994 and the incident his employment was again divided between flying the Bell 214 at Aberdeen and the Bell 222 and AS355 at a police air support unit.

1.5.1.2 Commander's deck landing recency

CATEGORY	UNSTABLE				STABLE	
DECK TYPE	SEMI SUBS & LARGE SHIPS		SMALL SHIPS & TANKER MOORING BUOYS		FIXED RIGS	
Day/Night	D	N	D	N	D	N
Last 7 days	0	0	0	0	0	0
Last 28 days	1	0	0	0	0	1
Last 3 months	2	0	0	0	4	1
Last 12 months	14	4	0	0	83	3

The commander had landed on a moving platform once during the previous 28 days; this took place on the Petrojarl 1 on 22 November in daylight. He had flown only one recent **night** deck landing. It took place on 2 November to a large, fixed platform. Before that, his previous night deck landing was on 21 February 1994, the day that he resumed Bell 214 flying duties at Aberdeen.

1.5.2 Co-pilot:	Male, aged 52 years	
Status:	Line Captain	
Licence:	Airline Transport Pilot's Licence (Helicopters) re-issued 10 May 1990	
Aircraft ratings:	Bell 212, Bell 214	
Instrument Rating:	Renewed 15 December 1993	
Base check:	7 June 1994	
Line check:	29 September 1994	
CRM course:	15 September 1994	
Medical certificate:	Class One renewed on 24 October 1994 with requirement to have near-vision corrective spectacles available	
Flying experience:	Total flying:	8,376 hours
	On type:	3,021 hours
	Last 90 days:	52 hours
	Last 28 days:	19 hours
	Last 24 hours:	3 hours 20 minutes
Previous rest period:		14 hours
Flying duty period at time of incident:		8 hours 55 minutes

1.5.2.1 Co-pilot's operational experience

The co-pilot commenced flying training with the Royal Navy in 1967. In 1975 he left the Royal Navy and joined an offshore oil support company flying the Bell 212. He remained flying that type from both onshore and offshore bases until 1979 when he temporarily ceased professional flying. Between 1980 and 1987 he was employed as a VIP and SAR helicopter pilot in the Middle East. Since 1987, on his return to the UK, he had flown the Bell 212 and Bell 214 on offshore oil support tasks.

1.5.2.2 Co-pilot's deck landing recency

CATEGORY	UNSTABLE				STABLE	
DECK TYPE	SEMI SUBS & LARGE SHIPS		SMALL SHIPS & TANKER MOORING BUOYS		FIXED RIGS	
Day/Night	D	N	D	N	D	N
Last 7 days	0	0	0	0	0	0
Last 28 days	1	2	0	0	3	0
Last 3 months	10	2	3	0	6	2
Last 12 months	37	6	3	0	213	9

1.6 Aircraft Information

The Bell 214ST is a commercial transport helicopter with seats for pilot, co-pilot and up to 18 passengers in a combined cabin. It is equipped for flight under Instrument Flight Rules (IFR) and in moderate icing.

1.6.1 Leading particulars

Manufacturer:	Bell Helicopter Textron Inc
Aircraft type:	Bell 214ST
Constructor's number:	28114
Year of manufacture:	1982
Certificate of Registration:	Issued 7 December 1982
Certificate of Airworthiness:	Transport Category issued on 12 January 1994
Total airframe hours:	11,270
Engines:	2 General Electric CT7 turboshaft engines
Main rotor:	Two-blade with elastomeric bearings and nodal suspension system
Tail rotor:	Two blade
Landing gear:	Tricycle wheels

1.6.2 Aircraft weight

Maximum gross weight:	17,500 lb
Actual take-off weight:	17,461 lb
Weight at time of incident:	16,641 lb

1.6.3 Pertinent limitations and speeds

Maximum transmission torque:	100% (two engines operating)
Take-off transmission torque:	83% to 100% (5 minutes < 120 KIAS)
Maximum continuous torque:	83% (two engines operating)
Take-off safety speed (V_{TOSS}):	55 KIAS
Minimum airspeed for IMC flight:	65 KIAS
Normal climb speed (V_Y):	78 KIAS (Flight Manual)
	75 KIAS (Company Operations Manual)

1.6.4 Aircraft systems

Details of the aircraft's systems which were relevant to the incident are at Appendix B.

1.6.5 Takeoff and climb procedures

Extracts from the aircraft manufacturer's Flight Manual regarding takeoff and climb procedures are at Appendix C. Extracts from the Operator's Operations Manual documentation regarding takeoff and climb procedures are at Appendix D.

1.7 Meteorological Information

1.7.1 Aftercast

An aftercast was obtained from the Meteorological Office. At the request of the AAIB, the Meteorological Office subsequently carried out a detailed study of the weather over the helicopter's route from Sumburgh to the Petrojarl 1 and in particular on the conditions which would have been experienced by the helicopter at the time of the incident. This study is at Appendix E.

1.7.2 Petrojarl 1 observations

Pre-departure weather observations were passed by the Petrojarl 1 to the operator as follows:

Time UTC	Wind Dir & Speed	Visi-bility	Cloud Cover & Base (feet)	Air Tempe-rature	QNH mb	Deck Pitch & Roll	Deck Heave Metres
0825	245°/38 gusting to 42 kt	> 10 km	Scattered 2000	7.2°C	989.8	P1.6° R4.5°	2.7
1125	248°/36 gusting to 42 kt	>10 km	Scattered 2000	7.1°C	994.5	P2.1° R5.0°	3.5
1300	275°/22 gusting to 38 kt	>10 km	Scattered 2000	6.0°C	996.0	P2.3° R5.0°	4.0
1425	280°/30 gusting to 38 kt	>10 km	Scattered 1800	6.0°C	998.0	P2.1° R4.0°	4.2

The current weather observation passed by VHF radio to the crew of 'JD' when they made RT contact with the Petrojarl 1 was as follows:

Wind direction over the helideck:	Mean direction 300° but varying between 290° and 310°
Windspeed over the helideck:	Mean 28 kt but variable in speed
Visibility:	10 km
Cloud:	5 oktas base at 1,500 feet or higher
Air temperature:	6.8°C
QNH:	1002.1 mb
Vessel's heading:	258°

The crew of the vessel reported that there was no major change in the weather situation during the period in which the incident took place. Although some wintry showers had passed through the area about one hour before the incident, there was no heavy shower observed at the time or shortly afterwards.

1.7.3 Natural light conditions

It was dark when the aircraft departed Sumburgh at 1700 hrs; the sun had set there at 1505 hrs and at the Petrojarl 1 it had set at 1444 hrs. Although the sky was partially clear, there was no bright moonlight; a new moon had occurred four days earlier on 2 December.

1.8 Aids to navigation

No external aids to navigation were in use during the incident. There was no primary or secondary ATC radar in use within the East Shetland Basin and during the incident, the aircraft was operating outside the coverage of land-based ATC radars.

1.9 Communications

The crew communicated with Viking Approach (the ATC authority for the airspace surrounding the Petrojarl 1) and with the Petrojarl 1 by VHF radio. Communications with ATC were confined to routine information; no recording was sought because it would not have assisted the investigation.

1.10 Aerodrome Information

The Petrojarl 1 was designed as a storage vessel for offshore oil installations. The vessel's main particulars are as follows:

Gross weight:	30,742 tonnes
Length:	215·25 metres (706 feet)
Beam:	32·03 metres (105 feet)
Helideck position:	Raised deck at the bow approximately 80 feet above the waterline
Helideck size:	27·16 by 25·3 metres (89 feet by 83 feet)

At the time of the incident the vessel was moored to the sea bed by eight anchor lines attached to a central turret around which the hull of the ship could rotate. The vessel maintained a steady heading of 258° using side thrusters fitted near the stern and near the bow.

The vessel automatically recorded its position and movement. During the period 1714 hrs to 1814 hrs the recorded movement parameters were as follows:

Parameter	Pitch	Roll	Heave	Heave Interval
Maximum	3.2°	1.6°	3.7 metres	-
Average	0.5°	0.2°	2.4 metres	8 seconds

1.10.1 Operations to unstable helidecks

For some time before the incident the operator's limits for Bell 214 day or night operations to large ships were as follows:

Pitch	4°
Roll	4°
Heave	5 metres

On the day before the incident, the operator had issued a change in the limits for operations to large ships in the Bell 214. The revised limits, valid by day and by night were as follows:

Pitch	5°
Roll	5°
Heave	5 metres

These revised limits were qualified by the statement: "Operations may now, at the discretion of the Captain, be conducted to the above limitations. Amendments will in due course be made to the company's Operations Manual and the Flight Manager's Instructions".

1.11 Flight Recorders

The aircraft was fitted with a Penny & Giles combined cockpit voice and flight data recorder (CVFDR). The CVFDR was undamaged and fully serviceable, both audio and numerical data were recovered using routine replay equipment. Recording durations were 5 hours for data and 1 hour for audio respectively.

1.11.1 Audio recording

The audio recording of the incident was overwritten by more recent audio because the flight back to Sumburgh lasted longer than one hour. However, during the return flight the crew discussed the incident. From the recording the following is a summary of the crew's appreciation and recollection of the incident. P1 was the handling pilot for the attempted landing on the Petrojarl 1, both P1 & P2 considered the conditions to be very rough and a 'go-around' was commenced. During the go-around P1 remembered seeing a torque of about 95% displayed, he was aware that the aircraft pitch attitude was high and that the airspeed was falling. When the airspeed was lost P1 estimated the aircraft at between 600 to 700 feet. At this stage the crew believed they encountered some atmospheric conditions which P1 described as "knocking them back". P1 remembered seeing the ship below and recollected calling "incipient vortex ring". The collective lever was lowered, P2 thought the pitch attitude reached about 25 degrees nose down during the recovery which he thought was accomplished at about 300 feet.

P1 did not comment on the pitch attitude but remembered seeing the tops of the waves in the aircraft searchlight, he had no recollection of height or rate of descent during the recovery.

P1 commented on the loss of the SCAS pitch channel during the incident and that the radar would not restart. The radar would have been set to standby during the approach to the Petrojarl 1. The return flight to Sumburgh was completed without incident, P2 acting as handling pilot.

1.11.2 Data recording

The data section of the CVFDR contained a time history on 76 parameters. Data on the flights from Aberdeen to Sumburgh, from Sumburgh to the Petrojarl 1 and the return to Sumburgh were recorded. No data on aircraft position, groundspeed, windspeed or wind direction were recorded.

A graphical representation of the time histories of relevant data parameters is at Appendix F, Figure F-1. As UTC time was not recorded the start of the time history is referenced to zero seconds. The following information may assist in interpreting the graph.

(i) recorded barometric altitude is referenced to 1013 mb

(ii) the range of "radio altitude" is 0 to 744 feet,

(ii) recorded airspeed (IAS) is only valid above 40 kt,

(iv) positive pitch attitude is aircraft nose up,

(v) positive roll attitude is aircraft banked left,

(vi) positive cyclic pitch is the cyclic stick aft of neutral

The time history begins with the aircraft on its approach to the Petrojarl 1. It made a slow approach, on a heading of 305 degrees (M); a precise speed could not be calculated because groundspeed was not recorded and recorded airspeed was unreliable below 40 kt. Calculations using recorded accelerometer data suggest that the aircraft entered the hover at 45 seconds at a height of about 100 feet above the sea. At 50 seconds the attempted landing was aborted, torque increased to 102% the aircraft pitched 7° nose down and began to climb. The initial rate of climb was approximately 600 ft/min and after 10 seconds airspeed increased to 46 KIAS. Increasing aft cyclic was applied, the aircraft began to pitch-up reaching +19 degrees at 70 seconds; the rate of climb increased to approximately 1,700 ft/min and airspeed reduced. At 75 seconds the pitch attitude began to decrease and over the following 15 seconds the rate of climb reduced to zero ft/min. Throughout this period the collective pitch input remained static at 38% and the cyclic pitch input continued to move aft. Appendix F, Figure F-2 shows an expanded time history of longitudinal cyclic pitch input and aircraft pitch attitude to the same time scale. When the aircraft lost height the airspeed began to rise. At 100 seconds the aircraft pitch was 53 degrees nose down. The collective pitch input was increased and the nose down pitch attitude was reduced. At 107 seconds the descent was arrested at a height of about 66 feet and by 140 seconds recovery was completed. The remainder of recording shows an uneventful flight and landing at Sumburgh.

1.11.3 Interpretation of recorder data

The absence of recorded groundspeed and wind data along with the unreliability of recorded airspeed below 40 KIAS made accurate determination of windspeed and wind direction impossible. In order to obtain a best estimate of the windspeed the recorder 3 axis accelerometer data were integrated to obtain inertial velocities. The accuracy of the results was impaired because no stable reference point was available on which to begin the integration process. However the calculated groundspeed showed a reasonable correlation to the windspeed data produced by the recording equipment on the Petrojarl 1 in those parts of the time history where recorded airspeed was reliable.

After making allowances for barometric pressure the recorded barometric altitude agreed with recorded radio altitude and height calculated from the accelerometer data. A similar correlation between airspeed and calculated groundspeed was only possible when the recorded airspeed was above 40 KIAS. From the integrations it was clear that between 72 seconds and 95 seconds, the groundspeed was negative reaching a maximum value of minus 30 kt at 85 seconds.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

None.

1.17 Organisational and management information

1.17.1 Flight Simulator

The operator did not have access to a Bell 214ST simulator. The nearest simulator of that type belonged to the aircraft manufacturer and was based in the USA.

1.17.2 Company pilot proficiency requirements

The operating company's policy was to ensure that all its pilots met or exceeded the recency requirements of UK legislation (see paragraph 1.18.4). In particular the operator had a world-wide policy of conducting a biannual line check (essentially every 6 months, but at least two checks in 13 months), rather than the required annual line check and, additionally, alternated the check between day and night. The initial line check required pilots to demonstrate five satisfactory offshore deck landings; the continuity line check required one satisfactory offshore landing. The company did not keep records of pilots' subsequent deck landing experience and there was no requirement, either company or regulatory, for pilots to keep such records in their personal flying logbooks.

1.18 Additional information

1.18.1 Human factors

The flight crew were interviewed on 18 December by a Principal Psychologist employed by the Defence Research Agency's Centre for Human Sciences who specialises in aviation human factors.

By the time they reached the Petrojarl 1, both crew members had already had a fairly long duty day and the commander stated that he had not slept as well as he might have wished during the previous night. Since 1250 hrs they had been airborne for a cumulative total of 3 hours 40 minutes without a recognised rest period but less than 9 hours had elapsed since their duty day began and neither had worked during the previous day. They had not been woken or asked to work during the hours when they would normally be asleep and they had sensibly shared the piloting task between them. Despite the considerable unforeseen delays to the flight, the crew remained well within the operating company's flight and duty time limitations. The operator's passenger lounge contained a restaurant which the flight crew could use and it was one floor beneath the briefing room. Both crew members were hungry at the time of the incident. The commander had eaten a sandwich since breakfast that morning but the co-pilot had chosen not to eat. Following the incident neither crew member considered that he was suffering unduly from fatigue.

1.18.2 Vortex ring

Vortex ring state (otherwise known as 'settling with power') is the recirculation of main rotor air flow producing a rate of descent which increases as power and main rotor pitch are increased. The recirculation is toroidal and may be likened to a smoke ring. The pre-conditions which are necessary before vortex ring is likely to occur are: zero or near-zero airspeed; 20% to 100% of engine power delivered to the rotor; and a rate of descent in excess of 300 ft/min.

When a helicopter comes to the hover out of ground effect, air is drawn in from above the rotor and accelerated downwards in the form of rotor wash. If the helicopter descends too rapidly in the hover, the rotor wash out near the edge of the rotor disc can curve outwards and upwards where it may be reingested by the rotor. This reingestion or recirculation decreases the efficiency of the rotor and the rate of descent begins to increase, which sustains the recirculation. The onset of vortex ring may be quite sudden but sometimes the incipient stage is accompanied by high vibration and buffet; instability in all three flight axes and the onset of small amplitude 'twitches' in roll and yaw. When established, vortex ring results in a very rapid build up in rate of descent, reduced effectiveness of cyclic inputs in roll and pitch, and the application of collective pitch having no effect in reducing rate of descent.

If no action is taken to recover from vortex ring, the high rate of descent can continue until the helicopter strikes the surface. To recover, the aircraft must escape from the column of disturbed air. This is normally achieved by applying forward cyclic to accelerate the helicopter forwards and gain airspeed, thus leaving behind the column of disturbed air.

1.18.3 Aircraft weather radars

The primary purpose of aircraft weather radars is to detect turbulent cloud. To do this, the radar must receive returns from the large water droplets contained in the upcurrents associated with turbulence. This is achieved by transmitting a beam of radio energy of about three centimetres wavelength which gives a strong return from large water droplets but no significant return from the smaller water droplets associated with non-turbulent cloud. In weather radars with colour displays, the reflectivities from clouds are colour coded. Green, which equates to low reflectivity, relates on average to mild turbulence. Yellow, which equates to intermediate reflectivity, relates on average to moderate turbulence. Red, which equates to high reflectivity, relates on average to severe turbulence. However, as the incident showed, severe turbulence can occur in areas where there is no reflectivity at all.

The radar echo given by a cumulo-nimbus cloud has definite characteristics which are easily recognised with experience. The echoes have high intensity (shown in red on a colour weather radar) with sharply defined edges and tops when the cloud is in the developing stage, but become diffuse when the cloud has passed its maximum development.

1.18.4 Handling recency requirements

The legal requirements for handling recency, broadly outlined in the ANO, were amplified in Civil Aviation Publication CAP 360 AIR OPERATORS CERTIFICATES Part ONE Chapter 5/11 paragraph 4.14. Three sub-paragraphs contained the requirements relevant to professional helicopter pilots flying under instrument flight rules (IFR). Pilots were required to have the following experience:

a. Carried out at least three takeoffs and three landings in the preceding three months in an aircraft of the type to be used. The commander should also have made at least one complete flight involving one takeoff and one landing in the type of aircraft to be used within the preceding 28 days.

b. Have flown at least 2 hours simulated or actual instrument flight in the preceding 60 days. This period could be extended to 90 days if the pilot had undergone, during the preceding 30 days, at least one hour in a simulator approved for the purpose of instrument rating renewal.

c. Flown four instrument approaches during the preceding 90 days, appropriate to company operations. This total could include flight simulator approaches in a simulator approved for instrument rating renewals.

d. Instrument rated helicopter pilots who were predominantly used on VMC operations required 2 hours simulated or actual instrument flight and two instrument approaches during the preceding 60 days.

e. Have flown at least one instrument approach within the preceding 30 days.

1.18.5 Helicopter pilots' periodic tests

CAP 360 Chapter 5/19 stipulates the requirements for periodic tests of pilots' proficiency. Amongst the many requirements are the following:

a. An annual line check of two sectors which tests a pilot's ability to perform satisfactorily a complete line operation from start to finish.

b. A base check to assess pilot competence at normal and emergency manoeuvres. An initial base check is valid for six months; thereafter two base checks in 13 months are required at an interval of not less than four months between tests.

c. Some helicopter manoeuvres can only be carried out in VMC. To ensure that those items of the base check which are appropriate to night operation and those which should only be attempted in daylight are checked at least annually, the check should be conducted alternately by day and night.

d. For pilots required to engage in IMC operations the content of the base check should include:

    (1) Engine failures before and after the decision point for each certificated take-off profile. At least one continued takeoff must be conducted in simulated IMC.

    (2) Recovery from unusual attitudes and techniques for autorotation in IMC.

e. Commanders who are required to operate as co-pilots must be checked in the co-pilot's duties, though not necessarily in the co-pilot's seat, and be certified to operate in that capacity.

1.18.6 Instrument rating tests

The instrument rating test for helicopter pilots is documented in Chapter 15 of CAP 54 'Professional Pilots' Licences'. During the test the execution of a missed approach and go-around follows on from an instrument approach down to appropriate minima. At this point the helicopter still has significant forward flying speed (ie not below the minimum speed for instrument flight). There is no regulatory requirement for helicopter pilots to demonstrate their ability to execute a go-around from a free air hover by sole reference to instruments.

2 Analysis

2.1 General

On the morning of the incident the wind was strong and the sea state rough in the East Shetland Basin. The heavy swell caused the Petrojarl 1 to pitch, roll and heave (vertical motion) to the extent that helicopters such as the Super Puma and S61N, with their relatively high centres of gravity, could not safely land on the vessel's helideck. The smaller Bell 214 with its lower centre of gravity could safely accept more deck movement and so one of the operator's two Bell 214 helicopters was substituted for the task. Because it was an ad hoc charter arranged on the day, the crew of 'JD' were called from standby at their homes to operate the flight. Apart from the strong winds and occasional showers, the weather forecast was good with no low cloud and excellent visibility. All being well, there was ample time to complete the landing and takeoff from the Petrojarl's moving helideck in daylight and the duty would have seemed reasonably routine to the flight crew, especially since both pilots had recently completed similar flights to the Petrojarl 1 in rough sea conditions. Only one aspect of the planned task was new to the crew; on the day before the incident, the deck motion limits applied by the operator had been increased by one degree in pitch and roll for both day and night operations. The incident flight was tasked on the basis that the crew could operate to the new limits which, although higher than those in recent use, were no higher than those used previously by another Bell 214 operator. In the event the deck motion at the time of the incident was within the previous (lower) limits.

The two factors which were eventually to make the task so much more difficult were firstly, the successive delays which made a night deck-landing inevitable, and secondly, air turbulence in the vicinity of the Petrojarl 1. However, neither factor should, by itself, have done anything more than demand an increase in the application of piloting skills which the crew undoubtedly possessed.

This analysis attempts to identify why the crew lost control of the helicopter at a critical stage of flight and why their joint response to the unexpected loss of airspeed caused such a hazardous loss of altitude. The report concludes with a summary of the findings, causal factors and recommendations that arise during the analysis.

2.2 Delays

The successive delays during the morning must have been frustrating for the crew but frequent changes of plan and task are the norm when flying helicopters to offshore oil installations. The crew would have suffered similar frustrations before and would have known instinctively how to deal with them. However, by the time they reached the Petrojarl 1, both had already had a fairly long duty day and the commander stated that he had not slept as well as he might have wished during the previous night. They had been airborne for a cumulative total of 3 hours 40 minutes without a recognised rest period and it would be natural for them to be feeling the first symptoms of weariness. On the other hand, less than 9 hours had elapsed since their duty day began which is well within accepted limits for fatigue and neither had worked during the previous day. They had not been woken or asked to work during the hours when they would normally be asleep and they had sensibly shared the piloting task between them. Probably the most significant factor which could have degraded their performance was lack of food. Both were hungry at the time and only the commander had eaten since breakfast that morning. He had eaten a sandwich and was less likely than the co-pilot to be suffering ill-effects from lack of food, yet he was the handling pilot when the incident first started. On the co-pilot's part, lack of food could not realistically be attributed to anything other than personal choice. The operator's passenger lounge contained a restaurant which the flight crew could use and it was one floor beneath the briefing room. The cumulative effect of the delays, frustrations and lack of food could have affected the crew to some small extent, but it is unlikely that they were factors which initiated the incident.

2.3 Weather at the time of the incident

At first it is difficult to reconcile the wind conditions passed by VHF radio to the helicopter by the Petrojarl's crew with those automatically recorded on board the vessel. The windspeed recorded at the time of the incident was 330°/15 kt whereas the wind conditions passed by radio were 300°/28 kt. However, the recorded wind direction was close to 300° at 1740 hrs when the helicopter crew first contacted the Petrojarl 1 by VHF radio and at that time the recorded strength was 20 kt or more.

A satellite weather photograph taken 10 minutes after the incident at 1805 hrs showed a cluster of large cumulus or cumulo-nimbus clouds in the vicinity of the Petrojarl 1 with other similar clouds stretching as far as the Norwegian coast. There can be little doubt about the vigour of these clouds since lightning was detected near that coast. Given the scale of the photograph, it is difficult to be precise about the location and size of these clouds but those near the Petrojarl 1 appear to surround it and to cover an area of at least 20 miles by 30 miles. There were no large clouds upwind of the vessel.

A detailed study carried out by the Meteorological Office is at Appendix E. This shows that the general synoptic variations in wind velocity and temperature within the lower 3,000 feet, particularly when combined with an atmosphere which was close to being unconditionally unstable, were such as to produce horizontal and vertical windshear and cause severe turbulence at low level.

The Meteorological Office study was also able to show that the atmosphere in the immediate vicinity of the Petrojarl 1 was being strongly affected by the adjacent cumulo-nimbus. The variation of windspeed and direction measured on the Petrojarl 1 as the cumulo-nimbus swept past showed good correlation with a mathematical model of a microburst. The combined effect of the general levels of windshear and turbulence together with the microburst activity would have been to produce the severe levels of turbulence reported by the helicopter's crew at the time of the incident.

2.4 Interpretation of the weather radar display

The red-centred weather radar returns noticed by both crew members were indicative of the active cells within the cluster of large cumuliform clouds which gave rise to the heavy rain showers consistent with the weather forecast and subsequent observations. The cells were widely scattered, relatively small in size when compared to a full-blooded thunderstorm, and generally to the north of the helicopter's track which meant that en route to the Petrojarl 1, there was no need for the crew to take avoiding action or to consider the potential consequences of flying very close to a storm. Both crew members noticed the heavy rain return near the Petrojarl 1 as they approached the vessel; their differing perceptions of the return's location relative to the vessel are probably related to them having viewed it at slightly different times. The area of heavy rain would have been travelling from west to east at around 29 kt and relative to the vessel, moving a nautical mile in about 2 minutes. Thus the co-pilot's perception that it was north west of the vessel by a mile or two remains consistent with the commander's perception that it was just to the north of it if a time difference of a minute or two existed between their mentally stored observations. What is certain is that their ability to keep track of the heavy rain's location was prevented by the need to cease radar transmissions as they approached the vessel. (Radar transmissions at close range are hazardous to people and electro-statically sensitive equipment).

Had there been a large storm cell directly overhead the vessel, the crew would most probably have approached with caution, held off until the storm passed, or diverted; in each of these options they would probably have kept the weather radar switched on. However, because no part of the radar return overlaid the vessel, the crew assumed that the area of heavy rain did not represent a hazard and they did not keep track of its location after switching the radar to standby during the first approach. Their perception that it was not a hazard would have been reinforced by the weather observation from the vessel, their clear view of its lights from several miles distance, the lack of any significant precipitation during the approach, the small size of the radar return, and the absence of lightning.

In common with most contemporary aircraft weather radars, the type of weather radar fitted to the Bell 214 cannot detect turbulence if the turbulent air does not contain precipitation. Moreover, there being no symptoms of a nearby thunderstorm, there were few if any clues to alert the crew to the presence of severe turbulence. Consequently, given the information available to them, when they began the first approach there was no obvious reason for the crew to suspect or be especially alert to the presence of a microburst.

However, three valuable insights can be drawn from this aspect of the incident. Firstly, when operating in the vicinity of storm cells, crews should keep a mental plot of the whereabouts of those cells, particularly in strong wind conditions when the local situation may be changing rapidly. Secondly, that microbursts can be generated by active storm cells which have much smaller radar returns than a full blooded thunderstorm, and thirdly, that microbursts can exist outside the radar echoes associated with precipitation (the 'dry' microburst). Consequently, helicopter crews should be advised to avoid operating near any active storm cell, particularly at low altitudes, unless absolutely necessary, and then only with great caution. To ensure that crews receive appropriate advice, it was recommended to the CAA that the Authority should require commercial helicopter operators to provide their pilots with guidance on avoiding microbursts.

2.5 Turbulence

The recorded flight data do not reveal severe excursions in normal acceleration but, compared with most fixed-wing encounters, in this incident the airspeeds are relatively low and the turbulence appears to have had a more pronounced buffeting effect rather than inducing harsh 'bumps'. In the judgement of the flight crew and the passengers, the turbulence and buffeting were severe. It was the worst the co-pilot had ever experienced and almost as bad as the commander's worst turbulence encounter. Moreover, both pilots felt the main effect of the turbulence was the difficulty of maintaining a steady aircraft attitude. The aircraft encountered severe turbulence only in the vicinity of the Petrojarl 1. It grew worse between the two approaches to the vessel and was at its worst during the second climb.

Moderate to severe turbulence would be present within an active cumuliform cloud, particularly a towering cumulus or a cumulo-nimbus, but compelling evidence that the aircraft did not enter cloud came from the deck crew of the Petrojarl 1 and the Master of the Toisa Conqueror who saw the aircraft throughout its climb and subsequent dive. The outflow from the microburst could have been responsible for the churning of the sea surface ahead of the vessel noticed by the co-pilot. On the other hand, the vessel was maintaining a steady heading in windy conditions by using her stern and bow side thrusters which also churn up the sea surface. Therefore, no conclusion about the wind should be drawn from the co-pilot's sighting. However, retrospective analysis strongly suggests that the crew went around from the second approach at much the same time as the microburst over the ship reached peak intensity. This explains why the turbulence was so severe and why it was encountered only in the vicinity of the vessel.

2.6 The decision to abandon the landing

Notwithstanding the air turbulence, deck movements and difficulties of stabilising the hover alongside the Petrojarl's helideck, the helicopter was not in danger because it was under control. The commander's decision to abandon further attempts to land on the deck was sensible and it should have led to nothing more than a frustrating return to the mainland for all involved. The only difficult manoeuvre that lay ahead was the transition into climbing forward flight. The manoeuvre was especially difficult because it had to be carried out by sole reference to instruments (there being no external visual cues upon which to judge the flightpath) and into the turbulence generated by the microburst.

2.7 Transition procedures

There were no written procedures for transitioning to forward flight from an abandoned hover but the manoeuvre was partially described within the takeoff and climb procedures in the aircraft manufacturer's Flight Manual (see Appendix C page 1 paragraph 2 onwards) and the company's Operations Manual (see Appendix D page 3 paragraph 3.7.1 e onwards). However, the Flight Manual procedures were based on operating from land sites and assumed that the manoeuvres would be carried out in sight of the ground until the single-engine safety speed of 55 kt (V_{TOSS}) was achieved at 50 feet above the ground. For various reasons, these procedures are unsuitable for offshore takeoffs and so the operator had placed modified procedures in the 'OFFSHORE PLATFORM PROCEDURES' section of the company's Operations Manual. Those procedures stated that up to 20% torque above the 5 foot hover torque should be applied without exceeding the 100% limit and that the nose should be lowered to approximately 12° nose down.

2.8 The entry into transition

The variety of offshore landing platforms, weather conditions and aircraft loads demands that each takeoff and transition be different. Using his acquired skills, the handling pilot must apply extra power with the collective lever and lower the nose an appropriate amount with cyclic control. Judgement of what is appropriate is an acquired skill which cannot be pre-determined before takeoff or written in a manual - it has to be learned and practised. Therefore, the absence within the operator's procedures of any recommendation for a specific pitch attitude with which to commence the transition was reasonable and the advice of using approximately 12° nose down was sound.

The flight data showed that about 90% torque was required to hover the helicopter at a height of approximately 100 feet above sea level alongside the Petrojarl 1 with the pitch attitude varying between 0° and +6°. This high power requirement was partly due to the helicopter's weight, partly due to the need to hover out of ground effect, partly due to the frequent and large cyclic control inputs which absorbed power, and partly due to the effects of the microburst. Transition to forward flight was begun by applying approximately 100% torque and lowering the pitch attitude to about 7° nose down in less than three seconds. Considering the high torque required to hover, there was probably insufficient power margin to lower the nose to 12° below zero without sinking or seriously overtorqueing the transmission. In the event the transmission was slightly overtorqued for about two seconds. However, since there was hardly any movement of the collective pitch lever between 94% torque just before the go-around was started and 102% torque a second or two later, the transient overtorque was probably caused by air turbulence and should not be considered as indicative of mishandling. The initiation of the transition was, therefore, safely and sensibly executed.

2.9 The transition

During the early stages of the transition the indicated airspeed began to increase as the aircraft climbed at a rate of about 600 ft/min, as shown in Appendix F, Figure F-1. However, just before the speed reached 40 kt, the pitch attitude started a long nose up trend, changing fairly steadily from 7° nose down to 19° nose up over 10 seconds. During this period the airspeed reached a maximum of 46 kt before decreasing rapidly whilst the rate of climb increased to about 1,700 ft/min.

The fact that the commander was attempting to control pitch attitude in turbulent conditions during the climb is demonstrated by the FDR trace of cyclic pitch control position, which was sampled four times per second. The trace is slightly erratic but some movements might have been involuntary due to turbulence. Pitch attitude changes, on the other hand, followed a smoother and more predictable pattern.

Although the record of cyclic pitch position is erratic, there is a clear trend of aft movement lasting some 30 seconds. The underlying movement is too slow to be caused either by the inadvertent application of nose up trim or by the stability augmentation systems, so the cyclic must have been eased aft by the commander. The physical displacement of the cyclic top was not great - about 1.7 inches - but it took place when the cyclic would normally be moving in the opposite direction to counteract the helicopter's natural tendency to pitch-up. The loss of forward airspeed was consistent with the increasingly nose up pitch attitude yet there was ample time to restore the correct attitude. Such action could have been taken by the commander on his own initiative or at the behest of the co-pilot. The remainder of this section addresses potential reasons why action was not taken before forward airspeed was lost.

2.9.1 Instrument readability

Airframe vibrations due to air turbulence and main rotor dynamics could and probably did induce vertical motions of the instrument panel and the pilots' heads. The possibility that these motions combined to render the attitude indicators difficult or impossible to interpret was considered unlikely because, during the post-incident interviews and on the cockpit voice recording, neither pilot mentioned that had been unable to read any of the instruments. As for instrument clarity, the main attitude indicators in the Bell 214 are large instruments with the horizon clearly defined by a change in colour from pale blue to black, and a level pitch attitude displayed by equal portions of each colour. Therefore, although the turbulence might have made it abnormally difficult for the pilots to read or set a specific pitch attitude, they should have been able to differentiate between nose up pitch and nose down pitch without undue difficulty. The ability to do so was confirmed by the co-pilot's action of alerting the commander to the undesirable nose up pitch attitude towards the end of the climb when the turbulence was reportedly at its worst.

2.9.2 Instrument error

The attitude indications recorded by the FDR were consistent with the helicopter's behaviour and so there was unlikely to be a gyro error. The commander eventually noticed the nose high pitch attitude and so there was unlikely to be a gross error within the system which slaved his main attitude indicator to the remote gyro. Moreover, during the flight to Sumburgh and the incident flight, the crew did not notice any discrepancy between the four attitude indicators either before or after the incident. Therefore, an insidious error in the commander's main attitude indicator was considered most unlikely.

2.9.3 Terrain clearance

Visual assessment of terrain and obstacle clearance is not always possible during offshore operations at night. Although on the night of the incident, the Petrojarl 1 was well lit and visual references for hovering were available, the helideck was over the vessel's bow and the transition to forward flight had to be made ahead of the vessel well beyond the illuminated area. The sun had set more than 3 hours earlier so there were no remnants of a natural horizon. There were no other rigs ahead of the helicopter, no moonlight and a lot of cloud. Consequently, it would have been very dark and the acceleration to V_{TOSS} would have had to be performed out of sight of the sea surface and by sole reference to instruments.

After committing the aircraft to the transition by applying power and lowering the aircraft's nose, the next step in the operator's procedure was to achieve the take-off safety speed (V_{TOSS}) of 55 kt. At night, provided the take-off path is clear of obstacles, the handling pilot's priorities are gaining height - or at least not losing height - and accelerating forwards. Given the obvious danger of losing height and hitting the sea, it is not surprising that a healthy rate of climb initially took priority over airspeed. This is reflected in the co-pilot's perception of events. Early during the transition he was aware that the airspeed was low but this did not worry him; he was more concerned by the rate of climb which he thought was low. The commander also had the impression that it was low. There were no guidelines on an acceptable rate of climb in the procedures but he considered that 800 ft/min was normal except when the aircraft was really heavy.

2.9.4 Pitch control demands

The time history of pitch attitude versus cyclic movement shows that during the period when the average cyclic position was moving aft, there were several distinct forward cyclic movements in response to undemanded pitch-ups. Although all were successful in reducing pitch attitude, none of them lowered the pitch attitude sufficiently to restore it to its position prior to the upset. The first attempt to oppose an undemanded pitch-up followed a reasonably rapid nose up rotation which may have been caused by turbulence or by the helicopter's natural 'flapback' tendency to pitch-up as it accelerated. The second rapid pitch-up was probably induced by turbulence. The third attempt to lower the nose was not in response to a pitch-up so it may have been made when the commander noticed for himself the nose high attitude or it may have been in response to a prompt by the co-pilot. The co-pilot remembered making a comment about high nose up pitch attitude to the commander during the climb. The fourth attempt, which was also the most pronounced, followed a sudden rapid pitch-up.

The commander was apparently making appropriate corrections to high nose up pitch rates, but did not correct the low rate trend. Several factors have a bearing on this trend and the crew's failure to notice it:

(i) The lack of external visual cues was certainly a prerequisite in that it denied the commander an immediate and easily interpreted impression of the vehicle's motion. The performance instruments provided a partial substitute for this impression. The attitude indicator could, in principle, complete the picture. His control of roll angle during the go-around must have been based on information derived from the attitude indicator. It is interesting, however, that neither he nor P2 has as clear a recollection of pitch attitude as they do of performance information. The fact that they did not have a target value for pitch attitude (as they do for airspeed, for example) may explain why the deviation in pitch went unremarked for some time.

(ii) A general, and probably increasing, desire to be climbing away from the (unseen) sea surface would certainly account for some tendency to pull back on the cyclic control - particularly as vertical speed did not initially conform to expectations.

(iii) The circumstances may not have been the most extreme ever encountered by the crew, but they were demanding and provocative. The severe turbulence and lack of visual cues may well have induced some apprehension, which conceivably might be expressed in a general tension in the arm musculature. The back pressure might, then, be partly unconscious in origin.

The first of these factors is certainly a necessary condition for the behaviour at issue. The second two provide more or less plausible mechanisms for generating an unnoticed cyclic back trend. It is important, however, to consider the possibility of illusions of motion and disorientation generally.

2.10 Disorientation

There being no logical need for the trend in aft cyclic movement, the possibility of some form of illusion or disorientation was considered.

2.10.1 True vertical and horizontal accelerations

Because they do not have thrust from a rearwards facing engine, helicopters accelerate in a different way to fixed wing aircraft. Most of the acceleration force in a transition to forward flight is generated by maintaining a nose down aircraft attitude. Similarly, the helicopter decelerates rapidly when a nose up attitude is selected although, unless the collective pitch angle is reduced, the aircraft tends to gain height in the process of decelerating. Consequently, the accelerations measured and recorded by the helicopter's FDR do not reveal a true picture of its manoeuvres relative to the earth's axes. The recorded accelerations do, however, represent most of the forces experienced by the crew.

At Appendix F, Figure F-3 the longitudinal and normal accelerations during the first 40 seconds of the transition have been tabulated. These show that, for the first 17 seconds of the transition, the normal accelerations are generally greater than 1g (average 1.06g). In the same period, the longitudinal accelerations are generally less than 0.1g. These figures hide the true picture of what is happening to the machine. To illustrate what is actually happening, the recorded accelerations have been converted into earth-related (true) horizontal and vertical accelerations by vector analysis using the aircraft's pitch angle. Also, the rate of climb has been derived from the radio altimeter height increments and smoothed by using a running average of three readings.

The earth-related accelerations reveal that the helicopter accelerates for about 10 seconds with a low rate of climb. After the 10 second point, it begins to decelerate but the rate of climb shows a dramatic improvement. Beyond the 16 second point, the aircraft is decelerating at a rate generally in excess of 0.2g which is equivalent to about 4 kt/sec. This is quite a rapid horizontal deceleration which the crew may not have sensed because the forces experienced by their bodies are related to the helicopter's axes and not the earth's axes. The period between 15 and 25 seconds after the start of the transition illustrates the point dramatically. The table at Appendix F, Figure F-3 shows the aircraft decelerating horizontally at more than 0.15g whilst the crew are subjected to a positive longitudinal acceleration of about 0.05g.

2.10.2 Illusions of motion

The potential for illusions of motion can be assessed by comparing the incident overshoot with the transition to forward flight after a normal takeoff. A normal takeoff was recorded at the start of the incident flight. Appendix F, Figures F-4 to F-7 compare the transition from the hover to 60 kt during that takeoff with the start of the incident overshoot. The data have been reduced to a uniform 1Hz sampling rate.

Both normal and longitudinal accelerations (Figures F-4 and F-5 respectively) during the incident manoeuvre show more variability than during the normal takeoff, as would be expected in severe turbulence. The general levels and pattern are, however, very similar. Between 4 and 16 seconds there is a sustained difference in normal acceleration, but it is only about 0.05g and would probably be undetectable in normal circumstances let alone in the turbulent conditions experienced at the time. In the absence of good visual cues the overall motion in these situations would be perceptually indistinguishable.

This is made clear by comparing the two manoeuvres in terms of both the actual pitch angles (Appendix F, Figure F-6) and the apparent pitch angles (Figure F-7). The apparent pitch angles are calculated by vector analysis to give the angle between the resultant acceleration vector and the vertical axis of the aircraft. A pilot's subjective impression of his orientation with respect to the vertical does not necessarily correspond at all times with this mathematical construct, but the apparent pitch angle does indicate a boundary on what his perceptions are likely to be. There is a clear difference between the pitch angles actually recorded in the incident and the normal transition, and this is the origin of the incident. The apparent pitch angles, on the other hand, are distinguishable only in terms of variability.

In these circumstances the importance of good visual references is paramount. The dynamic force environment endured by the crew during the incident overshoot may not have induced an illusion which caused the cyclic control to be moved aft, but it did not provide the stimuli necessary to identify the resulting change in pitch attitude. Only good visual references (external or artificial) could support a proper handling technique.

2.11 Pilot technique

None of the events described above, when taken in isolation, is conclusive but the sum of the evidence indicates that after he lowered the nose to begin the transition, the commander was not attempting to hold a specific pitch attitude. It is not intended to imply that the commander was not looking at the attitude indicator. What is more likely is that whilst being subjected to severe turbulence and buffeting, he did not notice the underlying and subtle trend in nose up pitch. He was reacting to sudden pitch rates which he either sensed physically or noticed on the attitude indicator but, sensing nothing untoward from the motion feedback cues, he was probably concentrating too much on the performance instruments (airspeed, altitude and rate of climb). At the same time, the co-pilot was probably concentrating primarily on the engine instruments because the commander was using high power and it was his task to notify the commander of any exceedances. What spare monitoring capacity he had was probably devoted to ensuring that the helicopter did not descend with occasional glances at airspeed and pitch attitude. The increase in the climb rate some 10 seconds after the transition started may have temporarily assured him that all was well and so he may not have monitored closely the aircraft's pitch attitude. In the conditions of extreme turbulence, the performance instrument readings were bound to be erratic and at times quite misleading, especially the airspeed which was affected by gusts. Therefore, the primary cause of airspeed loss during the transition was the handling procedure which was inappropriate to severe turbulence.

2.12 Adequacy of the procedures

The technique for transitioning from the hover into forward flight involves applying the right amounts of power and nose down pitch. The pilot then has to wait for the performance instruments to read (particularly the airspeed indicator which is unreliable below 40 kt) before he can judge just how appropriate were the inputs he made. Applying the correct inputs at the right rate and in the right order is an essential skill for helicopter pilots. For the offshore helicopter pilot community, their takeoff safety record indicates that it is a skill which has served them well for many years. However, there was no documented procedure for this manoeuvre in benign weather conditions, let alone the severe turbulence experienced at the time of the incident. The manufacturer's Flight Manual assumed that the part of the transition between hovering and V_{TOSS} would always be flown with external visual references and the Operator's Offshore Procedures did not specify an IMC technique.

2.13 The importance of pitch attitude in severe turbulence

The procedure stipulated in the Operations Manual (see Appendix D) stated: "At TDP rotate the helicopter to approximately 12° nose down to initiate forward acceleration. At V_{TOSS} reduce the nose down attitude ...". With this exception there were no laid down guidelines or limits for pitch attitude in the operator's procedures and neither pilot had any personal limit regarding sensible upper and lower boundaries for pitch attitude during transition. Without such boundaries, extra time is required to detect that a situation is deteriorating beyond safe limits. Both pilots were aware that a combination of reducing airspeed and nose up pitch was highly undesirable during the transition, but neither acted in time to prevent the rapid decay in airspeed. The aircraft never went faster than 46 kt (V_{TOSS} -9 kt) and most if not all the forward airspeed was lost before corrective action was called for by the non-handling pilot.

The crew were being buffeted making them feel uncomfortable, the performance instrument readings were seriously affected and the aircraft's attitude was being altered abruptly by external forces. In these conditions the crew needed a simple, correctly prioritised procedure which could be monitored by the non-handling pilot, and which would guarantee a safe transition to V_{TOSS} without loss of height.

The two parameters which were most important in these conditions were power and pitch attitude. Full power was applied by the commander and monitored by the co-pilot. Thereafter, what was needed - but not defined - was a pitch attitude range which the commander could aim to remain within and, if necessary, return to after undemanded divergences, and which would ensure that the helicopter accelerated without descending. Just as importantly, the co-pilot also needed to know the acceptable range of pitch attitude so that he could readily identify any gross divergence and immediately call for corrective action.

Undoubtedly, given the flexibility of helicopters and the diversity of their operating conditions, it would be difficult to pre-define a precise target attitude for every transition. Nevertheless, it should be possible to define safe upper and lower boundaries for pitch attitude during every transition even though it may be unnecessary or even undesirable to adhere strictly within those boundaries during visual transitions. However, the documentation of a method for transitioning from the hover to V_{TOSS} on instruments would address the discrepancy between current practice and the minimum speed for instrument flight specified in the CAA approved manufacturer's Flight Manual; it would also be invaluable for conditions of severe turbulence. Therefore, it was recommended to the CAA that they should require the documentation of procedures for helicopter transitions by sole reference to instruments from the hover into forward flight.

2.14 Training and testing in instrument flying techniques

It is important to remember that it was the departure into complete blackness that triggered the incident and not the commander's inability to land on the Petrojarl's helideck. Quite justifiably he decided that conditions were unsuitable for landing and there is no evidence to indicate they were within the ability of any other pilot. Had he landed on the Petrojarl 1, the subsequent departure would have demanded instrument flying skills almost from the moment the nose was lowered to begin the transition.

The incident need not have developed so seriously if the abnormal and emergency procedures had been more detailed and if the crew had been trained and tested in the skills required for an instrument transition from a hover outside ground effect. Admittedly, the combination of factors which provoked the incident will seldom be encountered but given the frequency of operations to offshore rigs and the long hours of darkness in winter over the North Sea, such circumstances will exist occasionally.

The operator met all the CAA requirements and more; the company had a policy of two line checks every 13 months (one of which was to be at night) instead of meeting the statutory requirement for one, which could be by day. However, the information systems and records used by the operator's management did not bring to their attention a pilot's lack of recency at certain difficult manoeuvres such as aborted deck landings by night. There was no regulatory requirement to do so and it was not normal practice within the helicopter industry to keep such records.

In fact, although both pilots were in current instrument flying practice and met all the legal requirements for proficiency and recency, neither had recently experienced a go-around on instruments from an out of ground effect hover. The commander had last flown an instrument go-around from a rig approach in July 1994 in foggy weather conditions. This go-around was the result of an aborted instrument approach when the required visual flying references were not available at decision height. The go-around would not have been commenced from the hover; it would have been commenced from a speed at or above the minimum speed for instrument flight and the air would have been relatively smooth. Proficiency at the instrument approach and this type of go-around from decision height is routinely tested and part of the instrument rating for all helicopter pilots aspiring to such a rating, irrespective of whether they are employed in offshore or onshore roles. However, only those pilots employed on offshore roles are expected to depart from helidecks in conditions which, although they may be nominally VMC and therefore legally permissible, have to be flown by sole reference to instruments because of the paucity of external visual cues.

The absence of a specific procedure for instrument transitions from the hover, plus the need for attitude parameters for the handling pilot to aim for and the non-handling pilot to monitor, have already been highlighted as areas of concern which deserve safety action. The documentation of the procedure is not the only necessary action; the procedure will have to be memorised by the pilots, practised often enough to maintain proficiency and tested regularly to ensure continued competency. This could best be achieved by adding a suitable requirement to routine testing and training for all pilots employed on offshore operations. Therefore, it was recommended to the CAA that training and testing for go-arounds from the hover outside ground effect by sole reference to instruments should be a formal requirement for all helicopter pilots employed in night, offshore tasks.

2.15 Recovery from unintentional loss of airspeed

From the pattern of cyclic inputs, it appears that the commander realised that the nose was too high about 24 seconds into the transition and a moderate forward cyclic input reduced the nose high attitude from 19° to 8°. Both pilots were acutely aware that airspeed had, in their perception, very suddenly dropped from 40 kt to zero; a situation similar to the symptoms of windshear. Given that the aircraft was 600 feet above the sea, there was some scope for trading altitude for airspeed and so appropriate action would have been to maintain full power whilst at the same time lowering the aircraft's pitch attitude to below the horizon in order to trade a little height for forward airspeed. Determining the appropriate nose down angle is beyond the scope of this report but a starting point could be the 12° nose down recommended in the offshore takeoff procedures. Had the commander taken this action and held a 12° nose down attitude, forward airspeed would have been regained in a few seconds and the subsequent steep dive would have been avoided.

The reasons why the commander did not recognise his predicament and react accordingly were probably threefold. Firstly, being unaware of the long trend of increasing nose up attitude, he probably thought that the sudden loss of airspeed was due to some other factor. Secondly, although he received biannual training and practice in recoveries from unusual attitudes, the attitude was no longer extreme; the 'wings' were level and the pitch was between zero and 10° nose up. Thirdly, and most importantly, there was no documented procedure for coping with 'unintentional loss of airspeed'.

In his attempt to recover airspeed the commander increased power but without selecting a nose down attitude this would have been ineffective. He still had control of pitch attitude but no clear intention of where to set it and, no matter what he did to pitch attitude, there was bound to be a significant delay before the desired increase in airspeed materialised on the airspeed indicator. Had there been guidance on the recovery from a sudden loss of airspeed in the form of a simple memorised drill, the commander would have been better placed to cope, even though the cause of his predicament may not have been windshear. Therefore, it was recommended that the CAA should require that training and practice on recovery from attitudes resulting from unintentional loss of airspeed should be included in the training which is already part of the biannual base check.

2.16 Vortex ring diagnosis

Observers on the Petrojarl 1 saw the helicopter's forward progress reduce until eventually, relative to them, it was flying backwards at an abnormally rapid speed. It is not possible to calculate with any certainty the helicopter's airspeed at this time because a proportion of its rearwards motion could have been induced by an increase in headwind as it climbed. On the other hand, an external force large enough to reverse the helicopter's progress would have been sensed along the aircraft's longitudinal axis but no deceleration greater than 0.05 g was recorded. Therefore, since most of the accelerations along this axis were actually positive, the contribution of increasing windspeed to the helicopter's rearward motion was unlikely to have been the dominant factor.

However, from the integrated CVFDR accelerations, it is clear that the helicopter was travelling rearwards relative to the vessel for at least 23 seconds and it reached a groundspeed of minus 30 kt. Consequently, there is a possibility that the helicopter was flying backwards relative to both the vessel and the free air.

By this time the commander was well aware that the helicopter was responding to control inputs in an unfamiliar way but he was unaware that it was travelling backwards relative to the vessel because that was some 600 feet beneath him. He had sensed that the aircraft was descending with more than full torque applied and there was no airspeed indicated. To him, all the classic symptoms of incipient vortex ring were present and he seized upon this explanation for the helicopter's unnatural behaviour. When he informed the co-pilot of his diagnosis, the co-pilot did not think that they were actually in a developed state of vortex ring but he realised that something bold had to be done to recover airspeed and so he accepted the commander's diagnosis.

Given that the helicopter's behaviour was consistent with the early symptoms of vortex ring and that there were no compelling cues to the contrary, the commander's diagnosis was logical. His announcement of the condition to the co-pilot and his decision to take suitable corrective action were appropriate responses.

2.16.1 Vortex ring recovery

To recover from vortex ring, the helicopter must escape from the column of disturbed air. This is normally achieved by applying forward cyclic to accelerate the helicopter forwards thus leaving behind the column of disturbed air. It may also be helpful to reduce power but the main key to recovery is to gain airspeed. The commander's actions of lowering the helicopter's nose and reducing torque were, therefore, entirely appropriate. Unfortunately, the pitch-down manoeuvre went on for too long (about 6 six seconds) and the aircraft reached a nose down attitude of 53° at a height of 630 feet above sea level. Neither pilot immediately realised the steepness of the nose down attitude and neither subsequently believed that such a steep nose down attitude was necessary to effect a recovery. Moreover, after the event, both thought that the attitude was about 20° to 25° nose down. Consequently, the reasons for the excessive nose down attitude and for the crew's failure to appreciate the situation deserve detailed analysis.

2.17 Pitch control

2.17.1 Duplication of control input

When the commander announced his diagnosis of vortex ring, the co-pilot instinctively joined him on the controls to ensure that recovery action was taken. At this stage, although both pilots were holding the controls, post-incident interviews with the crew indicated that the commander was probably the predominant mover of the controls when the dive was initiated and during the pull-out from it with the co-pilot being content to feel them being moved in the appropriate directions. At other times during the dive and the subsequent climb, the co-pilot thought he was the dominant mover of the controls. There is no way to determine exactly who did what but both pilots agreed that neither ended up fighting the other - they were both trying to achieve the same thing. Notwithstanding the shared perceptions of the crew, the possibility that in the heat of the moment the co-pilot added his own input to the commander's forward cyclic input, thereby resulting in a combined effort which exceeded the effort intended by either pilot could not be totally eliminated. However, given that the cyclic input which initiated the dive was not extreme, this factor seems unlikely to have been significant.

2.17.2 Stability and Control Augmentation System (SCAS)

One factor which very probably did contribute to the steep nose down attitude was drop-out of the SCAS pitch channel as the nose was being lowered. This is a design feature if the cyclic reaches full travel but drop-out can also be caused by a temporary mismatch between the system's dual channels which sometimes occurs during rapid manoeuvres. The other two channels remained engaged and when selected after the event, the pitch channel re-engaged and operated normally for the remainder of the flight. The FDR trace of cyclic position does not show a movement close to the limits of travel and so it seems likely that the drop-out was caused by the high pitch rates demanded rather than being a causal factor of the high pitch rates. Nevertheless, the effect of the drop-out would have been to make the helicopter less stable in pitch and for it to continue to pitch after the cyclic had been returned to neutral.

2.17.3 Fly-by-wire (FBW) Elevator

Another probable factor was the FBW elevator. This too suffered a drop-out at some time during the dive or subsequent recovery but the effect of the drop-out would have been to suspend further programmed movement of the elevator. This would have had little effect on pitch stability or control response; the main purpose of the elevator is to improve the helicopter's handling qualities during changes in power and centre of gravity in flight. However, reversal of air flow over the FBW elevator could have had a marked effect on pitch response. Although the elevator remains in the stowed position at low airspeeds (below 45 kt), in forward flight it has a stabilising effect on pitch attitude but in rearwards flight (relative to the free air) it will have a de-stabilising effect. If the helicopter did have a rearwards component of airspeed, once the commander started to lower the nose, the reversed airflow over the elevator would have aggravated the nose down pitch tendency by augmenting the commander's input. Moreover, the more the nose pitched down for a given rearwards airspeed, the stronger the pitch-down moment from the elevator would have become. However, the effect would have been short-lived for it would have decayed rapidly as the airspeed increased to zero and then became positive during the dive.

2.17.4 Pilot technique

The most probable reason for the inadvertent steepness of the dive was the technique adopted by the pilots. Uppermost in both their minds was the need for indicated airspeed and they knew instinctively that this had to be achieved by lowering the nose. They remained aware of the trend in pitch attitude but not its magnitude and so although both knew they were in a dive, neither had an accurate mental picture of how steep the dive was becoming. The situation arose because neither pilot was treating pitch attitude as the principal target parameter. Both pilots became engrossed in the need for airspeed at the expense of all other parameters.

When he lowered the nose, the commander was watching and waiting for the airspeed to increase. When it did not increase as soon as he expected it to, he made a second nose down control input which exacerbated the steepness of the dive. In total, the pitch-down lasted for some five seconds which is also the same time taken for the airspeed to increase to a positive value on the FDR trace. This is unlikely to be pure coincidence; it is more likely that the pitch-down was encouraged and allowed to develop by both pilots until the airspeed began to read. Because the aircraft was probably flying backwards when the pitch-down was started, it took an unusually long time for the airspeed to recover to a positive value and all the while, the nose was dropping. This was probably the main reason for the inadvertent steepness of the dive.

2.17.5 Vortex ring recovery procedure

Although there was no documented procedure for vortex ring recovery, the manoeuvre is practised in the aircraft as part of recurrent training and testing. Consequently, when the drill was called for, both pilots knew what to do and they did it together without fighting each other for control. However, both ended up with the same priorities and assumed the same duties; nobody monitored height and the aircraft was endangered by the unnecessarily steep dive.

2.17.6 Co-Captain

The aircraft was operated by two Captains of similar standing. Although one was nominated as the commander, they were friends who knew each other well. Theirs was a small fleet where every pilot had Captain status and they would from time to time have operated in the reverse roles with respect to commander and co-pilot. They naturally shared decisions and treated each other as equals both socially and professionally. No doubt this made for a happy working atmosphere but there are well known pitfalls when two pilots have equal status on the flight deck. Notably there can be a tendency for the non-handling pilot to be less vigilant than he would be when operating with a junior co-pilot and it can make him reluctant to draw to the handling pilot's attention minor deviations from normal standard procedures. To some small extent, this lack of clearly defined status may have been responsible for both pilots doing the same thing and for neither devoting sufficient attention to pitch attitude or height. However, the crewing of the helicopter by two Captains and the relaxed atmosphere and sharing of decisions were not the real problems. What was lacking was clearly defined, different and memorised roles for the handling pilot and the non-handling pilot when faced with this emergency, no matter what their seniority or status.

2.17.7 Recovery procedures

Once again, the predominance of performance targets over attitude targets during helicopter instrument manoeuvres was unsatisfactory. In practice, the procedure for recovery from either the loss of airspeed or vortex ring are very similar. Had there been a documented procedure for recovery from unintentional loss of airspeed (which included a target pitch attitude), the close encounter with vortex ring in this incident might have been avoided or, if not, the ensuing recovery from incipient vortex ring would have been less dramatic.

2.18 Dive recovery manoeuvre

The commander's 'MAYDAY' message broadcast on the VHF RT near the top of the steep dive was an unusual act in such circumstances. In diverting his mental effort into making an emergency call, he deprived himself of mental capacity at a time when it was most needed. To be in accordance with company instructions the call should have been made by the non-handling pilot. Nevertheless, the call was brief and probably represented his concern at losing control rather than any symptoms of 'giving up' or 'running out of ideas' for effecting a recovery. Fortunately, at about the same time as he was transmitting, he was also looking out and saw the surface of the sea which was illuminated by the helicopter's landing light. This was his cue to begin a swift recovery from the dive; the co-pilot had also seen the sea in the same manner but probably earlier than the commander and for the latter part of the dive he was concentrating on the flight instruments. The recovery manoeuvre was quite violent for a helicopter but necessarily so. Although the pitch angle was slowly increasing during the latter part of the dive, the full-blooded recovery did not begin until about 400 feet above sea level when the helicopter was still in a 40° dive. During recovery the pitch rate reached 36°/sec and the normal acceleration reached 2g; the minimum height recorded by the radio altimeter was 66 feet.

Thus neither pilot decided to begin recovery action based on the instrument readings and the successful recovery had depended on an element of luck - the landing light was still on and one of the pilots happened to be looking outside. This sequence of events further illustrates the need to divide the workload during emergency manoeuvres; one pilot should fly the aircraft and the other should assist him by monitoring and announcing the critical parameters. This can best be achieved by having clearly defined and different roles for the handling and non-handling pilots - irrespective of rank or status - with the proviso that the commander can become the handling pilot whenever he chooses to do so using the time honoured and unmistakable words of "I have control".

2.19 Post-recovery

After the dive recovery both pilots were still at the controls. Although the commander initiated the recovery, it was not possible to determine who was flying the helicopter during the climb but once again, there was no conflict on the controls. Shortly afterwards there was a formal handover of control to the co-pilot. This was logical since it was the 'co-pilot's leg' and the commander had taken control only briefly for the attempted landing and go-around. After returning control to the co-pilot, the commander busied himself with cancelling the 'MAYDAY', checking the state of the aircraft, resetting the SCAS and elevator, and explaining his intentions to the vessel's crew and his passengers. This allocation of duties and their execution were fully in keeping with the principles of Cockpit Resource Management.

2.20 Pilot recency in the offshore role

Crew changes on the Petrojarl 1 were normally serviced by a Super Puma or S61N but whenever the vessel's motion was too severe for the larger types, the Bell 214 was tasked. The Bell 214 fleet had no routine tasks or contracts with the oil companies. The two helicopters were used for ad hoc tasks and charters which, although irregular, were to some extent predictable when bad weather was forecast. With a tendency for the operator's Bell 214's tasks to include flights when the deck movement was unsuitable for other helicopter types and with a pilots' work pattern which was more sporadic than that of the operator's other pilots, they had less practice at deck landings and the landings they did achieve were often difficult because of the weather and the deck movements.

On the other hand, operating to the Petrojarl 1 was not a new task to either pilot for both had operated to the vessel within recent weeks in daylight. The successive delays in departing from Aberdeen on the day of the incident turned what should have been another daylight landing and takeoff into a night operation. Unfortunately the commander had not had a great deal of recent practice at night deck operations. He had been employed exclusively on police air support tasks from August 1992 until February 1994. Between February and the incident flight, he had been employed for several periods on each role with his duties split between Aberdeen and the south of England.

The commander had landed on an unstable deck twice in the preceding three months and both operations were achieved in daylight. In the same three month period he had landed on a deck only once at night. That operation was to a large, fixed platform and it was his only night deck landing in the previous nine months. The co-pilot, on the other hand had fared better. He was employed solely at Aberdeen and in the preceding three months had achieved 10 landings on unstable decks by day and two by night.

During this incident the commander was also handicapped by two factors which were circumstantial. Firstly, he had been the handling pilot earlier in the day and had flown mostly in daylight VMC conditions. Secondly, on departing from Sumburgh in the dark, it was the co-pilot's turn to fly the helicopter and he remained in control until after the first approach was abandoned. Thus, when the commander took control downwind for the second approach, he was suddenly faced with the need to execute a difficult manoeuvre in darkness and turbulence to a deck which was moving substantially; a task for which he was not in good recent practice.

Notwithstanding his skill, his experience, and the high regard in which he was held by his management and his colleagues, it was considered that the commander could not reasonably be expected to be fully 'up to speed' at the very difficult process of landing and departing from an unstable platform at night without recent practice. Therefore, it was recommended to the CAA that recency requirements for pilots employed on night offshore operations should be reviewed.

3 Conclusions

(a) Findings

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

(ii) At the time of the incident the crew had been on duty for 8 hours 55 minutes which was within duty time limits.

(iii) The aircraft had a valid Certificate of Airworthiness and had been maintained in compliance with the regulations.

(iv) There was no evidence of any defect or malfunction in the aircraft which could have caused or contributed to the incident.

(v) The helideck motion was within the operator's limitations for the Bell 214.

(vi) The general weather situation was conducive to a high level of atmospheric turbulence.

(vii) The microburst activity generated by the cumulo-nimbus adjacent to the Petrojarl 1 resulted in severe levels of turbulence at the time of the incident.

(viii) The crew could not have determined the presence of turbulence caused by the microburst before they encountered it.

(ix) The first approach to the Petrojarl 1 was made by the co-pilot but a landing was not attempted because the wind direction was unfavourable. After the go-around control of the aircraft was handed to the commander when the aircraft was downwind.

(x) Following the second approach, the commander's decision not to attempt a landing on the Petrojarl 1 was prudent.

(xi) The incident occurred within the influence of a microburst when the crew were carrying out a transition into climbing forward flight from a free air hover alongside the helideck of the Petrojarl 1.

(xii) During the transition, following an initial forward acceleration in conditions of severe turbulence, airspeed was lost and the aircraft then climbed with no airspeed indicated while the pitch attitude increased to 19° nose up.

(xiii) The procedure for transition from the hover to climbing flight by sole reference to the flight instruments was inadequately defined.

(xiv) At about 600 feet above sea level the aircraft began to travel rearwards in relation to the vessel, probably with rearwards airspeed.

(xv) When the aircraft began to descend the commander correctly diagnosed an incipient vortex ring condition.

(xvi) The steep nose down attitude during the recovery was probably achieved by the combined influence of both pilots' control inputs and possibly by the influence of reverse airflow on the fly-by-wire elevator.

(xvii) The procedure for both the handling and non-handling pilots for recovery by sole reference to the flight instruments from unintentional loss of airspeed was inadequately defined.

(b) Causes

The investigation identified the following causal factors:

(i) There were severe levels of turbulence close to the Petrojarl 1 brought about by the general weather situation combined with microburst activity generated by an adjacent cumulo-nimbus cloud.

(ii) The information available to the crew did not alert them to the potential influence of the cumulo-nimbus adjacent to the Petrojarl 1.

(iii) The commander lacked recent experience in operations by night to platforms in difficult weather conditions.

(iv) The crew did not maintain an accelerative pitch attitude in the severe turbulence experienced during the transition to climbing flight.

(v) The procedures for transition from the hover outside ground effect into climbing forward flight by sole reference to the flight instruments were inadequately defined.

(vi) The procedures for recovery, on instruments, from circumstances involving an unintentional loss of airspeed were not fully documented.

4 Safety Recommendations

The following safety recommendations were made during the course of the investigation:

4.1 It was recommended to the CAA that the Authority should require commercial helicopter operators to provide their pilots with guidance on avoiding microbursts.
[Safety Recommendation 95-29]

4.2 It was recommended to the CAA that they should require the documentation of procedures for helicopter transitions by sole reference to instruments from the hover into forward flight.
[Safety Recommendation 95-30]

4.3 It was recommended to the CAA that training and testing for go-arounds by sole reference to instruments from the hover outside ground effect should be a formal requirement for all helicopter pilots employed in night, offshore tasks.
[Safety Recommendation 95-31]

4.4 It was recommended that the CAA should require that training and practice on recovery from attitudes resulting from unintentional loss of airspeed should be included in the training which is already part of the biannual base check.
[Safety Recommendation 95-32]

4.5 It was recommended to the CAA that recency requirements for pilots employed on night offshore operations should be reviewed.
[Safety Recommendation 95-33]

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