AIRCRAFT ACCIDENT REPORT 4/83

Accidents Investigation Branch

Department of Transport

Report on the accident to Westland Wessex 60 G-ASWI 12 miles ENE of Bacton, Norfolk on 13 August 1981

LONDON
HER MAJESTY'S STATIONERY OFFICE

List of Aircraft Accident Reports issued by AIB in 1983

No	*Short Title*	*Date of Publication*
6/82	Lockheed Jetstar 1329–N267L Luton International Airport March 1981	January 1983
7/82	Britten–Norman Islander BN2A G–BBRP Netheravon Aerodrome Wiltshire February 1982	February 1983
8/82	Agusta Bell 206 B Jetranger G–BEKH Dundee Scotland December 1980	April 1983
9/82	British Airways Trident G–AWZT Inex Adria DC9 YU–AJR Zagreb Yugoslavia September 1976	June 1983
10/82	Bell 212 G–BIJF in the North Sea SE of the Dunlin Alpha platform August 1981	April 1983
1/83	Wasp Falcon IV Powered Hang Glider Wittenham Clumps nr Didcot May 1978	May 1983
2/83	Britten–Norman Islander G–BDNP St Andrew Guernsey Channel Islands September 1981	September 1983
3/83	Scheibe SF 28A G–BBGA Enstone Airfield Oxfordshire May 1982	September 1983
4/83	Westland Wessex 60 G–ASWI 12 miles ENE of Bacton Norfolk August 1981	
5/83	BAe HS 748 G–ASPL Nailstone Leicestershire June 1981	
6/83	Embraer Bandeirante G–OAIR Hatton nr Peterhead Scotland November 1982	

ISBN 0 11 550629 2

Department of Transport
Accidents Investigation Branch
Bramshot
Fleet
Aldershot
Hants GU13 8RX

23 August 1983

The Rt Honourable Tom King MP
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr D A Cooper, an Inspector of Accidents, on the circumstances of the accident to Westland Wessex 60 G–ASWI which occurred 12 miles ENE of Bacton, Norfolk on 13 August 1981.

I have the honour to be
Sir
Your obedient Servant

G C Wilkinson
Chief Inspector of Accidents

Accidents Investigation Branch

Aircraft Accident Report No 4/83
(EW/C764)

Operator:		Bristow Helicopters Ltd
Aircraft:	*Type:*	Westland Wessex 60
	Model:	Series 1
	Nationality:	United Kingdom
	Registration:	G–ASWI
Place of Accident:		12 miles ENE of Bacton, Norfolk Latitude: 52° 56′N Longitude: 001° 46′E
Date and Time:		13 August 1981 at 1542 hrs All times in this report are GMT.

Synopsis

The accident was notified to the Accidents Investigation Branch (AIB) by Bristow Helicopters Ltd (BHL) at 1645 hrs on 13 August 1981.

The helicopter was flying from the Leman Bank gas field to Bacton, Norfolk, when it suffered a complete loss of power to the main rotor gearbox. In the late stages of the ensuing autorotation the helicopter went out of control and crashed into the sea, all thirteen men on board being killed.

There was insufficient evidence to permit the cause of either the loss of power or the loss of control to be established. However, the report discusses possible causes and ten safety recommendations are made.

1. Factual Information

1.1 History of the flight

G–ASWI was one of two Wessex 60 helicopters operated by Bristow Helicopters Ltd (BHL) from their heliport at Great Yarmouth (North Denes) Airfield in support of offshore natural gas installations. On Friday 13 August 1981 the aircraft left North Denes at 1347 hrs on a routine flight to transport passengers and freight to and between various platforms in the Leman Bank and Indefatigable fields, before returning to North Denes via a landing site at Bacton (see map at Appendix 1). The crew consisted of a pilot (the Commander) and a cabin attendant, and the aircraft carried 1,900 lbs (862 kg) of fuel.

After leaving North Denes the Commander changed frequency to 125.9 MHz, used by RAF Coltishall to provide a flight information and alerting service for helicopters operating in the Southern North Sea Helicopter Corridor. On reaching the Leman Bank field at 1415 hrs the Commander changed to the offshore field frequency of 123.45 MHz. After landing on three platforms in the Leman Bank Field, WI flew on to the Indefatigable field landing on four platforms, on one of which an extra 504 lbs (229 kg) of fuel was taken on board with rotors turning. WI then returned to the Leman Bank field visiting one platform before landing at its last point of call, platform 27E, at 1525 hrs carrying 8 passengers. Another 3 men embarked for the return flight to Bacton and North Denes, making a total of 11 passengers seated in the cabin together with the cabin attendant. WI took off from platform 27E at 1528 hrs and established contact with RAF Coltishall on 125.9 MHz at the same time.

WI was cleared to climb to 1,500 feet altitude en route for Bacton, and shortly afterwards spoke briefly with the Bristow North Denes heliport radio operator on the company frequency of 123.45 MHz. The Commander reported that he had 11 passengers and some manifested freight on board, this information being for the Operator to pass onto HM Customs. The Commander made no mention of any unserviceability although it is normal Bristow practice for any defect on a returning aircraft to be notified at this time so that the engineering department can be forewarned.

Between 1536 and 1536.30 hrs there was a short and normal conversation between Coltishall and WI in connection with the controller identifying the helicopter's radar return as it became visible on his screen. It was then on track for Bacton and on the southern edge of the Hewitt field. Nothing further was heard from WI until 1541.18 hrs when the Commander transmitted a distress message on 125.9 MHz reporting that he was ditching due to engine failure. This message was followed almost immediately by another which repeated that WI was ditching. About 3 seconds later the helicopter's radar echo faded from the screen and radio contact was lost. Search and rescue action was initiated and a Royal Air Force Sea King helicopter from Coltishall took off at 1547 hrs. At 1557 hrs the Sea King sighted floating wreckage from G–ASWI.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	2	11	–
Serious	–	–	–
Minor/none	–	–	

1.3 Damage to aircraft

The aircraft was destroyed by impact forces.

1.4 Other damage

There was no other damage.

1.5 Personnel information

1.5.1 Commander:	Male, aged 51
Licence:	Airline Transport Pilot's Licence/Helicopters and Gyroplanes. Valid until 19 August 1988, and endorsed for the Wessex 60 type as pilot in command.
Flying Instructor Rating:	Last rating test was on 4 October 1979.
CAA Authorised Examiner Certificate:	Last test was on 8 October 1980. Certificate valid until 31 October 1983 for Aircraft Rating tests on Wessex 60 and Instrument Rating (Renewal) tests.
Instrument rating:	Last renewal test was on 9 October 1980.
Competency checks on Wessex 60:	Last base check was on 5 May 1981. Last line check was on 22 May 1981. Last emergency equipment check was on 23 April 1981.
Medical certificate:	Last medical was on 4 February 1981. Class 1, no limitations.

Total pilot hours:	8,940
Total helicopter pilot hours:	About 6,000
Total hours on Wessex type:	4,937
Total hours in last 28 days:	46 hours 35 minutes.
Total hours in last 7 days:	6
Rest period prior to reporting for duty:	65 hours 45 minutes.
Last training flight:	The Commander carried out a base check on another pilot in WI on 3 August 1981. Amongst the items covered in flight was a simulated runaway of the starboard engine, and a simulated transmission failure and autorotation during which the secondary hydraulic system was switched off.
Previous accidents:	One helicopter accident in 1972 caused by a flying control malfunction, in which he sustained serious injuries including severe burns.

1.5.2 *Cabin attendant:* Male, aged 37

Emergency survival equipment annual check on Wessex 60:	Last check was on 26 January 1981.
Annual route check:	Last check was on 25 September 1980.
Rest period prior to reporting for duty:	23 hours.

1.6 Aircraft information

1.6.1 G–ASWI had been used by Westland Helicopters Ltd (WHL) for flight test and demonstation purposes between 1964 and 1970, when it was sold to BHL. Since 1975 it had been based at North Denes heliport and used on offshore operations.

1.6.2 *Main particulars*

Manufacturer:	Westland Helicopters Ltd.
Aircraft type:	Wessex 60 Series 1.

Date of manufacture:	1965
Manufacturer's serial number:	WA 199
Registered owner:	Bristow Helicopters Ltd.
Engines:	Two Rolls Royce Ltd Gnome H. 1200 MK66C.
Autostabiliser:	Ferranti FAS 2W, operating through the secondary hydraulic system.
Flotation equipment:	One inflated bag in tailcone and an inflatable float on each main wheel, to Westland Mod No 6076.
Internal communication systems:	Intercomm between pilot and cabin attendant. Passenger address system through headsets and a cabin warning light and klaxon system.

The Wessex 60 is a twin-engined helicopter of conventional main and tail rotor configuration. The power unit of two Gnome engines inputs to a coupling gearbox from which the drive to the main rotor gearbox passes through the cockpit in an inclined tunnel. Also located in this tunnel are flying control linkages and secondary hydraulic system pipes. The main drive components are, from the lower end: an expansion coupling, a torquemeter unit containing a short shaft, the main shaft, and the main freewheel unit (see Appendix 2).

The fuel is contained in two tank groups (called 'forward' and 'aft') each with a capacity of 154 Imperial gallons (1,234 lbs) of which two gallons in each group is unusable and ungauged. Two gauges indicate the contents of the tanks in pounds. The forward group normally supplies the starboard engine and the aft group the port one, but an electrically operated cross-feed cock permits either or both engines to be fed from either group. There is no jettison system. Refuelling is carried out through two filler points on the starboard side. When the engines are running refuelling is permitted only through the aft filler point, which feeds the aft tank group.

The Wessex 60 has conventional dual flying controls. During normal flight servo control assistance is provided by two main hydraulic systems. The primary system pump is driven from the main rotor gearbox and the secondary system pump from the coupling gearbox; each system is hydraulically independent of the other and a cockpit servo selector switch enables either system to be switched off. The design is such that in the event of a secondary system failure (eg following a double engine shut down) a secondary servo unit actuating cylinder renders the servo unit hydraulically inoperative and eliminates a 'sloppy link' in the control mechanism so ensuring that there is no backlash between the cockpit controls and the primary system servo jacks. With the secondary system inoperative the controls become heavier; and the autostabilisers, the tail rotor servo jack, and the pedal damper become inoperative. In the event of the secondary system hydraulic pump ceasing to be driven reversion to the primary system occurs in about 20 to 30 seconds, depending on flying control activity.

1.6.3 *Radio altimeter*

A Telecommunications Radioelectriques et Telephoniques (TRT) AHV–8 radio altimeter had been fitted to G–ASWI and the other Wessex based at North Denes since February 1981, being connected to the emergency battery. The altimeter indicates radio height from 2,500 feet to surface level with a typical accuracy at any height of 0.5 feet plus or minus 2% of true height. A decision height cursor could be set to any height and a warning lamp on the instrument would light up when radio height was below the cursor setting. A BHL modification introduced a repeater warning lamp in a position between the main attitude indicator, the barometric altimeter, and the airspeed indicator. BHL stated that it was standard practice for the radio altimeter to be 'ON' throughout a flight, and for the cursor to be set at 200 feet on offshore flights; the altimeter had proved reliable and accurate in service over all types of water surface.

1.6.4 *Safety equipment*

The aircraft carried an 18 man liferaft externally mounted on the starboard fuselage aft of the cabin door. A Burndept Model BE 369 portable electronic flotation distress beacon was mounted inside the cabin on the starboard side immediately aft of the door. Life jackets stowed in pouches were required to be worn tied around the waist by passengers throughout flight. In the event of an emergency, or on instructions from the crew, the pouch should be opened and the life jacket stole pulled over the head. Both crew members wore life jackets, the pilot's being fitted with a personal locater radio beacon. A Dukane model N15F 210B underwater acoustic beacon was mounted on the forward bulkhead of the helicopter's cabin. Its operating frequency was 37.5 KHz, with a pulse rate of one per second.

1.6.5 *Maintenance information*

Certificate of Airworthiness:	No 1739, valid to 27 October 1981, Transport Category (Passenger).
Total airframe hours:	9496.05 including 1068.35 hours since last renewal of Certificate of Airworthiness.
Total engine hours: Port –	6818.55 since new, including 1352 hours since last complete overhaul.
Starboard –	8333.05 since new, including 1403.20 hours since last complete overhaul.
Engine overhaul:	2000 hours.

Transmission components:	Hours run since last complete overhaul	Overhaul period (hours)
Coupling gearbox, serial no WH006:	1948.25	3000
Expansion coupling, serial no WAT369:	743.35	1000
Torquemeter unit, serial no 177:	817.35	1200
Freewheel unit, serial no WAN466:	693.20	1000
Main gearbox (MRG), serial no WAX565:	1006.35	1200
Main drive shaft, part No WB5–68–1679:	Unlifed item	

The Wessex 60's main drive shaft has no individual serial number and no finite life since its fatigue life had been established by calculation as unlimited. It is visually inspected at 50 hour intervals in the course of routine maintenance, and is required to be removed for crack detection check procedures whenever the main gearbox is changed. This was last carried out when the main gearbox was installed in G–ASW1 on 22 November 1980, 1006.35 flying hours before the accident flight. The total record of the component since new could not be established with certainty, although it is probable that it had been installed in the aircraft since manufacture as there is no record of the shaft having been changed.

The torquemeter shaft also has no finite service life since its fatigue life was established by testing as being infinite. However it does carry a serial number. The shaft is checked at intervals of 1200 hours, when the torquemeter unit is required to be overhauled. The torquemeter unit fitted to G–ASWI had last been overhauled by the manufacturers 817 flying hours prior to the accident.

Since it was acquired by BHL in 1970 G–ASWI had been maintained in accordance with the provisions of the authorised maintenance schedule, reference BHL Wessex 60/1 Issue 2. According to the aircraft's records all prescribed maintenance operations had been carried out in accordance with the schedule. The aircraft was last approved for the renewal of its Certificate of Airworthiness in November 1980, since when it had flown 1073.30 hours. The Certificate of Maintenance was valid, having been issued on 24 July 1981 following scheduled maintenance when the aircraft had flown a total of 9395.50 hours; it would have remained valid until 27 October 1981 or the completion of 165 flying hours since issue. Examination of the records covering the period since the issue of the last Certificate of Maintenance showed that all pre-flight and daily inspections were recorded in the Technical Log, and the prescribed maintenance operations had been carried out at appropriate times up to 13 August 1981. Various items of equipment were removed for overhaul or replacement as they became time expired according to the provisions of the maintenance schedule; these included the cockpit hand fire extinguisher, the starboard tachometer, the pilot's and co-pilot's attitude indicators, the port starter relay, the starboard main oleo, the fire extinguisher discharge indicators, the aft fuel booster pump, the secondary hydraulic pressure indicator, and the lateral and the fore and aft trim actuators.

Unscheduled maintenance operations carried out as a result of defects found during these routine inspections included replacement of the port intake duct at 9393.45 hours, following discovery of a cracked anchor nut bracket; replacement of two main rotor blade tip sheaths due to erosion at 9387.35 hours; and replacement of a main rotor blade at 9391.45 hours, following which main rotor blade tracking was carried out.

A further unscheduled maintenance operation as a result of a defect arising during flight took place on 28 July 1981 at 9413.15 hours when the port engine suffered a partial run-down. The port fuel computer was diagnosed as the cause, it was replaced by a serviceable unit and a test flight carried out. No further problems were reported with the port engine.

On 3 August 1981 WI was flown on a training flight which included an autorotation during which the secondary hydraulic system was switched off. The aircraft behaved normally throughout the flight. Practice engine failures were carried out on each engine from a twin torque setting of at least 2,500 lbs/ft. On 10 August 1981 a tail rotor balance check became due and was carried out using stroboscopic balancing equipment. The tail rotor was found to be serviceable and within the prescribed balance limits.

On 11 August 1981, at 9484.40 hours, the lateral trim actuator had failed to function and was reported in the Technical Log as an after flight defect. It was replaced by a serviceable unit, functionally checked, and a duplicate inspection carried out. Also on this date a log book certificate recorded the removal of the passenger life jackets for annual check. These were replaced by serviceable items having nil time since overhaul.

On 12 August 1981 at 9490.15 hours the pilot's attitude indicator was replaced after the instrument had been found to fail to respond to movements of the setting knob. Maintenance checks carried out following completion of flying on 12 August 1981 included a check of the main gearbox oil filter. This was recorded as having been found in satisfactory condition. During the course of these checks the port air speed indicator, which had been reported as 'sticky' in operation, was replaced by a serviceable instrument.

The aircraft made four flights on 13 August 1981 totalling 3.45 hours. No defects were recorded after these flights and the aircraft was reported to have functioned normally in all respects. Before taking off from North Denes on its last flight the aircraft was refuelled to a total of 1,950 lbs with 1,050 lbs in the forward tanks and 900 lbs in the aft tanks, 50 lbs being allowed for starting and ground running.

According to its records, therefore, G–ASWI was in serviceable condition and fit to undertake the proposed flight on 13 August 1981. None of the recent operations recorded in the maintenance history appear to be abnormal or untypical of general experience of the Wessex in service.

1.6.6 *Loading and fuel*

1.6.6.1 *Loading*

The aircraft's maximum permissible take-off and landing weight was 13,600 lbs (6170 kg). Acting in accordance with a CAA exemption from the provisions of paragraphs (4) and (5) of Article 27 of the Air Navigation Order 1980, BHL pilots based at North Denes only prepared a load sheet for departures from North Denes. On flights between platforms, and on inbound flights, the intention of the ANO was met by the pilot transmitting load details on the offshore field radio frequency before each take off. These messages were normally recorded automatically on tape recorders located on platform 18A in the Indefatigable field and platform 27D in the Leman field. Unserviceability was catered for by the fact that each recorder unit covered both fields, and by provision of a spare recorder. On the day of the accident not only was the recorder on platform 18A unserviceable but so was the spare. Satisfactory recordings were made for operations in both fields on the recorder at Platform 27D, except between 1330 and 1630 hrs during which time the platform suffered a power failure. Consequently no load sheet data was available except for WI's departure from North Denes. However an assessment made from other records indicated that on take-off from platform 27E the aircraft's gross weight was about 13,226 lbs (5999 kg), and that at the time of the accident about 13,030 lbs (5910 kg). It was not possible to establish WI's centre of gravity either at take off from 27E or at the time of the accident, but there was no evidence to suggest that it was not within the laid down limits throughout the flight.

1.6.6.2 *Fuel*

WI lifted off from North Denes with about 1,900 lbs (862 kg) of Avtur Jet Al. A further 504 lbs (229 kg) of Jet Al was taken on at 1445 hrs from a facility on Indefatigable field platform 23AQ, the total quantity being put in the aft tank group. WI's fuel state was then about 1,660 lbs (753 kg). It was calculated that on its final take-off from platform 27E at 1528 hrs WI carried 990 lbs (449 kg) of fuel giving an endurance of 71 minutes; this was in accordance with the requirements of the BHL operations manual.

When the accident occurred at 1542 hrs some 794 lbs (360 kg) should have remained. Fuel samples taken from the facilities at North Denes and platform 23AQ were analysed and found to be within the approved specification. Nothing abnormal was observed during the last refuelling, nor when the underside of the aircraft was checked for leaks by the helicopter landing officer prior to its last take off from platform 27E.

The Wessex 60 Flight Manual contains the following information on the management of the fuel system:

> 'The fuel required must be loaded so that the forward and aft groups of tanks each contain equal quantities. This equality must be maintained during flight and checks by means of the contents gauges should be made. If the contents of a group exceed the contents of the other group by more than 100 lb, fuel balancing must be carried out. To do this open the cross-feed cock and switch off the booster pump of the group with the lesser contents until the contents are equal.
>
> The minimum fuel quantity is an indicated 50 lb in each group.
>
> Prior to starting the forward and aft groups booster pumps switches should be set to on and should normally remain on until the engines are stopped. The cross-feed cock must not be open when either fuel tank group contains less than 200 lb of fuel.'

While each engine should normally be operated from its own separate system, it was the practice within BHL that fuel imbalances up to 300 lbs were effected in flight so as to avoid having to shut down the engines when refuelling on an offshore installation. WI's 504 lb (229 kg) uplift at platform 23AQ was, on the crew's instructions, all put into the aft tanks indicating that an imbalance of at least 250 lbs (114 kg) must have existed either before or after the refuelling.

1.6.7 *Emergency procedures*

1.6.7.1 *Complete power loss*

The symptoms and effects of a complete and sudden loss of power, whether from double engine or transmission failure, in the circumstances of this accident would be as follows. Once the drive to the MRG ceased the helicopter would yaw left and rotor speed would decrease rapidly until collective pitch was decreased. A pilot might hear a noise associated with a failure and also the change in note of the dynamic components. Within a few seconds 'ENG P' and 'ENG S' captions on the centralised warning system would illuminate, indicating low engine oil pressure due to the gas generators running down. These captions would be accompanied by the attention lights and the red cancel button flashing, as well as by an audio warning through the pilot's headset. If an engine fire accompanied the failure red 'FIRE P' and/or 'FIRE S' captions and separate 'fire port' and/or 'starboard' extinguisher pushbuttons would light as appropriate. When free turbine speeds fell below the 50 rotor rpm equivalent figure, amber 'THR P' and 'THR S' captions would light together with a flashing amber cancel button. As coupling gearbox speed fell, both generators would come off-line this being indicated by 'GEN P' and 'GEN S' amber captions. The normal battery should have been able to supply all services for 5 minutes in daylight flight but when voltage decreased below 25 volts a red 'BUS V' caption would light, and an amber 'AC PRI' caption would indicate that the invertor was off-line. This would cause 'OFF' flags to appear in both the main attitude indicators but they would continue to give attitude information for longer than the elapsed time of WI's descent. The stand-by horizon would continue to operate, as would the radio altimeter, as both are supplied directly from the emergency battery. Also due to the fall of coupling gearbox speed a red 'COUP G' would indicate low oil pressure and an amber 'HYD 2' caption the fall of secondary hydraulic pressure to 1000 psi. The secondary hydraulic system would fail shortly afterwards (probably within 30 seconds of the power failure) and then the flying controls would become heavier, the stability augmentation system would cut out, and the tail rotor pedal damper and servo would become inoperative.

In this sequence each time a red caption lit the attention lights, the red cancel button and an audio warning would operate if the pilot had cancelled any previous red warning. Similarly each new amber warning would cause the amber cancel button to flash. If the loss of power was due to a sequential engine failure the pattern of events described would differ according to the nature and timescale of the two failures.

1.6.7.2 *Transmission failure*

Neither the Wessex 60 Flight Manual nor the BHL Operations Manual contained any emergency procedure for a double engine failure. However the procedure is the same as for transmission failure and BHL stated that pilots were always trained to treat them in the same manner. Section 3 of the Flight Manual states:

'TRANSMISSION FAILURE IN FORWARD FLIGHT

Indications: Loss of height and yaw to the left. The power turbine noise will rise and then die away as the overspeed trips operate. Torque will reduce to zero.

Immediate actions: Establish autorotation and warn the cabin occupants of an immediate landing.

Subsequent actions: Initiate distress procedure.
Make an engine-off landing.
Carry out shut-down checks.

Considerations: If the battery switch is selected to ground before touchdown the stick trim will be inoperative. Secondary hydraulic pressure will be lost and both generators will come off-line.'

1.6.7.3 *Ditching procedure*

The BHL Operations Manual, Wessex 60 Emergency Procedures, lays down the power-off ditching procedure as follows:

'Autorotate at 55 to 65 kts depending on aircraft weight.

Rotor rpm controlled between 210 and 243.

Warn passengers to put on life jackets and fasten seat belts.

Transmit Distress Call.

Arm flotation gear.

Turn into wind for final approach.

Flare between 100 and 150 feet to reach zero ground speed at 10 to 20 feet. Level aircraft and cushion touchdown with lever.

After touchdown hold aircraft attitude and direction steady until flotation gear operates.'

1.6.8 *Aircraft limitations*

Relevant aircraft limitations given in the Flight Manual were as follows:

Never exceed speed (VNE) at 1,500 ft, +16 °C, and 13,000 lbs (5897 kg)	111 knots IAS
Normal operating limit speed (VNO):	101 knots IAS
Rotor speed limits in autorotation:	Never exceed 258 Maximum permissible 243 Minimum permissible 210

The BHL Operations Manual, Wessex 60 Operating Procedures, Limitations, contained the following information:

'Rotor RPM

	Maximum	Minimum
Power off steady	243	210
Power off transient	258 (never exceed)	210'

1.6.9 *Composition of crew*

The Air Navigation Order 1980 Article 17(3) states:

'A flying machine registered in the United Kingdom and flying for the purpose of public transport having a total weight authorised exceeding 5700 kg shall carry not less than two pilots as members of the flight crew thereof.'

The Wessex 60 is slightly above this weight and is the civil version of a military helicopter which was designed for single pilot operation, with its flight deck laid out accordingly. When the Wessex 60 was given civil type approval by the Air Registration Board (now the CAA) it was also certificated as suitable for single pilot operation in visual flight conditions, and this was later extended to include instrument flight above minimum safe altitude outside controlled airspace. Bristow Helicopters operated the Wessex 60 under a CAA exemption to Article 17 (3) permitting single pilot operations subject to certain conditions. All these conditions were complied with during the accident flight.

1.7 Meteorological information

1.7.1 Aftercast

An aftercast provided by the Meteorological Office, Bracknell, for the accident area for the period 1500 hrs to 1600 hrs was as follows:

General Situation:	A large area of high pressure with centres over North Germany and to the SW of the British Isles was the dominant feature in the area of the accident. A warm front was producing rain over much of northern and eastern England as far south as Lincolnshire, but its only effect off East Anglia was the spread of extensive upper cloud.
Winds:	Surface: Variable between 150 and 220 degrees 5 knots or less. Temp +18°C.
	2,000 feet. Mainly 200 to 240 degrees 5 to 10 knots. Temp +15°C.
Weather:	Haze overland, local mist patches over the sea.
Visibility:	Generally 4000 metres to 8 km, but 1000 to 2000 metres in local mist patches.
Cloud:	No low cloud, or at the most 1/8 shallow SC around 4,500 feet. Thickening layers 6 to 8/8 ACAS above 12,000 feet.

Height of O° C Isotherm:	12,500 feet.
Icing:	Nil at flight levels involved.
Turbulence:	Nil.
Sun:	Sun's bearing 251°, elevation 31°.

All heights are above mean sea level (AMSL). All directions in degrees true. Tidal conditions were such that at the place and time of the accident the water was approximately at mean sea level.

1.7.2 *Actual report*

A report of the weather at the accident site made by the RAF Sea King was as follows:

'Overcast with haze. Visibility 4000 metres, nil wind and calm sea.'

1.7.3 *Barometric pressure*

The Yarmouth regional pressure setting for 1500 hrs and 1600 hrs GMT on 13 August 1981 was 1017 mbs. The North Denes heliport (height 6 feet AMSL) QNH for the same period was 1019.

1.8 Aids to navigation

Not relevant.

1.9 Communications

At 1528 hrs, shortly after taking off from Leman Bank field platform 27E, G-ASWI contacted Coltishall on 125.9 MHz and maintained contact on this frequency except for a short period at about 1635 hrs when load details were transmitted to BHL North Denes on 123.45 MHz.

Communications were normal until 1541.18 hrs when WI transmitted 'Mayday, Mayday, Mayday. Golf Whiskey India is ditching. Engine failure.' Coltishall acknowledged the message, and at 1541.31 hrs WI sent a second message 'Whiskey India is ditching'. Coltishall replied 'Golf Whiskey India, Roger. Thirteen on board. What is your position?'. There was no reply from WI but at 1541.37 hrs a loud noise (not speech) lasting ¾ second was recorded on the tape. The Coltishall controller estimated that WI's radar echo remained on his screen throughout the two distress messages and disappeared at about halfway between the last call and the unusual noise, ie at about 1541.35 hrs. Tests with a Wessex established that in this area its radar echo vanishes at about 400 feet AMSL. Tests with a Sea King over the accident site showed that Coltishall could not receive transmissions on 125.9 MHz when the Sea King was below 100 feet AMSL. The ATC tape covering the period from 1528 hrs was examined. Frequency analysis was complicated by the presence of a periodic tone of approximately 800 Hz, which is a feature of certain military ATC equipment.

Analysis of WI's six recorded transmissions prior to the emergency yielded some main rotor gearbox frequencies equivalent to the meshing frequencies of the epicyclic gears, the main input gears, and the tail rotor take-off gear. They indicated a main rotor speed of about 230 rpm, a normal figure for the flight conditions.

While analysis of the two distress messages revealed no discrete frequency information, audio analyses on other helicopters has shown that the level of the audio signal obtained from the main rotor gearbox decreases significantly when collective pitch is low, power-on or power-off. It also proved impossible to detect gear frequencies in RTF transmissions during autorotation in trials carried out in a similar Wessex 60. Attempts were made to identify discrete frequencies by means of tracking filters, wave analyser, digital spectrum analyser, and sound spectrograph, but without success. It was thus not possible to establish rotor speed during either of the distress messages, but the lack of such data indicates a low collective pitch setting at these times, ie the helicopter was probably in autorotation but at an unknown rotor speed.

Each of WI's transmissions from 1528 hrs was also examined for switching characteristics. At the end of each transmission a characteristic transient due to the press to transmit button being released was present except on the final call made at 1541.31 hrs. Data obtained from Wessex 60 flight tests proved that radio failure and total loss of electrical power could be discounted as possible causes of there being no transient. A possible reason for the absence of the transient was considered to be that the pilot held the transmit switch depressed for one second or more after he ceased speaking. If the button had been released during Coltishall's reply to WI's last transmission it would not be evident, as the recording equipment does not accept incoming transmissions whilst the ATC controller has his own transmit switch on.

The loud noise on the tape lasting ¾ second starting at 1541.37 hrs, five seconds after the end of WI's last transmission, proved to be a broad band random noise but it could not be positively identified as originating from WI, nor could it be related to any other aircraft or ATC transmission. Any switching transients that might have been present in the body of the noise signal would have been obscured by the high level broad band spectrum, and none were evident. However the absence of a transient at the end of the signal indicates that it was not transmitted by another aircraft or a ground station, although it is possible it may have emanated from an electrical source in the Coltishall control tower. A number of typical equipment failures were simulated in a Wessex 60 in flight and their sounds transmitted and recorded on the ground. The characteristics of all these events were totally different from the unusual noise heard on the ATC tape. The amplitude characteristics of the noise were also markedly different from the open microphone background sounds obtained from WI's previous transmissions. If this noise did emanate from WI it indicates the occurrence of a significant event in the aircraft producing an electrical or mechanical noise at a time when the pilot was operating the press to transmit switch, and the termination of the transmission by means other than the release of that switch.

1.10 Aerodrome information

None.

1.11 Flight recorders

G–ASWI was not equipped with a flight data recorder or a cockpit voice recorder, nor were these required to be fitted.

1.12 Wreckage and impact information

1.12.1 Salvage

The salvage attempt was conducted in three separate phases. Phase 1 was under the control of Bristow Helicopters Ltd. On the evening of 13 August, the vessel British Enterprise II was diverted from its current task on the AMOCO rig in the Leman Field to the accident site together with its team of 9 divers, reaching it at 1930 hrs . Also despatched to the scene was the vessel Gardline Resolution with underwater search gear, this vessel being later replaced by the Gardline Locator.

The wreckage was pinpointed on Haisborough Sands by 2040 hrs on Friday 14 August by a British Airways team using a location device compatible with the aircraft's Dukane automatic underwater acoustic beacon. Divers located the wreckage lying in 15 to 20 feet of water during the morning of 15 August and recovered two bodies. A large number of colour photographs were taken by the diving team before recovery began. By 1830 hrs the main rotor gearbox, rotor head, and one main rotor blade had been recovered. The weather worsened during the night of 15th, and from 16th operations were increasingly hampered by weather and by drifting sand. By 19th the wreckage was covered by an extensive sandbank and BHL gave AIB notice that they intended to abandon salvage attempts. AIB decided to continue and took over the contract on 20 August, and the second phase began. Westland Helicopters Ltd and Rolls Royce Ltd each made a large financial contribution to the cost of this phase of the operation.

The Gardline Locator was in position over the wreckage site with a new diving team by 0600 hrs on 22 August. A dive on that day found small items of wreckage but nothing significant, other than that the area was still covered by a large sandbank estimated to be some 10 feet high. The sand itself was very fine and liquid and the use of air lift equipment made little impression upon it. Since it was clear that nothing would be achieved until the sand was removed a suction dredger was sent for, arriving on the evening of Monday 24th. In the interim a trawler was hired to drag the area to the south of the main wreckage, but nothing was found.

Dredging operations were conducted on 25, 26 and 27 August with dives being made at each slack water. Altogether some 1800 cubic metres of sand was recovered from the site. Although this brought to light some items of wreckage, notably the tail rotor, main rotor blades, and cockpit instruments, the dredging had no major effect on the sea bed due to the fluid nature of the sand which refilled almost immediately any dredged area. Since no significant progress was being made the AIB salvage attempt was abandoned on 28 August after seven days on the site, and the second phase ended.

In the autumn, following local expert advice that the sea bed conditions could well have changed, AIB chartered the tug Salvageman together with a team of divers to make a further attempt. This was undertaken on 3 and 4 November, but it was found that the sea bed conditions were unchanged and that a sandbank still covered the wreckage area. The prolonged use of heavy air lift equipment, as before, made no impression on the sea bed. The attempt was therefore abandoned at 2100 hrs on 4 November.

Altogether six vessels and a total of sixteen professional divers spent sixteen days on site but were able only to recover some 25% of the wreckage. In the opinion of the salvage and diving experts who were involved in the operation the remainder was totally irrecoverable.

1.12.2 Examination

Neither the engines, the coupling gearbox, the drive to the main gearbox, or the main body of the fuselage structure were salvaged. The recovered wreckage comprised the main rotor blades and rotor head together with the main gearbox and the upper parts of its support structure with the primary flying control servo units still attached, the tail rotor and gearbox, and fragments of structure and parts from the cabin interior found floating on the surface.

None of the cockpit controls or flight instruments were recovered, and of the engine instrumentation only the two fuel flow indicators, and a pressure and a temperature gauge. Examination of the fuel flow indicators revealed marks showing that the needle of each had been indicating near zero at impact.

From the condition of the few structural parts available it was apparent that the aircraft struck the water violently with sufficient force to disrupt the main structure including the passenger cabin. The attitude of the aircraft on impact was assessed as steeply nose down whilst turning or slipping to port. Examination of the main rotor blades, rotor head, and tail rotor, showed that at the moment of impact there was no power being transmitted through the main gearbox and that the main and tail rotors were rotating at a speed well below their normal operating range. The possibility that the yellow main blade might have broken off at the root just prior to impact could not be precluded. All four main blades had coned upwards to the extent that damage was evident where each blade's folding rachet knob retention nut had struck the drag hinge pin top cover. Alignment tests showed that this had happened at a coning angle of 28 degrees, and contact could only occur with the collective pitch lever in a low position. This indicates that at some stage extreme coning/flapping angles had been achieved with low collective pitch, although it could not be determined whether the damage occurred in-flight or during the impact with the water. During the examination of all components, including the main gearbox, no evidence was found of any pre-impact mechanical failure or defect to which the cause of the accident could be attributed.

According to the reports of the divers the whole of the wreckage, when first seen, was contained within a radius of 25 metres. The divers took 98 underwater colour photographs before the wreckage was disturbed. Most of these were general views of the wreckage and little useful information was gained from them. The radio altimeter height cursor was seen to be set at 200 feet, and this is believed to be its pre-impact position. The radio altimeter needle showed 210 feet with the 'OFF' flag evident. In view of the facts that the equipment was immersed and not recovered for examination and that the aircraft had gone out of control and then suffered a destructive impact, these two indications are not reliable evidence that there had been a pre-impact failure of the radio altimeter equipment or its power supply.

One photograph showed a badly damaged part of the instrument panel on which were visible the starboard engine (forward tank group) fuel gauge, the fuel crossfeed cock, and the two booster pump switches. The latter appeared both to have suffered damage and their positions could not be determined; but the crossfeed cock switch was in the closed position, which is the position to be expected if BHL's method of fuel balancing had been correctly followed. The starboard fuel gauge indicated about 400 lbs; although again this is the indication that would be expected at the time the emergency commenced, it was not possible to say whether this was indicative of the reading before the helicopter went out of control.

The primary hydraulic pump was rig tested at the manufacturer's works. It was found to be still operative and performing to specification and thus of producing a pressure sufficient to prevent manual reversion of the primary system down to a main rotor speed of 100 rpm. The primary powered flying control units (PFCU's) were strip examined and rig checked as far as impact damage would permit. The right lateral unit performed normally on test, but the fore and aft and the left lateral units could not be fully operated because of impact damage. The by-pass and servo valves of all three PFCU's were found to be correctly set and in operable condition. Nothing was found which indicated that there might have been pre-impact damage to, or a failure of, the primary hydraulic system.

The aircraft's externally mounted liferaft was found floating uninflated and still contained in its pack at the scene of the accident. The liferaft was undamaged and bore no evidence of having been struck by a main or tail rotor blade; it had become detached from the aircraft when its support structure separated from the fuselage on impact with the water. The BE 369 emergency flotation beacon was returned to the manufacturer for examination. It was found to have suffered slight damage due to impact but was still electrically satisfactory. The discharged battery was replaced and the beacon was tested and found to be performing to specification. The fact that it was transmitting after the accident was due to its operating switch having been actuated by damage sustained on impact.

1.13 Medical and pathological examination

Full autopsies with toxicology and histology were carried out on the twelve recovered bodies. All twelve were killed outright by very severe injuries whose pattern indicated an appreciable longitudinal deceleration at impact. No sign of fire was found on any of the bodies. One passenger had been recovered with the stole of his life jacket fitted over his head, and the examination indicated that at least two others had also managed to perform the same action.

The Commander had been found fully fit at his last licence medical examination and his general practitioner knew of nothing which might have been relevant to the accident. The autopsy of the Commander produced negative results for alcohol and drugs. Whilst no specimen suitable for carboxyhaemoglobin was available, the levels from the other bodies were all within the normal range. The Commander was found to have had slight to moderately severe coronary artery disease, which would not be unusual for a person of his age and build, and showed histological evidence of a microscopic haemorrhage into a plaque whose appearance indicated that it had occurred a week or so beforehand. This might well have been symptomless, and there is no record of his ever having complained of any symptoms. The pathologist considered that the chance of a further episode which may have contributed to the accident was very unlikely but that the possibility existed. The pathologist stated that whilst the autopsy of the Commander revealed no evidence of pre-impact injury the possibility could not be excluded.

1.14 Fire

No evidence suggesting fire was discovered either during the examination of the wreckage or in the post-mortem examination of the 12 recovered bodies.

1.15 Survival aspects

The RAF search and rescue Sea King took off from Coltishall at 1547 hrs and was directed by ATC along a vector of 050° M towards the accident area. Shortly before crossing the coast the Sea King detected a crash locator beacon signal on 121.5 MHz, homed on to it, and spotted wreckage when 1½ miles distant. The Sea King recovered the bodies of six passengers and the cabin attendant as well as items of floating wreckage. The bodies of the Commander and four passengers were recovered during the next fortnight but that of one passenger was never found. The Sea King also recovered WI's BE369 emergency beacon which had floated away from the aircraft transmitting on 121.5 and 243.0 MHz. A BHL helicopter, the rig supply vessel MV Liberty Moon, and HMS Alderney also took part in the search operation.

1.16 Tests and research

1.16.1 Rotor behaviour

During the investigation WHL carried out a computer simulation of rotor speed decay following a sudden and complete loss of power in a Wessex 60 in cruising flight under comparable conditions to those of WI. Various delay times from 0.3 seconds upwards were used following power loss to simulate a range of pilot reaction times. At the end of each delay period the collective pitch was reduced to the minimum setting at a rate of 12° collective pitch angle per second, a rate derived from an RAE technical report[1]. This resulted in a simulated lever motion time of 0.75 seconds, with the total time from engine failure to minimum pitch thus being the relevant delay time + 0.75 seconds. The results for delays of 0.3, 1, 2 and 3 seconds are shown at Appendix 3. The WHL Wessex computer rotor model however, did not incorporate a blade stall term and so another simulation was carried out by the Royal Aircraft Establishment, Farnborough (RAE) using a computer model which did. The RAE results showed good correlation with those of WHL down to delay times of 3 seconds, but beyond this the characteristics of each curve changed adversely and the minimum rotor speed reached was significantly lower. The difference was ascribed to the onset and development of the drag rise associated with retreating blade stall.

1.16.2 *Pilot response times*

As there was no experimental information available on how long it would take the pilot of a helicopter to recognise a sudden and complete loss of power and react to it by lowering the collective pitch lever it was decided to obtain measured data. With the co-operation of British Airways Helicopters (BAH) and BHL, the RAF Institute of Aviation Medicine (IAM) carried out a trial using the BAH Sikorsky S–6IN flight simulator at Aberdeen Airport, which was considered to be adequately respresentative of the S–61 aircraft. BAH and BHL S–61 pilots undergoing routine training were given an unexpected, simultaneous failure of both engines when flying with hands and feet on the controls in straight and level flight. The time interval between the moment the engines were switched off and the instant the collective pitch lever reached the bottom stop was recorded electronically. The report (Appendix 4) indicates that a realistic expectation of the time taken by a pilot to respond to a sudden and complete power loss by lowering the collective pitch lever fully is about three seconds. It also states that the trial results indicate that there is a small but not negligible chance that a pilot's response time will exceed five seconds.

A separate paper [2] discussed the results of the Aberdeen trial together with those of another pilot response experiment carried out during the investigation into an accident to an HS 748 in 1979 (Aircraft Accident Report 1/81). The following extract is taken from the paper's conclusion:

'Clearly aircraft should not be designed to require impossible feats of pilots; aircraft and operating procedures should permit safe operation by the least able pilot who might be exposed to them. Although the shortest response time measured in each of these experiments was 1.5 seconds and the means were about 3 seconds, these are thus not the values of importance. The longest response time measured are the values of interest, and in these experiments these times were 5.5 seconds and 7 seconds, times which parallel closely the time taken by the pilot involved in the HS 748 accident referred to above.'

1 RAE Technical Report 77098, 'A Theoretical Investigation of Rotor Blade Icing on the Performance of a Wessex Helicopter' by C Young.

2 'Response Times to Simulated Aircraft Emergencies' by R G Green, J W Chappelow and R J Skinner. RAF Institute of Aviation Medicine, Farnborough.

1.17 Other information

1.17.1 Power system

The following areas in which the Wessex 60's power system below the main gearbox might be vulnerable because of a lack of independence were considered during the investigation:

1 The closely installed engines separated only by a firewall.

2 The common engine air intake.

3 The interacting engine control systems.

4 A common fuel supply when the crossfeed cock is open.

5 The common engine power drive through the coupling gearbox and the main shaft.

The history of power failures in both the civil and military versions of the Gnome engined Wessex was examined against these criteria and is now summarised under the headings double engine malfunction, single engine malfunction, and main transmission failure.

1.17.1.1 Double engine malfunction

The evidence was that during the entire history of the civil and military versions of the Gnome engined Wessex, amounting by the end of 1981 to some 767,000 flying hours over twenty years, there had been four known cases of total power loss from double or consecutive engine failures. Three of these were due to the ingestion of ice, and one to ingestion of the engine intake cover which had not been removed before take-off. The ambient conditions G–ASWI experienced throughout its flight precluded any possibility of intake icing, and the intake cover had not been used prior to take off.

However, in the event of compressor damage it is possible for the Gnome engine to eject debris forward out of the compressor which, in the Wessex 60, may be ingested by the other engine since the intakes are not separated. Rolls Royce (RRL) were aware of four cases in which both engines in a Wessex had been damaged in this way, although in none of the cases was the power remaining available insufficient for continued flight. Whilst the original design incorporated a dividing wall which achieved separation of the compressor intakes difficulties in achieving a satisfactory anti-icing standard led to its removal in a modification approved by the CAA but not by RRL. The possibility therefore exists that a failure in one engine could, by cross ingestion, lead to a complete loss of power. Since the Wessex 60 was certificated BCARs have been revised, and now require engine intakes to be independent of each other.

Finally, a total power loss due to contamination of the fuel filters in both engines was considered as a possible cause of an unexplained fatal accident to a Wessex 60 in the South China Sea in 1974. Since subsequent improvements to the Wessex's fuel filtration system and to the associated maintenance practices no accidents have been attributed to this cause. In respect of G–ASWI, the improved filtration was embodied in the engines, the recommended maintenance practices had been followed, and the post-accident analysis showed the bulk fuel supplies to be up to specification.

1.17.1.2 Single engine malfunction

There have been many cases of failure or malfunction in Gnome engined Wessex aircraft, civil and military, which have resulted in loss of power or have necessitated one engine being shut down by the pilot. The causes have included malfunctions of the electronic fuel control system and inlet guide vanes, foreign object ingestion, and mechanical failures such as the loss of compressor blades. According to Rolls Royce records, separated compressor blade debris has always been contained within the engine casing, without causing secondary damage to the surrounding structure. Two cases are known where a complete turbine disc has become detached in a military Wessex – and the discs were not contained within the engine casing. In both events the aircraft were engaged in ground running, and failure resulted from a maintenance error. Severe damage was caused to the aircraft structure in each case and was accompanied by fire. In one case the separated disc lodged in the radio compartment forward of the cockpit, and in the other the disc entered a forward fuel tank. Excepting for a burst compressor drum in a hovercraft installation there has been no other non-contained failure in 3.5 million hours of Gnome engine operation.

As far as malfunctions of the fuel control system and inlet guide vanes are concerned, there is no recorded case where total power failure had resulted from a malfunction of the second engine (eg a surge) as it responded to power demands resulting from the failure of the first. There is no record of an accident resulting from the pilot of a Wessex 60 wrongly diagnosing an engine malfunction and shutting down the sound engine in error, but one case was found where this was a possible factor in an accident to a military Wessex crewed by two pilots.

1.17.1.3 Main transmission failure

During the life of the Gnome engined Wessex there has been no known case of a loss of drive to the main gearbox resulting from a failure of the coupling gearbox, or of the main drive shaft or its components – the expansion joint, the torquemeter unit, and the freewheel unit. An analysis of the possible effects of assumed mechanical failures of each of the main drive system components indicated that failure of any of these units would result in the engines being shut down by their respective overspeed units, since any separation of the drive train would off-load the engines which instantaneously respond by speeding up. A further hazard in the assumed case of a broken main drive (ie of the main shaft, the torquemeter shaft or the expansion coupling) is the possibility of the portion of the main shaft above the fracture whirling and inflicting damage to the flying controls within the transmission tunnel, as once out of alignment the shaft would be back driven from the main rotor through the main gearbox and the freewheel unit. Tests indicated that the portion of shaft above the assumed failure point could be driven at speeds up to 2600 rpm, dependent on main rotor speed.

1.18 New investigation techniques

None.

2. Analysis

2.1 The flight path

The evidence indicates that while the helicopter was in level flight at about 1,560 feet above the water (1,500 feet AMSL) and an estimated 100 knots IAS, a sudden substantially total loss of power to the main gearbox forced the Commander to initiate an immediate descent on track with the intention of making an emergency landing. The fact that spectral analysis of the two RTF distress message recordings did not yield discrete main gearbox frequencies indicates that the collective pitch lever was in a low position, commensurate with autorotative flight, during these two periods. It would thus be reasonable to suppose that WI was in a state of controlled autorotative flight from the loss of power until at least the end of the second distress message, although there is no evidence as to whether the autorotation was normal in every respect.

However, on the assumption that the Commander was able to make a satisfactory entry to autorotation he would have established the helicopter in a descent at 60 to 65 knots with about 235 rotor rpm, resulting in a stabilised rate of descent of about 1,850 feet per minute. Whether the loss of power was the result of a stoppage of both engines or of a transmission failure the Commander would have had to carry out the relevant emergency actions, and would have followed up by initiating the ditching procedure. It is considered that in this sequence between 15 and 25 seconds would elapse before he was able to transmit a distress message, and this would put the helicopter's height at the start of the first message as 1,100 ± 150 feet. The helicopter would then be at 670 ± 150 feet at the end of its second transmission at 1541.32 hrs, and at 515 ± 150 feet at the time of the unidentified noise at 1541.37 hrs.

The other piece of evidence relating height and time is that of the Coltishall controller. This was to the effect that WI's radar echo faded quickly and disappeared about midway in the five second gap between the end of the second distress message and the unidentified sound. As such an echo would disappear at about 400 feet, a height estimate on this basis would put the helicopter at around that height at 1541.35 hrs. While both estimates are somewhat speculative they are reasonably compatible and, taken with the evidence that Coltishall could not receive the VHF transmissions of a Sea King in the accident area when it was below 100 feet, indicate that WI was almost certainly airborne when the unidentified noise was recorded on the ATC tape. The evidence is that this noise bore no transient, always a characteristic of a transmitter switch being released, and so could not have come from any other aircraft or ground station. This indicates that, unless it was caused by an extraneous electrical source within the Coltishall control tower, the signal is likely to have emanated from WI and might signify the transmission of mechanical or electrical noise terminated by some event other than the release of the transmitter switch. At some point after the end of the second distress message the helicopter went out of control and crashed violently into the sea in a steep nose-down attitude and with a left yaw rate or left sideslip. If the noise signal was in fact transmitted by WI it might indicate the point at which control was lost, but the evidence is not conclusive.

The investigation centred on the two main elements of the accident: firstly, the reason for the loss of power and, secondly, the reason why the helicopter went out of control and crashed instead of landing on the water.

2.2 Loss of power

2.2.1 For the purposes of the investigation it was assumed that the pilot's report of 'engine failure' could indicate either a substantial or complete loss of power from both engines, or alternatively a failure of the transmission between the engines and the main rotor gearbox. The only wreckage evidence relevant to this point was that there had been no failure in the main rotor gearbox, that it was not under power at impact, and that the fuel flows to both engines at impact indicated that neither was running at that instant. These findings are equally consistent with a loss of drive resulting from a cessation of power of both engines for whatever reason, a coupling gearbox failure, or a transmission main drive failure. The available evidence was insufficient to allow discrimination between these possibilities and the cause of the loss of power to the main gearbox therefore remains unknown.

2.2.2 It was, however, noted that whilst the Gnome's engine casing has in the past contained shed compressor blades, a break up of a turbine disc or compressor rotor would not be contained and could disable the other engine. While British Civil Airworthiness Requirements do not include a requirement for such protection, the Civil Aviation Authority made a submission to the United States Federal Aviation Administration during the 1980 Regulatory Review Programme that FAR 29.903 be supplemented to the effect that 'design precautions must be taken to minimise the hazards to the rotorcraft in the event of an engine rotor failure or a fire originating in the engine which burns through the rotor case'. Engine turbine or compressor rotor failure is a hazard in both single and multi-engine helicopters and it is important that maximum practicable protection be provided. Design precautions should be taken to minimise the risk of damage to vital components in the event of such failures. BCARs should accordingly be revised to require this.

It was also noted that the Wessex 60's common engine intake was at variance with the concept of engine independence, so that damage to one compressor could affect the other. While BCARs now cover this aspect of design, the Wessex 60 remains vulnerable and the CAA should review the matter.

2.2.3 Whilst it is clear that G–ASWI had ample fuel on board when the power failure occurred the evidence shows that the Commander had not carried out fuel balancing in accordance with instructions in the Flight and Operations Manuals, but had been using another procedure approved by BHL. Although the photographs of the forward fuel tank gauge reading 400 lbs and of the fuel cross feed cock in the closed position are consistent with a total fuel state of about 800 lbs equally balanced between the two tanks, as would be expected immediately prior to the emergency, the evidence is not strong enough for a conclusion to this effect to be drawn.

One danger of using fuel balancing as a matter of operational practice, rather than for the short periods necessary to correct the small imbalances that result from differing engine fuel consumption rates, is an increased chance of running the selected tank dry through forgetfulness. There is no evidence that fuel starvation was the cause of the loss of power, and BHL's cross-feeding procedure was designed to avoid the possibility of accidentally running one tank dry. However, as a flight safety matter, it was observed that the Wessex 60's central warning system did not contain captions for low fuel tank contents although both engines could be fed from the same tank group. It was recommended that the CAA should require all helicopters to have a means, separate from the fuel gauges, of automatically alerting the crew when the fuel state in any tank capable of directly feeding an engine reaches a pre-determined low value.

2.3 Loss of control

2.3.1 The impact was characterised by the destruction of the aircraft, severe injuries to the bodies, a steep nose-down attitude with left sideslip or a left yaw rate, and a rotor speed significantly below any acceptable flight figure. This evidence leads to the conclusion that the helicopter was out of control before it struck the water. Discounting remote possibilities (eg a bird strike penetrating the windscreen) four possible causes were considered: decay in rotor speed at the time of the loss of power, misassessment of height during a landing manoeuvre, pilot incapacitation, and degraded aircraft handling qualities due to a flying control problem.

2.3.2 Rotor speed decay

2.3.2.1 There is the question whether, however the loss of power occurred, the rotor speed might have decayed to a low value before the pilot was able to react by reducing collective pitch, and that it did not then recover in time to permit the helicopter to be stabilised in normal autorotative flight by the height at which the landing flare should have been commenced. Such a theory postulates an autorotation at a much lower rotor speed and a higher rate of descent than normal, with the rotor experiencing severe stall and the helicopter going out of control at some point after the second distress message – either while the descent phase was still in progress or at the point where a landing flare was attempted.

The need to decrease collective pitch at once following a total loss of power has been well known since the start of helicopter flight and great emphasis is put on it in pilot training. Nonetheless the required reaction time is small and accidents to single engine helicopters have been attributed to excessive decay of rotor speed following total power loss. There have also been two such accidents to military Wessex helicopters. In one of these a single engine Wessex had an engine failure in level flight at about 60 knots and 700 feet and then autorotated with low rotor speed, but otherwise apparently under control, until it crashed into the sea at a high rate of descent. In the other a Gnome engined Wessex suffered a sequential engine failure when in a cruising descent from 1,000 feet, lost rotor speed, and went out of control in blade stall at about 300 feet. Nonetheless the usual result of a sudden and complete loss of power in a helicopter is a successful entry to autorotation. This is borne out as far as the Wessex type is concerned by the results of the simulator trials and the computer simulation of Wessex rotor decay rates. These suggest that the mean response time of 3 seconds would result in a minimum rotor speed of about 179 rpm with recovery to the normal range within a further 6 seconds, although response times greater than 3 seconds are possible and would result in significantly lower rotor speeds being reached due to the rise in rotor drag associated with the onset of blade stall.

As far as G–ASWI is concerned there is insufficient evidence to prove that normal autorotation was established following the loss of power. However the experience and ability of the pilot, the fact that a successful entry is achieved on almost all occasions, the BHL record of 81 successful autorotations following engine or drive train failures in various types of helicopters in the fourteen years preceding the accident, and the results of the simulator trials and rotor decay rate study, suggest that a successful autorotation at normal rotor speed was likely to have been achieved provided the helicopter remained undamaged following the event which deprived it of power.

2.3.2.2 Nevertheless, the investigation has highlighted an important flight safety matter. It is apparent that typical pilot reaction time following a sudden and complete loss of power is too slow to contain rotor speed anywhere near the autorotation minimum permissible figure of 210 rpm laid down in the Wessex Flight Manual and the BHL Operations Manual, even in cruising flight. The drop in rotor speed would be worse in a climb or if the rotor blades carried any ice.

Although BCARs require twin-engine helicopters to be capable of carrying out emergency autorotative landings they contain no requirement relating to minimum rotor speed following a simultaneous failure of both power units in a twin-engined helicopter, or for the case in which one engine fails a finite time after the other, since paragraph 2 of the Appendix to Chapter G2-8 does not apparently apply to either of these circumstances. However, it is noted that the delay time of 2 seconds quoted in this paragraph when added to a lever lowering time of 0.75 secs matches closely the mean response time of 3 seconds measured in the simulator trial, which would result in a rotor speed far below the minimum permissible figure quoted in the Wessex Flight Manual. Although the Wessex rotor system was designed over 25 years ago there was evidence that many modern helicopters suffer similarly high or worse decay rates, with the probability that rotor speeds well below the specified minima will be reached following a total loss of power and the possibility that they may approach a value below which a hazardous condition could exist. This is an unsatisfactory position which should not be allowed to continue longer than is necessary and so it is suggested that the CAA carry out a review of of BCARs in relation to rotor behaviour following total power loss. The review should include consideration of:

1 A complete power loss in both single and twin-engined helicopters, whether the latter occurs simultaneously or by one engine failing some time after the other.

2 The Institute of Aviation Medicine papers on pilot response times mentioned in paragraph 1.16.2.

3 The practicability of requiring all helicopters to be fitted with an audible warning system to give early indication of a high decay rate of rotor speed by revising BCAR Chapter G6-1, paragraph 3.2.1 (r), so as to delete sub-paragraphs (i), (ii) and (iii).

4 Means by which rotor decay speeds might be reduced in future helicopters – for example by blade design, or by automatic reduction of collective pitch (the equivalent of a stick pusher in fixed wing aircraft).

Additionally, useful pilot training against the possibility of a sudden power failure at high power settings can be done in helicopter simulators, and a suitable exercise should be introduced where these are available and practiced at regular intervals. It should be pointed out however, that BHL Wessex 60 pilots practised this on every six monthly base check from cruise power settings and so were given realistic aircraft training for such an emergency although this was not general practice amongst operators, nor was it required by the regulations.

2.3.3 Misassessment of height in an attempted landing

2.3.3.1 The possibility was considered whether even assuming no significant damage resulted from the power failure and the pilot was neither injured nor incapacitated he might have misjudged the helicopter's height in the existing conditions of calm sea, indifferent visibility and lack of a natural horizon with the sun ahead of the aircraft. The postulated pattern of events would be one in which the pilot was misled by inadequate visual cues into initiating the landing flare above the height of 100 to 150 feet recommended, had not realised this, and had then applied a large collective pitch input at an excessive height with the result that rotor speed decayed to a very low figure and the helicopter went out of control and crashed. Such a loss of control could be caused by blade stall, with the helicopter pitching nose up and rolling left before entering a nose down left spiral. An impact during such a spiral would be compatible with the wreckage damage observed.

On the other hand there is good evidence that such an accumulation of errors would be unlikely in this case. BHL have a very good record of successful autorotative landings. The captain of the RAF Sea King, who was also an experienced Wessex pilot, said the surface of the sea was clearly defined. He also said that in the prevailing weather he would not have expected an experienced pilot to have made errors of judgement large enough to bring about the destruction of the aircraft during an autorotative landing. Further, WI was fitted with an accurate and reliable radio altimeter with warning lights set to operate at 200 feet. The information obtainable from this instrument should have been sufficient to enable the Commander to flare at the correct height, although he might not have been able to refer to it thereafter. Moreover, the Commander was exceptionally experienced in the Wessex, and was a training captain with regular and recent experience of practice autorotations. Finally, he had a good opportunity to familiarise himself with external height assessment in the weather and water conditions pertaining during the course of the flight, which had included nine descents to 70 feet when landing on platforms. The evidence taken together suggests that misassessment of height by the Commander was unlikely to have been the cause of the loss of control, but the possibility could not be ruled out.

2.3.3.2 However, a further important flight safety matter has been highlighted by the investigation. A successful autorotative landing is always a finely judged manoeuvre involving pilot control of exchange of kinetic, potential and rotor energy in which the assessment of height to a fine limit is vital. Because of this consideration was given to the situation of other helicopter pilots, who would often be considerably less experienced than the Commander of WI and who might be faced with an autorotative landing on water in less favourable weather than in this accident – and this could be at night. It was therefore recommended that the CAA should conduct a special review of autorotation procedures and training for all helicopter types to determine whether improvements could be made.

Although the Wessex 60 flight manual included an emergency technique for autorotative landing on water, the standard autorotation landing technique described in flight manuals is often based on the assumption of an autorotation over land with good visibility and excellent visual cues. But very different conditions pertain at sea, especially in unfavourable weather and/or at night, and there are differences of opinion as to the best landing technique for any particular type of helicopter in such conditions eg whether a flare type landing or a constant attitude one is safer. The review should therefore consider, for each relevant helicopter type, whether the laid down technique is best for use in all conditions offshore or whether a separate technique should be devised and introduced. Whatever technique is recommended it should be practised in simulators where these are available.

It is also important for all helicopters operating over sea to be equipped with a radio altimeter having audio as well as visual decision height warning, so that pilots faced with an emergency power-on or power-off landing can have an accurate indication of height as well as an aural warning of a pre-selected height. Such an altimeter would also be an important safeguard in normal operations. In the longer term, consideration should be given to the possibility of utilising instrument and auto-pilot systems to compute, indicate visually and/or aurally, and perhaps eventually fly the autorotation landing manoeuvre for the pilot. An emergency autorotative landing on water is too critical an operation to continue indefinitely to be left entirely to human judgement relying primarily on external visual cues, and this situation should be remedied as soon as it is practicable to do so.

2.3.4 *Pilot incapacitation*

Two aspects of pilot incapacitation were considered. Firstly, the possibility of the Commander having suffered a pre-impact injury resulting from the event which deprived the helicopter of power. The post-mortem examination provided no evidence of pre-impact injury but the pathologist stated that the possibility could not be excluded. Secondly, it was considered whether the Commander might have suffered a medical episode of an incapacitating or severely distractionary nature soon after the initial emergency which so affected his performance that he became unable to control the helicopter. Whilst the Commander was found on post-mortem to have had slight to moderately severe coronary artery disease and showed histological evidence of a microscopic haemorrage into a plaque about one week prior to the accident, the pathologist concluded that the chance of a further episode which might have contributed to the accident was very unlikely. However the possibility cannot be excluded.

2.3.5 *Flying controls*

The evidence that G–ASWI had had an uneventful flight up to the moment of the loss of power, together with the results of the examination of the recovered components of the primary hydraulic system, lead to the conclusion that a malfunction of the primary system can be ruled out as a reason for the loss of control. Similarly as this system is entirely contained around the main gearbox, well clear of the possible failure areas of engines and main transmission drive, the possibility of the loss of control having resulted from damage to the primary system is discounted.

Operation of the secondary servo unit actuating cylinder is vital to the continued effectiveness of the flying controls once secondary servo assistance is no longer available. Operation of the actuating cylinder is capable of being verified on each pre and post flight check carried out by pilots in accordance with the BHL check list. Because of this, because the aircraft had flown satisfactorily in autorotation with the secondary system switched off during a training flight ten days before the accident, and because there was no record of any previous failure of the Wessex's actuating cylinder to operate, a malfunction of the actuating cylinder such as to create a control problem resulting in a loss of control of the aircraft was considered to be extremely improbable.

Finally, the possibility was considered whether the helicopter's handling qualities were adversely affected by some damage resulting from the initial power failure. Such damage might have been inflicted either at the instant of the power loss and been followed by a progressive degradation into an uncontrollable state,or in a single catastrophic event later in the descent.

It seems that if damage to the aircraft resulted in the loss of control, it must have occurred or had its ultimate effect in the last few hundred feet of the descent. Whilst there is no evidence to prove conclusively that it came from WI, the noise on the tape at 1547.37 hrs might indicate some mechanical event at a low height which either caused or was the result of the loss of control. The only possibility of a causal event that came to light during the investigation was that the main shaft, the torquemeter shaft, or the expansion coupling may have failed (causing the power loss) in such a manner that the shaft was constrained for most of the descent and then became free to inflict damage by whirling. No failure of this type has occurred before and in previous Wessex 60 accidents these components were recovered intact. Whilst the nature and the time scale of such a possible sequence of events is unknown it is conceivable that a whirling shaft might be capable of inflicting progressive or delayed damage to the cyclic control rods in the transmission tunnel, resulting in loss of control some time later than the initial shaft failure. Although there is no evidence to indicate that this was the cause of the loss of control it must remain a possibility.

The CAA stated that changes to BCARs subsequent to the date of certification of the Wessex 60 now require the design of a rotorcraft to be such that the probability of a failure of a component such as a main drive shaft resulting in a catastrophic effect is extremely remote.

2.4 Other matters arising out of the investigation

2.4.1 Accident data recorders

The effectiveness of the investigation was considerably affected by a serious lack of evidence. If G–ASWI had been fitted with flight data and cockpit voice recorders, and if these had been retrieved, the additional information obtained would have significantly increased the possibility of the cause of the accident being established although the determination of the nature of any mechanical failure would still have depended on the recovery of appropriate wreckage. The lack of recorded data makes the investigation of accidents to helicopters a significantly more difficult and rudimentary process than an investigation to a fixed wing aircraft in similar circumstances. Experience has shown that to have a reasonable chance of bringing investigations of helicopter accidents to a successful conclusion it is vital to have flight data and cockpit voice recorders fitted to as wide a range of machines as is practicable.

At the time of the accident requirements for flight data and cockpit voice recorders for public transport helicopters on the British register were being considered by the AIB and CAA. A recommendation was made that these should be completed as a matter or urgency. With effect from March 1984 the Air Navigation Order will require helicopters in the Transport Category which have either a maximum total authorised weight exceeding 2700 kg (5,952 lbs) or which can carry more than 9 passengers, to be fitted with a 4 channel cockpit voice recorder. This CVR will record the captain's and co-pilot's incoming and outgoing radio communications and intercom, plus navaid audio idents, and aural warnings. An area microphone will record all flight deck ambient noise, from which certain helicopter transmission speeds and/or malfunctions can be detected. A fourth track will record (as a minimum) rotor speed data, ensuring that a knowledge of this parameter is available throughout all phases of flight. The specification allows operators who so desire to record multiplexed digital flight data on this fourth track.

Discussions to define the flight data recorder requirements for larger helicopters are still in progress. But action in this case and on the 1984 CVR fit will still leave the small turbine engined helicopters without a recorder. It is to be hoped that FDR's and CVR's suitable for these will become available in the not too distant future as they are vital investigative tools.

2.4.2 *Single pilot operation*

The helicopter was being operated within the terms of the CAA exemption to ANO 1980 Article 17 (3) which allowed BHL to carry out single pilot Wessex 60 operations in visual meteorological conditions. The Wessex was designed as a single pilot helicopter and is only slightly above the upper weight limit laid down in the ANO for single pilot operations, a figure which it would be unreasonable to regard as totally inflexible. Whilst in this particular use of the Wessex the concept of single pilot operation is not considered to have been unsound, the question of whether a co-pilot might have influenced events favourably was examined. A co-pilot is of especial value in cases of the commander's incapacitation, and can share the work load in other emergencies. In an emergency such as this one a co-pilot could have carried out the necessary drills allowing his commander to concentrate solely on handling the helicopter. In particular he could have called out radio heights during the descent, flare and touch-down. He might also have been able to transmit a more comprehensive distress message. However there is no evidence to indicate whether or not the presence of a co-pilot in WI would have resulted in a favourable outcome to the emergency.

2.4.3 *Automatic survival radio beacon*

In different circumstances WI's impact with the water might have been a much less violent one, survived by severely injured occupants unable to operate the survival beacons carried and in need of prompt location and transport to hospital. Fortuitously, the Burndept 369 beacon carried in the cabin cleared the wreckage, floated and transmitted a signal. The rescue Sea King was thus able to quickly locate the accident site.

This raises the question of whether offshore helicopters should be equipped with an automatic survival radio beacon. The main case for the automatic survival radio beacon in aircraft rests on increasing the chances of survivors being rescued before they deteriorate so much that they die. Such a beacon, activated by immersion or by impact forces, would give an increased probability that electronic distress signals will be transmitted. It would be of especial value where the crew are unable to switch on the manually operated survival beacons now carried, due to injury or other reason. Passengers carried in aircraft over hostile survival environments are especially at risk, and this applies to helicopters operating around the British Isles. The use of automatically operated survival beacons in helicopters operating offshore can also be invaluable in the location of wreckage for accident investigation, as the underwater sonar location beacon carried by helicopters still entails a surface vessel search at short range. The CAA was therefore recommended to consider requiring helicopters operating offshore to be fitted with an automatic survival radio beacon.

2.5 Summary

Early in the investigation it became apparent that the emergency had its origin in a loss of power from both engines (either simultaneously or in close time sequence) or in a failure of the transmission system somewhere between the engines and the input to the main rotor gearbox. It has not been possible to discriminate between these alternatives and so the reason for the loss of power could not be established.

In respect of the loss of control various possibilities have been considered but the evidence did not permit any of them to be identified as being the cause. Thus the reason why G–ASWI went out of control and crashed instead of landing on the water also remains undetermined.

However, the examination of the circumstances and possible causes of the accident highlighted areas of helicopter design, equipment and operation which deserve consideration by the CAA with the aim of action being taken to reduce the chance of another similar accident occurring to a helicopter. Some of the recommendations can be readily implemented, others are for the longer term. They are aimed firstly at reducing the possibility of a double engine failure, and also of rotor speed decaying to a hazardous level immediately following a power failure. Secondly at improving a helicopter pilot's chances of performing a survivable autorotative landing at sea, and of the survivors then being recovered alive. Thirdly, are recommendations designed to increase the probability of establishing the cause of accidents such as that to G–ASWI, with consequent benefits to safety.

3. Conclusions

(a) Findings

(i) G–ASWI had been maintained in accordance with the approved maintenance schedule and its Certificate of Airworthiness was valid.

(ii) The Commander held a valid licence and was highly experienced on the Wessex type.

(iii) The weather was suitable for the intended flight.

(iv) Sufficient fuel was carried for the flight. However, fuel management was not carried out in accordance with Flight and Operations Manual instructions in that a larger imbalance than permissible was effected to make refuelling offshore easier. This was in accordance with established Company procedure.

(v) Although no load sheet data were available in respect of the inbound flight the helicopter's weight was assessed as having been within the prescribed limits. Whilst it was not possible to assess the position of the centre of gravity there was no evidence to suggest that it was not within the prescribed limits.

(vi) While en route from Leman Bank field platform 27E to Bacton at an altitude of 1,500 feet G–ASWI suffered a loss of power to the main rotor gearbox.

(vii) There was insufficient evidence from which to establish the reason for this loss of power.

(viii) Following the loss of power the Commander put the helicopter into an autorotative descent with the intention of carrying out an emergency landing on the sea.

(ix) The two distress messages transmitted by G–ASWI were acted upon promptly and commendably by RAF Coltishall and the crew of the RAF search and rescue Sea King helicopter.

(x) G–ASWI went out of control in the late stages of the autorotative descent and crashed into the sea with a very low rotor speed, all thirteen men on board being killed.

(xi) The reason for the loss of control could not be established.

b) Cause

Whilst the emergency originated in either engine or transmission failure, the accident was the result of the helicopter going out of control instead of landing on the water. However the evidence was insufficient to permit the cause of the loss of control, and thus of the accident, to be determined.

4. Safety Recommendations

It is recommended that:-

4.1 The practicability of modifying the Wessex 60's intake to provide engine independence in this area should be investigated.

4.2 The requirements for the protection of essential rotorcraft systems following an uncontained engine failure should be reviewed.

4.3 Helicopters be required to have a means, separate from the fuel gauge system, of automatically alerting the crew when the contents of any tank capable of directly feeding an engine reaches a pre-determined low value.

4.4 The BCARs relating to helicopter main rotor behaviour following total power loss should be reviewed. The review should consider the latest data on pilot response times, the practicability of requiring all helicopters to be fitted with a rotor speed decay warning system, and means by which rotor decay rates might be reduced.

4.5 There should be a review of autorotation techniques and training in respect of every type of helicopter used on offshore operations to see whether improvements should be made. The review should include consideration of whether the autorotative landing technique recommended in each flight manual is a satisfactory one for poor weather conditions offshore. The review should also consider the inclusion of a total power loss exercise, and an autorotation landing exercise, in flight simulator training.

4.6 Radio altimeters incorporating audio as well as visual decision height warning be fitted to all helicopters operating offshore around the British Isles.

4.7 Consideration should be given to the possibility of employing future helicopter instrument and autopilot systems to compute, indicate, and perhaps eventually fly, the autorotative landing manoeuvre on to water.

4.8 Public transport helicopters be fitted with a survival radio beacon which is automatically deployed on immersion in water or by impact forces.

4.9 Flight data and cockpit voice recorders be fitted to as wide a range of helicopters as is practicable.

4.10 Measures should be adopted to ensure that helicopter dynamic components, the failure of which is likely to lead to catastrophe, are traceable for the purposes of accident investigation and consequent remedial action.

D A Cooper
Inspector of Accidents
Accidents Investigation Branch
Department of Transport

July 1983

Produced in England by Her Majesty's Stationery Office, Reprographic Centre, Basildon

Bas 254104/R151 750 10/83 TP