

Accidents Investigation Branch

Department of Transport

**Report on the accident to
DHC-6 Twin Otter 310 G-STUD
at Flotta Aerodrome, Orkney
on 20 April 1983**

LONDON

HER MAJESTY'S STATIONERY OFFICE

List of Aircraft Accident Reports issued by AIB in 1983/84

<i>No</i>	<i>Short Title</i>	<i>Date of Publication</i>
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	November 1983
5/83	BAe HS 748 G-ASPL Nailstone Leicestershire June 1981	February 1984
6/83	Embraer Bandeirante G-OAIR Hatton nr Peterhead Scotland November 1982	January 1984

<i>No</i>	<i>Short Title</i>	<i>Date of Publication</i>
7/83	Sikorsky S76A Spirit G-BNSH Aberdeen Airport October 1981	
8/83	DHC-6 Twin Otter 310 G-STUD Flotta Aerodrome, Orkney April 1983	

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

2 February 1984

The Rt Honourable Nicholas Ridley
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr C C Allen, an Inspector of Accidents, on the circumstances of the accident to DHC-6 Twin Otter 310 G-STUD which occurred at Flotta Aerodrome, Orkney on 20 April 1983.

I have the honour to be
Sir
Your obedient Servant

G C Wilkinson
Chief Inspector of Accidents

Accidents Investigation Branch

Aircraft Accident Report No. 8/83
(EW/C 825)

Operator: Air Ecosse

Aircraft: *Type:* DHC-6 Twin Otter
 Model: 310
 Nationality: British
 Registration: G-STUD

Place of accident: Flotta aerodrome, Orkney
 Latitude: 58° 49' 35"N
 Longitude: 03° 08' 32"W

Date and time: 20 April 1983 at 1200 hrs

All times in this report are GMT

Synopsis

The accident was reported to the Accidents Investigation Branch at 1235 hrs on 20 April 1983 and the investigation commenced the following morning.

The aircraft, a twin-engined light turbo-prop, was engaged on a charter flight from Aberdeen Airport to Flotta aerodrome, Orkney. The aircraft commander, a pilot's assistant, and 10 passengers were on board. The flight progressed without incident until the landing at Flotta. With the surface wind reported there as 260°/26 knots, the commander elected to make a straight in approach to runway 35. Shortly after touch-down, the aircraft's left wing started to rise and, despite taking full corrective action, the commander was unable to prevent the right wing from contacting the ground. The aircraft departed the runway to the right, and 'cartwheeled' through an aerodrome boundary fence before finally coming to rest on its left side, with both wings detached. The occupants escaped with minor injuries.

The report concludes that the accident was caused by a loss of control, shortly after touch-down, following a strong lateral gust which was in excess of the maximum cross-wind capability of the aircraft. The lack of accurate surface wind information at the runway threshold was a contributory factor.

1. Factual Information

1.1 History of the flight

The aircraft was on a charter flight from Aberdeen Airport to Flotta aerodrome, Orkney Islands, with a crew of two, comprising the aircraft commander, a pilot's assistant and ten passengers. The commander had reported for duty at 0750 hrs on the day of the accident, and had operated the sectors Aberdeen to Wick and return in the accident aircraft. Both these flights were completed on schedule and without incident.

The aircraft took off from Aberdeen Airport at 1118 hrs, with sufficient fuel on board for the flight to Flotta aerodrome and the return flight to Aberdeen, since there were no re-fuelling facilities at Flotta. The weather was fine, with strong gusting westerly winds over the entire route. The aircraft departed from Aberdeen on a Visual Flight Rules (VFR) clearance to cruise at 2000 feet. The flight proceeded normally and at 1152 hrs the commander obtained the latest Kirkwall weather, which was reported as a surface wind of 260°/28 knots, with gusts to 34 knots, and no significant cloud.

The wind velocity as indicated by the anemometer situated near the Flotta aerodrome Air/Ground (A/G) station gradually increased during the morning until a reading of 260°/32 knots was observed at about 1045 hrs. The aircraft first contacted the A/G station on RTF at 1156 hrs, and was informed that the surface wind was indicating 260°/26 knots. The commander accordingly elected to make a straight in approach to runway 35. He subsequently stated that, when faced with a ninety degree cross-wind, assuming a choice of landing direction is available, he preferred the cross-wind to come from his left-hand side, so that he could 'see' the left mainwheel onto the runway.

At 1158 hrs the aircraft reported to Kirkwall Tower: 'LONG FINALS TO 35 AT FLOTTA', and the commander stated that he established the aircraft on a stable approach.

When the aircraft was approaching short finals, the Flotta A/G radio station operator transmitted an instant read-out of the surface wind as 260°/21 knots. The radio operator stated that he also transmitted successive wind reports of 260°/28 knots, 260°/26 knots, and that the final anemometer reading observed before the aircraft touched down was 240°/24 knots, but that this reading was not transmitted to the aircraft. The flight crew agree that successive wind strength readings were received, but do not recall receiving a higher wind speed than 26 knots. At this stage in the approach the final checks and adjustments to the flight path were being carried out. The commander stated that the final stages of the approach were normal, that full flap was selected at about 200 feet above touch-down, and that the 'wing down' cross-wind landing technique was used. No abnormal handling problems were experienced. The aircraft crossed the runway threshold left wing down and with right rudder applied to keep the aircraft aligned with the runway.

There is evidence that the aircraft touched down left mainwheel first, then on the right mainwheel and that, as the nosewheel touched, the commander selected reverse thrust from the propellers. As the aircraft touched down, the

audible stall warning sounded momentarily. Shortly after reverse thrust from the propellers had been selected and achieved, the aircraft's left wing started to rise. The commander took immediate corrective action by applying full left wing down aileron and full left rudder, then cancelling reverse thrust from the right-hand propeller and increasing forward power on that engine. However, he was still unable to prevent the left wing from rising further. The right-hand wing-tip contacted the ground, the aircraft yawed to the right and then fell back momentarily onto the main wheels before 'cartwheeling' through an aerodrome boundary fence and coming to rest on its left side, with both wings detached.

The flight crew managed to release themselves and vacated the aircraft through the right-hand cockpit door. They then went to the rear of the aircraft and assisted the passengers to escape via the right-hand rear emergency exit. The crash and rescue vehicles arrived at the accident site within one minute of the occurrence, and foam was applied to the left-hand engine, which was emitting a considerable quantity of dark smoke.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	—	—	—
Serious	—	—	—
Minor/None	2	10	

1.3 Damage to aircraft

Aircraft destroyed.

1.4 Other damage

An aerodrome boundary fence was damaged when it was struck by the aircraft. There was minor ground damage close to the boundary fence.

1.5 Personnel information

(a) <i>Aircraft commander:</i>	Male
Age:	42 years
Licence:	Airline Transport Pilot's Licence issued March 1980 valid until 19 March 1990
Ratings:	Emb-110 Bandeirante, DHC-6 Twin Otter. Current Certificate of Test on Twin Otter aircraft, with current Instrument Rating valid until 8 September 1983
Last medical examination:	11 January 1983, valid until 10 June 1983, Class 1 with the restriction 'to have spectacles to correct distant vision'

Flying experience:

Total hours as pilot: 9010
Total hours (P1) on type: 1503
Total hours preceding 28 days: 50
Rest period: 14 hours 35 minutes rest prior to commencement of duty on day of the accident

(b) Pilot's assistant:

Male
Age: 23 years
Licence: Private Pilot's Licence, permanently valid Groups A and B and self-launching Motorised Glider
Last medical examination: 26 August 1982, Class 1 with no restrictions

Flying experience:

Total hours as pilot: 184
Total hours as P1: 100
Total hours (P1) on type: nil
Total hours operating as Pilot's assistant: 194

(c) Additional information

The commander was well experienced in flying to the Orkney Islands, and had landed at Flotta on numerous previous occasions. His most recent landing at Flotta was at 0745 hrs on 19 April 1983, the day before the accident.

1.6 Aircraft information

(a) Leading particulars

Type: DHC-6 Series 310 Twin Otter
Manufacturer's serial number: 545
Date of manufacture: June 1972
Certificate of Registration: First issued in the United Kingdom on 10 October 1979. The registered owners were Fairflight Limited
Certificate of Airworthiness: Renewed on 29 October 1982 and valid until 28 October 1983

Certificate of Maintenance:	Renewed on 18 April 1983 at 6989.10 aircraft hours and valid until 8 May 1983 or 7109.10 aircraft hours, whichever is the sooner
Total aircraft hours:	7000.30
Engines (2):	Pratt & Whitney PT6A-27
Engine serial numbers:	Left PCE 41503 Right PCE 41508
Propellers (2):	Hartzell HC-B3TN
Propeller serial numbers:	Left BU 11402 Right BU 7133
Total engine hours since new:	Left 6504 Right 6387
Total engine hours since complete overhaul:	Left 1037 Right 1533
Maximum authorised take-off weight:	5700 kg
Actual take-off weight:	4991 kg
Maximum authorised landing weight:	5584 kg
Actual landing weight:	4791 kg

(b) Centre of Gravity (CG)

The CG limits at both the actual take-off weight and landing weight were between 20% and 36% mean aerodynamic chord (MAC). The actual CG at take-off was about 29% MAC, and remained within the aircraft's weight and CG envelope throughout the flight.

(c) Fuel

Type:	Jet A-1 (AVTUR)
Total fuel at take-off:	835 kg
Estimated fuel on landing:	635 kg

(d) Minimum flight crew

The minimum flight crew as specified in the Aircraft Flight Manual is one pilot. The aircraft operator provided, as an additional crew member, a pilot's assistant who was not type rated on the Twin Otter. This was not a factor in the accident.

(e) Cross-wind landing limitations and technique

The Aircraft Flight Manual contains the following advice on cross-wind landings:

“Adequate controllability during landing has been demonstrated using flaps ‘full’ (37.5°) in cross-wind components up to 20 knots measured at 6 feet (this is equivalent to 25 knots measured at

tower height of 33 feet). This is the maximum cross-wind experienced during cross-wind trials and is not considered limiting. The recommended technique is to approach and touch-down with the windward wing lowered, using rudder to align the aeroplane with the runway. After touch-down, the nose-wheel should be lowered onto the runway and held there with elevator throughout the ground roll. The rudder provides adequate control to keep the aeroplane straight down to nominal speeds, when brakes may be used. Early use of brakes may induce lateral skidding, thereby making directional control more difficult. Where runway lengths permit, flap deflections may be reduced to further improve controllability and tolerance to cross-winds."

The company cross-wind limitation for landing on a dry runway is 25 knots.

(f) Landing distance required

Details of the landing distance required for varying aircraft weights, aerodrome altitudes, runway slopes and surface conditions are presented in graphical form in the Aircraft Flight Manual. Graphs are included for both normal and short field operation, and indicate the scheduled landing distance required from 50 feet to a complete stop. The essential difference between the two distances is that normal field operation takes no consideration of the effect of reverse thrust, whilst the short field landing distance assumes both engines at full reverse thrust after touch-down. On the day of the accident the scheduled landing distances required on runway 35 (dry conditions) at Flotta, at an aircraft weight of 4791 kg were:

(i) Normal field operation – 625 m (2050 ft)

(ii) Short field operation – 472 m (1550 ft)

(g) Stall warning system

The aircraft stall warning system comprises two lift-detecting vanes and switches in the left wing leading edge, and in circuit with a warning light and audible alarm horn. The two vanes are set at slightly different levels in the wing leading edge to ensure the effectiveness of the stall warning system at all flap settings and aircraft attitudes. The stall warning system activates at between 4 to 9 knots above the stall speed. At an aircraft weight of 4791 kg and with full flap selected, the minimum speed at the stall is 51 knots.

1.7 Meteorological information

Meteorological observations are not made at Flotta aerodrome; however landing forecasts are issued for Kirkwall Airport, which is situated approximately 20 kilometres to the north-east. An aftercast, prepared by the Principal Meteorological Officer, Prestwick, included the following weather information:

Synoptic Situation:	A depression, central pressure 987 mb, was centred at a position 61°30'N, 01°30'W at 1200 hrs, and moving slowly to the north-north-west. A strong unstable westerly airstream had become established over the area
Surface wind:	260°/28 knots, with gusts to 38 knots 4 oktas cumulus/stratocumulus at 2000 feet occasionally 7 oktas cumulonimbus at 1500 feet
Visibility:	Over 30 kilometres, 8 kilometres in showers
Weather:	Occasional 'showers of rain or hail

These winds are derived from the anemometer traces from Kirkwall Airport and the Flotta Oil Terminal. The Flotta aerodrome anemometer is not recorded. However, the Oil Terminal anemometer is recorded and showed peak gusts of 38 knots close to the time of the accident. There is no evidence of the proximity of cumulonimbus clouds at the time of the accident.

The Kirkwall Airport weather, as reported to the aircraft at 1154 hrs, was as follows: Surface wind: 260°/28 knots, gusting 34 knots; visibility 30 kilometres; nil weather, and 1 okta of cloud at 1800 feet. The aftercast includes the comment that, with a westerly wind, it would be expected that the Flotta winds would be slightly stronger than those recorded at Kirkwall, due to the more open exposure. There is evidence from the wind traces that this was the case.

The accident occurred in daylight.

1.8 Aids to navigation

Not relevant.

1.9 Communications

Radio communications between the aircraft and ground stations were normal throughout the flight.

1.10 Aerodrome information

1.10.1 General

Flotta is a private aerodrome operated by Occidental of Britain Incorporated, and is situated on the western coast of the island of Flotta, Orkney. A diagram of the aerodrome lay-out is included at Appendix 1. The single runway 35/17 is sited about 125 metres from the west coast, and measures 759 metres in length and 18 metres in width. The runway surface is tarmac-adam and was dry at the time of the accident. The threshold elevation of runway 35 is 70 feet above mean sea level, and the average slope is 1.6% down. The threshold elevation of runway 17 is 30 feet above mean sea level. The runway is equipped, at both ends, with Low Intensity 2-colour Approach Systems (LITAS) which are set to an approach angle of 4°. The

LITAS equipment for runway 35 was on and serviceable at the time of the accident.

An aircraft parking area is situated abeam the threshold of runway 17, on the eastern side, and there is an adjacent building which houses the A/G station radio equipment and anemometer read-out. The anemometer mast is sited about 50 metres north of this building, on a further down slope, and the height of the measuring device is 40 feet above ground level at that point. When compared against runway slope, this places the anemometer head at an equivalent height of about 41 feet below the landing zone of runway 35. An instantaneous, digital, read-out of the wind strength and direction is displayed on an instrument in the aerodrome building. The surface wind information passed to pilots operating in and out of Flotta aerodrome is a direct read-out from the anemometer instrument.

1.10.2 *Topographical*

The western coast of the island of Flotta is bounded by a steeply rising rocky surface, and the touch-down area of runway 35 is about 125 metres from the water's edge.

1.11 **Flight recorders**

The aircraft was not fitted 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 *On site examination of the wreckage*

The wreckage was situated alongside runway 35 at Flotta aerodrome, about 350 metres north of the threshold, and 50 metres to the east of the centre line. It was not possible to establish the precise point of touch-down; however a tyre scrub mark, thought to have been made by the aircraft's right main-wheel, was discernible commencing 180 metres from the threshold and close to the runway centre line. The mark, which was 60 metres in length, veered gently towards the right-hand side of the runway. At the point directly abeam where the tyre mark ceased, a scrape mark from the right-hand wing tip could be seen to start just off the right-hand edge of the runway. This mark continued for 40 metres, and was the only visible evidence of aircraft contact with the ground along that distance. At the point directly abeam where the wing tip scrape mark ceased, two diverging tyre scrape marks were visible in the softer ground alongside the runway, some 7 metres inboard of the wing tip mark. The tyre marks are attributed to the aircraft's nose and right landing gear. After a short distance the right tyre mark ceased, and a left wheel mark was evident on the far side of the nosewheel mark. The marks showed that, at the time, the aircraft had been increasingly veering to the right. There was a shallow ditch alongside the airfield boundary fence, running parallel to the runway. Shortly before this ditch, all wheel marks ceased, and there was a shallow indentation on the far side of the ditch; this was thought to have been made by the nose of the aircraft. The aircraft was lying on its left side just beyond the boundary fence with the nose pointing in the original direction of travel. Both wings were detached; the left wing was inverted and lying in a position close to the fuselage; the right wing was lying near the tail of the aircraft, with the right-hand propeller embedded in the fin.

1.12.2

Impact parameters

Evidence from the flight crew and eye-witnesses indicated that the touch-down had been normal, albeit in a strong cross-wind from the left, and that the aircraft was firmly on three wheels when reverse power from the propellers was selected and achieved. The evidence suggests that it was very shortly after this that the left wing started to rise, and that the aircraft commenced to veer towards the right-hand edge of the runway. Initially the aircraft was banked to the right with some weight being borne by the right main landing gear. There were scuff marks on the right mainwheel tyre which confirmed this assessment. As the bank angle increased to approximately 20 degrees, the right-hand wing tip contacted the ground. Lack of significant damage to the right wing tip indicated that the contact pressure was light and that the aircraft was, to all intents and purposes, flying again. From this point onwards, the tyre marks disappear for some distance; however, it is considered that the wing tip dragging along the ground and the aircraft deceleration would have applied a moment about the yaw axis, thus causing the nose to drop towards the ground from the banked attitude. It thus appears that the final motion of the aircraft was a 'cartwheeling' action, with the nose digging into the ground on the far side of the ditch. It was evident, from the negligible impact damage to the right wing, that the final motion caused an inertial failure of the right wing attachment. The left wing was then brought into violent contact with the ground, causing considerable distortion to the leading edge and resulting in the wing detaching at its root. The fuselage, which by this time was pointing in the direction from which it had come, was arrested by the tail digging into a section of peat bog.

1.12.3

Subsequent detailed examination

The wreckage was recovered from the accident site, and transferred to the Accidents Investigation Branch facility at Farnborough in order to facilitate a more detailed examination.

The complete aircraft control system was checked and no evidence was found of any pre-existing faults. Breaks in the aileron and flap operating mechanisms were all consistent with damage during the final impact. The flap selector lever was at the 'full flap' ($37\frac{1}{2}^\circ$) position.

The aircraft's tyres, wheel brakes, and nosewheel steering system were checked and found to be serviceable. The tyres were in good condition and correctly inflated. The right-hand mainwheel tyre had lateral scuff marks, consistent with the recent application of a sideways force. The mainwheel brake packs had recently been changed, and their condition was good, with no sign of any abnormality. Examination of the nosewheel steering spring-loaded centralising latch showed that it had operated correctly, and that the nosewheel had been centrally aligned on touch-down.

The power plants and propellers were subjected to strip examination. During dis-assembly it was established that both engines' fuel system components were still primed with fuel, and that both engines had been rotating under power during impact. Evidence from the impact damage showed that the right engine was under greater power than the left. No pre-existing faults were found in either of the propeller pitch control mechanisms. Due to impact damage and the operation of the automatic propeller feathering system as the engines stopped after the accident, it was not possible to establish the precise blade angles of the individual propellers prior to impact.

The aircraft had been properly maintained and there was no evidence of any mechanical failure, or system unserviceability, which could be regarded as a causal or contributory factor to the accident.

1.13 Medical and pathological information

There was no evidence that any medical condition contributed to the accident.

1.14 Fire

When the Flotta aerodrome crash and rescue vehicle arrived at the scene of the accident, the fire crew reported seeing a considerable quantity of black smoke rising from the left engine. About 50 gallons of foam compound was applied to the engine and surrounding area, and the smoke subsided. Subsequent examination revealed that there were fractures, caused by the impact, within the left engine oil system which had allowed oil to spill onto the hot section of the engine. There was no evidence of a fuel-fed fire.

1.15 Survival aspects

In spite of the most severe damage to the aircraft, which was destroyed, the injuries to crew and passengers were remarkably light. The deceleration during the final 'cartwheel' before the aircraft came to rest was not severe, and the most significant hazard was caused by the failure of the right wing. When this wing detached, the propeller of the engine cut through the aircraft fuselage at a position between the cockpit and the passenger cabin, close to the co-pilot's seat. In so doing, the propeller severed the pilot assistant's upper torso restraint harness behind his back, without touching either the seat or its occupant.

At the time of landing, all the aircraft occupants, except one, were restrained by safety harnesses. The two flight crew had full harness including upper torso restraint; the passengers were secured by seat-belt harness only. The one exception was an infant, aged 2½ years, who was seated on her mother's lap. Nevertheless the infant suffered only minor bruising. All the aircraft seats and their associated restraint harnesses remained firmly attached to their mountings.

As soon as the aircraft finally came to rest the flight crew managed to release themselves from the cockpit, and immediately went to the rear of the aircraft and assisted the passengers to escape via the right-hand emergency door, which was by then above them. The crash and rescue vehicle arrived at the scene within one minute of the occurrence, by which time the flight crew were assisting the last of the passengers to escape from the wreckage. At 1204 hrs, four minutes after the accident, the deputy aerodrome manager confirmed that all the aircraft's occupants were accounted for and in transit to the medical centre.

1.16 Tests and research

1.16.1 *Surface wind – Flotta aerodrome*

During the on-site investigation, it was noticed that the exposure of the southern end of runway 35 was such that strong, sudden gusts of wind were

frequently experienced. It was also apparent that the siting of the aerodrome anemometer was such that its instantaneous readings could well be different from the actual wind occurring at the runway 35 threshold. Accordingly, tests were carried out in order to determine the variation in surface wind conditions that might occur over the aerodrome, and to assess the incidence of high winds in the landing area.

The measurements were taken on 2 July 1983, when a broad, unstable westerly airstream was established over the Orkney area, with surface winds of $260^{\circ}/28$ knots, and with gusts of up to 40 knots. Measurements were recorded during two twenty minute, and one ten minute, periods within a total elapsed time of $2\frac{3}{4}$ hours. A hand-held anemometer was positioned at the touch-down point of runway 35 at Flotta aerodrome, at a height of 9 feet above the runway surface, and simultaneous readings were recorded from that anemometer and the anemometer at the terminal building. The height of 9 feet above the surface was selected as being closely similar to the height of the under surface of the Twin Otter wing, when the aircraft is on the ground. During a twenty minute period 94 simultaneous readings were recorded.

Analysis of these results showed that there was frequently a difference in the wind strength measured by the anemometers, but that there was no discernible pattern as to which anemometer consistently recorded the strongest gust. However, when the difference in the measured velocity was 4 knots or greater, the highest reading was obtained from the touch-down anemometer by a ratio of 1.24 to 1. The greatest difference recorded was a wind of 30 knots registered by the aerodrome terminal instrument when, at the same time, the instrument positioned on the runway recorded 40 knots. During the measurement period a difference of 8 knots or more between the two anemometer read-outs was recorded on 16 separate occasions.

The complete test data was sent to the Meteorological Office, Bracknell, for analysis and comment. A computer simulation of the touch-down winds was carried out in order to establish the persistence of high winds in the landing area. This showed that the probability of a gust of 50 knots or more for any length of time was about 0.05%. The probability of a gust between 35 and 40 knots for the same length of time was 11.3%.

1.16.2 *Aerodynamic considerations*

In order to try to establish an estimate of the strength of cross-wind that could be expected suddenly to affect the handling characteristics of a Twin Otter aircraft on a landing run, to such an extent as to make recovery unlikely, expert advice was sought from the Department of Industry. An excerpt from the Department report is included below:

“The configuration of the Twin Otter with high wing, full span dihedral and a large fin area leads to a very high value of the rolling moment due to sideslip, particularly with the aircraft in the normal ground attitude with the fin well above the CG. Calculations show that immediately after touch-down the rolling moment from a steady crosswind near the limit allowed by the operator considerably exceeds the available control moment for correction, but that the weight on the wheels is sufficient to prevent the aircraft turning over at the lower incidence in this condition.

The calculations of the quantities involved cannot be exact in this sort of case, in particular because just what is going on behind the propellers is not known. Nevertheless it is considered that the results of the calculations are sufficiently good to be helpful. At a touch-down speed of 58 knots, it is calculated that a lateral gust of 32 knots would be enough to start the aircraft overturning; as the aircraft forward speed falls off the critical gust speed goes up rapidly, to about 37 knots at 56 knots forward speed, so the danger period is very short. However, once the aircraft has started to turn over, the restoring moment from the weight on the outside wheel will reduce rapidly and the pilot will continue to be unable to prevent an accident."

1.17 Additional information

1.17.1 *Cross-wind limitations*

Civil Aviation Publication (CAP) 360 contains the requirements to be met by the operators of public transport aircraft in order that they may be issued with an Air Operators' Certificate. Amongst these requirements is the responsibility of the aircraft operator to include, in the Operations Manual, an instruction stipulating the cross-wind limitations to be observed by pilots operating aircraft of the company to which the Air Operators' Certificate applies. The requirements for including the cross-wind limitations in the Operations Manual are detailed in CAP 360, Chapter 2, paragraph 5.3.5, and are as follows:

Cross-wind limits for take-off and landing. It is not sufficient to repeat a statement in a flight manual that a particular cross-wind component has been found to be acceptable; operator's limitations should be stated in unequivocal terms and account taken of the effects of gusts and surface conditions. Limits in excess of any figure in the flight manual normally will not be acceptable.

There is no officially defined limit or guidance concerning the strength or frequency of wind gusts that should be considered when setting cross-wind limits.

2. Analysis

2.1 General

From the outset it was apparent that the aircraft made a normal approach, albeit in turbulent conditions, followed by a cross-wind landing in the normal touch-down zone. The momentary sounding of the audible stall warning system on touch-down indicates that the landing speed was at, or close to, the target value. It was after the aircraft was firmly on the ground, and with reverse power applied, that the left wing started to rise and that the commander, despite taking full and immediate corrective action, discovered he was unable to retain lateral control.

The possibility that it was a control or system failure within the aircraft which caused the left wing to rise can be discounted for two reasons. Firstly, because the detailed investigation of the aircraft's controls, systems and power plants revealed that they had been operating normally on landing and that there was no evidence of any failure that could have caused, or contributed to, loss of control on the ground. Secondly, because the ground witness marks and eye-witness accounts of the accident sequence were not consistent with control or system failure. A failure of this type would be likely to produce a sudden loss of control; however the ground marks showed that the aircraft veered only slowly to the right, and eye-witnesses describe the accident sequence as if it happened "in slow motion". By a process of elimination, therefore, it could be deduced that the weather, and in particular the surface wind, was probably the most significant factor in the accident.

2.2 Meteorological considerations

The aftercast of the local weather at the time of the accident confirms the prevalence of strong, gusty, surface wind conditions, and the nearest recorded wind measurements, although taken some distance from the aerodrome, registered peak gusts of 38 knots close to this time. The tests carried out after the accident revealed that a significant difference in surface wind strengths over the length of the aerodrome was not uncommon, differences as great as 10 knots having been recorded. Therefore, in the case in which the wind direction is across the runway and the anemometer reading passed to a pilot is less than the actual wind affecting the aircraft, a situation could well arise in which a pilot might unintentionally land in conditions outside the cross-wind limitations of his aircraft. Accordingly, it is recommended that the aerodrome operating authority consider re-positioning the anemometer mast to a site which should provide a more accurate indication of the mean surface wind at both ends of the runway; or, alternatively, that the cross-wind limits for aircraft taking off and landing at Flotta be re-assessed.

On the accident flight, it appears likely that the wind strengths recorded by the aerodrome anemometer and passed to the commander during the final stages of the approach were, on average, at or close to the company's cross-wind limit of 25 knots. However, there is little doubt that, shortly after touch-down, the aircraft was subjected to a considerably higher cross-wind speed, which could well have been as high as 38 knots.

2.3

Aerodynamic considerations

Expert opinion concerning the strength of cross-wind that would be sufficient to affect severely the control characteristics of a Twin Otter during the landing run concluded that, at a touch-down speed of 58 knots, a lateral gust of 32 knots would be enough to start the aircraft overturning. At the accident weight, the minimum speed in the stall is calculated to be 51 knots, and the audible stall warning, which sounded momentarily on touch-down, is programmed to operate at between 4 and 9 knots above the stall. This provides confirmation that the actual touch-down speed was between 55 and 60 knots. As there was no evidence of any control failure or malfunction of the aircraft, it must therefore be concluded that a sudden increase in the strength of the cross-wind, that is, a lateral gust of 32 knots or more, started the aircraft overturning, and that thereafter the commander had insufficient control authority to regain control.

2.4

Operational considerations

In view of the circumstances of the accident, the commander's decision to land on runway 35 at Flotta aerodrome merits examination. With hindsight it is easy to say that, had he diverted the aircraft to Kirkwall, where there was an into-wind runway, or elected to land 'up the slope' on runway 17 at Flotta, then the accident might well not have occurred.

On the other hand, the landing performance of the Twin Otter is such that, on runway 35 with a zero head-wind component, and taking the other accident conditions into consideration, the landing distance required was well within the landing distance available. Also, when given a choice of directions for landing in a 90° cross-wind, the commander quite understandably chose that which gave him a cross-wind from the left-hand side. As regards the surface wind strengths reported to, and received by, the aircraft, there is some slight conflict of evidence. In particular, the flight crew recall receiving wind reports of between 21 and 26 knots, but do not recall a report as high as the 28 knots which the Flotta radio operator believes he transmitted to the aircraft.

Nevertheless, whichever recollection is correct, the commander's assessment that the mean cross-wind component was at or close to 25 knots, and that the level of the strength of gusts above that figure was acceptable, does not appear unreasonable, particularly in view of the fact that the company's Operations Manual, in common, it is believed, with the corresponding manuals of some other operators, contained no guidance as to whether, in gusty conditions, the cross-wind limit for take-off and landing is absolute, or whether some tolerance is allowed. No abnormal handling characteristics were experienced during the approach, there was no difficulty in aligning the aircraft with the runway centre-line, and the initial touch-down was normal. Accordingly, although subsequent events proved that the choice of runway 35 and the decision to land were unfortunate, it cannot be said that it was incorrect in the light of the information available to the commander at the time. With such information, a lateral gust of the strength actually encountered at a crucial moment during the landing run could not reasonably have been anticipated.

The accident has indicated the desirability of providing guidance to pilots as to whether the full effects of gusts should be taken into account when planning cross-wind take-offs and landings, and a recommendation is made accordingly.

The prompt reaction of the aerodrome crash and rescue services, and the flight crew's timely evacuation of the passengers from the aircraft are worthy of note.

3. Conclusions

(a) *Findings*

- (i) The commander was properly licensed and well experienced for the flight.
- (ii) The aircraft had been properly maintained and a valid Certificate of Airworthiness was in force.
- (iii) With the information available to him at the time, the commander's decision to land the aircraft on runway 35 at Flotta aerodrome was a reasonable one.
- (iv) Shortly after a normal touch-down, the aircraft was subjected to a lateral gust of wind in excess of the maximum permitted cross-wind limit. There was insufficient control authority available to the commander to prevent the aircraft from overturning.
- (v) The siting of the anemometer mast at Flotta aerodrome was such that, during periods of gusty winds, an accurate measurement of the surface wind conditions over the runway thresholds was unlikely.
- (vi) The Flotta aerodrome crash and rescue services reacted promptly and with initiative.

(b) *Cause*

The accident was caused by a loss of control, shortly after touch-down, following a strong lateral gust which was in excess of the maximum cross-wind capability of the aircraft. The lack of accurate surface wind information at the runway threshold was a contributory factor.

4. Safety Recommendations

It is recommended that:

- 4.1 The aerodrome operating authority at Flotta consider re-positioning the anemometer mast; or, alternatively, that the cross-wind limits for aircraft taking off and landing at Flotta be re-assessed.
- 4.2 Pilots should be given guidance as to whether the full effects of gusts should be taken into account when planning cross-wind take-offs and landings.

C C Allen
Inspector of Accidents

Department of Transport

February 1984