AAIB Bulletin No: 2/95 **Ref: EW/B94/11/1** **Category: 1.2**

Aircraft Type and Registration:	De Havilland Canada DHC-6-300 Twin Otter, C-GKBD
No & Type of Engines:	2 PT6A turboprop engines
Year of Manufacture:	1971
Date & Time (UTC):	24 November 1994 at 0301 hrs
Location:	Rothera Air Facility, Adelaide Island, Antarctica
Type of Flight:	Ferry
Persons on Board:	Crew - 2 Passengers - 2
Injuries:	Crew - Fatal Passengers - Fatal
Nature of Damage:	Aircraft destroyed by impact and subsequent fire
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	30 years
Commander's Flying Experience:	3,984 hours (of which 3,414 were on type) Last 90 days - 190 hours Last 28 days - 60 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft, which was based at Calgary, Canada, had been chartered to carry out a Radio Echo Survey task for the Italian National Antarctic Programme and the accident occurred during the ferry flight, as the aircraft took off from Rothera, a UK base on Adelaide Island, and struck an iceberg which was situated just off the end of the runway in use. The aircraft was fitted with two ferry fuel tanks in the fuselage and there were two pilots, an aircraft engineer and a technical adviser aboard. The aircraft was destroyed by a post-impact fire.

It was not possible to recover or closely inspect the wreckage because the iceberg was considered to be too unstable and fissured to allow any safe form of approach to be made by either sea or air.

History of the flight

The flight departed Calgary on 9 November 1994 and was planned to route via Montana to Houston (1,363 nm), Grand Cayman (1,032 nm), Panama City and Guayaquil Equador (1,295 nm), Arica Chile (1,253 nm), Santiago and Puerto Montt (1,429 nm), Punta Arenas (781 nm), Rothera Adelaide Island (1,000 nm), Patriot Hills, Byrd, McMurdo to Terra Nova Bay (about 2,000 nm).

When the flight passed through the various staging posts, they did not leave Load Sheets or other documentation. Although the records of the flight details were therefore not recovered, radio communications between the aircraft and the operating company established the following achieved schedule:

9 November:	Calgary to Houston, Texas
10 November:	Houston to Grand Cayman. Aircraft delayed due to weather and the replacement of a Fuel Control Unit and a governor[1], due to erratic flowmeter and torque readings
14 November:	Departed Grand Cayman
16 November:	Aircraft delayed in Punta Arenas due weather
23/24 November :	Punta Arenas to Rothera

Following the rectification at Grand Cayman, the commander reported by radio to his base at Calgary that the problem had now been rectified. The aircraft took off from Punta Arenas at 1806 hrs on 23 November. On making first radio contact with Rothera, the crew were told that there was an iceberg, measuring about 50 metres diameter and about 100 feet in height, floating about 10 metres off the end of Runway 18 on the extended centreline. Being the Antarctic Summer, it was daylight and, on arrival at Rothera, a low circuit of the airfield was flown in order to examine the iceberg before landing. The aircraft landed without event, on Runway 18, at 0110 hrs.

The inbound crew were greeted by the Base Commander together with two of his pilots who were to perform ground handling duties for the aircraft. One of the Rothera pilots filled the main fuel tanks, under the supervision of the co-pilot and the engineer; and the engineer then filled the two ferry tanks. The total uplift of fuel was 2,861 litres (5,100 lb).

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[1]The operating company has no record of a separate "governor" being replaced. It is therefore believed that the spoken reference, upon which this suggested part change is based, refers to the fuel governor which is an integral part of the fuel control unit, rather than, say, a propeller governor.

Standard operating procedure suggests that the aircraft would have landed at Rothera with empty wing tanks and these were not re-fuelled directly. These have a total capacity of 574 lb (88 US gallons). Although the wing tanks can be re-fuelled using an internal electrical transfer system, it is unlikely that this would have been done using the aircraft batteries, and ground power was not used. These tanks are sometimes filled from the residual main tank fuel whilst taxiing after landing, but the small size of this airfield did not provide sufficient taxiing time for this to have been accomplished. It is therefore probable that the wing tanks were empty on departure. Therefore, the total fuel capacity of the aircraft was 5,750 lb, and it is probable that the 650 lb difference between this and the fuel uplift reflects the amount of fuel remaining in the aircraft on arrival. As this would be a reasonable minimum fuel with which to arrive, it is probable that both the main and the ferry tanks were full for departure.

The basic weight of the aircraft was 8,097 lb, the fuel weighed 5,750 lb and the occupants, at the standard weight of 165 lb each, weighed 660 lb, totalling 14,507 lb. The aircraft was also loaded with personal gear, survival gear, aircraft spares, a Honda lighting plant and skis, but the actual weight of this equipment is not known and there is no evidence to suggest that any weight and balance calculations were made by the crew before departure.

Having had coffee and sandwiches, despite having just flown a seven hour leg, the crew decided not to nightstop at Rothera, but carry on for the next leg of about the same duration. During the break, all the Rothera pilots discussed the impending departure with the crew and it was generally agreed that the safest course of action was to turn gently right immediately after lift off and fly past the side of the iceberg. This appeared to have been accepted by the crew. The crew then thoroughly studied the meteorological conditions for the onwards flight and, following an external inspection of the aircraft, boarded, with the aircraft commander in the left pilot's seat, the co-pilot in the right one, the adviser in the frontmost passenger seat row and the engineer in the rearmost row. The aircraft then taxied out to the extreme (northern) end of Runway 18, where it was observed to conduct quite a lengthy engine run-up. Although the commander's last communication with Calgary had indicated that the previous problem of fluctuating instrument readings on the left engine seemed to have been solved, he had commented to one of the Rothera pilots that it was still not solved to his entire satisfaction. This may have been the reason for the apparently protracted run-up.

The wind for the take-off roll was from about 190° to 200° at 20 kt and take-off power was applied, initially against the brakes, which were released at 0300 hrs. The take-off run was exactly 408 metres (1,335 feet), at which point the aircraft initiated what was described variously as a healthy rate of climb or a slow but stable initial climb which was increased. Whichever form the climb took, the aircraft

was seen to climb to about 100 feet, which it achieved at about 200 metres (656 feet) from the end of the runway, at which point the wings rocked and the climb decreased to become a shallow descent. As the aircraft approached the nearer ridge of the iceberg, the wings rocked again, the nose pitched up to a very steep angle and the aircraft sank, in this attitude, to impact with the very top edge of the further ridge. It then began to slide down into the ravine and, as it did so, a fire started in the middle fuselage section. As it reached the floor of the ravine, the whole aircraft exploded into flame.

The crash alarm was immediately sounded and, under the leadership of the Base Commander, a smoothly executed emergency drill was set in motion and the rescue boats launched. Sadly, the sea state and the unstable nature of the iceberg precluded an immediate landing and, also, the closest rescue boat reported that the heat generated by the fire would have denied access to the wreckage in any case. Within a short period of time, the iceberg began to tilt, making it even more unstable and the wreckage sank beneath the surface of a melt-pool in the cleft between the two ridges. Subsequent landing on the iceberg, which has drifted into the bay, has not been possible without seriously endangering life.

Crew information

The aircraft commander had joined the operating company in 1990 and had served in the Antarctic, as a co-pilot, during the 1991/92 season. He was upgraded to Co-Captain, flying with another Captain, in June 1992 and returned to the Antarctic in that capacity for the 1992/93 season. He was promoted to Captain in May 1993, returning to the Antarctic from October 1993 to February 1994. His Medical Certificate and all required competency checks were valid.

The co-pilot had joined the company as a First Officer in June 1994, with an Airline Pilot's Transport Licence and 2,733 hours total flying time on Cessna single engined aircraft and the twin engined Piper Senecas. Since that time he had accumulated 448 hours on Twin Otters, giving him a total of 3,180 hours flying time. This was his first experience of Antarctic flying. His Medical Certificate and all required competency checks were valid.

Aircraft information

This de Havilland Canada DHC 6-300 was manufactured as Serial Number 314 in 1971 and was powered by two Pratt & Whitney PT6A-27 turboprop engines and for this flight it was fitted with wheel/ski combinations. It was last registered on 26 February 1992, it received its Certificate of Airworthiness on 5 March 1992 and the last Annual Inspection was carried out on 8 September 1994.

The fuel system comprised two under-floor main tanks, two integral wingtip tanks and two ferry tanks positioned at the front of the cabin. The ferry tanks were ex-Boeing KC97, 250 US gallon capacity, cast aluminium, cylinders fitted in a cradle which was bolted to the aircraft floor at the extreme front of the passenger cabin.

Supplement 14 of the non-approved Supplementary Operating Data Manual contains data which describes the fitting, operation and limitations associated with the ferry tank configuration, states: "When a ferry fuel system is installed, each flight with the system in use must be authorised by the appropriate Airworthiness Authority." The operating company has stated that "Since there is no Airworthiness Authority within the Antarctic, we were unable to apply for and obtain (these) permissions. We were, however, operating as per Supplement 14.....in all other respects." It was, however, the general belief that the permission of the Airworthiness Authority was merely a formality. This permission, when granted, allows the Maximum Allowed Take-off Weight (MTOW) to be raised from 12,500 lb to 17,500 lb. Without this permission, regardless of ferry tanks being fitted, the MTOW remains at 12,500 lb. This was apparently not appreciated by the operating company.

Airfield information

Rothera Airfield has a single hard crushed gravel runway, 36/18, which is 915 metres long and bounded by the sea at each end. Although the surface is crushed gravel, its consistency is sufficiently hard that, for aircraft performance calculations, it may be considered as a paved surface. The iceberg was aligned with and 10 metres from the southern end of the runway. The iceberg was very roughly square, with sides about 500 metres in length, and had two ridges of about 100 feet high, running approximately at right angles to the runway. The first (more northerly) ridge had a deep 'V' shaped cleft at about the middle of its length. The second (more southerly) ridge was separated from the first by a wide and deep ravine. The temperature was minus 2.6°C and the winds reported at the time were:

At the runway anemometer	130°/15 gusting 23 kt
At "The Peak" (144 feet high to the east of the airfield)	190°/17 gusting 22 kt
At the windsock (at the western edge of the runway)	190°-200°/20 kt

(In these conditions the runway anemometer was in the lee of the iceberg)

Weight and balance

Assuming that a similar amount of fuel and the same traffic load were carried from Punta Arenas to Rothera, an approximately similar distance to that from Rothera to Patriot Hills, the aircraft weight for the two takeoffs must have been similar, although the actual weight is not recorded. The only significant difference in the takeoff conditions was that Punta Arenas has a long runway and an obstacle free climbout path, allowing a long shallow climb.

If the aircraft was loaded in the manner subsequently suggested by the operating company, with both ferry tanks at the front of the cabin, the equipment, personnel and fuel would put the Centre of Gravity (C of G) at 32.5 % of the Mean Aerodynamic Chord (MAC), which is within its permissible limits of 30% MAC Forward and 36% Aft. This is, however open to some speculation, as the actual positions of the various items may well have been changed during the several stopovers. However, again assuming that there were no major changes made in the loading after landing at Rothera, the uneventful departure and flight from Puntas Arena suggests that the C of G was within limits.

The fuel

Following the accident, the fuel at Rothera was sampled and analysed by the RAF on the Falkland Islands. The fuel was found to be generally within specification but was not so regarding the low percentage of anti-icing additive (FSII) present and the Flash Point (FP), which was also too low. The FSII deficiency is caused by it leeching out of the fuel during the protracted period of storage necessary in such a remote location. It has no real significance to this accident as the fuel is heated in a heat exchanger before combustion and the temperatures were well above those at which fuel is likely to freeze. The lowered FP has significance only in its cause: A lowered FP is sometimes brought about by contaminants. Most contaminants are harmless, but if the contaminant is lead, in the long term this could be detrimental to the engine. However, other samples taken at the time from the same source, did not display the low FP.

Furthermore, prior to the accident flight on 23 November, one of the Base aircraft was re-fuelled from the same source and, since then, on 24 November, another three flights were re-fuelled from the same source. No fuel related incidents occurred on these flights or on any others flown out of Rothera since the accident.

Performance

There is some evidence to suggest that, contrary to the aircraft manufacturer's recommendation that 10° of flap be used for takeoff in the ferry tank condition, the pilot used 20° on this occasion: Firstly, the operating company has stated that they usually use 20° in these conditions, in order to give the skis less chance of contacting the hard ground surface. Secondly, analysis of an enhanced photograph of the aircraft approaching the iceberg, although not able to define an exact angle, shows a flap deployment which appears to be greater than 10°. However, in case this is an incorrect assessment, both configurations have been considered.

A known characteristic of the Twin Otter's takeoff is that, when the appropriate take-off speed has been reached, it "flies itself off the ground" and that it is very difficult to prevent it from becoming airborne at that time. The time which the aircraft takes to reach this speed, or the length of ground roll, in a given set of environmental conditions, is entirely dependent upon its weight. Therefore, as the take-off roll is known to have been 408 metres, the aircraft weight can be calculated.

A study of the achieved take-off performance was compared with the aircraft's unfactored performance parameters using a paved runway surface. In the event of the actual wind being stronger, the weights would be greater than those quoted and the climb would be about the same because of the increased weight. From the Take-Off Run (TOR), it was possible to establish that, in the conditions as stated, with 10° of flap extended, a TOR of 408 metres (1,335 feet) would be achieved by an aircraft weighing 18,600 lb. With 20° of flap selected, the all-up weight would have been 18,700 lb.

The climb performance was also calculated for the above weights and configurations. The distance from the start of the take-off roll to the iceberg was 925 metres (3034 feet) and, with 10° of flap selected, at a weight of 18,600 lb, the aircraft would have attained a height of 64 feet. With 20° of flap, at a weight of 18,700 lb, the height attained would have been 50 feet.

Summary

There was no evidence to show that any weight and balance calculations had been made for the accident flight. The 'approved' Flight Manual MTOW for this aircraft is 12,500 lb and it was operating more than 6,000 lb over that weight. However, the operating company (incorrectly) believed that it was permissible to operate under the Supplement 14 dispensation, which allowed an MTOW of 17,500 lb, but the aircraft was more than 1,000 lb above that limit as well. It is not known at what stage the aircraft became overloaded as no load sheets had been left at the ground stations along the route. For example, this overloaded condition would not have been critical for the takeoff at Punta Arenas, from a runway which allowed a long gentle climb after takeoff, and so may not have drawn itself to the pilot's attention. Nevertheless, it was critical for the necessary maximum performance climb needed to overfly the iceberg at Rothera.

It is not possible to determine why the pilot chose to ignore the advice to fly round the side of the iceberg, rather than to attempt to climb directly over it. Having become airborne in 408 metres, the remaining 517 metres before the iceberg was ample room for the turn to be made and, indeed, the wind would have been helping the turn. There may have been some turbulence in the lee of the iceberg, but this would not have affected the aircraft's ability to establish a gentle turn, which would almost certainly have enabled a gentle but safe climb away as, for example, at Punta Arenas.

The aircraft was seen to roll from side to side just prior to the stall which occurred at a height which was insufficient to allow recovery before striking the iceberg. This may have been caused solely by turbulence, but it is also a typical characteristic of entry to a stall, particularly in turbulence.

As the aircraft, at the quoted weights, was not capable of such a climb in a normal flight regime, in order to have reached or even initially exceeded the height of the iceberg well before arriving there, it can only have performed a climb which traded attained speed for height. The inevitable result of this manoeuvre, if uncorrected, is a stall. Downdraughts, if there were any, would not have been a necessary factor for the aircraft to have stalled on this occasion.