INCIDENT

Aircraft Type and Registration:	Dornier 328-110, D-CPRW
No & Type of Engines:	2 Pratt & Whitney PW 119B turboprop engines
Year of Manufacture:	1998
Date & Time (UTC):	28 November 2005 at 0923 hrs
Location:	Isle of Man (Ronaldsway) Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 16
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	5,575 hours (of which 310 were on type) Last 90 days - 150 hours Last 28 days - 30 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft had a covering of frost and was de-iced/anti-iced using a heated mixture of Type II+ de-icing fluid and water. The commander commenced the takeoff run and at the calculated rotation speed pulled the control column aft. The aircraft did not appear to rotate in response to the control input and he abandoned the takeoff. The aircraft was brought to a stop on the runway.

The probable cause of the incident was the incorrect V_1/V_R speed selected. Contamination must have been present on the tail surfaces because the aircraft would not rotate at the 'normal' rotation speed for its configuration and load but it was not possible to determine whether the contaminant was ice or thickened fluid. The problem may have occurred because fluid was sprayed from the trailing edge towards the leading edge. Two safety recommendations were made.

History of the flight

Having completed their flight planning the crew arrived at the aircraft. Large areas of the aircraft surfaces had a covering of hoar frost; in particular, the central areas of the wing and tailplane upper surfaces were covered with a depth of 1 to 2 mm. In accordance with the company operating procedures, the commander requested de-icing/anti-icing. The aircraft was the fifth aircraft to be de-iced/anti-iced that morning and at 0833 hrs a vehicle-mounted articulated work platform used for de-icing/anti-icing arrived at the aircraft. The aircraft was subsequently de-iced/anti-iced using a one step process with a heated mixture of 75% Type II+ fluid and 25% water. The operator sprayed the fluid from the rear of the wings and the rear of the horizontal tail surfaces to remove the frost. He also removed the frost from the vertical tail surfaces by spraying from the rear. The operation was completed by 0844 hrs. Whilst he was outside the aircraft, the commander monitored the de-icing/anti-icing of the aircraft as it was carried out.

The crew completed the pre-start checks and a 'full and free' check of the flying controls that is normally performed during the taxi checks. The loading calculations confirmed that the aircraft was within mass and balance limits. The aircraft was started and whilst taxiing, the flaps were checked and set, and the trim was set by placing the indicator on the EICAS on the nose-down edge of the green band displayed.

The 0850 hrs ATIS was current and gave the runway in use as 26 with a surface wind of 360º/09 kt, 10 km visibility, cloud FEW at 2,500 ft, outside air temperature +4ºC, dew point -4ºC and QNH 1002 hPa. The takeoff mass was 12,396 kg, which with the flaps set at 12º, required a V_1/V_R of 109 kt under normal conditions.

At 0922 hrs the aircraft was lined up on Runway 26 and the CONFIG check was completed with no abnormal items identified. Having been given takeoff clearance, the commander, who was the Pilot Flying (PF), smoothly advanced the power levers to set takeoff power. The CONFIG warning illuminated briefly but immediately ceased when the power levers were retarded. The power levers were then advanced with no CONFIG warning and the takeoff was continued. The Pilot Not Flying (PNF) called the IAS as the aircraft passed through 80 kt. The V_1/V_R call was made by the PNF at 109 kt and the commander moved the control column aft for rotation. Immediately he was aware that the aircraft was not responding to his elevator control inputs and so he selected the power levers to idle and applied heavy braking. Maximum reverse thrust was selected and the aircraft was brought to a stop on the runway. The only abnormal indication was of high wheel brake temperatures and the aircraft was taxied back to the parking area. Following discussion with the fire service the passengers disembarked and boarded a bus. The pilots undertook an elevator movement check; full and free movement with no restriction was found.

Personnel background, experience and training

Commander

The commander joined the operator on 16 April 2005, having previously flown a number of different aircraft types in Europe and North America. His previous employment was with a European operator flying SA 226/227 Metroliner aircraft on cargo flights throughout Europe. He successfully completed his Dornier 328 type conversion on 24 May 2005 and carried out 100 sectors of line training. His final line check was carried out on 20 July 2005 and he had been flying as an aircraft commander with the operator since that date.

Co-pilot

The co-pilot joined the operator on 6 March 2005 having previously worked as a flying instructor and charter pilot on light single and multi, piston-engined aircraft. He successfully completed a four week Dornier 328 type conversion course in August 2005. He commenced line training on 15 September 2005 and carried out 96 sectors including his final line check on the 27 November 2005, the day before the incident flight. At the time of the incident he had accumulated a total flying experience of 1,305 hours of which 63 hours were on the Dornier 328.

Type Rating Training Organisations (TRTOs)

Both pilots had attended two separate, approved TRTOs for their type conversions. During the 'Performance' element of the course, the requirements relating to V_1/V_R speeds following the application of thickened fluid should have been covered.

Whilst the theory of ground de-icing/anti-icing was covered, at no time during the flight phase of the training were weather conditions encountered that required ground de-icing/anti-icing. Neither pilot could recall being made aware that the icing takeoff speeds should be used following application of thickened fluids. This information was, however, set out in the Aeroplane Flight Manual within the Normal Procedures.

Ground handler who carried out de-icing/anti-icing operation

The task was carried out by a ground handler with 12 years experience. He was a shift supervisor and had completed his computer-based 'winterisation' training course at the start of the winter season.

When interviewed the ground handler noted that there had been some debate during the last few years as to whether they should spray fluid from the leading edge or the trailing edge of horizontal surfaces. The benefits claimed for spraying from the rear were a warmer jet being applied to the aircraft surface, better access and increased speed.

Aircraft loading

The aircraft was correctly loaded with the 16 passengers distributed evenly throughout the cabin. The 48 kg of cargo was loaded into the rear hold. The aircraft Takeoff Gross Mass (TOGM) was 12,396 kg. The CG range at that mass is 22% to 37% MAC[1]; the CG position for departure was at 24.5% MAC.

Additional information

De-icing/anti-icing fluids

There are several types of fluids used for de-icing and anti-icing of aircraft. Type I fluids have a high glycol content and low viscosity; resulting in a fluid with good de-icing performance but with only limited anti-icing protection.

Thickened fluids such as Type II and Type IV have a lower glycol content than Type I fluids and, due to the addition of thickening agents, are designed to flow off the aircraft surfaces during the takeoff and climb; hence they provide good anti-icing protection between the application and the takeoff. The type II+ fluid used on D-CPRW was qualified to the industry standard specification SAE AMS 1428D, during which tests confirmed that under simulated takeoff conditions around 90% of a 75/25 fluid/water mix is eliminated from a surface based on an initial 2 mm thickness.

Contamination of aerodynamic surfaces

The aerodynamic performances of wing and horizontal tail surfaces are affected by changes to their profiles due to contamination from ice or de-icing/anti-icing fluids. The most critical region for a wing is typically the leading edge on the upper surfaces since this is the area where the aerodynamic flow is most likely to break down and cause the wing to stall. However, the direction of the horizontal tailplane force during rotation on takeoff is downwards and the most critical region for the tailplane is, therefore, the leading edge on the lower surface.

Footnote

[1] Mean Aerodynamic Chord.

Contamination of the tailplane can lead to the separation of the air flow over the tailplane lower surfaces. For aircraft with a fixed tailplane and elevator and without powered flying controls, such as the Dornier 328, this can ultimately lead to the aircraft pitching down, possibly violently, as the elevator operates in a region of separated flow on the lower surface.

Dornier 328 decision speeds

Decision speeds in icing conditions or in non-icing conditions with thickened fluids applied

As part of the certification process for a new aircraft type, a flight test programme is undertaken to establish the operational performance. The performance data derived from these tests are documented in the Aeroplane Flight Manual (AFM). For the Dornier 328 the operational performance in icing conditions was determined using artificial ice shapes attached to the leading edges of the wings. As a result the V_1/V_R speeds in the AFM for icing conditions are typically around 20 knots higher than those for non-icing conditions to allow an appropriate increased margin above the stall speed. Such a large increase is not unusual for turbo-prop aircraft such as the Dornier 328 that are fitted with de-icing, but not anti-icing, systems.

The application of de-icing/anti-icing fluids with a thickening agent also degrades the aerodynamic performance of the aircraft. Flight tests were also undertaken with the Dornier 328 in non-icing conditions with thickened fluid applied. As a result, the V_1/V_R speeds for non-icing conditions with thickened fluids applied were determined to be the same as those for icing conditions. Using the higher V_1/V_R speeds in such conditions increases the amount of fluid that is blown off the aircraft and counteracts the loss in aerodynamic performance due to the fluid remaining on the aircraft. However it was the wing's lift performance, not the tailplane effectiveness, that was the main driver for these raised V_1/V_R speeds.

Operators' procedures for scheduling takeoff speeds

The V_1/V_R speeds are calculated from a Takeoff Gross Mass (TOGM) obtained from the aircraft Flight Management System (FMS). The operator had provided laminated flip charts in which speeds for every 500 kg increase in TOGM were tabulated, and the crew select the speeds from the next highest chart weight corresponding to their calculated TOGM. The standard flap setting for takeoff is 12° and charts are provided for takeoff in icing and non-icing conditions.

Icing conditions are defined in the company Operations Manual as:

> *'Whenever the temperature is below 8°C and the visibility is less than 1,000 metres or in conditions of precipitation.'*

The Aeroplane Flight Manual, under 'Takeoff Normal Procedures', provides a NOTE which states:

> *If the aeroplane was treated with de/anti-icing type II or IV fluids, icing speeds V1, Vr, V2 and Vsec with horn heat on and related TAKEOFF performance for ICING CONDITIONS must be used irrespective of ambient conditions even if non-icing conditions exist. Dissipation of de/anti-icing fluids may be assumed after completion of the takeoff flight path'.*

The speeds for the incident TOGM contained in the laminated flip chart used in the incident are set out in Table 1 below:

12,500 kg	V_1/V_R	V2
Takeoff non-icing conditions	109	113
Takeoff icing conditions	128	129

Table 1

Takeoff speeds at 12,500 kg

The V_1/V_R speed used by the crew for the incident takeoff was 109 kt. Having used type II fluid for de-icing/anti-icing, the correct V_1/V_R was 128 kt.

The accelerate/stop distance for a V_1 of 109 kt extracted from the flight manual performance graphs is 1,020 m and for a V_1 of 128 kt it is 1,350 m. The useable length of Runway 26 is 1,613 m.

Flight recorders

The aircraft was fitted with a Flight Data Recorder (FDR) and a Cockpit Voice Recorder (CVR). The CVR and FDR were downloaded and the recordings analysed.

The FDR provided more than 90 parameters over a period of over 81 hours, covering 52 flights and the rejected takeoff. All speeds referred to are indicated airspeeds.

The CVR provided two types of recording, a half-hour four-track recording and a two-hour two-track recording. The recordings were of good quality and free from excessive noise. The CVR had remained powered for more than half an hour after the event so the two-hour recording was used. This contained one channel for the Cockpit Area Microphone (CAM) and another channel which was a mix of the crew channels and the PA. Some of the recording covered a period when the crew were not using their headsets and so the communications were only picked up on the CAM which was also subject to aircraft noise. The commander was providing instructional information to the first officer, which in combination with noise problems, caused difficulties when determining whether a conversation was related to an actual aircraft problem or was training related.

Recorded information

From the CVR recording it was apparent that the commander had observed frost on the aircraft but he was satisfied with the de-icing/anti-icing work that he had observed whilst outside the aircraft.

The aircraft was subjected to several delays. The aircraft waited in turn for de-icing/anti-icing and was then held back by a failure of the de-icing/anti-icing rig which all resulted in a loss of the assigned ATC slot and a need to wait for a new slot. During the delay a passenger, without any hold luggage, left the aircraft. The crew decided that the load figures did not need to be altered.

There were discussions relating to fuel indication problems and an issue with the park brake. The commander advised the co-pilot of the need to take things steadily when faced with multiple problems, such as they had suffered during that morning.

The gust locks were found 'in' just after the aircraft was declared configured for takeoff. The pertinent recorded parameters for the event are shown in Figure 1.

The takeoff roll sequence was started at 0921 hrs with 12º of flap, propeller speeds of 74% and engine torques of 7% (propeller speed and torque values are averages for the left and right engines). The engine torques started to rise and the aircraft started to accelerate. The engine torques then temporarily stabilised at 30% before climbing further to just over 90%. The propeller speeds dipped twice, once before the torque level-off and once after, and then climbed to 97%. The ground spoilers deployed during the first dip in propeller speed and then

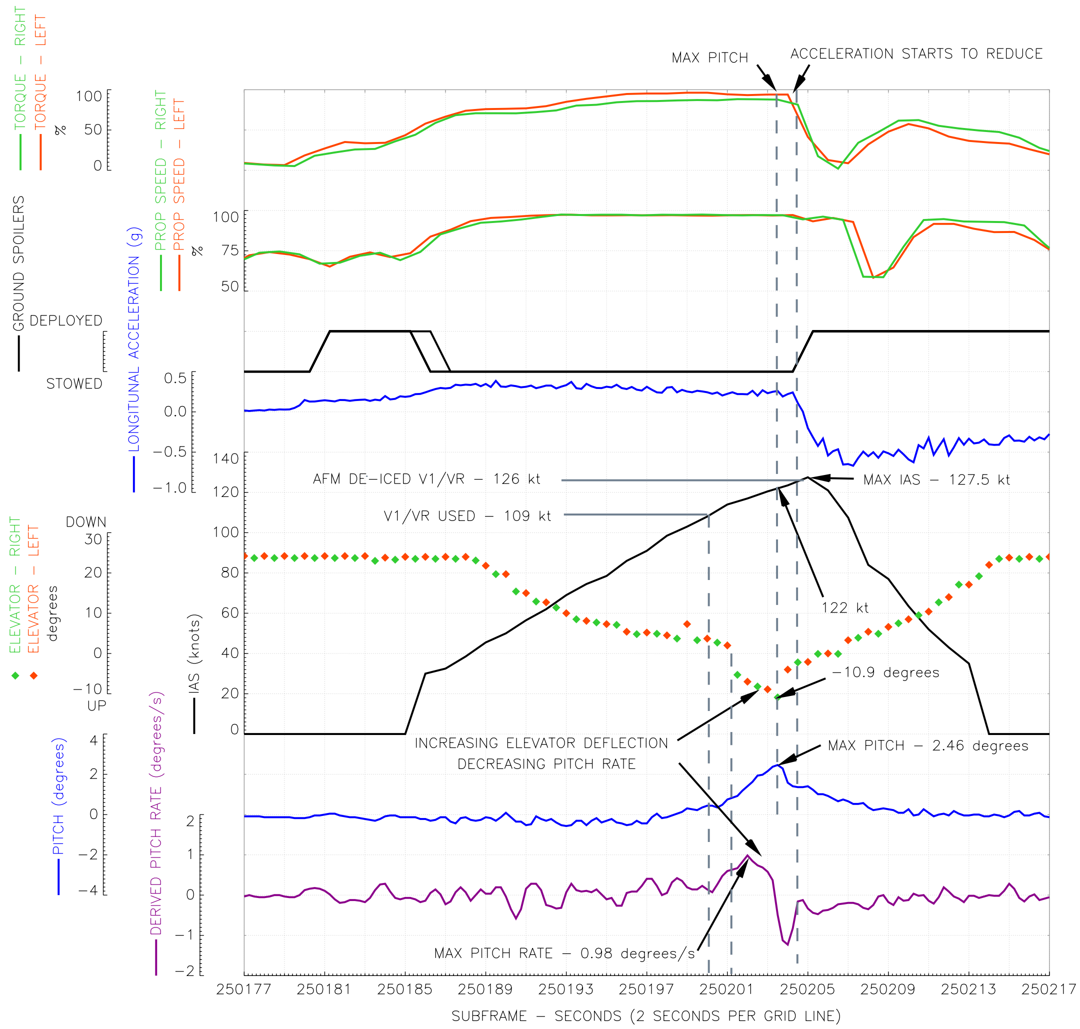

Figure 1

Pertinent Recorded Parameters for the Event

stowed during the final increase in propeller speed as the indicated airspeed parameter came 'on line' with a value of 30 kt. With the indicated airspeed passing 90 kt the aircraft pitch slowly increased by a small amount. Approximately 1 second after the aircraft reached the nominated rotate speed of 109 kt the elevator was brought to the 5º trailing edge up position. The aircraft pitch carried on increasing and the elevator angle was slowly increased. One second after the initial elevator input, the pitch rate of the aircraft peaked at just under 1º/sec with the aircraft pitch at 1.4º degrees and the elevator at 7º. By this time the aircraft had reached 117 kt.

One and a half seconds after the peak pitch rate was achieved, the pitch attitude peaked at just under 2.5° with a maximum elevator deflection of 10.9° and an air speed of 122 kt. A further second later the aircraft acceleration and engine torques started to reduce, the elevator was brought to a more neutral position and the aircraft pitch reduced. Within the next second the aircraft speed peaked at 127.5 kt and then started decelerating with the ground spoilers deploying.

Throughout the event, the elevator trim did not change. There were no parameters recorded for wind speed or direction, gust lock status or brake status (pressure or temperature).

A comparison of speed, elevator input, pitch and pitch rate with three other flights is shown in Figure 2. The recordings are aligned to elevator movement at the point of rotation. This diagram further illustrates the abnormality of the aircraft's pitch response to elevator movement during the incident takeoff.

Aircraft inspection

The aircraft was inspected by the AAIB some eight hours after the incident. The elevator movement was full and free and de-icing/anti-icing fluid residue was still present on the tail surfaces, wings and the aft fuselage. The de-icing/anti-icing fluid streak marks on the lower surface of the horizontal tailplane surfaces, made either during the takeoff run or by the effects of

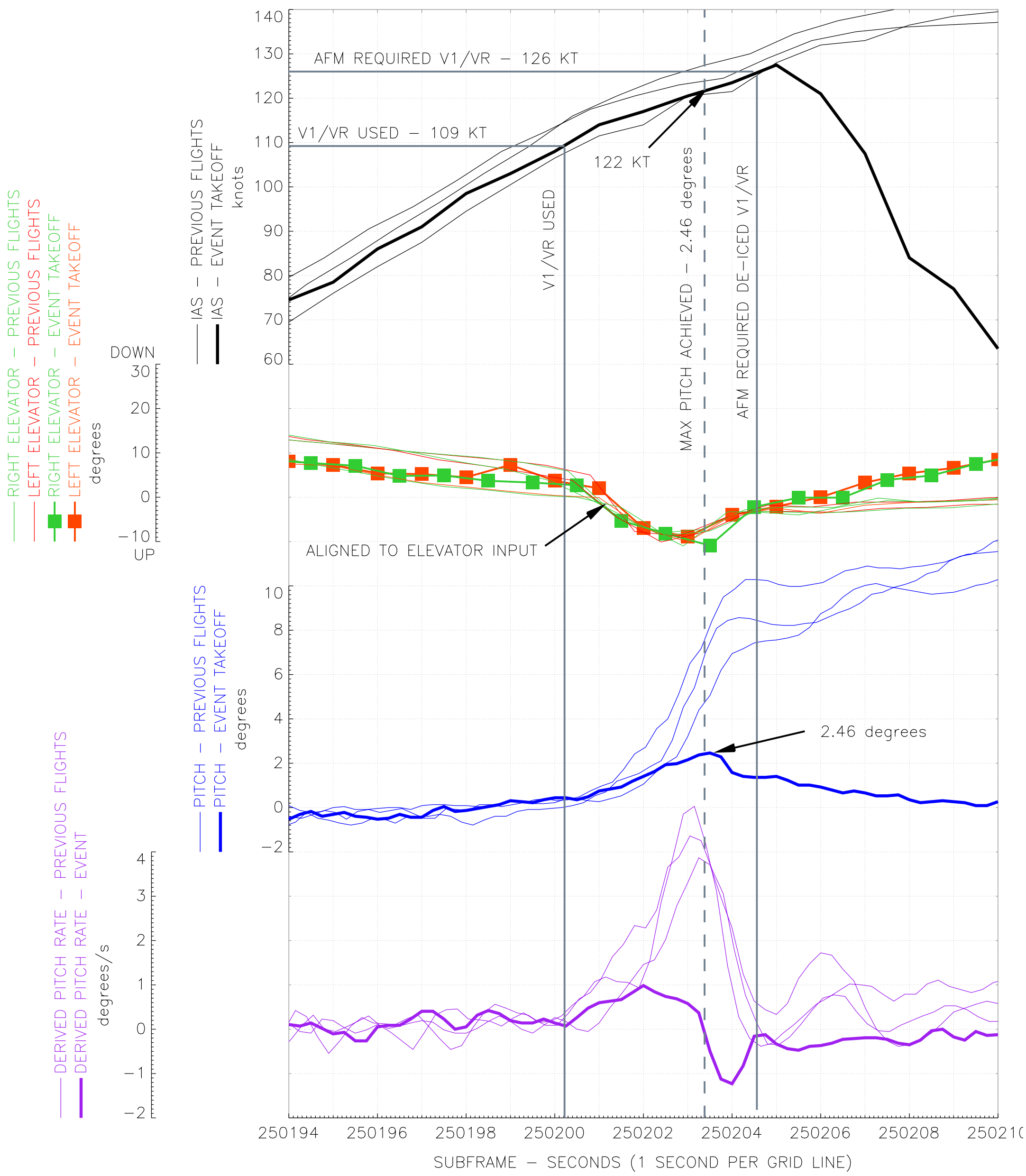

Figure 2

Comparison of Speed, Elevator Input, Pitch & Pitch Rate With 3 Other Flights gravity, provided some evidence that little or no fluid had been applied to the leading edge of the horizontal tailplane lower surfaces.

The aircraft was released to service after an inspection of the brakes and the elevator system. The elevator system was also inspected during base maintenance six weeks after the event. This inspection included checks for residue from de-icing/anti-icing fluids. Nothing significant was found.

Additional information

De-icing and anti-icing techniques

There are several sources of information regarding the de-icing and anti-icing of aircraft. Perhaps the most notable are the UK CAA's FODCOM[2] 30/05 'Winter Operations', JAR-OPS 1 published by the JAA and '*Recommendations for De-icing/Anti-icing of Aircraft on the Ground*' published by the Association of European Airlines (AEA). These all state the importance of removing deposits of ice, frost, snow or slush from aircraft; the need for adequate inspections before and after removal of deposits; and the need to comply with any type specific aircraft ground operations.

Only the AEA guidance document (revised September 2006 and available from the AEA website http://www.aea.be/AEA) gives clear advice to spray operators whether fluids should be applied from the leading edges or trailing edges of wings and horizontal tailplane surfaces. Within paragraph 3.9.2.4 it advises:

> *'Spray from the leading edge to the trailing edge. Start at the highest point of the surfaces and work to the lowest parts. On vertical surfaces, start at the top and work down.'*

There is also a pilot's guide to ground de-icing produced by the USA's NASA GRC Icing Branch. Aircraft icing on-line courses and resources are available on the Internet using the link http://aircrafticing.grc.nasa.gov/index.html. The on-line pilot's guide to ground de-icing contains a module entitled *'Supervise the Application'*. Within this module advice is given to pilots that:

> *'Whether you start at the wing tip or root, sweep from leading to trailing edge'.*

For the horizontal stabiliser it states:

> *'Sweep from leading to trailing edge. Make sure the anti-icing fluid forms a nominally uniform layer.'*

Analysis

The de-icing/anti-icing operation was undertaken by an experienced ground handler who had recently undertaken an annual refresher training course for winter operations. The commander monitored the process in accordance with his company procedures. The TOGM was calculated and the 'drop-line' trim sheet completed. The weights were loaded into the FMS and the trim set. Until this point the procedures followed by the flight crew were normal and correct.

Having determined the TOGM of 12,396 kg, the flight crew correctly took the next highest weight in the takeoff speed data charts of 12,500 kg. The weather at the time did not fall within the definition of icing conditions. However, the pilots were, not aware that they should use the 'Takeoff in icing conditions' scheduled charts instead of the 'normal' takeoff charts when the aircraft had been de/anti-iced with thickened fluid. For this reason, the incorrect V_1/V_R speeds were calculated. There was, therefore, a discrepancy of 19 kt between the normal speed of 109 kt and the 'icing conditions' speed of 128 kt.

Footnote

2 Flight Operations Department COMmunication.

The FDR data showed that the aircraft was rotated significantly before the AFM stated rotation speed for the given weight and conditions. A comparison with previous flights indicates that the effect of the given elevator input did not result in the normal aircraft pitch behaviour. The comparison flights did not match the event flight with regards to the speed at which the elevator input was initiated so a comparison of elevator effectiveness at a given speed cannot be made from this limited data.

The crew actions to abandon the takeoff occurred within three seconds of the pitch rate reducing.

Aerodynamic contamination due to ice or de-icing/anti-icing fluids

The dominant force for rotating the aircraft is produced by the tailplane and elevator. In the absence of any robust physical evidence or any appropriate flight test data, it would seem that some form of contamination of the leading edge of the lower surface of the horizontal tailplane, either by ice or by de-icing/anti-icing fluid, was the most likely reason for the lack of rotation.

Configuration warning

The cause of the CONFIG warning as the commander advanced the power levers was not identified. There had been problems previously with a spurious BRAKE warning as the power levers were advanced activating the CONFIG warning. The action of retarding the power levers to the aft limit of their travel caused the ground spoilers, which were armed, to deploy. When the power levers were advanced to continue the takeoff, the ground spoilers stowed. Consequently, the activity of the spoilers was not the cause of the CONFIG warning.

Conclusion

The probable cause of the incident was the incorrect V_1/V_R speed selected. Had the correct V_1/V_R speed been selected then the effects of any contamination of the horizontal stabiliser and elevator undersurfaces with thickened fluid would probably have been negated by the increased airflow and fluid run-off. Had the contamination been untreated frost, it is possible that the aircraft may not have rotated normally, even at the higher rotation speed.

Contamination must have been present because the aircraft would not rotate at the 'normal' rotation speed for its configuration and load but it was not possible to determine whether the contaminant was ice or thickened fluid. However, the de-icing/anti-icing fluid streak marks on the lower surface of the horizontal tailplane surfaces suggested that little or no fluid had been applied to the leading edge of the horizontal tailplane lower surfaces. This may have occurred because the fluid was sprayed from the trailing edge towards the leading edge instead of the recommended method of spraying from the leading edge towards the trailing edge.

Safety action taken

Following the incident, the operator issued a 'Notice to Aircrew' to all pilots on the Dornier 328 fleet. Attached was the relevant extract from the AFM. The brief summary was:

> *'If the aeroplane was treated with de/anti-icing fluids, irrespective of ambient conditions or temperatures and even if non-icing conditions exist: V1, Vr, V2 and Vsec with horn heat on and related takeoff performance for icing conditions <u>MUST</u> be used'.*[3]

Footnote

[3] Vsec = speed for single-engined-climb.

Safety Recommendations

Both pilots had completed type rating and line training. They were provided with an easy reference chart listing the appropriate takeoff speeds but they could not recall the need to use icing speeds in non-icing conditions following the application of thickened fluids. Therefore, it was recommended that:

Safety Recommendation 2006-072

The Joint Aviation Authorities should contact all Dornier 328 Type Rating Training Organisations within JAA member States and emphasise the need to train pilots to use icing speeds following de-icing/anti-icing with thickened fluids, even when in non-icing conditions.

Safety Recommendation 2006-073

EuroManx should provide annual pre-winter flying awareness refresher training and information to all its flight crews. This refresher training should emphasise the need to use the correct icing speeds even in non-icing conditions.