DATA SUMMARY

LOCATION

Date and time	**Monday, February 28, 2005; 06:16 h UTC**
Site	**Barcelona Airport**

AIRCRAFT

Registration	**EC-IHD**
Type and model	**CESSNA 208B Grand Caravan**
Operator	**Alaire**

Engines

Type and model	**PRATT AND WHITNEY CANADA PT6A-114A**
Number	**2**

Crew

	Pilot in command	Copilot
Age	**30 years**	**23 years**
Licence	**Commercial pilot (Aerop.)**	**Commercial pilot (Aerop.)**
Total flight hours	**3,360 h**	**600 h**
Flight hours on the type	**750 h**	**400 h**

INJURIES	Fatal	Serious	Minor/None
Crew			**2**
Passengers			
Third persons			

DAMAGES

Aircraft	**Minor**
Third parties	**None**

FLIGHT DATA

Operation	**Commercial air transport – Scheduled – Domestic cargo**
Phase of flight	**Takeoff**

REPORT

Date of approval	**September 27, 2006**

1. FACTUAL INFORMATION

1.1. History of the flight

On Monday, February 28 2005, the aircraft EC-IHD began takeoff from runway 07L of Barcelona Airport at 06:13h UTC[1], in order to carry out a cargo flight (urgent post) to Palma de Mallorca.

Approximately one minute after having started the takeoff run, when the aircraft was in the phase of initial climb at an altitude of around 800 ft, the pilot, noticing that the aircraft was beginning to vibrate and that he was not able to maintain airspeed or altitude despite increasing power, declared an emergency and his intention to return to the airport.

After making a 180° turn to the left, and judging it impossible to reach the runway given his low altitude, the pilot landed (with prior authorization from ATC) on taxiway Tango parallel to runway 07L-25R at 06:16 h.

The emergency landing was carried out normally and the aircraft did not suffer any apparent damage, making the taxi without assistance to the same parking position from which it had left.

During the taxi, when the ground control controller asked the reason for the emergency, the pilot answered that it had been due to the formation of ice.

The meteorological conditions at the airport the hours before the incident and during were bad (there had been a wave of polar air in the peninsula, the temperature was low, the air humidity was high and it was snowing).

1.2. Damages sustained in the incident

The direct and indirect damages caused by the emergency landing were as follows:

- **Crew:** none.
- **Aircraft:** around 60 seconds passed between when the pilot noticed that the aircraft was incapable of climbing and maintaining speed and altitude, to when he landed it on the taxiway. During this time, in an attempt to recover control of the aircraft, the pilot applied full power to the engine, so that upon first inspection, the damages were limited to the effects of operating the engine with excessive power (over-torque of the engine).

[1] Unless specified otherwise, time reference used in this report will be Universal Coordinated Time (UTC). For the winter season, during which this incident happened, the equivalent is Local time = UTC time + 1.

— **Collateral damages:** to allow the emergency landing, an aircraft that was approaching to land on runway 07L had to be diverted.

1.3. Crew information

The aircraft crew was made up of a pilot and a co-pilot who usually flew together. The pilot, who was 30 years old and of Spanish nationality, had 3,360 h of flying experience and 750 h in this type of aircraft.

The flight log for the four days prior to the incident shows the following pattern of activity:

- Four night flights per day of approximately one hour duration made at around 20:00, 01:00, 03:00 and 06:00 h.
- Flights between Barcelona - Palma de Mallorca - Ibiza.

On the day of the incident, the crew's activity had been less than that of the previous days as the 20:00 h and 03:00 h flights had not been made:

Date	Flight[2]			
	Origin		Destination	
27-02-05	05:50	PMI	06:31	IBZ
28-02-05	01:24	PMI	02:12	BCN
	06:13	BCN	06:16	PMI

1.4. Aircraft information

The Cessna Caravan 208B is a high-wing aircraft, equipped with a single engine and tricycle landing gear. Two versions of this model exist, depending on whether designed for the transportation of passengers or for goods. In each version, it is possible to install an additional cargo hold in the lower part of the fuselage.

The aircraft EC-IHD, which was the cargo version, had the lower hold installed and was certified, among other things, to make flights in VFR, VFR night, IFR and icing conditions.

[2] The times recorded under Origin and Destination correspond to the time between takeoff and landing, in other words, effective flight time. PMI: Palma de Mallorca, BCN: Barcelona, IBZ: Ibiza.

In August 2004, the same aircraft suffered another incident during the landing roll at Ibiza Airport, when the nose landing gear leg remained partially folded forwards. This incident left the aircraft inoperable until February 2005, meaning that the airworthiness certificate, which expired in September 2004, had to be issued again in February 2005.

General information		
Registration	EC-IHD	
Manufacturer	Cessna Aircraft Company	
Model	208B Grand Caravan	
Serial Number	208B0934	
Year of Manufacture	2002	
Engine	Manufacturer	Pratt and Whitney Canada
	Model	PT6A-114A
Propeller	Make	McCauley
	Model	3GFR34C70
Certificate of airworthiness	Class	Normal
	Use	Category: Public transport of cargo; Aerial work (AW)
		Performance: Normal
		Type of AW: Parachute Jumping
	Issued on	21-02-05
	Valid until	20-02-06

Technical characteristics		
Dimensions	Wingspan	15.88 m
	Height	4.71 m
	Length	12.68 m
Limitations	Maximum takeoff weight (with cargo hold)	9,062 lb (4,110 kg)
	Maximum takeoff weight in icing conditions	8,550 lb (3,878 kg)
	Minimum crew	2 pilots for public transport of cargo

1.5. Meteorological information

During the month of February more than 13 autonomous regions were on alert due to the masses of artic air which reached the peninsula. In the Spanish air transportation sector, the greatest impact of this wave of cold air was felt not only at Madrid-Barajas Airport on 23rd February, but also at Barcelona Airport on 28th February when 202 of the 840 scheduled flights had to be cancelled and the average delay time in 520 operated flights reached 94 minutes.

— **General situation at low levels[3]:** an anticyclone situated SW of Iceland and a major depression SW of Cadiz generated an intense gradient of pressure, especially in the north of the Iberian Peninsula, provoking a flow of air from E to NE with strong gusts of wind. Very cold air penetrated from the North, causing rain showers and snowfall at low altitudes.

— **Barcelona Airport[4]:** the information contained in the ATIS[5] messages from 05:00 h until 5 minutes after the incident indicate the following conditions at Barcelona Airport both before and during the flight:

- The sun rose at 07:50 h local time, meaning that the flight preparation, the taxi and the takeoff took place at night.
- The air temperature was at approximately the freezing point.
- The difference between the air temperature and the dew point was one degree from 05:10h until 06:00 h and equalised from 06:00 h to 06:20 h, which indicates that the air was saturated at the time of the incident.

[3] Information provided by the National Institute of Meteorology.
[4] Information provided by AENA-Barcelona Airport.
[5] ATIS is the service of continuous information broadcasting in the terminal area which, on VHF frequencies, informs of the meteorological conditions existing in a determined aerodrome. Between 05:00h and 07:00h inclusively, the information issued by the ATIS Barcelona was updated a total of 14 times (ATIS H to ATIS U). The updating of the information occurs every 10 minutes, and in some cases, every 2 minutes.

- When the aircraft began the takeoff run it had been snowing already for one hour at the airport (the ATC logbook of the Barcelona tower recorded at 05:30 h the annotation "strong snow storm").
- The conditions from 5:00 h until the time of takeoff were worsening in terms of visibility, air saturation and temperature. The wind changed direction but decreased intensity from 13 to 6 kt. The cloudiness (in terms of cloud density and cloud cover) remained the same.

Time ATC	Information issued by ATIS						
	Wind		Visibility (m)	Current weather	Cloud base (ft)	Temp. (°C)	Dew point (°C)
	Degrees	kt					
05:00	350	13	7,000	Light rain	BKN 1,600	04	02
05:10	360	13	5,000	Light snow	BKN 1,600	01	00
05:20	340	12	5,000	Light snow	BKN 1,600	01	00
05:30	340	12	5,000	Snow	BKN 1,600	01	00
05:32	350	10	5,000	Snow	BKN 1,600	01	00
05:40	330	10	4,000	Snow	BKN 1,600	01	00
05:57	330	10	1,400	Snow	BKN 1,600	01	00
06:00	010	07	1,400	Snow	BKN 1,600	01	01
06:10	040	06	1,400	Snow	BKN 1,600	01	01
06:20	020 VRB	08	3,000	Light snow	BKN 1,600	02	01

1.6. Aerodrome information

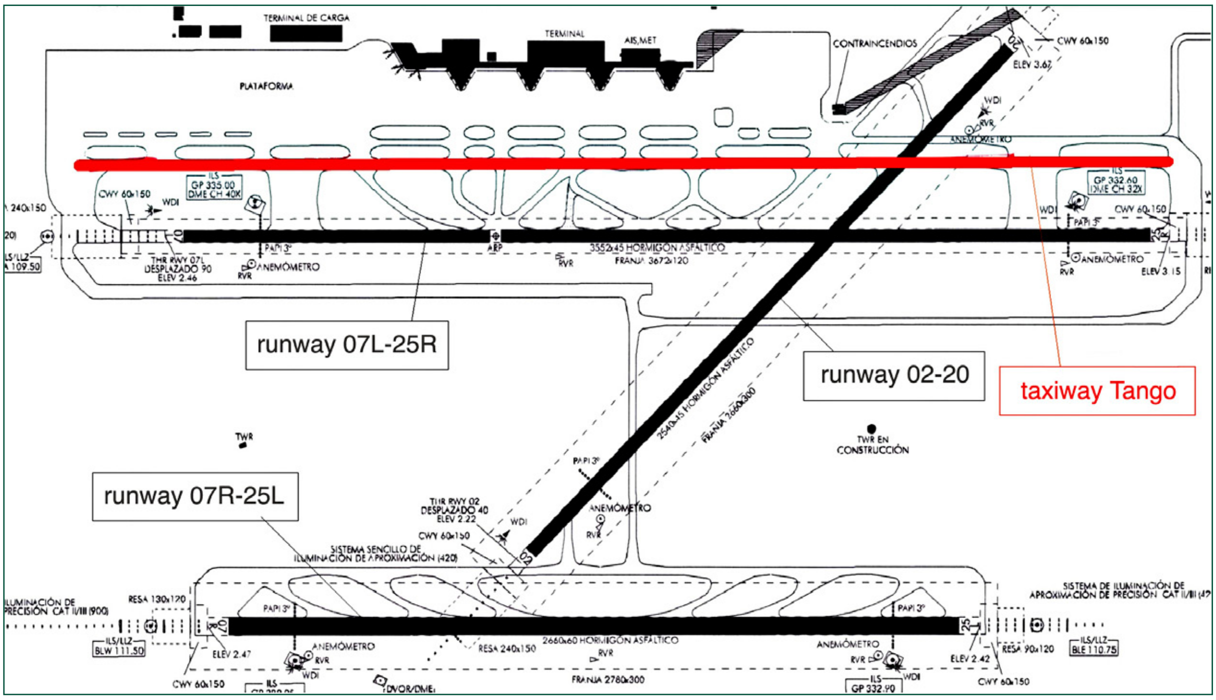
1.6.1. *Taxiway Tango*

Barcelona-El Prat Airport is situated at an altitude of 3.8 metres above sea level (elevation of the aerodrome reference point) and has three runways, two of which are parallel (07L-25R and 07R-25L) and a third which crosses the other two (02-20).

Taxiway Tango, on which the aircraft landed, runs parallel to runway 07L-25R and has a similar length to it.

1.6.2. *Barcelona-El Prat Airport Winter Plan*

The Winter Plan is a set of procedures and actions defined by Aena to minimise the effect on operations occurring in winter conditions of ice and snow. The inclusion of an airport in the Winter Plan is determined based either on weather criteria (if the yearly



average number of days of snowfall is more than 2, or if the yearly average number of days of frost is more than 10) or for operational reasons (if they have heavy traffic with a direct impact on other airports).

Due to its geographical situation, at sea level and with an average temperature in February of 14.6 °C Barcelona Airport does not fulfil the climatic requirements. It does, however, satisfy the operational requirements and is therefore included in the AENA Winter Plan.

Among many other aspects, the Winter Plan covers the planning of the technical means necessary to face adverse meteorological situations, in accordance with the climatic particularities of each airport. In the case of Barcelona, these equipment and systems were as follows:

Ice or snow on:	Action by:	Means:
• Apron • Taxiways • Runways	AENA-Barcelona Airport	• Vehicle fro spraying glycol with water • Urea chemical de-icing spreader • Snow plough • External equipment (grader…)
• Aircraft	Handling agents	Two pieces of equipment for de-icing aircraft at the parking lot (ther is no de-icing platform)

On the day of the incident, one of the two pieces of equipment used for de-icing aircraft, belonging to the Barcelona Airport handling operators, broke down, causing long delays in the aircraft de-icing process. As a result of the operational problems suffered in Barcelona on 28th February and 1st March 2005, the fire service had to help with the aircraft de-icing process. This was not considered the responsibility of the fire service under the winter plan.

1.7. Investigation

1.7.1. *Statements*

Some of the details provided by the pilot and the co-pilot concerning the incident are as follows:

Flight preparation

— From the time at which the aircraft arrived at Barcelona from its previous flight, until the time at which it took off again, it was parked on the platform (out in the open).
— When they arrived to prepare the flight it was snowing and the aircraft was covered with recently fallen snow.
— They had never encountered meteorological conditions like those on the day of the incident. They had never before had to implement de-icing or anti-icing procedures on the ground.
— They removed the snow from the front wheel and the nose with a brush. On the wings they removed a bit of snow using a small ladder that they keep inside the aircraft. This ladder does not allow good access to the wing as they do not normally climb onto it and it is used only for checking the oil. There still remained some snow but they thought that the effect of the propeller and the takeoff would blow it off.
— They believed that they would not have any problems due to ice as the information given by the ATIS indicated a temperature of 4 °C.
— There was a three hour queue for aircraft to be de-iced.
— The information given by the Barcelona TWR was that there were no patches of ice on the runway.
— The aircraft was carrying a lighter load than on other occasions: it was carrying 8,004 lb.

Operation

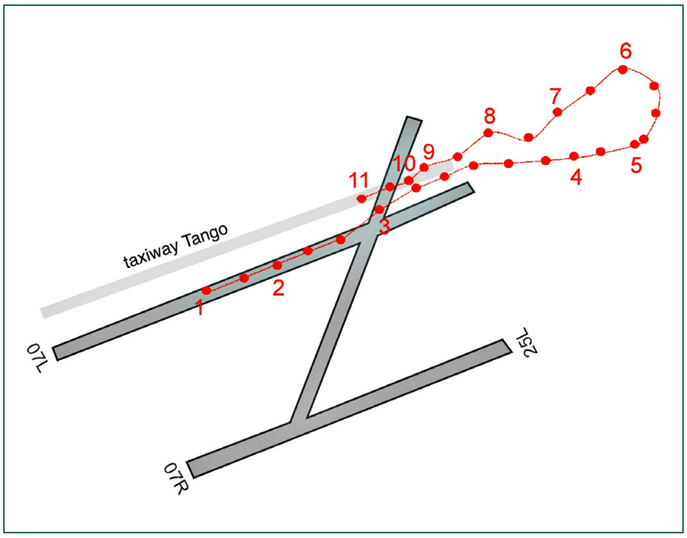
— They took off with flap setting 2. The speed at takeoff and initial climb was 80/90 kt.
— When they were at an altitude of around 400 ft, they retracted the flap setting 1, after which the aircraft began to vibrate and the controls began to react slower.
— They increased again to flap setting 2 and did not change this for the rest of the flight.
— The aircraft started to lose speed and become incapable of maintaining the climb despite the pilot applying full power. They therefore decided to return to the aerodrome and declare an emergency due to loss of altitude (around 1,000 ft/minute).

— They increased speed to around 100-110 kt.
— When moving the control wheel in order to begin the left turn, it got blocked or jammed and could not be centred again. The co-pilot had to help to pull the control wheel towards the right until a "crack" was heard and they recovered control of the roll.
— At around 250 feet they recovered control of the aircraft and made a normal landing on the taxiway, due to the impossibility of reaching runway 25R.
— After being questioned by ATC, they confirmed that the reason for the emergency was the ice accretion.

1.7.2. *Aircraft flight path*

Although it is not a type of information that is a required part of the control service, TWR does offer airport radar data presentation of the airport. These records, along with the transcript of the communications held with the tower[6] during the flight and the statements of the crew, show the following:

— The maximum height reached by the aircraft was 800 ft (point 5).
— The rate of climb calculated between points 1 and 5 was 564 ft/minute, a value appreciably less than 835 ft/minute which is set by the POH (Pilot´s Operating Handbook) for such flight conditions.
— The aircraft declared an emergency a few seconds before reaching 800 ft (point 5).
— From point 5 (800 ft) the aircraft began to lose height. The point to point calculations show a descent of 1,200 ft/minute until the aircraft descended to an height of 300 ft (point 7), from which point onwards the rate of descent was around 600 ft/minute.



Point	ATC hour	Height (ft)
1	06:13:33	0
2	06:13:43	100
3	06:14:13	400
4	06:14:43	600
5	06:14:58	800
6	06:15:13	500
7	06:15:23	300
8	06:15:33	200
9	06:15:43	100
10	06:15:48	0
11	06:16:08	0

[6] Information provided by AENA.

— The next radar echo after initiating the turn is very near to point 5, which indicates a rapid loss of altitude.
— The turn to return to the aerodrome was very steep.
— At around point 8, when the aircraft was at approximately 200 ft, they notified TWR of their intention to land on the taxiway. ATC authorized the landing and informed them of the wind conditions.

1.8. Additional information

1.8.1. *Conditions of ice formation*

The process of ice formation is that in which water passes from a gas or liquid state into a solid state due to a decrease in temperature. Therefore, the meteorological conditions which must exist for this to occur are twofold:

— That there is humidity in the air (in other words, that there is water in the air), and
— That the temperature decreases to freezing point (0 °C), at which point the water contained in the air solidifies and forms ice.

Depending on the temperature, the state of the water can vary in the following way:

— At temperatures close to 0 °C, the water in the air is in a liquid state.
— At temperatures less than 0 °C, the water starts to transform into ice and the liquid content decreases. As an exception and under certain conditions, water can exist in a liquid state at less than 0 °C (supercooled water).
— At temperatures of around –20 °C, the ice content is very high.

As a general rule, the probability of ice formation on an aircraft is greater the greater the content of liquid in the atmosphere, as the water sticks to the surface and later freezes to it (the adherence of ice is much less as it bounces off). Icing therefore occurs at temperatures near 0 °C, when the content of water in a liquid state is higher.

In addition to this general condition, other situations do exist in which ice can form, despite the temperature not being close to 0 °C:

— When humid air comes into contact with the cold surface of the aircraft, it is possible for ice to form at temperatures higher than 0°C.
— Despite being at temperatures below zero in which under normal conditions the quantity of ice should be much greater than that of liquid water, drops of supercooled water freeze when coming into contact with the aircraft.

— In the case of aircraft with heat-based de-icing and anti-icing devices, these systems melt the ice, the water runs down and refreezes in areas behind the protection systems.

The ice which accumulates on the airframe can be one of three types, depending on how it is formed.

Type of ice	Temperature (°C)	Characteristics
Clear	Between 0 and –10	• Associated with high speeds and large drops that slide over the surface before freezing. • Ice can form in other areas apart from the protected surfaces. • Transparent. • Difficult to see.
Mixed	Between –10 and –15	• It has the worst characteristics of both the other types of ice. • Clear ice forms first and then rime ice sticks on top. • Very rough.
Rime	Between –15 and –20	• Associated with low speeds and small drops that freeze when they hit the aircraft. • White. • Normally forms on strut leading edges and wings.

1.8.2. Effects of ice formation

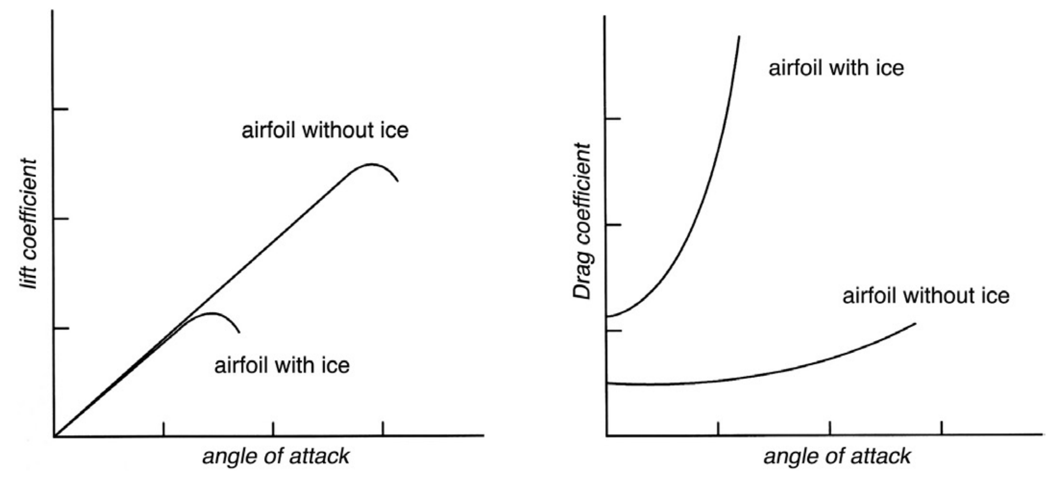
Depending on the area of the aircraft on which the ice forms, it is distinguished between:

— Structural ice: ice which accumulates on the airframe (wings, tail, landing gear, pitot tube, etc.).
— Ice on the engine induction system (carburettor, etc.).

The accumulation of structural ice on the aircraft affects its aerodynamic characteristics as well as its controllability and airworthiness:

— **Effect on the airfoil:** alters the curvature of the airfoil producing the following effects on lift (L) and resistance (D):

- With low angles of attack, there is practically no influence on L, meaning that when cruising the effect of the ice may not be noticed.
- With high angles of attack (takeoff and landing) the maximum C_L has reduced as well as the critical angle of attack. In other words, the aircraft stalls earlier.
- The effect on drag occurs at any angle of attack and increases of 100% in drag are not uncommon.
- Disturbances occur in the local flow of the airfoil air flow, interfering with and restricting the movement of the flight controls.



— **Effecto on roll control:** having a thinner section than the wing root, the tips of the wing have a greater tendency to accumulate ice than the rest of the wing. Ice accretion in front of the ailerons can cause the detachment of the boundary layer on top of them and as a consequence the stalling of the tip of the wing and loss of control of the ailerons. If the flaps are extended, it is advisable not to retract them as this movement increases the wing's angle of attack and it could stall.
— **Effecto on the tail:** as happens with the wing tips in respect to the wing root, the horizontal stabiliser, being a thinner surface, also has a tendency to accumulate ice quicker than the wings. When the tail stalls, the pitch-up trim effect that it performs in normal operational conditions, no longer exists, meaning that the aircraft enters into a sometimes uncontrollable dive. When there is a stall of the tail in flight, it is not advisable to extend the flaps as these, in airplanes where the horizontal stabilizer is lower than the wing, increase the angle of attack of the horizontal stabiliser and may therefore start or accelerate the stall. The accumulation of ice on the tail is very difficult to detect visually and the stall occurs without the pilot being prepared for it.
— **Effect on the weight:** although it is not the most important effect, if there is a lot of ice formation, the increase in weight may cause the deterioration or loss of the aircraft's airworthiness characteristics, for example being unable to maintain altitude.

Therefore, the probability of the effects of structural ice appearing, depending on the flight phase of the aircraft, is the following:

— **Takeoff and landing:** the aircraft's high angle of attack and low speed during these phases make it very vulnerable to the formation of ice. In particular, ice can form in areas where in cruise mode it normally would not, such as areas behind the leading edges and on the upper surface of the wings. Stalling of the tail and of the wings frequently occurs in these flight phases, when the angle of attack is very high.

— **Cruise phase:** configuration changes during the cruise phase should be made gradually, as often the effect may not be noticed much during level flight. If, however, the flaps or spoilers are operated, the effect would be noticed suddenly.

The consulted documentation on aircraft Cessna Caravan 208B[7] describes the following effects caused by ice formation on the aircraft:

— When there is a 1/4 inch accumulation of ice on the wing's leading edge, the pilot should be prepared for a significant increase in the required power, in the approach speed, in the stall speed and in the landing distance.
— An accumulation of 1 inch of ice on the wing's leading edge can cause a rapid loss in the rate of climb (up to 500 fpm), a reduction in the cruise speed of up to 40 KIAS, significant vibrations and an increase in the stall speed of up to 40 kt. Even after operating the de-icing boots, the remaining ice can cause a loss of up to 200 fpm in ascent, 20 kt in cruise and an increase of 5 kt in the stall speed.
— The accumulation of ice alters significantly the curvature of the airfoil as well as increases the weight of the aircraft. The stall speed increases and the speeds of optimum performance change. Flying at high angles of attack can cause accumulations of ice on the wing's upper surface and on the horizontal stabiliser behind the protected surfaces.

1.8.3. *Cessna requirements for flight in icing conditions*

To operate safely in meteorological conditions of ice formation, three requirements should be fulfilled:

— That the meteorological conditions are suitable.
— That the aircraft is equipped with specific ice protection systems.
— That the crew apply the right procedures for conditions of ice formation.

1.8.3.1. Meteorological conditions

In the case of the Cessna 208B, these conditions are those established by the American administration in Title 14, Part 25, Appendix C of the Federal Aviation Regulations (FAR) and which define, by means of a set of variables, the situations of ice formation in which a suitably equipped aircraft can fly safely[8].

[7] Consulted documentation: Pilot's Operating Handbook (POH), Pilot Safety and Warning Supplements (PSWS), Caravan Cold Weather Operations (CCWO) and Caravan Safety Awareness Programs (CSAP).
[8] This regulation distinguishes between extreme conditions in which the aircraft is able to fly continuously and those in which it can fly intermittently. They are presented in a graphic form that links atmospheric variables such as water drop diameter, temperature, altitude, etc.

Outside these margins of certification, it is possible for ice formation to occur with such severity that the ice protection equipment cannot remove it, and therefore significant deterioration in the aircraft's performance and controllability could occur.

On a practical level, the use of the information in Title 14, Part 25, Appendix C of the FAR to determine whether or not the meteorological conditions are within those certified is complicated, which is why aircraft operation manuals provide a series of general visual directions that can guide the pilot as to the severity of the conditions the flight will encounter.

In the aircraft documentation, Cessna provides the following information on how to identify conditions of ice formation:

- It is considered that icing conditions exist if the outside air temperature (OAT) is 10 °C or less and there are visible signs of humidity. No aircraft which is not certified for flight in icing conditions can fly (PSWS).
- Icing conditions always exist if the OAT is between 10 °C and –30 °C and there are visible signs of any kind of humidity (CCWO).
- Caution must be increased in temperatures close to the freezing point with visible presence of humidity (valid POH)[9].
- Maximum icing occurs when the OAT is between 0 and –10 °C (CCWO).
- Although it is noted that flying under meteorological conditions outside the margins of FAR certification is dangerous, it is not specifically prohibited. Various indications are however listed that may help a pilot recognise meteorological conditions outside those certified. In such cases, the pilot is warned to take measures and to abandon these conditions (valid POH).

1.8.3.2. Protection systems

In order for an aircraft to be certified for flight in icing conditions, it must undergo a set of trials and tests to prove that, when suitably equipped, it is capable of flying safely in this type of situation.

In general, there are two types of aircraft ice protection systems:

- De-icing systems: these are reactive systems, in other words, they remove ice after it has formed. De-icing systems are usually of the pneumatic or boots kind (rubbers situated on the leading edges of certain surfaces which, on inflating, detach the ice

[9] On 02-03-05, two days after the incident, Cessna issued a revised POH in which the chapters relating to conditions of icing were modified. The most important modification in the revised POH is that takeoff with contamination on the aircraft is expressly prohibited and that a tactile as well as visual inspection of different aircraft surfaces is obligatory to check that there are no remains of snow, ice, etc.

formed on them) or electro-impact (pulses which cause rapid movements in the aircraft's surface).
— Anti-icing systems: these are preventive systems which avoid the accretion of ice on the aircraft through the application of hot air, chemical products or electric systems.

In the case of the Cessna Caravan 208B, the specific on board de-icing and anti-icing systems, defined in the regulations of certification for operation in conditions of maximum continuous or intermittent icing, are the following (POH):

— On the leading edge of the horizontal stabiliser: de-icing boots.
— On the leading edge of the vertical stabiliser: de-icing boots.
— On the windscreen: anti-icing panel.
— On the leading edges of the wing and strut: de-icing boots.
— On the propeller: anti-icing boots.
— On the pitot-static system: anti-icing heating system.
— On the stall warning system: anti-icing heating system.
— Wing ice detection lights (for night flight).

In addition to the equipment on board, on the ground there are three types of product or chemical fluid (Type I, Type II, Type IV)[10] which can be applied to remove existing ice and prevent its formation in flight for a certain period of time (defined as holdover time).

1.8.3.3. Specific procedures

In addition to the certification and the appropriate onboard systems, flight in conditions of icing changes, to varying degrees, the aircraft's flight characteristics and, therefore, requires some specific operational procedures.

Listed below are some interesting aspects taken from the aircraft's technical documentation[11] and which are relevant to the incident:

— When to operate:

- Deliberately flying in known icing conditions is prohibited, unless having the suitable equipment and the aircraft weight is 8,550 lb or less (valid POH).
- Flying under meteorological conditions outside the margins of FAR certification, although dangerous, is not specifically prohibited (valid POH).

[10] De-icing fluids (Type I) or anti-icing fluids (Type II and Type IV) are watery solutions that work by lowering the water's freezing point, whether it be in its liquid phase or crystallisation phase.
[11] Technical documentation references have been taken from the POH. New procedural aspects, as a consequence of the publication of the new POH in March 2005, have been included.

— Takeoff conditions[12]:

- In cold meteorological conditions it is essential to remove any small accumulation of ice, frost or snow from the wing, tail and control surfaces. Also, it must be ensured that there are no accumulations of snow or other remains in the internal areas of the control surfaces (valid POH).
- During operation in cold weather, the crew is responsible for ensuring that the aircraft is free of contamination (valid POH).
- No takeoff should ever be carried out with ice or snow on the wings (CCWO).
- Taking off with ice, snow, frost or any other remains stuck to the wing, horizontal stabiliser, propeller blades or engine intakes is prohibited (revised POH).

— Procedures before takeoff:

- In addition to a visual check, a tactile check of the leading edge of the wing, the upper surface of the wing, the leading edge of the horizontal stabiliser and of the propeller blades is required when the conditions are (revised POH):

  – OAT less than 5 °C and visible humidity, or
  – The aircraft has been exposed to visible humidity since its previous landing, or
  – The difference between the dew point and the OAT is less than 3 °C, or
  – There is water on the wing, or
  – The aircraft suffered from an accumulation of ice on its last flight.

- The ice protection equipment is not designed to remove snow, ice or frost which has accumulated on a parked aircraft to a standard suitable to ensure a safe takeoff and flight. It is not the purpose of the de-icing fluids to remove snow accumulated on the aircraft. The best way to do this is by mechanical brushing or sweeping (valid old POH).
- The de-icing fluid Type I and the anti-icing fluids Type II and Type IV, can be used sequentially to ensure compliance with the FAA regulations, which state that all critical components (wings, control surfaces, for example) must be free of snow, ice and frost before takeoff (valid POH).
- When icing conditions are present on the ground, in the 5 minutes before takeoff an inspection should be made to check that there is no contamination on the aircraft and that the applied fluids are still working effectively (valid POH).

— In-flight procedures:

- When observing signs of severe ice, the flaps must not be retracted until the aircraft surface is free of ice (valid POH).

[12] The American FAR regulations, Title 14, 121.629, 125.221 and 135.227 says that "No person may take off an aircraft when frost, ice, or snow is adhering to the wings, control surfaces, propellers, engine inlets, or other critical surfaces of the aircraft".

- When operating at 4 °C or less with visible humidity, the flaps must not be extended above 20° for landing (valid POH).
- When an accumulation of ice occurs, it is necessary to increase the speed of the aircraft.

1.8.4. *Background*

Owing to a total of 26 accidents related to the formation of ice on Cessna Caravan 208 aircraft between 1987 and 2003, on 15th December 2004, the National Transportation Safety Board (NTSB) published a study[13] in which the circumstances of these accidents were analysed.

As a conclusion, the NTSB issued a total of four recommendations in the report, which related to various aspects of the operation of Cessna 208 in icing conditions:

— Periodic training of pilots in de-icing procedures on the ground and flight in conditions of ice formation.
— Operators to develop, together with Cessna, effective strategies of operation in conditions of ice formation (identifying conditions of icing, use of flaps and engine with ice, etc.).
— Request all Cessna 208 pilots and operators to carry out a visual and tactile inspection of the wings' leading edges and the horizontal stabiliser.
— Revision of the FAA supervision procedures, relating to the verification of compliance with the FAA requirements of companies certified to fly in conditions of icing.

2. ANALYSIS

The analysis of the incident suffered by aircraft EC-IHD is considered in two parts: on the one hand, an analysis of several aspects or determining factors relating to the operation and on the other, an operational evaluation of the flight.

2.1. Determining factors in the operation

It is concluded that the decisions made by the crew in relation to the operation could have been influenced by the following aspects:

Type of operation

In the air transportation sector, time is one of the most important determinants, above all in very congested airports where missing the predetermined departure time can cause

[13] Safety recommendation. Date: 15th December 2004. In reply to: A-04-64 through-67.

significant operational delays. In addition, companies usually plan the operations of their aircraft in a linked or sequential way, meaning that a delay in one flight can effect subsequent operations.

In the case of the aircraft EC-IHD, in addition to the two previous determinants, the aircraft was carrying urgent post, meaning that punctuality and compliance with schedules, as regards to connections and delivery times, could have been more important than with other types of goods.

Activity times

From the information provided by the company, it was concluded that the crew of aircraft EC-IHD usually had a work routine of approximately 12 hours of activity and 12 hours of rest[14]. Among other criteria, flight planning includes crew activity times, meaning that a delay of more than three hours, as the crew stated the application of anti-icing fluids would have caused them, would have meant that in addition to missing their slot (planned departure time), the crew would have probably exceeded the maximum activity time permitted.

De-icing and anti-icing processes

Despite the exceptional nature of the meteorological conditions at Barcelona Airport on the day of the incident, its inclusion in the AENA Winter Plan should have ensured a more effective response, above all in relation to the aircraft de-icing services.

According to the crew's statement there was a three hour wait, meaning that if they had decided to apply the de-icing and anti-icing fluids before takeoff, the delay to the operation would have been at least this amount of time, with the subsequent consequences for the rest of the day's operations, goods delivery deadlines and crew activity times.

Previous experience and crew training

In Spain in general, and in particular in the area where the crew usually flew, it is very rare for atmospheric situations like those on the day of the incident to occur, this day also being the first time that the crew had found themselves in such a situation.

The very low probability of such situations occurring in Spain means that the companies that fly in these areas most likely have other training priorities, and that this aspect

[14] The current regulation in respect to this (Operational Circular 16B of the DGAC) establishes, for a 2 pilot operation in public cargo transport, an aerial activity period of 12.15 h with 10.5 h of rest, depending on the time of start of the period and the number of landings.

is devoted less attention. In fact, the crew of aircraft EC-IHD had not received any kind of training in flying in conditions of ice formation beyond the content of the courses in aircraft familiarisation. In other words, they found themselves in a new situation that they were not accustomed to and for which they had not received specific training[15].

Technical means

Before takeoff, to ensure that the aircraft's critical surfaces were free from any remaining snow, ice, frost etc. the crew had to gain access to, among other areas, the upper part of the wings and remove the remains of ice or contamination which could have been there. For this they had a brush and a small ladder which they used for routine tasks, such as checking the oil level, but which they had never before used to gain access to, for example, the upper part of the wings.

In the case of this aircraft, the high height of the wing did not allow sufficient access, with the ladder that they had, to areas such as the lower surface to be able to remove any remaining contamination from there before takeoff.

Manufacturer information

After consulting the chapters relating to flying in conditions of ice formation in the aircraft Cessna 208B technical documentation, current at the time of the incident, it is noted that:

- The instructions on how to identify icing conditions are clear and with easily obtainable data: temperatures lower than 10 °C and the presence of visible humidity.
- The warning that it is possible to find meteorological conditions outside those certified, which could cause severe icing and significant deterioration in the aircraft's airworthiness, is constant throughout the document. Visible indications to determine if conditions are outside those permitted are described.
- The only prohibition existing in the document refers to flying an aircraft which is not certified to fly in icing conditions. With a certified aircraft, the pilot is ultimately responsible and, in this sense, can operate under any meteorological conditions.
- The terminology used in the documentation is not very categorical in relation to the importance of taking off with a "clean" aircraft, insofar as it uses words such as "...it is essential..." or "...it should not be..." which seem to contradict with the reference to the "...responsibility of the crew to ensure that the aircraft is free of contamination...". In the new version of the POH, edited on 2nd March 2005, this ambiguity is removed by means of phrases such as "...it is prohibited...".

[15] A short time after the aircraft EC-IHD incident, all the company's personnel attended a course on flying in conditions of ice formation.

— In almost all the general information on flying in icing conditions, the suitability of carrying out tactile as well as visual inspections is mentioned, in order to check that there is no ice on the aircraft before takeoff. This aspect, included in the safety recommendations issued by NTSB in December 2004, was not considered in the aircraft documentation, but was incorporated in the latest version of the POH from March 2005.

2.2. Flight analysis

Flight preparation

On 27th February 2005 at 02:12 h, the aircraft arrived from Palma de Mallorca to Barcelona Airport, where it was then parked out in the open until just before 06:00 h, when the crew began the preparation for the next flight.

During the four hours that the aircraft was on the apron, the meteorological conditions were worsening: more specifically, 1 hour before takeoff it began to snow and the temperature decreased from 4 °C to 1 °C with the air at practically 100% saturation. In the aircraft's technical documentation, as well as in the rest of the material consulted on the subject, these are considered icing conditions (being less than 10 °C and with visible humidity). In fact, temperatures close to the freezing point, as in the case of the incident, are the most dangerous in terms of the formation of ice on an aircraft, as the content of water in liquid state is at its highest and it sticks to the aircraft's surface and freezes (due to the cooling effect caused by the aircraft's movement and/or the decrease in temperature during climb).

According to their statements, the meteorological information which the crew took into account in the process of flight preparation was that the ATIS temperature was 4 °C, meaning that they did not think that they would have problems with icing. Firstly, and related to this point, it is highlighted that the information which they used corresponded to the ATIS information at 05:00 h, and that the aircraft took off at 06:13 h. In other words, they did not update the information despite the adverse conditions and the fact that they were in a situation different from what they were used to. Secondly, the fact that with a temperature of 4 °C the crew did not consider the possibility of an icing problem, shows a training deficiency regarding the basic conditions of ice formation.

In the checks prior to flight, the crew attempted to remove the remains of snow that had accumulated, for which they used a brush (as the procedures recommend) and a ladder with which they could reach the high surfaces such as the lower surface of the wings, the control surfaces and the horizontal stabiliser. They swept a bit of snow from the aircraft's nose and a bit from the upper surface of the wings but the problems of accessibility to this area, together with the fact that at the time it was still night, prevented them from checking that the aircraft was free of all contamination. Also, they thought that if any snow remained it would be blown off by the spinning of the propeller.

Despite the fact that the meteorological conditions posed a hazard of ice formation, that other aircraft were being sprayed with de-icing and anti-icing fluids and that they could not be certain that there were absolutely no remains of ice, snow or frost on the aircraft, the crew still decided to takeoff without any protection against ice formation[16] (fluid Types I, II and IV).

Flight

Under these conditions the aircraft began the takeoff run and initial climb with a rate of 564 ft/minute, calculated during the first minute of flight after rotation (in other words, up to an altitude of 800 ft). This value is appreciably less than the one defined by the POH for flight conditions similar to those of the incident. The weight of the aircraft was less than the limit defined for operating in icing conditions, meaning that this is ruled out as an influencing factor in the performance deterioration which occurred. In addition, the fact that just one minute after takeoff the aircraft began to descend at a rate of 1,200 ft/minute, supports the hypothesis that it may have taken off with remains of snow, ice or frost which had accumulated during the four hours when it was parked, and that this may have accelerated the process of ice accumulation.

Nobody from the company or the airport has specified the area on the aircraft where the ice formed, therefore it is very difficult to discern, beyond a generic evaluation based on the symptoms described by the crew, which areas may have been affected.

Firstly, given the aircraft's position in respect to the air flow, takeoff is dangerous due to the accumulation of ice which can occur in unprotected areas or those not usually affected, such as the lower surface of the wing.

In critical situations, such as takeoff, aircraft configuration changes can accelerate the process of stalling, which is why the valid POH recommends not retracting the flaps until it is assured that surfaces are free of ice. The crew, however, took off with the flaps deployed at 20° and retracted them in accordance with normal procedures, without checking for possible contamination on the wings.

After reducing the flaps to setting 1, the aircraft began to vibrate and to lose altitude (the crew ruled out that the vibrations were due to ice on the propeller, as in this case they would have been less severe). Ice generally accumulates in an asymmetric form,

[16] The conditions on the day of the incident are not part of the conditions of FAR certification and according to the evaluation made by Cessna, using humidity and type of precipitation data, the takeoff should have been made with an aircraft completely clean of all contamination and after the application of de-icing and anti-icing fluids.

meaning that the vibrations in the aircraft, in addition to the loss of altitude, reinforced the hypothesis of ice formation. As explained in section 1.8.2, reducing the flaps means a lower angle of attack of the horizontal stabiliser and therefore, should have reduced the risk of the tail stalling. However, the effect of this action on the wing is completely the opposite, whereby reducing the flaps increases the wings' angles of attack and their risk of stalling. Therefore, based on the aircraft's reaction to the flaps' retraction, it is considered likely that the accumulation of ice occurred (at least) on the wings and that these stalled first. Studies on flight in icing put special emphasis on the need to recognise quickly if ice is forming on the wings or tail because the recovery procedures are conflicting, as has been seen in respect to the flaps setting.

In this case, despite reopening the flaps to 20°, the aircraft did not stop vibrating or improve performance and it continued to lose altitude. In cases where ice accumulates on the tail and the horizontal stabiliser stalls, the most important effect is the loss of altitude and the dive into which the aircraft enters due to the loss or cancellation of its pitch-up effect. The flaps deflection with which the aircraft was flying most likely increased the angle of attack of the tail in respect to the wings, and it is believed that the tail could have also stalled.

After the aircraft began to lose altitude and the crew declared an emergency, they began a sharp turn in order to return to the aerodrome. Turns, due to the risks that they pose, are not normally recommended in such conditions and, in the case of the incident, after the movement of the ailerons to execute the turn they became blocked, therefore preventing the crew from recovering the neutral position of the control wheel. In aircraft which use cables to transmit movement, the physical jam of controls can be caused by thermal contraction of the cables, by the freezing of the transmission mechanisms' lubricating oil, or by the formation of ice on the ailerons themselves. In this case, it is believed that the temperature was not low enough to cause the cables to contract or for the oil to freeze (they are also normally designed to withstand low temperatures), meaning that it is very possible that the blocking of the control wheel was due to some kind of accumulation of ice which prevented the movement of the ailerons. When the crew pulled the controls, at some point they must have detached the ice and the cable, which was under tension, made a "crack" sound which was heard in the cabin.

As soon as the crew detected the first problems of controllability, they increased the aircraft's speed, as recommended in the procedures for counteracting the modification in the stall characteristics and for promoting the detachment of ice. Despite this, the aircraft was uncontrollable and was losing altitude at a rate of between 1,200 and 600 ft/minute.

Control of the aircraft was recovered at a height of around 250 ft and when they were still not aligned with runway 25R, for which reason they decided to land on taxiway Tango after obtaining clearance from the control tower.

3. CONCLUSIONS

The probable cause of the aircraft EC-IHD incident is believed to be the stalling of the aircraft due to the formation of ice during takeoff, with the aircraft not protected by de-icing or anti-icing fluids and with some possible remains of frost, snow or ice accumulated on the airframe.

It is believed that the crew's decision to operate in these conditions could have been influenced by:

- Lack of knowledge of the effects of ice on the control of the aircraft, of the conditions of its formation and of the limitations of de-icing and anti-icing equipment.
- Lack of knowledge of the specific procedures to be applied, for this type of aircraft, in conditions of ice formation.
- Lack of suitable technical means to access and carry out pre-flight inspections, which are defined for such situations in the aircraft's documentation.
- Lack of previous experience in meteorological situations similar to those of the incident.
- A certain degree of pressure to comply with the planning of the operation due to the kind of goods that were being transported, the implications for the rest of the operations and the possible consequences for activity times.
- Delay in the de-icing processes at Barcelona-El Prat Airport.

4. SAFETY RECOMMENDATIONS

REC 24/06. Unusual operational scenarios imply a risk to the operations due to the novelty factor faced by crews. Flight in conditions of ice formation is very dangerous due to the effects on the aircraft's characteristics of controllability and airworthiness and, therefore, crew training is important. For this reason, it is recommended that the Civil Aviation General Directorate (DGAC) ask commercial aerial transport companies to carry out specific periodic training courses on flight in adverse meteorological conditions that, at least, would cover aspects such as:

- Conditions of ice formation and how to recognise them.
- Types of ice.
- Formation of ice on the aircraft.
- Recovery procedures.
- Procedures in icing conditions on the ground.
- Capability and limits of de-icing and anti-icing equipment and systems.

REC 25/06. In order to comply with the Pilot's Operating Handbook issued in March 2005, it is recommended that the Civil Aviation General Directorate

(DGAC) guarantee that companies with Cessna Caravan 208 aircrafts are equipped with the necessary technical means to enable crews to access appropriate areas of the aircraft and to carry out the mandatory visual and tactile inspections before takeoff. The crews should be aware of the necessity of the aircraft taking off without any kind of contamination (remains of ice, etc.) on the airframe, given the unpredictable effects which it can have on the performance and controllability of the aircraft.

REC 26/06. It is recommended that the Spanish Airports and Air Navigation (AENA) revise the suitability and applicability of plans addressing adverse meteorological situations in order to guarantee, in a effective way, that the effects on operations occurring in winter conditions are minimised.