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Report

Accident on **4 March 2013**
just after takeoff from Annemasse (France)
to the **Beechcraft Premier 1A**
registered **VP-CAZ**

BEA

Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile

Ministère de l'Ecologie, du Développement durable et de l'Energie

Safety Investigations

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SPECIAL FOREWORD TO ENGLISH EDITION

This is a courtesy translation by the BEA of the Final Report on the Safety Investigation. As accurate as the translation may be, the original text in French is the work of reference.

Table of Contents

SAFETY INVESTIGATIONS 2

GLOSSARY 5

SYNOPSIS 6

ORGANISATION OF THE INVESTIGATION 7

1 - FACTUAL INFORMATION 8

1.1 History of Flight 8

1.2 Injuries to Persons 9

1.3 Damage to Aircraft 9

1.4 Other Damage 10

1.5 Pilot Information 10

1.6 Aircraft Information 11

1.6.1 Airframe 11

1.6.2 Engines 11

1.6.3 Anti-icing Protection 11

1.6.4 Angle of Attack Protection System 12

1.6.5 Flaps 12

1.6.6 Weight and Balance 12

1.7 Meteorological Information 13

1.7.1 Meteorological Conditions on the Day of the Accident 13

1.7.2 Meteorological Conditions the Day before the Accident 13

1.8 Aids to Navigation 13

1.9 Telecommunications 13

1.10 Aerodrome Information 14

1.10.1 Annemasse 14

1.10.2 Other Neighbouring Aerodromes 14

1.11 Flight Recorder 14

1.12 Wreckage and Impact Information 17

1.13 Medical and Pathological Information 18

1.14 Fire 18

1.15 Survival Aspects 18

1.16 Tests and Research 18

1.16.1 Examination of the Anti-icing Systems 18

1.16.2 Examination of the Flaps 18

1.16.3 Performance Study 19

1.16.4 Effects of Wing Contamination on Aeroplane Performance 20

1.16.5 *"Cold-Soaked Fuel Frost"* Phenomenon 21

1.16.6 Ice Detection Systems 21

1.17 Organizational and Management Information. 22
1.17.1 Inspection of the External Condition of the Aeroplane before Take-off 22
1.17.2 Training on Operations in Icing Conditions 24
1.17.3 Aerodrome Operation in Winter Conditions 25
1.18 Additional Information 25
1.18.1 Previous Events 25
1.18.2 Interviews 28

2 - ANALYSIS 29

2.1 Scenario 29
2.1.1 Wing Icing 29
2.1.2 Accident Scenario 29
2.2 Awareness of Risks Associated with Ground Icing 30
2.3 Operation of Aerodromes during Winter 31

3 - CONCLUSION 32

3.1 Findings 32
3.2 Causes of the Accident 32

4 - SAFETY RECOMMENDATIONS 33

4.1 Training on Risks on Takeoff with Contaminated Wings 33
4.2 Ground Ice Detection System 33
4.3 Anti-icing/de-icing Facilities at Aerodromes 34

LIST OF APPENDICES 35

Glossary

AAIB	Air Accidents Investigation Branch (United Kingdom)
AET	Safety investigation administration Administration des Investigations Techniques (Luxemburg)
AFM	Airplane Flight Manual
CVR	Cockpit Voice Recorder
DGAC	General civil aviation directorate Direction Générale de l'Aviation Civile (France)
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration (United States)
GPWS	Ground Proximity Warning System
ICAO	International Civil Aviation Organisation
NTSB	National Transportation Safety Board (United States)
VOR	VHF Omnidirectional Range

Synopsis

Stall after takeoff in icing conditions, collision with the ground, fire

Aircraft:	Beechcraft Premier 1A Model 390 registered VP-CAZ
Date and time:	4 March 2013 at 7h39[(1)]
Operator:	Private
Site:	Near Annemasse aerodrome, in the commune of Cranves-Sales (74)
Type of flight:	General aviation
Persons on board:	One pilot and two passengers
Consequences and damage:	Pilot and one passenger killed, one passenger injured, aeroplane destroyed

(1)Unless otherwise mentioned, the times given in this report are expressed in Universal coordinated time (UTC). One hour should be added to calculate the time in metropolitan France on the day of the accident.

The pilot and two passengers arrived at Annemasse aerodrome at about 7 h 00 for a private flight of about five minutes towards Geneva airport. The temperature was -2°C and the humidity was 98% with low clouds. The aeroplane had been parked on the parking area of the aerodrome since the previous evening. The taxiing and the takeoff run were nominal. As soon as the main landing gear wheels left the ground, the aeroplane stalled, as a result of the presence of ice on the surface of the wings. The low height reached by the aeroplane did not allow the pilot to exit the stall situation and to avoid the collision with the ground. The pilot and the passenger seated to his right were killed. The female passenger seated at the rear was seriously injured.

The investigation showed that the pilot's insufficient appreciation of the risks associated with ground-ice led him to take off with contamination of the critical airframe surfaces. This may have contributed to the occurrence of 32 accidents recorded since 1989 for which no de-icing of the aeroplane had been undertaken before takeoff. The investigation also showed that an onboard device for the detection of ice on the ground could have prevented the accident and that Annemasse aerodrome does not have any ground de-icing facilities.

The BEA addressed three safety recommendations to EASA and the DGAC relating to:

- training on the risks associated with takeoff with contaminated wings;
- the installation of ice detection systems;
- the availability of anti-icing/de-icing facilities on aerodromes.

ORGANISATION OF THE INVESTIGATION

On 4 March 2013, the BEA was informed of an accident to a Beechcraft Premier 1A aeroplane, registered VP-CAZ that occurred after takeoff from Annemasse aerodrome (France), in the commune of Cranves-Sales. In accordance with the provisions of the (EU) n°996/2010 regulation of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety investigation was immediately initiated by the BEA.

A team of four BEA investigators went to the site of the accident from 4 to 6 March 2013. This made it possible for them to study the dispersal of the wreckage, make the initial interviews and recover the Cockpit Voice Recorder (CVR). The latter was read out in the BEA headquarters at Le Bourget on 6 March 2013.

Three working groups were formed in the following areas: Aircraft, aeroplane systems and Operations.

In accordance with Annex 13 to the Convention on International Civil Aviation, the BEA associated with its investigation foreign counterparts who nominated accredited representatives:

- from the NTSB (USA), the aeroplane and the engines being of American manufacture. This made it possible to benefit from the assistance of technical advisers from Beechcraft, the manufacturer of the aeroplane, and Williams International, the manufacturer of the engines;
- from the AAIB (UK), the aeroplane being registered in the Cayman Islands, a British overseas territory;
- from the AET (Luxemburg), the pilot being an employee of a Luxemburg company.

One of the victims being of Italian nationality, an expert from the ANSV (Italy) was named.

The draft final report was sent for consultation to the accredited representatives in accordance with the provisions of Annex 13. It was also sent to ANSV, EASA and the French DGAC.

1 - FACTUAL INFORMATION

1.1 History of Flight

Note: the following elements were taken from the data recorded on the CVR, from radio-communications, from interviews and from the study of the accident site.

On Monday 4 March 2013, the pilot and two passengers arrived at Annemasse aerodrome (France) at about 7 h 00. They planned to make a private flight of about five minutes to Geneva airport on board the Beechcraft Premier 1A, registered VP-CAZ. The temperature was -2°C and the humidity was 98% with low clouds. The aeroplane had been parked on the parking area of the aerodrome since the previous evening.

At 7 h 28, the Geneva ATC service gave the departure clearance for an initial climb towards 6,000 ft with QNH 1018 hPa towards the Chambéry VOR (CBY).

At about 7 h 30, when the CVR recording of the accident flight started, the engines had already been started up.

At about 7 h 34, the pilot called out the following speeds that would be used during the takeoff roll:

- V1 : 101 kt
- VR : 107 kt
- V2 : 120 kt.

At about 7 h 35, the pilot performed the pre-taxiing check-list. During these checks, he called out *"anti-ice ON"*, correct operation of the flight controls, and the position of the flaps on 10°.

Taxiing towards runway 12 began at 7 h 36.

At 7 h 37 min 43, the pilot called out the end of the takeoff briefing, then activation of the engine anti-icing system.

At 7 h 38 min 03, the pilot called out the start of the takeoff roll. Fifteen seconds later, the engines reached takeoff thrust.

The aeroplane lifted off at 7 h 38 min 37. Several witnesses stated that it adopted a high pitch-up attitude, with a low rate of climb.

At 7 h 38 min 40, the first GPWS *"Bank angle - Bank angle"* warning was recorded on the CVR. It indicated excessive bank.

A second and a half later, the pilot showed his surprise by an interjection. It was followed by the aural stall warning that lasted more than a second and a further GPWS *"Bank angle - Bank angle"* warning.

At about 7 h 38 min 44, the aeroplane was detected by the Dole and Geneva radars at a height of about 80 ft above the ground (points ❶ on figure 1).

Other *"Bank Angle"* warnings and stall warnings were recorded on the CVR on several occasions. Several witnesses saw the aeroplane bank sharply to the right, then to the left.

At 7 h 38 min 49 the aeroplane was detected by the radars at a height of about 150 ft above the ground (points ❷ on figure 1).

At 07 h 38 min 52, the main landing gear struck the roof of a first house. The aeroplane then collided with the ground. During the impact sequence, the three landing gears and the left wing separated from the rest of the aeroplane. The aeroplane slid along the ground for a distance of about 100 m before colliding with a garden shed, a wall and some trees in the garden of a second house. The aeroplane caught fire and came to a stop.

The pilot and the passenger seated to his right were killed. The female passenger seated at the rear was seriously injured.

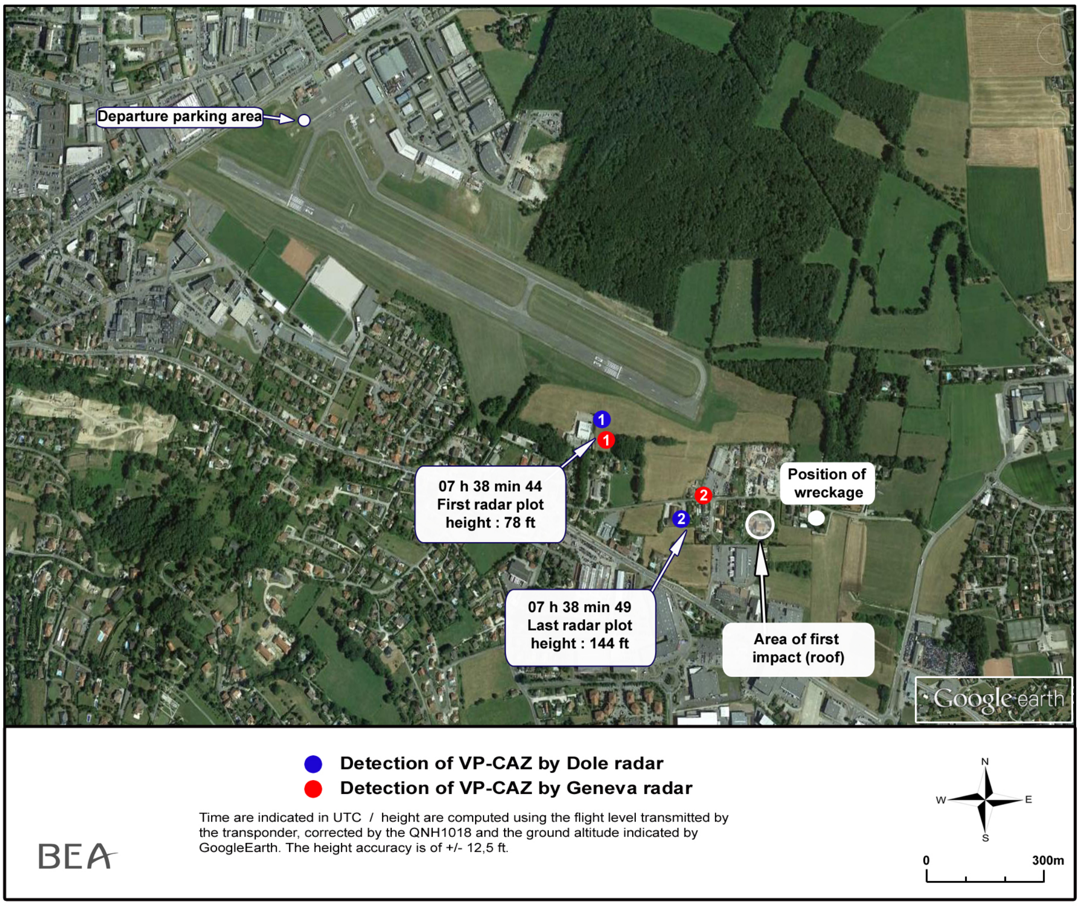

Figure 1 - Radar plots and position of the wreckage

1.2 Injuries to Persons

	Injuries		
	Fatal	Serious	Slight/None
Crew members	1	-	-
Passengers	1	1	-
Other persons	-	-	-

1.3 Damage to Aircraft

The aeroplane was destroyed and almost completely burned.

1.4 Other Damage

The aeroplane struck the roof of a house about 500 m from the threshold of Annemasse runway 30, and then struck trees located 10 to 20 m further. The damaged section of the roof was located about 5 m up. The person inside the house at the time of the accident was not injured.

Figure 2 - Damage to the house

The aeroplane also destroyed a low garden wall and a shed on a second property.

1.5 Pilot Information

Male, 49 years old.

- French Commercial Pilot's (A) Licence issued in 2002, validated in 2005 by the Swiss Confederation.
- Initial type rating issued in 2007.
- Last type rating renewal in May 2012 obtained at the Philadelphia/Wilmington centre of Flight Safety International.
- Valid medical certificate with compulsory wearing of corrective lenses.
- Experience:
  - Total: 7,050 flying hours;
  - On type: 1,386 flying hours;
  - In the previous 30 days: 17 h 17 min flying hours;
  - In the previous 7 days: 2 h 26 min flying hours.

The pilot, employed by Global Jet Luxembourg, only flew VP-CAZ, for the benefit of the owner of this aeroplane.

Note : The pilot's logbook not having been found and information on the previous days' flights not having been supplied by the pilot to Global Jet Luxembourg at the time of the accident, the flight times of the previous days may be incomplete.

1.6 Aircraft Information

The Beechcraft Premier 1A is a light single pilot twinjet built by Beechcraft (division of Hawker Beechcraft). It was certified in 2005 according to the American requirements of 14 CFR Part 23. It is a development of the Premier 1, the first flight of which took place in 1998. It has a certified maximum take-off weight (MTOW) of 5,670 kg, and seats a total of eight people, including crew.

VP-CAZ was operated in the context of general aviation by its owner.

1.6.1 Airframe

Manufacturer	Hawker Beechcraft
Type	RA390 (Premier 1A)
Serial number	RB-202
Registration	VP-CAZ
Entry into service	August 2007
Airworthiness certificate	N°1019 of 7 August 2012 issued by the Civil Aviation Authority of the Cayman Islands, valid until 9 August 2013.
Owner	CHAKIBEL Associates Limited, based in Tortola in the British Virgin Islands
Use as of 4 March 2013	1,388 flying hours and 1,404 cycles

The VP-CAZ fuselage and wing skin was white. The leading edges were metallic.

1.6.2 Engines

The aeroplane was equipped with two FJ44-2A turbojets built by Williams International.

	Engine n°1	Engine n°2
Serial number	105 317	105 314
Total running time	1,388 hours and 1,408 cycles	1,303 hours and 1,353 cycles

1.6.3 Anti-icing Protection

The Beechcraft Premier 1A is equipped with aerofoil de-icing (wings and horizontal stabilizer) and engine anti-icing systems.

The wing and engine air inlet anti-icing protection is done by injecting warm air taken from the engines. This air circulates in a network of piping in the wing leading edges and in the engine air inlets.

The elevator anti-icing protection is done through electrical heating of the leading edges of the tailplane, and through the use of electromagnetic systems that generate a deformation of the tail surface. This deformation is intended to break the ice as it forms so that it is evacuated by the airflow on the surface of the elevator. If it is used in automatic mode, the system is controlled by a de-icing computer based on ice detection data supplied by two detectors placed on either side of the aircraft nose.

All these systems are intended for use in flight in icing conditions. They are not designed to de-ice an aeroplane on the ground.

The anti-icing protection of the sensors (angle of attack sensors, Pitot probes, and static vents), and windscreen anti-icing protection is done by electrical heating.

The ICE PROTECTION panel enables the pilot to control these functions.

Figure 3 – ICE PROTECTION panel

1.6.4 Angle of Attack Protection System

A warning system, triggered if the measured angle of attack exceeds a predefined threshold, makes it possible to anticipate a stall situation by triggering:

- ❒ an aural warning audible in the cockpit;
- ❒ a mechanical warning via the stick shaker and a pitch-down input (stick pusher).

1.6.5 Flaps

The aeroplane is equipped with four flaps (two on the left wing and two on the right wing), extended or retracted by eight actuators. Flap movement is controlled by an electrically-actuated electronic unit. Their position is continuously monitored using sensors on each actuator. In the event of asymmetric deflection, a *"FLAP FAIL"* warning lights up on the warning panel. There is no associated aural warning.

The aeroplane is not equipped with slats.

1.6.6 Weight and Balance

Refuelling was carried out at Le Bourget airport the day before the accident. An estimate of consumption for the Le Bourget-Annemasse flight of 3 March made it possible to assess the weight of the aeroplane at the time of the accident at about 11,500 lbs (5,200 kg), and the quantity of remaining fuel at 2,700 lbs (or about 75% of total capacity).

In addition, knowledge of the distribution of people on board and the small quantity of luggage made it possible to state that the aircraft weight and balance were within the limits defined by the manufacturer.

1.7 Meteorological Information

1.7.1 Meteorological Conditions on the Day of the Accident

Annemasse aerodrome is not equipped with any meteorological measuring equipment.

The observations(2) made at 7 h 20 at Geneva airport, 13 km away, indicated no wind, visibility of 4,500 m, mist, a temperature of -3°C, dew point -4°C and QNH of 1018 hPa. At 7 h 50, the temperature measured was - 1°C and dew point - 2°C.

The conditions estimated by Météo France at Annemasse aerodrome at the time of the accident were: risk of fog, temperature -2°C, humidity 98%(3) and a calm wind.

A photo of the aerodrome taken about 50 minutes before the accident shows the presence of low stratus, as well as snow on the ground.

Figure 4 – Photo taken on the morning of the accident at the aerodrome

According to witnesses, the pilot consulted meteorological information on his mobile phone shortly before departure.

1.7.2 Meteorological Conditions the Day before the Accident

The day before the accident, the pilot had taken off from Paris-Le Bourget for Annemasse where he landed at about 16 h 00. He had flown at a cruise altitude of 27,000 ft, where the air temperature was about -40°C. In the evening, the ground temperature at Annemasse was 0°C. It dropped further during the night.

1.8 Aids to Navigation

Not applicable.

1.9 Telecommunications

Annemasse aerodrome is restricted to aircraft with radios. Communications are not recorded.

The passenger in the right hand seat had contacted Geneva ATC by radio for departure clearance.

He then switched to the Annemasse aerodrome air-to-air frequency for taxiing and take-off.

(2)METAR LSGG 040720Z 00000KT 4500 BR NSC M03/M04 Q1018 BECMG 6000 METAR LSGG 040750Z 00000KT 5000 BR NSC M01/M02 Q1018 BECMG 6000

(3)A dew point of -2.25 °C.

1.10 Aerodrome Information

1.10.1 Annemasse

Annemasse aerodrome is situated at an altitude of 1,620 ft. It has a 12/30 runway 1,300 metres long. Runway 12 is preferred.

It is not controlled and does not have AFIS service. There is no de-icing equipment at this aerodrome.

The runway was dry on the morning of the accident.

In 2012, there were 27,924 aeroplane movements at Annemasse. Among them 978 involved departures under instrument flight plans, that is to say a little less than three per day, including in winter. About half had been performed on aeroplanes of a similar weight category to that of a Beechcraft Premier 1A, such as Pilatus PC12, Socata-Daher TBM700, or business twinjets like Cessna Citations (C510 or C525).

1.10.2 Other Neighbouring Aerodromes

In 2012, 22,680 movements were observed at Annecy aerodrome, 37,872 at Chambéry aerodrome and 37, 892 at Grenoble-Isère. These three aerodromes receive commercial air traffic and are equipped with de-icing equipment. Business aeroplanes, in particular those mentioned in paragraph 1.10.1, use the de-icing equipment at these aerodromes when necessary.

1.11 Flight Recorder

The aeroplane was equipped with a flight recorder. This was not required by the regulation in force. It was a cockpit voice recorder (CVR)[4] with a recording capacity of at least thirty minutes. It was damaged in the fire that followed the accident. Data readout, carried out at the BEA, showed two separate periods.

The first corresponds to the end of the approach and the arrival at Annemasse aerodrome the day before the accident. Listening to the recording of the end of this flight made it possible to note the following points:

- a single person was in the cockpit. This was identified as being the one in the left hand seat (the pilot's seat) at the time of the accident;
- there was no mention of the current meteorological conditions on the ground at Annemasse (precipitation, disruption, etc.).

The second period corresponds to the time between switching on the CVR on the day of the event and the moment of the accident. It lasts 8 min 35 s. The CVR recording starts during the checking phase before taxiing. The two engines were already running. The checks before taxiing were recorded, and the pilot specifically stated *"Flight controls okay and correct"*.

[4]- Manufacturer: L3-COM
- Model: FA2100
- Type Number: 2100-1010-51
- Serial Number: 314209

The CVR data was synchronised from time data obtained on the radar detections of VP-CAZ. The chronology of noises and warnings is as follows:

- 07 h 38 min 37 / Take-off;
- 07 h 38 min 39.6 / GPWS *"Bank angle – Bank angle"* warning;
- 07 h 38 min 41.4 / Stall warning (duration: 1.2s);
- 07 h 38 min 41.9 / GPWS *"Bank angle, … , Bank angle"* warning;
- 07 h 38 min 45.2 / Stall warning (duration: 1,8s);
- 07 h 38 min 47.1 / GPWS *"Bank angle – Bank angle"* warning;
- 07 h 38 min 48.2 / Stall warning (until the first impact);
- 07 h 38 min 52 / First sound of impact;
- 07 h 38 min 52.3 / Second sound of impact;
- 07 h 38 min 52.5 / Last sound of impact;
- 07 h 38 min 52.9 / End of recording.

The pilot did not mention any visual warning. The stick shaker could not be identified because of the background noise.

Spectral analysis of the recording made it possible to determine the rotation speeds of the rotating parts of both engines, of the nose landing gear wheel and the main landing gear wheels. It was possible to deduce from this the various speeds of each engine (N1 and N2), as well as the wheel rotation speeds, and therefore a ground speed during taxiing.

Data from the CVR is summarised in the following diagram.

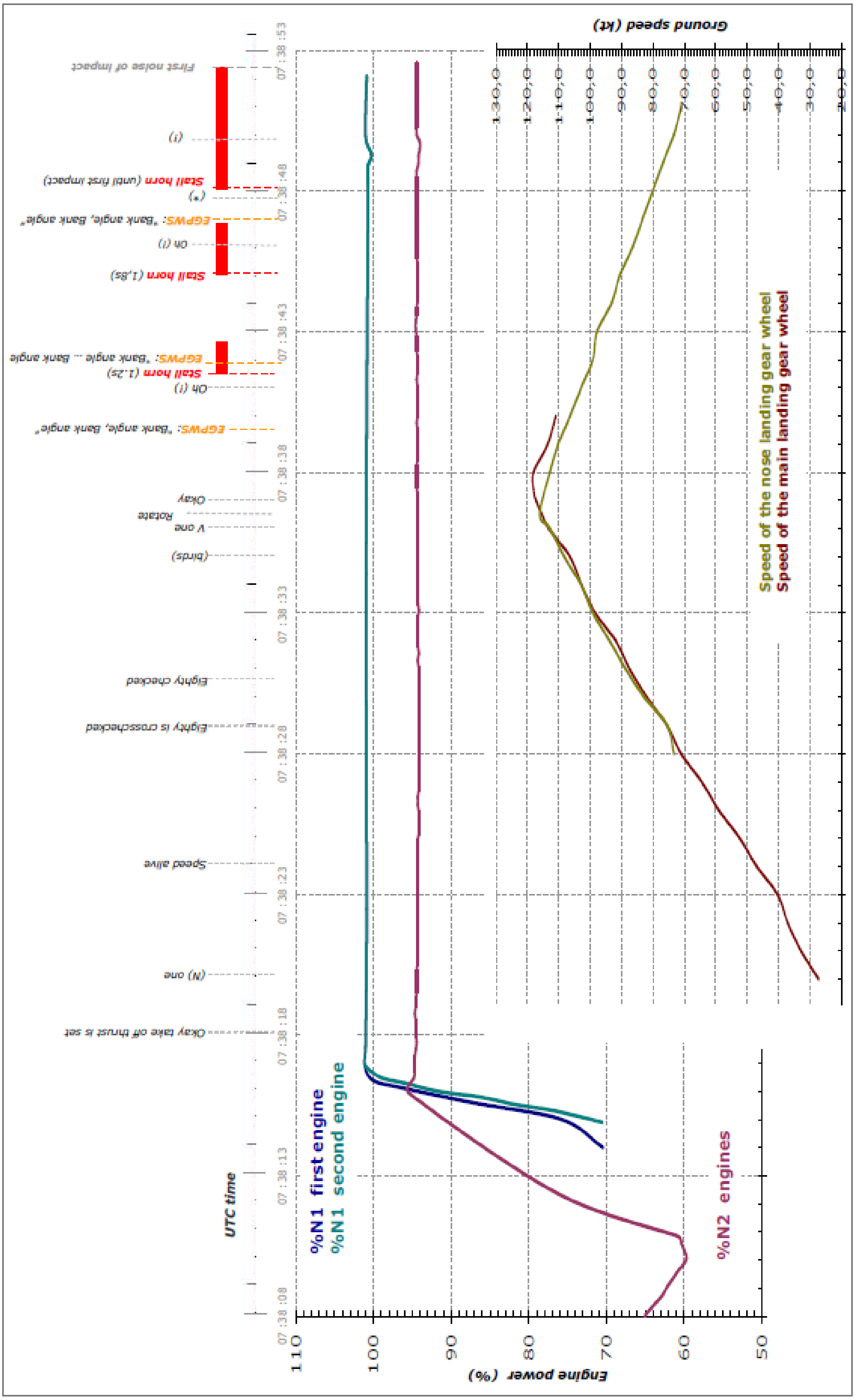

Figure 5 – Summary of data from the CVR

1.12 Wreckage and Impact Information

The wreckage was located about 600 metres south-east of Annemasse aerodrome runway 30 threshold, in the town of Cranves-Sales (France). It was located in an individual's garden. The main part included the fuselage the tail section, the two turbojets, the right wing and the left wing root. The right wing, the central spar and a segment of the left wing were separated from the airframe and were found several metres behind the rest of the wreckage. There was a large quantity of fuel in the right wing.

The trimmable horizontal stabiliser was found close to the neutral position corresponding to the take-off setting.

Initial impact of the aeroplane with the roof of another individual's house was observed about 150 m to the west of the main wreckage.

The other parts of the aircraft were found mainly in a field between the two properties, in particular:

- the left wing, which showed marks of the same colour as that of the roof tiles of the first damaged house. Marks of fire (soot) were observed on this wing, at fracture level;
- the left main landing gear, on which pieces of wooden structure and deposits the colour of tiles were found.

The first major mark of impact with the ground was observed in the field, 20 m from its western edge, over about 15 m. It showed a slight curve to the left (in the direction of the flight path). The right main landing gear was found at the end of this mark.

A second mark, less spread out but deeper, was observed to the left of the previous mark.

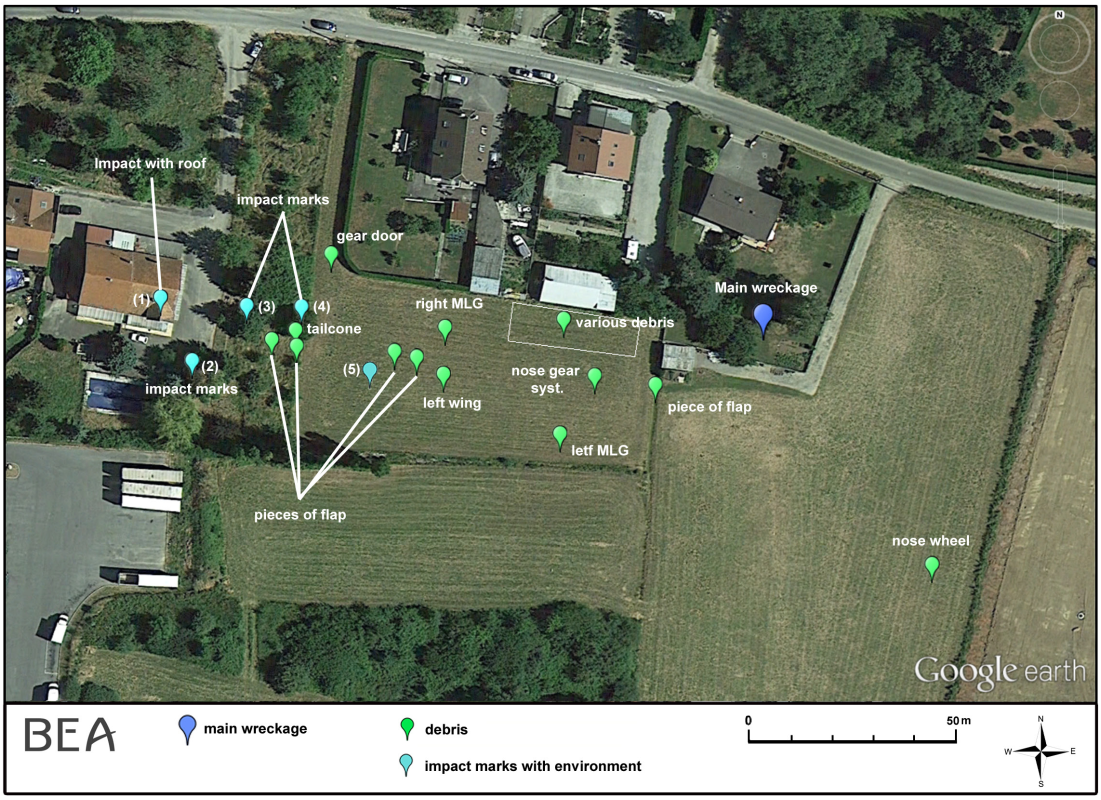

Figure 6 - Distribution of main debris

1.13 Medical and Pathological Information

Medical and pathological examinations were carried out on the pilot and passenger. They did not bring to light anything likely to explain the accident.

1.14 Fire

The whole of the main wreckage burned in the fire that followed the impact, with the exception of the upper part of the tail section. The composite airframe was completely destroyed by the fire.

1.15 Survival Aspects

The occupants seated in front were killed due to the force of the deceleration on impact and the extent of the fire.

The surviving passenger was thrown clear along the aeroplane's final flight path. She was rescued. The vegetation that separated her from the centre of the fire and the rapid help of passers-by probably prevented her from being exposed to the risk of burns.

1.16 Tests and Research

1.16.1 Examination of the Anti-icing Systems

Neither the ICE PROTECTION panel nor any computer linked to the anti-icing protection was found at the site of the accident. It was therefore not possible to determine the position of their controls at the time of the collision.

Both of the engines' anti-icing valves and the two anti-icing valves for the wings were removed from the wreckage. Their examination did not determine if they had been operating or not during the accident flight.

1.16.2 Examination of the Flaps

Among the eight flap actuators, six were recovered and examined. The positioning of five of them was identified (circled on the figure below).

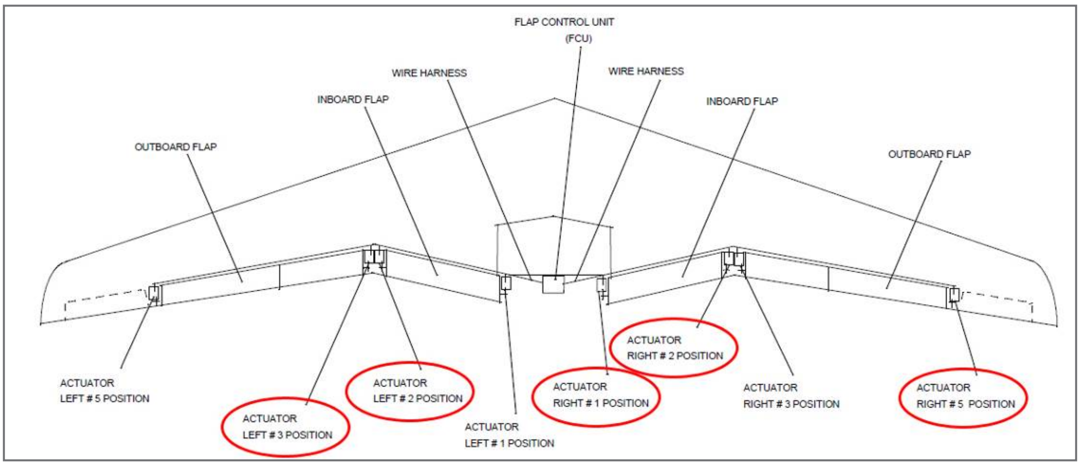

Figure 7 - Position of the flap actuators found at the site

Each flap is activated by two actuators, one at each end.

Examination of the actuators showed that their extension corresponded to a flap position of about 10°, for:

- the left outer flap;
- the left inner flap;
- the right outer flap.

Actuator n°2 of the right inner flap showed an extension to 10°, which was not the case for n°1. The latter was probably deformed on impact with the ground. It is not likely that two actuators connected to the same flap would have had two positions in flight corresponding to two different flap positions.

1.16.3 Performance Study

A digital simulation conducted by the manufacturer enabled the values of the take-off roll distance, the speed and angle of attack to be determined. This work was carried out based on a *"clean"* aeroplane model, which means without contamination[5] on its surfaces. This simulation was carried out by reproducing the meteorological conditions at the time, the estimated weight and balance for the accident flight as well as flap configuration at 10° and a dry runway. The simulation was also based on the hypothesis of a take-off flight attitude of 10°, which is an average value for a normal take-off.

[5]Accumulation of frost, ice or snow on the critical surfaces of an aircraft is called "contamination".

Under these conditions:

- the V1 / VR / V2 values given in the flight manual are respectively 101 kt / 107 kt / 120 kt. These speeds were also those called out by the pilot before take-off;
- The trigger threshold for the stall warning and the stick shaker is a 10.3° angle of attack.

The comparison between the results of the simulation and the calculations from CVR data shows that the take-off run of VP-CAZ on the day of the accident was similar to that of the model with a *"clean"* aircraft:

	Model with *"clean"* aircraft	VP-CAZ on the day of the accident
Distance of the take-off run from the moment the main landing gear wheels are detected rotating by spectral analysis	590 m	625 m approx.
Time of the take-off run from the moment the main landing gear wheels are detected rotating by spectral analysis	16 s	17 s approx.
Speed at lift-off	117 kt	118 kt

Note: the speeds from the model are airspeeds, and those from CVR data are ground speeds. As the wind was calm on the morning of the accident, both types of speeds may be considered as having the same values.

The simulation also showed that a *"clean"* aircraft with a constant flight attitude of 10° and these speeds on take-off would have had a positive climb rate with angles of attack lower than the threshold for triggering the stall warning. The heights reached by the *"clean"* model and VP-CAZ at different moments of the flight are compared below:

	Model with *"clean"* aircraft			VP-CAZ on the day of the accident
Time since lift-off	Vertical speed	Angle of attack	Height	Height
7 s (1st radar detection)	1,400 ft/min	3.8°	120 ft	80 ft
12 s (2nd radar detection)	1,700 ft/min	2.7°	270 ft	150 ft
15 s (impact with the 1st house)	2,000 ft/min	2.2°	370 ft	15 ft

1.16.4 Effects of Wing Contamination on Aeroplane Performance

The deposit of frozen contaminants on the wing, even a small quantity, makes its surface rough. This roughness modifies the airflow locally and causes airflow to separate from the wing surface. The wing aerodynamic characteristics may in this way become significantly degraded. A decrease is observed specifically in:

- Lift for a given angle of attack;
- Maximum lift;
- The angle of attack at which the stall appears.

In these conditions, the true stall angle of attack may be much lower than the thresholds allowed for the stall warning calibrated for a *"clean"* wing.

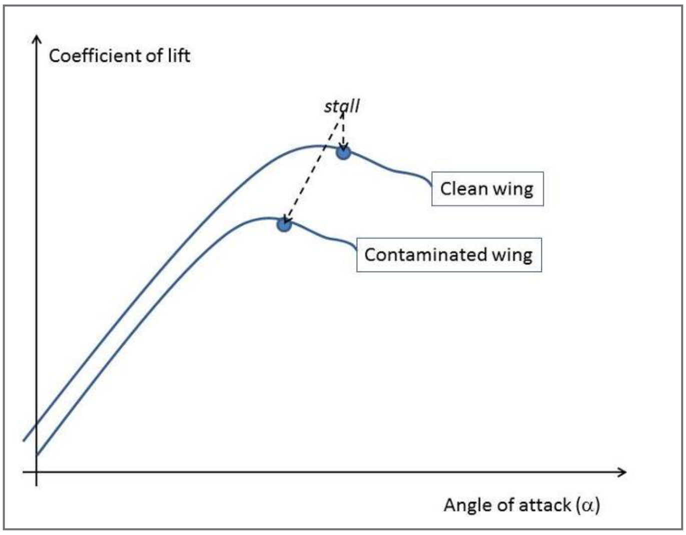

Figure 8 - Effects of contamination on lift

The accretion of frost may also cause roll instability characterised by successive uncontrolled excursions to the left and right.

In addition to these negative effects on lift, both drag and the aeroplane weight are increased.

Studies[6] show that aeroplanes equipped with wings which:

- have a short chord length,
- have no slats,
- have a swept leading edge,

are more specifically sensitive to the effects of ground ice. The Beechcraft Premier 1A wings have these three features.

1.16.5 *"Cold-Soaked Fuel Frost"* Phenomenon

The Cold-Soaked Fuel Frost phenomenon may occur when the tanks of an aeroplane on the ground contain enough fuel at temperatures lower than 0°C. This may be the case after a flight at high altitude. During the stopover, the water contained in the air may then condense, freeze on the upper surface of the wing cooled by the fuel and form a layer of frost that may not be easily visible. Experiments have shown that when ambient temperatures are between -2° and +15°C, ice or frost may form in the presence of a high rate of humidity if the surface of the wings of the aeroplane on the parking area is maintained at a temperature of 0°C or less.

This phenomenon contributed to the occurrence of several accidents, including:

- the accident to the Bombardier CL600-2B16 (Challenger 604), registered N90AG on take-off from Birmingham (United Kingdom) on 4 January 2002[7];
- the accident to the CRJ100, registered EW-101PJ on take-off from Erevan (Armenia) on 14 February 2008[8].

1.16.6 Ice Detection Systems

The risks associated with the effects of contamination mean that take-off should not be undertaken unless the outer surfaces have been cleared of any deposit likely to have a negative effect on aeroplane performance and/or handling, except within the limits specified in the flight manual. This is the concept of a *"clean aircraft"*.

For this, a visual and/or hands on surface check must be carried out by the captain. It is intended to detect the presence of roughness on the surfaces or different sensations to those of the skin of the aircraft, in particular on critical surfaces such as the wings and the horizontal stabiliser. The wings photographed below are those of a Beechcraft Premier 1A which had parked all night outside at Le Bourget airport in meteorological conditions similar to those that prevailed at Annemasse on 4 March 2013. Rime ice, showing roughness in several places, had been deposited over the whole wing surface, without any previous precipitation.

Figure 9 - Roughness on a wing contaminated by frost

[6] See the DGAC *"Flight in Icing Conditions"* document - http://www.developpement-durable.gouv.fr/IMG/pdf/DGAC_Icing_flight_manual.pdf See also: FAA study: DOT/FAA/AR-05/39 *"Experimental Investigation of Ice Accretion Effects on a Swept Wing"*.

[7] AAIB report: http://www.aaib.gov.uk/publications/formal_reports/5_2004_n90ag.cfm

[8] MAK report (in Russian): http://www.mak.ru/russian/investigations/2008/report_ew-101pj.pdf

There are sometimes visual aids, such as coloured strips on the wings, allowing better detection of the presence of frost or snow on flying surfaces painted white or grey. These coloured strips are ineffective, however, when covered with clear ice.

In addition, contamination may spread to all the aeroplane surfaces, some of which may be difficult to observe without using a step ladder, particularly the upper part of the tail plane surfaces.

There are many systems enabling the detection of frost or ice formation in flight. The Beechcraft Premier 1A is equipped with one of these systems. It is not designed to detect contamination on a wing on the ground.

Current technology may however make it possible to determine on the ground if the aircraft surface is contaminated and by what type of contaminant[(9)]. The objective is to reassure pilots that critical surfaces are free from frozen contaminants before take-off. Among these technologies are ground devices and on-board devices.

- Ground devices are designed to detect ice, snow, slush or frost on the aeroplane's critical surfaces and/or to assess the state of anti-freeze liquid. These are, for example, infra-red cameras, portable or attached to trucks which, after digital processing of the images, make it possible to visualize any possible contaminated areas on a surface[(10)].
- The on-board devices warn the pilot in the cockpit of the presence of ice, snow, slush or frost on the aeroplane's critical surfaces. These systems are, for example, based on:
  - ultra-sound propagation: sensors under the aircraft skin make it possible to detect and to distinguish several types of contaminants according to the response of the skin to the waves transmitted, or
  - measuring electro-magnetic waves (depending on the type of contaminant) with the aid of waves brushing the surface and installed in areas that are specifically favourable to accretions.

Various systems using these technologies have been available to the aviation industry since the 1990s. Some systems, already certified by the FAA and operational at Toronto airport in Canada, for example, are used by major US airlines. Regulations do not require their installation.

1.17 Organizational and Management Information.

1.17.1 Inspection of the External Condition of the Aeroplane before Take-off

1.17.1.1 Regulation in force on the day of the accident

On the day of the accident, VP-CAZ was being operated in the context of general aviation.

In accordance with the ICAO convention on international civil aviation (Chicago convention), it should be operated both according to the regulations of the country overflown (France) and according to those of the country of registration (Cayman Islands).

(9) The ICAO manual on de-icing and anti-icing activities of aircraft on the ground (Doc 9640) defines in chapter 12, the types and objectives of systems of icing detection and warning.

(10) See the FAA and Transport Canada technical note, published in February 2006 http://www.tc.faa.gov/its/worldpac/techrpt/tc06-20.pdf

The French decree of 24 July 1991 relating to the conditions of use of civil aircraft in General Aviation states in paragraph 5.10.2 *"Deposits of snow, ice or other"* that:

"No aircraft may be used unless it has been cleared of any deposits of snow, ice or other that could affect its performance or correct operation."

Registered in the Cayman Islands, the aeroplane should also have been operated according to the rules of the *"Overseas Territories Aviation Requirements (OTAR)"*. In this it is specified in paragraph 91.210:

> *"The pilot-in-command:*
>
> *a. shall not operate an aircraft in conditions where ground icing is known or suspected to be present, unless the aircraft has been inspected for icing and if necessary given such de-ice and anti-ice treatment as may be required;*
>
> *b. shall at no time perform a take-off in an aircraft that has snow, ice, or frost adhering to the wings, rotors, stabilisers, or control surfaces; and*
>
> *c. may only perform a take-off in an aircraft that has frost adhering to a propeller, windscreen, or powerplant installation if such action is specifically permitted by the aircraft flight manual and the take-off is performed in accordance with the aircraft flight manual procedures."*

It should be noted that for commercial air transport, European regulation n°859/2008[11] states in paragraph OPS1.345 *"Ice and other contaminants – ground procedures"* that:

> *"A) an operator shall establish procedures to be followed when ground de-icing and anti-icing and related inspections of the aeroplane(s) are necessary.*
>
> *b) A commander shall not commence take-off unless the external surfaces are clear of any deposit which might adversely affect the performance and/ or controllability of the aeroplane except as permitted in the Aeroplane Flight Manual."*

[11]European regulation n°859/2008 of the Commission of 20 August 2008 modifying (EEC) regulation n°3922/91 of the Council as regards common technical rules and administrative procedures applicable to commercial transport by aeroplane.

1.17.1.2 Regulatory change

European regulation n°800/2013 of 14 August 2013 will be applied by all member states of the European Union by 25 August 2016 at the latest. Completing the regulation called *"Air OPS"*, its provisions will also apply to non-commercial operations. It will require in particular for all non-commercial operations with complex motor-powered aircraft, the abbreviation of which is *"NCC"*, the same requirements as for commercial flights. The Beechcraft Premier 1A Model 390 is a complex motor-powered aircraft and the flight of VP-CAZ would have been an *"NCC"* type if this regulation had been in force on the day of the accident.

> *"NCC.OP.185 Ice and other contaminants — ground procedures*
>
> *a) The operator shall establish procedures to be followed when ground de-icing and anti-icing and related inspections of the aircraft are necessary to allow the safe operation of the aircraft.*
>
> *b) The pilot-in-command shall only commence take-off if the aircraft is clear of any deposit that might adversely affect the performance or controllability of the aircraft, except as permitted under the procedures referred to in (a) and in accordance with the AFM."*

1.17.1.3 Manufacturer's Manuals

The *"limitations"* part (see appendix 1) of the Airplane Flight Manual (AFM) states that takeoff is prohibited with frost, ice, snow or slush adhering to the wing control surfaces, engine inlets or other critical surfaces.

The procedures also state that during the pre-flight inspection, a visual and hands on surface check must be performed to ensure that the wing is free from frost, ice, snow or slush when the outside temperature is less than 10 °C or if it cannot be ascertained the wing fuel temperature is above 0 °C and :

- if there is visible moisture (rain, drizzle, frost, snow, fog, etc.), or
- if water is present on the wing, or
- if the difference between the dew point and the external temperature is 3 °C, less, or
- if the atmospheric conditions have been conducive to frost formation.

The *"Normal procedures"* part of the AFM (see appendix 1) also specifies the need to ensure the wings are free of ice during the external pre-flight check.

They also state:

- the elevator anti-icing protection must be placed in automatic mode;
- if there is visible moisture and the temperatures are less than 5 °C, then the wing anti-icing protection must be activated for takeoff and that of the engines during taxiing and takeoff.

The manufacturer's AFM also indicates the negative effects of contamination of the critical surfaces of the aircraft:

> "*Ice buildup on unprotected surfaces will increase drag, add weight, reduce lift, and generally, adversely affect the aerodynamic characteristics and performance of the airplane. It can progress to the point where the airplane is no longer capable of flying.*"

1.17.2 Training on Operations in Icing Conditions

1.17.2.1 General provisions

The means of compliance with Part-FCL (Appendix 1 of (EU) regulation 1178/2011 of the Commission of 3 November 2011) state that the initial training of flight crew must include a course on the effects of contaminants such as frost, snow or ice on the wings, in particular on stall and loss of control.

During type rating extensions, these themes are not mandatory. Part FCL 740.A does not make it mandatory: only knowledge of the use of anti-icing/de-icing systems is tested during the check.

The recurrent training followed by the pilot at the Flight Safety International centre in Philadelphia/Wilmington did not provide for courses on the risks associated with ground icing. The simulator sessions were specifically aimed at the impact of icing conditions on runway adherence, the ingestion of ice by the engines and the increase in the aeroplane weight.

During type rating extensions on Beechcraft Premier 1A, Flight Safety International at Philadelphia/Wilmington reminds pilots of the requirement to check that the wings are free of ice or any other contaminant, by presenting the limitations described in the manufacturer's AFM (see appendix 1). This Flight Safety International centre stated that these reminders had been given to the pilot during his type rating extension in May 2012. The simulator sessions undertaken during periodic checks are above all oriented to the impact of icing conditions on adherence to the runway, the ingestion of ice into the engines and the increase in the aeroplane's weight.

1.17.2.2 Commercial transport

European regulation n°859/2008 requires commercial transport operators to ensure recurrent training for its crews. In particular, recurrent training must include a refresher ground course on operational procedures and regulations including de-icing and anti-icing. The knowledge acquired during the refresher course is checked using a questionnaire or with any other suitable method.

In addition, this regulation requires that the operations manual describe the policy and procedures for de-icing and anti-icing aircraft on the ground. It must also include a description of the types and effects of frost and other contaminants on aeroplanes stopped on the runway, during ground movements and on take-off.

In practice, commercial operators provide courses to crews on flights in winter conditions (or *"Winter Ops"* courses) before each winter in order to raise awareness of the risks of icing and to act as a reminder of procedures and good practice in order to mitigate them.

1.17.3 Aerodrome Operation in Winter Conditions

ICAO Annex 14 recommends in paragraph 3.15.1 that aeroplane de-icing/anti-icing facilities should be provided at an aerodrome where icing conditions are expected to occur. In addition, the ICAO manual on de-icing and anti-icing activities on aircraft on the ground (Doc 9640) states in paragraph 8.1 that such facilities are necessary when snow or ice conditions on the ground are likely to occur. The document states that this also involves aerodromes receiving aircraft on whose wings frost may form from *"Cold-Soaked Fuel Frost"*, even if the conditions on the ground are not freezing.

The French regulation does not require the implementation of de-icing/anti-icing facilities, nor more generally de-icing equipment at national airports.

Note: The European Regulation on the safety of aerodromes will apply by 31 December 2017 at the latest to French aerodromes with traffic in excess of 10,000 passengers per year. It will make it mandatory for these aerodromes to be equipped with de-icing facilities whenever icing conditions may occur. At the time of the accident, traffic at Annemasse aerodrome was less than 10,000 passengers per year.

1.18 Additional Information

1.18.1 Previous Events

1.18.1.1 Statistical survey

A search undertaken using the ICAO occurrence database identified 45 accidents that occurred on takeoff between 1989 and 2012 to aeroplanes whose wings were contaminated by frost or ice, that is to say about two accidents per year (see appendix 2 for the complete list). Thirteen of them involved aeroplanes operated in the context of general aviation, and 32 in Public Transport. The majority were linked to a loss of aerodynamic performance resulting from the presence of frost on the wings. The spread by maximum takeoff weight category was as follows:

- weight below 5.7 t: 28 (62%)
- weight between 5.7 t and 27 t: 7 (16%)
- weight above 27 t: 10 (22%)

None of these accidents involved a Beechcraft Premier 1A.

An analysis of the circumstances of these accidents reveals the following facts:

1. The temperature was always close to 0 °C or lower, with a high relative humidity.
2. The precipitation was in the form of:
   - snow in 53% of the cases,
   - rain in 4% of the cases,
   - none in 22% of the cases,
   - unknown in 20% of the cases.
3. No de-icing of the aeroplane was performed before the takeoff in 71% of the cases, that is to say 32 accidents. For thirteen of them, the pilot was aware of the presence of ice or of snow on the wings before takeoff and nevertheless decided to undertake the flight.
4. In 18% of the cases, the pilot tried to remove the snow and the ice by manual scraping of the surfaces or with the aid of a scraper, but the wings remained nevertheless contaminated during the takeoff.
5. The period of effectiveness of the de-icing fluid applied was exceeded in 7% of the cases.
6. Sudden aeroplane banking to the left and/or right were observed just after the takeoff in 33% of the cases.
7. A significant number of these involved aeroplanes with swept wings not equipped with slats, like Fokkers of the F28/F70/F100 family, some Douglas DC 9/MD80s and, more recently, the Bombardier CRJ.

1.18.1.2 Accident to the Fokker 100 at Pau in January 2007

One of the events mentioned in the previous paragraph occurred to the Fokker 100 registered F-GMPG near Pau airport (France) on 25 January 2007. It was the subject of an investigation by the BEA[12], which issued several safety recommendations.

Just after takeoff, the aeroplane banked left, right, then left again. It touched the ground with a slight right bank, bounced, ran through the ground services area to the right of the runway, and went through the wire fence around the aerodrome. It then crossed a road, hitting the cabin of a truck, fatally injuring its driver. The aeroplane slid into a field for about 535 metres, to the right of the runway 31 approach lights before coming to a stop. No occupants were injured. The aeroplane was destroyed.

De-icing of the wings and of the tail plane had not been performed.

The investigation concluded in a loss of control resulting partly from the presence of frozen contaminants on the surface of the wing linked to insufficient attention to the meteorological situation during the stopover, and partly due to a fast pitch-up rotation, a reflex reaction to avoid birds. The investigation also showed that the following factors may have contributed to this accident:

- the limited awareness in the French aeronautical community of the risks associated with ground icing as well as modifications of aeroplane performance linked to this phenomenon;

[12] See BEA investigation report : http://www.bea.aero/docspa/2007/f-pg070125/pdf/f-pg070125.pdf.

- the particular sensitivity of aeroplanes not equipped with slats to the effects of ground icing;
- inadequate crew awareness of procedures for a hands on surface check of the state of the surfaces in freezing conditions and the operator's failure to implement well-adapted organisation at stopovers;
- the routine aspect of the flight and the meteorological situation encountered, which was not of the kind that encouraged the crew to be particularly vigilant.

In order to avoid similar accidents in the future, the BEA specifically recommended that:

- *"The DGAC ensure that operators have implemented the organisation and necessary means, including training that would allow effective implementation of the procedures to check the condition of the flight surfaces when there is a risk of ground icing." (Recommendation FRAN-2008-028)*

The DGAC answered this recommendation and took the following actions:

- *"Sub-chapter IV.5 appendix 1.1.2 of the MCT-TP relating to the guide for auditing operations manuals includes, in paragraph A.8.2.4, a part relating to de-icing and anti-icing procedures. The criteria for detection of the presence of a contaminant and follow-up on environmental conditions that are described therein have been revised and developed. This modification was published in amendment n° 14 of the MCT-TP dated 19 January 2010.*
  Checking application of the de-icing and anti-icing procedures is provided for in the MCT in the audits programmed for the preparation of flights and of assistance at stopovers. It can also be the subject of random checks. This point is part of the priority actions for DSAC oversight during the 2009/2010 winter season, a priority repeated for 2010/2011. A review was carried out in January 2013. This showed that appropriate procedures were in place and only led to requests for minor improvements. Some remarks were specifically made on airlines' supervision of their sub-contractors in charge of de-icing."

The BEA also recommended that

- *"While maintaining the operational requirements concerning the inspection of de-icing before the flight, EASA improve the certification specifications to require analysis of the behaviour of aeroplanes when the wing surfaces are contaminated on the ground and to guarantee that acceptable safety margins be maintained in case of light contamination." (Recommendation FRAN-2008-029)*

In answer to this recommendation, a new rule-making task was created by EASA (RMT.0118 - *"Analysis of on-ground wings contamination effect on take-off performance degradation"*). The objective of this task was to propose an amendment to the CS-25 to require that holders of type certificates evaluate the effect of ground wing contamination on takeoff performance, as well as the manoeuvrability and controllability of aircraft. The contaminants to take into account should be:

- slight contamination difficult to detect with the naked eye;
- contamination of the upper wing surface due to the temperature of the fuel (*"cold soaked fuel frost"* phenomenon);
- residual contamination after wing de-icing;
- de-icing fluid residues.

This ongoing task is considered as a priority by EASA, and should be completed in 2017.

1.18.2 Interviews

Many witnesses saw the aeroplane take off:

- they described a high nose-up attitude just after the take-off, followed by a steep bank to the right then to the left followed by a loss of altitude;
- they stated that there was no precipitation during the night and that the temperature was close to 0°C;
- they saw the aeroplane take off about half-way down the runway.
- some stated that they had removed some frost from their car windscreens on the morning of the accident.

The female passenger confirmed having seen the pilot remove the cover from the Pitot probe and from the engine air inlets before the flight. She stated that a short time after take-off the aeroplane banked steeply to the left and to the right, almost making a *"complete turn"*. She saw the pilot make left and right inputs to try to get back onto the flight path.

A Beechcraft Premier 1A pilot, who knew the accident pilot, stated that the latter usually put the aeroplane in a hangar over night when he knew that he would be flying the next morning when the weather was cold. At Le Bourget and Geneva airports, the usual destinations for the aeroplane, he had a dedicated place in a hangar. The pilot only occasionally needed to have his aeroplane de-iced before a flight.

This same pilot, flying on a Beechcraft Premier 1A, added that pilots switch on the anti-icing on the ground and count on the warm air flow during taxiing to de-ice the wings and tail plane. At Annemasse the distance between the aeroplane's parking area and the threshold of runway 12 is only a few dozen metres, the taxiing time was limited, less than two minutes in the case of VP-CAZ. It was not possible to determine if this *"procedure"* was applied at the time of the accident flight.

He also stated that the pilot had tried to file a flight plan from Paris-Le Bourget to Geneva on 3 March 2013. He had not managed to do so due to a lack of arrival slots and had therefore filed a flight plan to Annemasse.

2 - ANALYSIS

2.1 Scenario

2.1.1 Wing Icing

The factual elements show that there was no:

- Technical malfunction that could explain the accident;
- Pilot or passenger incapacitation;
- Influence of an aft centre of gravity on the climb slope;
- Incorrect configuration or asymmetric extension of the flaps.

However, the investigation showed that:

- The meteorological conditions during the night and on the morning of the accident were consistent with formation of ice on the aeroplane's flight surfaces, in particular on the wings;
- The aeroplane's behaviour was consistent with a stall due to contamination of the wings with frost or ice: steep uncontrolled banking immediately at lift-off and impossibility of establishing an adequate climb speed, though the takeoff speed and the configuration of the aeroplane were appropriate;
- These stall effects appeared before the triggering of the stall warning with angle of attack values lower than the theoretical activation value. This is typical of the behaviour of a contaminated wing profile;
- The aeroplane's behaviour was comparable to those of many accidents around the world caused by icing contamination on the wings, leading to a stall then a loss of control on takeoff;
- The physical characteristics of the wings of this type of aeroplane make it particularly sensitive to the effects of ground icing.

2.1.2 Accident Scenario

Taking into account the lack of an arrival slot at Geneva, the pilot had performed the flight from Paris-Le Bourget towards Annemasse on 3 March, with the intention of positioning the aircraft at Geneva the following day.

During the flight on 3 March, the external temperature in cruise dropped to about -40 °C. The fuel inside the wings thus reached very low temperatures. After landing at Annemasse, in the evening at about 16 h 00, the aeroplane was parked on the aerodrome parking area. The fuel contained in the tanks could have kept the temperature of the wing surfaces at a negative temperature that was lower than the external temperature. The meteorological conditions (temperature of -2 °C and high relative humidity) at the aerodrome the previous evening and on the morning of the accident led to frost or ice deposits on the wings. This deposit may have been accentuated by the phenomenon of *"cold-soaked fuel frost"*.

On the day of the accident, the pilot made his pre-flight inspection. This was intended to ensure the absence of any ice on the wings. The usual practice is to make a visual and hands-on surface check of the surface of the wings, in order to detect any roughness. The flight manual details the conditions under which this check should be carried out. On the day of the accident, these conditions were met. It is likely that the layer of ice present on the wings was thin. Consequently, it may have been difficult to detect with the naked eye. This difficulty may have been increased by the fact that the wings were white in colour, like the frost that covered them. It is also possible that the pilot detected the layer of ice, and considered it thin enough to have no consequences on takeoff performance.

The taxiing and takeoff run took place normally. The flap configuration was correct and the rotation speed slightly higher than the planned value. As soon as the main landing gear wheels left the ground, the aeroplane stalled as a result of the presence of frozen contaminants on the surface of the wings. The stall caused the loss of control of the aeroplane and prevented an adequate gain in altitude. Ice accretion caused roll instability, which explains the uncontrollable roll excursions to the left and right, which the pilot countered.

However, the low height reached by the aeroplane made it impossible for the pilot to exit the stall situation and avoid the collision with the ground.

2.2 Awareness of Risks Associated with Ground Icing

The investigation could not determine whether the pilot had detected the frost deposit or not during the pre-flight inspection. In any case, he was not inclined to remove the layer of ice before undertaking the flight. However, the flight manual and the regulation require that this be done since, even with a small quantity, the deposit of contaminants can significantly degrade the aerodynamic characteristics of an aeroplane, especially on takeoff. Considering the meteorological conditions on the day, the pilot would probably have delayed his flight until later if he had had a better appreciation of the risks associated with ground icing. Insufficient consideration of this can be explained as follows.

In general aviation, the effects of contaminants on stall and the loss of control on takeoff are dealt with in basic training. This subject is not necessarily reinforced during type rating extensions. The requirement to make the check that is mandatory in the flight manual and reinforced during his last recurrent training was not sufficient to make the pilot appreciate the risks associated with takeoffs in icing conditions. A stricter regulatory framework on type rating extensions, which would make mandatory regular reminders on the risks associated with ground icing, would doubtless have allowed the pilot to grasp them better.

In addition, the pilot did not have at his disposal any systems to assist detection that would have allowed him to ensure that the critical surfaces were clear of frozen contaminants before takeoff. An onboard system could, however, have supplied him an unquestionable indication on the danger of undertaking a takeoff, even if a visual or hands-on surface check of the wings, as required by the flight manual, had not alerted him to this. The current regulation does not make mandatory the installation of such devices, although existing technology would allow them to be developed.

This lack of appreciation, as well as the lack of any devices to assist detection of ground icing, led the pilot to take off without ensuring that the external surfaces were sufficiently free of any deposit to ensure safe operation of the aircraft. These same factors may have contributed to the occurrence of 32 accidents identified since 1989 in which no de-icing of the aeroplane had been undertaken before takeoff.

2.3 Operation of Aerodromes during Winter

The accident occurred in meteorological conditions that are regularly observed in winter at the majority of French metropolitan aerodromes, and in particular at Annemasse.

Every day in 2012, including in winter, around three aeroplanes whose weight and type of operation were similar to the Beechcraft Premier 1A took off from this aerodrome. This level of activity is likely to continue in years to come, specifically as a result of the proximity of Geneva airport.

Conditions favouring ice formation will certainly reappear at Annemasse, where no de-icing / anti-icing system is available. French regulations do not make mandatory the presence of such equipment, while ICAO, in Annex 14 and in Doc 9640, recommends it when snow or ice conditions are likely to occur.

The number of movements at Annemasse aerodrome is comparable to that of neighbouring aerodromes such as Annecy, Chambéry or Grenoble-Isère. These aerodromes have de-icing facilities, because they receive commercial traffic in addition to business traffic of a weight category similar to that of VP-CAZ.

In the case under consideration, the investigation could not determine if the pilot would have de-iced the aeroplane before takeoff if such facilities had been available. However, in the absence of any de-icing/anti-icing facilities, the pilot could not do it, even if he had wanted to.

3 - CONCLUSION

3.1 Findings

- The pilot possessed the licenses and ratings required to undertake the flight.
- The aeroplane had a valid certificate of airworthiness.
- The aeroplane was operating within the certified weight and balance limits.
- The pilot had made, with this same aeroplane, a flight between Le Bourget and Annemasse on 3 March 2013.
- The aeroplane had been parked on the parking area of the aerodrome all night from 3 to 4 March 2013.
- The meteorological conditions on the morning of 4 March 2013 at Annemasse aerodrome favoured the formation of ice on the flight surfaces of the aeroplane.
- Annemasse aerodrome is not equipped with anti-icing/de-icing facilities.
- The pilot and two passengers took off from Annemasse at about 7 h 35 bound for Geneva.
- The flaps configuration for takeoff was in accordance with the instructions in the flight manual.
- The pilot made the rotation at a speed that was in accordance with the instructions in the flight manual.
- The aeroplane stalled on takeoff, banking to the left and to the right.
- The engines were operating at nominal takeoff power until the end of the CVR recording.
- The observed behaviour of the aeroplane was consistent with a stall due to contamination of the wings with frost or ice.
- The low height reached by the aeroplane made it impossible for the pilot to exit the stall situation and avoid the collision with the ground.
- The pilot did not have at his disposal any system on board the aeroplane that would have ensured that he was provided with unquestionable information on the presence of ice and the danger of undertaking a takeoff.
- The manufacturer’s procedures state that takeoff is forbidden if any frost, ice, snow or slush is adhering to the wing surfaces, to the engine air inlets or to any other critical surface.

3.2 Causes of the Accident

The pilot’s insufficient appreciation of the risks associated with ground-ice led him to take off with contamination of the critical airframe surfaces. This contaminant deposit then caused the aerodynamic stall of the aeroplane and the loss of control shortly after lift-off.

4 - SAFETY RECOMMENDATIONS

Note: In accordance with Article 17.3 of European Regulation (EU) 996/2010 of the European Parliament and Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety recommendation shall in no case create a presumption of blame or liability for an accident, a serious incident or an incident. The addressee of a safety recommendation shall inform the safety investigation authority which issued the recommendation of the actions taken or under consideration, under the conditions described in Article 18 of the aforementioned Regulation.

4.1 Training on Risks on Takeoff with Contaminated Wings

Contamination of the wings of an aircraft on the ground, even minor, may considerably degrade its aerodynamic characteristics and lead to a stall on takeoff. The regulation does not make it mandatory to recall the negative effects of ice for pilots flying non-commercial operations during their periodic checks. The latter may thus not be fully aware of the risk and may then find themselves in dangerous situations whenever frozen contaminants are present on the critical surfaces of their aeroplane. This insufficient appreciation of the risks may have contributed to the occurrence of 32 similar accidents reported since 1989 for which no de-icing of the aeroplane was undertaken before takeoff. In the context of the investigation into the accident to the Fokker 100 registered F-GMPG at Pau on 25 January 2007, the BEA already recommended that *"DGAC ensure that operators put in place the necessary organisation and means, including training, that would allow effective implementation of the procedures to check the condition of the flight surfaces when there is a risk of ground icing."*. Following this recommendation, DGAC took steps targeting commercial transport.

Consequently the BEA recommends that:

- **EASA, in coordination with national civil aviation authorities, make changes to the training requirements for pilots so as to include periodic reminders on the effects of contaminants such as ice on stall and loss of control on takeoff. [Recommendation 2014-005]**

4.2 Ground Ice Detection System

Systems based on infra-red cameras or on sensors integrated into the aeroplane may help pilots and/or operators to detect the presence of frost or ice on the wings of an aircraft. Such systems have been in existence since the 1990s. An on-board system, if it had been available for VP-CAZ, would have made it possible to clearly warn the pilot of the presence of frozen contaminants on the critical surfaces of the aeroplane before he undertook the flight and of the consequent danger that should have led him to cancel the takeoff. This would also have helped to avoid the occurrence of 32 other accidents that happened on takeoff to aeroplanes whose wings were contaminated by frost or ice between 1989 and 2012.

Consequently the BEA recommends that:

- **EASA, in coordination with the FAA and the other non-European civil aviation authorities, study the technical and regulatory means to put in place in order to install systems for the detection of frozen contaminants on the critical surfaces of aircraft. [Recommendation 2014-006]**

4.3 Anti-icing/de-icing Facilities at Aerodromes

The investigation was unable to determine if the pilot would have asked to de-ice the aeroplane before takeoff if de-icing/anti-icing facilities had been available at Annemasse aerodrome. However, ICAO recommends installation of such facilities at aerodromes where there is a risk of icing. This recommendation is included in the future European regulations on aerodromes. Despite the fact that the French regulation does not make it mandatory, many French aerodromes have them, according to the type and the volume of traffic. When they are available and the meteorological conditions warrant it, these facilities are used by pilots of aeroplanes comparable to the Beechcraft Premier 1A. Annemasse aerodrome is not equipped in this way, although icing conditions are nevertheless observed every winter and many business aircraft and/or complex motor-powered aircraft take off from it regularly. There are, however, no criteria for exposure to the risk that would make it possible to identify the necessity to install such equipment.

Consequently the BEA recommends that:

- **The DGAC define criteria intended to make it mandatory for aerodrome operators to have de-icing/anti-icing facilities at aerodromes. [Recommendation 2014-007]**

List of appendices

Appendix 1

Extract from the Beechcraft Airplane Flight Manual (AFM)

Appendix 2

Accidents on Takeoff with Wings Contaminated by Frost or Ice 1989-2013

Appendix 1

Extract from the Beechcraft Airplane Flight Manual (AFM)

TAKEOFF AND LANDING OPERATIONS

Runway Surface . . . . SMOOTH, HARD, PAVED RUNWAY ONLY

Maximum Weights . . . . SEE SECTION 5, PERFORMANCE

Maximum Airfield Elevation (Pressure Altitude) . . . . 9400 ft.

Ambient Temperature . . . . -40°C to ISA + 37°C

Maximum Tail Wind Component for Takeoff and Landing . . . . 10 kts.

Maximum Fuel Imbalance for Takeoff . . . . 200 lbs.

Maximum Fuel Imbalance for Landing . . . . 200 lbs.

Jet Pumps and Boost Pumps . . . . OPERABLE FOR TAKEOFF

Engine Synchronizer. . . . . OFF FOR TAKEOFF, APPROACH, LANDING, AND ENGINE OUT OPERATION

Yaw Damp . . . . OFF FOR TAKEOFF AND LANDING

Time between landings is limited by the brake energy Turnaround Time Between Landings tables in Section 5, APPR/LDG & TURNAROUND.

Takeoff is prohibited with frost, ice, snow or slush adhering to the wing control surfaces, engine inlets, or other critical surfaces.

A visual and tactile (hand on surface) check of the wing leading edge and the upper surface must be performed to ensure the wing is free from frost, ice, snow or slush when the outside air temperature is less than 10° C or if it cannot be ascertained the wing fuel temperature is above 0° C; and:

- There is visible moisture (rain, drizzle, sleet, snow, fog, etc.) present; or
- Water is present on the wing; or
- The difference between the dew point and the outside air temperature is 3° C or less; or
- The atmospheric conditions have been conducive to frost formation.

ENROUTE OPERATIONS

Maximum Operating Altitude . . . . 41,000 ft.

Ambient Air Temperature . . . . -65°C to ISA + 37°C

Maximum Fuel Imbalance . . . . 200 lbs.

Yaw Damp . . . . OPERABLE AND ON

7. Pitot/Static Mast . . . . CONDITION/CLEAR

RIGHT NOSE

1. Pitot/Static Mast . . . . CONDITION/CLEAR
2. Ice Detector Probe . . . . CLEAR
3. Angle of Attack Sensor. . . . . CLEAR, ROTATES FREELY
4. RAT Probe . . . . CLEAR
5. Standby Pitot-Static Drains (RB-258, RB-266, RB-267, RB-270 thru RB-273, RB-275 and After, and prior serials modified by Service Bulletin 34-3972) . . . . DRAIN AND SECURE
6. Forward Avionics Door . . . . SECURE

RIGHT FUSELAGE/WING

1. Landing Lights . . . . CONDITION
2. Single-Point Refueling Door (if installed) . . . . SECURE
3. Emergency Exit Hatch . . . . SECURE
4. Wing Inspection Light (if installed) . . . . CONDITION
5. Fuel Drains and Access Doors. . . . . DRAIN AND SECURE
6. Wing Leading Edge and Upper Surface. . . . . CHECK, FREE OF FROST OR OTHER CONTAMINANTS
7. Fuel Cap. . . . . SECURE
8. Fuel Vents . . . . CLEAR
9. Navigation and Strobe Lights . . . . CONDITION
10. Wing Anti-ice Flow Exit . . . . CLEAR
11. Static Wicks . . . . CONDITION
12. Aileron and Trim Tab, Flaps, and Spoilers . . . . CONDITION, TAB CENTERED
13. Spoiler Control Unit Door . . . . SECURE
14. Main Gear, Doors, Tire, and Brake . . . . CONDITION/SECURE
15. Fuel Filter Drain (2) . . . . DRAIN AND SECURE
16. Pylon Inlet and Exit . . . . CLEAR

AFT MAINTENANCE BAY

1. Circuit Breakers (aft relay panel) . . . . CHECK
2. ECU TEST (L & R). . . . . PUSH AND HOLD (VERIFY TEST LAMP ILLUMINATES THEN EXTINGUISHES)

Appendix 2
Accidents on Takeoff with Wings Contaminated by Frost or Ice 1989-2013

DP = Dew Point ; N/A = Not available

N°	Date (day/mo./yr.)	Place	Country	Regis.	Type	Operation		T; DP (°C)	Circumstances
1.	10/02/1989	Fairbanks, Alaska	United States	N5056Q	DHC3 Otter	Commercial		N/A	**Precipitation:** None Before the flight, the pilot removed the snow that was on the aeroplane, but left a layer of clear ice on the wings. He then lost control of the aeroplane during takeoff, at the time of flap retraction at about 100 ft ground. The investigation also showed that takeoff weight was slightly higher than the maximum authorised.
2.	09/03/1989	Covington, Kentucky	United States	N3281T	Beech BE-18	Commercial		-3 ;-5	**Precipitation:** Unknown. Presence of fog The pilot took off with a layer of ice on the aeroplane, which led to the degradation of lift during the initial climb. The pilot had not de-iced the aeroplane before takeoff, unlike other aeroplanes located on the same parking area at the time of the accident.
3.	10/03/1989	Dryden, Ontario	Canada	C-FONF	Fokker F28	Commercial		0 ;-2	**Precipitation:** Snow The aeroplane struck some trees shortly after takeoff. The crew had not de-iced because of the failure of the APU and of impossibility of de-icing with engines running.
4.	25/11/1989	Seoul	South Korea	HL7285	Fokker F28	Commercial		N/A	**Precipitation:** Unknown The ice on the wings was ingested by engine n°1, causing a loss of power during takeoff. The pilot aborted takeoff and the aeroplane made a runway excursion.
5.	29/01/1990	Williston, Vermont	United States	N4688B	Cessna 208B	Commercial		-1 ;N/A	**Precipitation:** Snow The aeroplane stalled shortly after takeoff, then a struck some trees and crashed 1,600 m from the runway. Witnesses stated that the takeoff run was long, and that the aeroplane banked sharply left and right. The pilot had not de-iced the aeroplane before takeoff and decided to take off with a weight higher than the maximum authorised weight.
6.	29/01/1990	Schuyler Falls, New York	United States	N854FE	Cessna 208B	Commercial		2;N/A	**Precipitation:** Wet snow The aeroplane stalled shortly after takeoff. At around 700 ft from the ground, it dropped suddenly, struck some trees and collided with the ground on its back. The pilot had not de-iced the aeroplane before takeoff.
7.	17/10/1990	Jackson Hole, Wyoming	United States	N26853	Cessna 414	GA		N/A	**Precipitation:** Unknown The pilot started the takeoff with snow and ice on the aeroplane. The aeroplane left the ground before of coming back down again. The pilot then aborted takeoff. The aeroplane left the runway and struck some antennae.

N°	Date (day/mo./yr.)	Place	Country	Regis.	Type	Operation		T; DP (°C)	Circumstances
8.	17/02/1991	Cleveland, Ohio	United States	N565PC	DC-9	Commercial		-5 ;-7	**Precipitation:** Snow The crew did not detect, nor remove, the ice contamination present on the wings, which led to a wing stall and a loss of control during takeoff. This can be explained by a lack of appropriate response by the FAA, Douglas Aircraft Company, and the operator to the known critical effect that a minute amount of contamination has on the stall characteristics of the DC-9 series 10 airplane.
9.	27/12/1991	Gottröra, after takeoff from Stockholm	Sweden	OY-KHO	MD-81	Commercial		0 ;-1	**Precipitation:** Snow During the takeoff run, ice on the wings was detached and ingested by the engines. This led to a surge on both engines and destroyed them. During the emergency landing at an aerodrome on the departure runway extended centreline, the aeroplane hit some trees, which ripped off the right wing. The aeroplane collided with the ground and slid for about 110 m. The aeroplane had been parked on the parking area of the aerodrome since the evening before. The aeroplane took off without being de-iced. This can be explained by the operator's inadequate instructions and the habits that did not ensure that clear ice was removed before takeoff.
10.	04/01/1992	Steamboat Springs, Colorado	United States	N1974G	Cessna 421B	GA		N/A	**Precipitation:** Unknown The aeroplane collided with the ground just after takeoff. Ice was found on the wings and the horizontal tailplane. The meteorological observations showed icing conditions. The pilot had swept the snow off the wings but had not de-iced the aeroplane before takeoff. The weight of the aeroplane was higher than the maximum authorised weight. The pilot's licence was not valid.
11.	22/03/1992	New York	United States	N485US	Fokker F28	Commercial		-1 ;-1	**Precipitation:** Snow, fog Just after takeoff, the aeroplane swerved sharply left. It was then collided with the surface of the sea. The aeroplane had been de-iced, but the effective time limit of the product had been exceeded by 35 minutes. The wings were contaminated during takeoff, which led to the stall.
12.	20/02/1993	Nome, Alaska	United States	N4182G	Cessna 402C	Commercial		0 ;N/A	**Precipitation:** Snow Shortly after the rotation, the aeroplane was subjected to aerodynamic buffeting and was not climbing. It collided with the ground on a surface covered with snow. When he left the aeroplane, the pilot noticed a rough layer of ice on two thirds of the wing. He had not removed the ice present on the wings before takeoff.

N°	Date (day/mo./yr.)	Place	Country	Regis.	Type	Operation		T; DP (°C)	Circumstances
13.	05/03/1993	Skopje	Former Yugoslav Republic of Macedonia	PH-KXL	Fokker F100	Commercial		0 ;-1	**Precipitation:** Snow Shortly after rotation, the aeroplane banked sharply left then right, and collided with the ground. The aeroplane had not been de-iced before takeoff and the wings were contaminated, which degraded the lift by about 20 to 30%.
14.	18/03/1994	Limerick, Pennsylvania	United States	N36444	Piper Aerostar 601P	GA		-1 ;N/A	**Precipitation:** Snow Shortly after takeoff, the aeroplane banked left and started to descend then collided with the ground. An aerodrome employee had swept the snow off the wings, but a thin layer of ice remained on the left wing before takeoff. The fact that the pilot did not ensure that the ice had been removed may be explained by his having taken medicine (valium) that may have altered his judgement.
15.	24/09/1996	Aniak, Alaska	United States	N5343G	Of Havilland DHC2	Commercial		N/A	**Precipitation:** Snow During takeoff from a lake, the pilot did not manage to climb more than 5 ft. He decided to abort the takeoff and the seaplane collided with the bank. The pilot had seen the snow on the wings, but observed that it was blown by the engines during start-up. He supposed that the snow would go away during the takeoff run. The ice probably present on the wings degraded the takeoff performance.
16.	22/01/1997	Crystal, Minnesota	United States	N5AS	Cessna 401	Commercial		N/A	**Precipitation:** Unknown Before takeoff, the pilots observed a layer of white ice on the wings. They tried to remove it manually. During takeoff, the aeroplane collided with a barrier. Some ice was found on the wings after the accident.
17.	14/03/1997	Detroit, Michigan	United States	N753RA	McDonnell Douglas DC-9-87	Commercial		1 ;N/A	**Precipitation:** Rain During the pre-flight walk-around at night, the copilot did not observe any ice on the surfaces of the aeroplane. The crew decided not to de-ice the aeroplane. During the initial climb, the crew felt that the climb performance was poor. A left engine surge occurred. The crew turned back and landed back at the departure aerodrome. The aeroplane had been subject to a temperature of -47°C during cruise on the previous flight. It had remained on the ground in the rain for about 2 h 30 before the accident takeoff.
18.	08/11/1997	Barrow, Alaska	United States	N750GC	Cessna 208 B	Commercial		-11 ;N/A	**Precipitation:** Unknown The aeroplane collided with the surface of the sea shortly after takeoff. Some ice was observed on the left wing of the aeroplane by an aerodrome employee before takeoff. There was also some ice on the vehicles and the aeroplanes located nearby. The pilot had not de-iced the aeroplane before takeoff, which led to an aeroplane stall during initial climb. Time pressure on the pilot to depart quickly and the operator's inadequate surveillance of its operations may have contributed to the accident.

N°	Date (day/mo./yr.)	Place	Country	Regis.	Type	Operation		T; DP (°C)	Circumstances
19.	30/12/1997	Watertown, South Dakota	United States	N5087Q	Cessna 402B	Commercial		-7 ;N/A	**Precipitation:** Snow The aeroplane collided with the ground after an initial climb observed up to 50 ft. Some ice on the horizontal tailplane and curved pieces of white ice along of the wreckage trail were found. The pilot had not de-iced the aeroplane before takeoff.
20.	23/09/1998	Peleduy	Russia	RA-70679	Antonov AN-2	Commercial		N/A	**Precipitation:** Snow The airflow over the wings and the horizontal tailplane were disturbed by the presence of snow on the runway. The pilot made an emergency landing just after takeoff.
21.	06/12/1999	Bethel, Alaska	United States	N5187B	Cessna 208B	Commercial		-23 ;-25	**Precipitation:** Unknown The pilot swept the snow and the ice from the aeroplane's flight surfaces two hours before the departure. The aeroplane stayed outside during this time. During flap retraction on initial climb towards 200 ft, the aeroplane started to descend and to bank sharply left. The pilot regained control by applying right stick, and landed 200 ft before the end of the runway. The aeroplane then made a runway excursion.
22.	26/01/2000	Oklahoma City, Oklahoma	United States	N7VS	Cessna 414	GA		-3 ;-4	**Precipitation:** Snow and freezing fog The aeroplane was towed from a hangar in which the temperature was 20°C. It then spent 20 minutes outside before takeoff. The pilot had not de-iced the aeroplane, because he was told that the aerodrome did not have the equipment. During takeoff, the aeroplane climbed to about 30 ft, then dropped and collided with obstacles after the end of the runway.
23.	20/12/2001	Lewiston, Maine	United States	N207TA	Cessna 208B	Commercial		+1 ;-1	**Precipitation:** Snow The pilot swept the snow off the aeroplane's flight surface, but did use any de-icing fluid. At the time of the rotation, the wheels briefly left the ground, but the aeroplane did not climb. The pilot aborted takeoff. The aeroplane overran the runway. The operator's inadequate de-icing procedures contributed to the accident.
24.	26/12/2001	Bremerhaven	Germany	D-IAAI	Britten-Norman	Commercial		0 ;-1	**Precipitation:** Snow The aeroplane collided with the surface of the river Weiser shortly after takeoff. The presence of snow on the wings disturbed the airflow over the wing and reduced lift during takeoff. The operator's lack of knowledge of winter weather procedures was a contributing factor to the accident.

N°	Date (day/mo./yr.)	Place	Country	Regis.	Type	Operation		T; DP (°C)	Circumstances
25.	04/01/2002	Birmingham	United Kingdom	N90AG	Bombardier CL-600	GA		-2 ;-3	**Precipitation:** None After takeoff, the aeroplane banked quickly on the left. The left wingtip struck the lower side of the runway and the wing came off. The aeroplane ended up on its back. The loss of control resulted from the presence of ice on the wing, which degraded the wing stall characteristics. The crew did not ensure that there was no ice before departure. This decision may be explained by the combined effects of medicines, of jetlag and fatigue. An FAA instruction indicating that a polished layer of ice on the wings was acceptable, may also have contributed to the accident.
26.	25/01/2002	Gorna Orjahovitza	Bulgaria	LZ-ASE	Cessna 414	Commercial		-6 ;N/A	**Precipitation:** None The aeroplane collided with an electric pole shortly after takeoff. During the pre-flight walk-around, the crew noted the presence of ice but refused de-icing aeroplane before takeoff. The weight of the aeroplane was higher than the maximum authorised weight.
27.	20/09/2002	Bethel, Alaska	United States	N144Q	Of Havilland DHC2	GA		-2 ; -2	**Precipitation:** Unknown Shortly after takeoff from a lake, about 50 ft up, the seaplane stalled and banked sharply to the right. It collided with the ground. Ice was observed on the wings of the aircraft after the accident. The captain had not de-iced the seaplane before takeoff.
28.	06/01/2003	Le Ravoire (73)	France	F-GGJR	DR400	GA		+1 ;-5	**Precipitation:** None Stall on initial climb, with a heavy aeroplane with an aft centre of gravity, flaps in the landing position and the wings contaminated by some ice. The pilot had removed the snow that covered the wings but not the ice as someone had advised him not to do it by scraping the skin.
29.	04/02/2003	Burlington, Washington	United States	N48K	Beech E18S	GA		-1 ;-1	**Precipitation:** None The aeroplane stalled shortly after takeoff and collided with the ground 400 m from the aerodrome. The pilot had noticed some ice on the aeroplane and stated that he had put on some glycol and brushed the aeroplane. It was then about 15 to 20 minutes before takeoff. Ice was observed on a large part of the aeroplane after the accident.
30.	06/12/2003	Reading, Pennsylvania	United States	N700QD	Socata TBM700	GA		-3 ;-4	**Precipitation:** Snow The pilot's poor decision not to apply of de-icing fluid on the wings before takeoff led to contamination of wings by snow/ice, a stall and an emergency landing in a field.

N°	Date (day/mo./yr.)	Place	Country	Regis.	Type	Operation		T; DP (°C)	Circumstances
31.	20/12/2003	Covington, Kentucky	United States	N9469B	Cessna 208B	Commercial		-9 ;-9	**Precipitation:** None The aeroplane stalled shortly after takeoff a height of about 300 to 400 ft. The pilot landed on the side of the runway. Ice was observed on the wings and on the tailplane after the accident. After the pre-flight walk-around, the pilot reckoned that it was not necessary to de-ice the aeroplane before takeoff. She had followed a training course on the winter operations in November 2003.
32.	17/01/2004	Pelee Island (lake Erie)	Canada	C-FAGA	Cessna 208B	Commercial		-5 ;-7	**Precipitation:** Snow and freezing rain The aeroplane stalled shortly after takeoff while the wings were contaminated by some ice. The aerodrome was not equipped with de-icing facilities. Pilot stress and fatigue may explain his decision to take off, despite the ice that had been observed before takeoff.
33.	21/11/2004	Baotou	China	B-3072	Canadair CL-600-2B19 (CRJ200)	Commercial		N/A	**Precipitation:** Unknown Shortly after the rotation, the aeroplane banked sharply left, then right, then left gain. It stalled, reached a height of 180 ft before colliding with a frozen lake. The aeroplane was parked on the parking area of the aerodrome overnight. The wings were contaminated by ice during the night, which degraded their aerodynamic characteristics. The aeroplane was not de-iced before takeoff.
34.	28/11/2004	Montrose, Colorado	United States	N873G	Canadair CL-600-2A12	Commercial		-1 ;-2	**Precipitation:** Snow During takeoff, at a height of about 20 to 50 ft, the aeroplane swerved suddenly left, then right, and then left again. The left wing struck the ground, and then the aeroplane crashed and slid 400 m before stopping. The aeroplane was parked under the snow for about 45 minutes before taxiing. The crew did not check if there was any ice on the wings before takeoff. The takeoff was performed with the wings contaminated, which led to a stall after the rotation. The pilots' lack of experience of flights in winter conditions was a contributing factor to the accident.
35.	09/01/2005	Harbor Springs, Michigan	United States	N194JA	Cessna 414	GA		-1 ;-3	**Precipitation:** None At the time of the rotation, the pilot felt that the controls were « soft » and aborted takeoff. The aeroplane made a runway excursion and collided with a pile of snow and a barrier. The pilot had inspected the aeroplane before departure and reckoned that there was no ice on it. Some ice was found on the wings of the aeroplane after the accident. This accumulation of ice on the wing degraded the aeroplane's takeoff performance.
36.	02/03/2005	Panama City, Florida	United States	N5006V	Air Tractor AT-602	GA		-2 ;N/A	**Precipitation:** None At the time of takeoff, the aeroplane banked left and the wing struck the ground. The pilot had observed some ice on the aeroplane before takeoff. He did not remove it. The presence of this ice on the wing led to a stall just after the rotation.

N°	Date (day/mo./yr.)	Place	Country	Regis.	Type	Operation		T; DP (°C)	Circumstances
37.	18/06/2005	Balmaceda	Chile	CC-CCB	Cessna 402B	Commercial		-3 ;N/A	**Precipitation:** None The aeroplane made a runway excursion during takeoff. The pilot had removed snow and ice from the wings of the aeroplane with a scraper, but the wings nevertheless remained contaminated.
38.	25/01/2007	Pau (64)	France	F-GMPG	Fokker 100	Commercial		0 ;-1	**Precipitation:** Snow Loss of control on takeoff caused both by the presence of frozen contaminants on the wing surfaces associated with a lack of awareness of the meteorological situation during the stopover, and also by the fast pitch-up rotation, a reflex reaction to birds flying up. The following may have contributed to this accident : • The limited awareness in the French aeronautical community of the risks associated with ground icing as well as modifications of aeroplane performance linked to this phenomenon; • The particular sensitivity of aeroplanes not equipped with slats to the effects of ground icing; • Inadequate crew awareness of procedures for a hands on surface check of the state of the surfaces in freezing conditions and the operator's failure to implement of well-adapted organisation at stopovers ; • The routine aspect of the flight and the meteorological situation encountered, which was not of the kind that pushed the crew to be particularly vigilant.
39.	13/02/2007	Moscow	Russia	N168CK	CRJ100	Commercial		-6 ;-7	**Precipitation:** Snow Immediately after the rotation, the aeroplane banked sharply left, then right. The right wing hit the ground and the aeroplane flipped over onto its back and was then crashed. It had been de-iced before takeoff. The time spent between treatment and the takeoff may have reduced the effectiveness of the de-icing product, and the wings were probably contaminated during takeoff.
40.	02/01/2008	Teheran	Iran	EP-IDB	Fokker 28	Commercial		0 ;-2	**Precipitation:** Snow, mist Shortly after takeoff, the aeroplane swerved left then was straightened before hitting the frozen ground hard. The aeroplane had not been de-iced before takeoff.
41.	14/02/2008	Yerevan	Armenia	EW-101PJ	CRJ100	Commercial		-3 ;-4	**Precipitation:** None, mist Immediately after the rotation, the aeroplane swerved left and the left wing hit the ground. The aeroplane flipped over onto its back, and crashed. The wings were contaminated by ice, which was probably formed by condensation of air on the wings chilled by the fuel contained in them.

N°	Date (day/mo./yr.)	Place	Country	Regis.	Type	Operation		T; DP (°C)	Circumstances
42.	11/01/2009	Hayden, Colorado	United States	N604WP	Pilatus PC-12	GA		-7 ;-8	**Precipitation:** Snow Shortly after takeoff, the aeroplane swerved right until it flipped over. Il then collided with the ground about 1,500 m from the runway. The airport manager had suggested that the pilot de-ice the aeroplane, but the latter refused. The wing surfaces were contaminated with snow/ice, which led to the loss of control in flight.
43.	17/02/2010	Kwigillingok, Alaska	United States	N207DR	Cessna 208B	GA		-5 ;-5	**Precipitation:** Freezing rain, fog The aeroplane stalled shortly after takeoff a height of about 200 ft, then collided with the surface of a frozen lake. The pilot had noticed traces of ice on the wings before takeoff, which led to the stall on initial climb.
44.	02/04/2012	Tioumen, Siberia	Russia	VP-BYZ	ATR72	Commercial		-1 ;-1	**Precipitation:** Snow Shortly after takeoff, at a height by about 700 ft, the crew lost control of the aeroplane during flap retraction. The aeroplane stalled and struck the ground. The crew had refused de-icing of the aeroplane before takeoff. The aeroplane had been parked outside overnight.

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