Accident Investigation Board Norway

Issued January 2013

REPORT SL 2013/03

REPORT ON SERIOUS INCIDENT AT BERGEN AIRPORT 9 NOVEMBER 2007 WITH ATR-42-300, OY-JRY

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This report has been translated into English and published by the AIBN to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

The Accident Investigation Board has compiled this report for the sole purpose of improving flight safety. The object of any investigation is to identify faults or discrepancies which may endanger flight safety, whether or not these are causal factors in the accident, and to make safety recommendations. It is not the Board's task to apportion blame or liability. Use of this report for any other purpose than for flight safety should be avoided.

Photos: AIBN and Trond Isaksen/OSL

REPORT

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This report has been translated into English and published by the AIBN to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.
This investigation is limited in its extent. For this reason the AIBN has chosen to use a simplified report format. The report format indicated in the ICAO Annex 13 is only used when the scope of the investigation makes it necessary.

All hours stated in this report are local time (UTC + 1 hour) unless otherwise indicated.

Aircraft:	
- Type and reg.:	ATR-GIE Avions de Transport Régional ATR 42-300, OY-JRY
- Year of manufacture:	1996
- Engine(s):	2 Pratt & Whitney Canada PW120
Operator:	Danish Air Transport
Radio call sign:	DTR56
Date and time:	Friday, 9 November 2007 at 1606 hrs.
Incident site:	Bergen Airport Flesland (ENBR)
ATS airspace:	Controlled airspace (Flesland CTR), class D
Type of incident:	Serious incident, temporary control problems during ascent
Flight type:	Commercial air transport, passenger
Weather conditions:	METAR ENBR 091520Z 32016G30KT 9999 7000W VCSH FEW015 SCT020CB BKN034 02/M01 Q1005 TEMPO 1500 SHSNRA VV008 RMK WIND 1200FT AMSL 31032G43KT= The commander has reported freezing sleet and moderate icing in connection with the flight in question.
Light conditions:	Daylight
Flight conditions:	VMC-IMC-VMC
Flight plan:	IFR
Persons on board:	2 pilots, 1 cabin crew and 24 passengers
Injuries:	None
Damage to aircraft:	None
Other damage:	None
Commander:	
- Gender and age:	Male, age not stated
- Licence:	Not stated

- Pilot experience:	Not stated
Sources of information:	Form NF-2007 “Accident/Incident/Occurrence Reporting in Civil Aviation” from the commander, “Flight Safety Report” from the commander to the Danish Civil Aviation Authority (Statens Luftfartsvæsen – Danmark), de-icing log from SAS SGS ENBR, as well as the AIBN's own investigation.

FACTUAL INFORMATION

The course of events

On the day of the incident, OY-JRY was operating on scheduled domestic flights between Bergen and Florø. The incident occurred when the aircraft was taking off on a return flight from Bergen Flesland following a flight from Florø (ENFL). The crew observed that snow was forming on the aircraft during the stopover at Flesland, in addition to remnants of clear ice from the previous flight on the wings, the horizontal tail surface and the propeller spinners. Prior to departure, the aircraft was de-iced and treated with anti-icing fluid.

At 1606 hrs, OY-JRY started its take-off roll at Flesland. In his report, the commander has stated that 15° flaps were applied. Mass and centre of gravity was within limitations. 10 kt before achieving rotation speed, the aircraft took off without any input being applied to the controls. The aircraft then continued in a shallow climb at low speed.

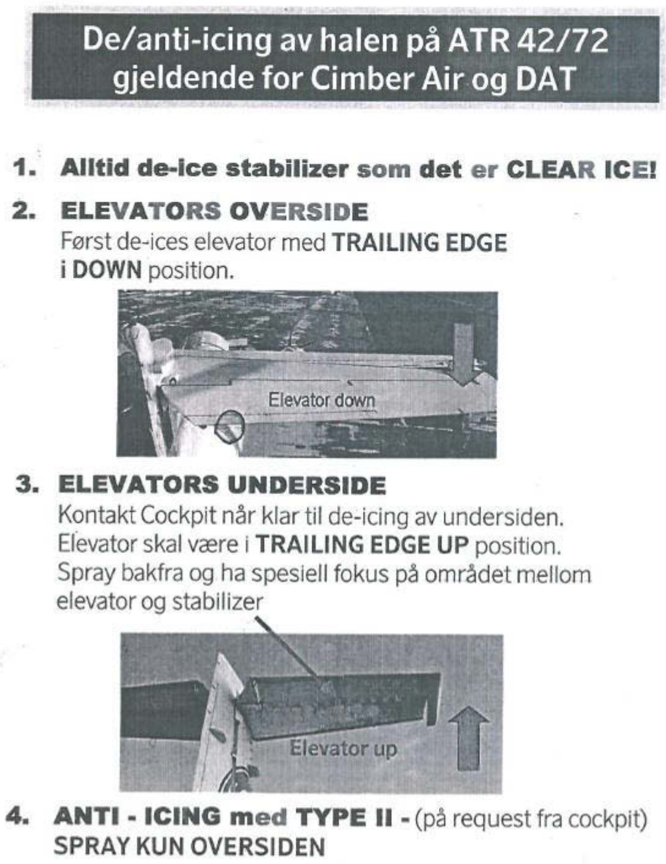
According to the commander, the aircraft continued the uncontrolled ascent in spite of both control columns being moved to the full forward position (stop) and engine power being increased. The stick shaker activated and the “cricket sound” was heard for a few seconds while the airspeed decreased. Eventually, the nose of the aircraft started to come down and speed gradually increased, at which point the stick shaker ceased. While the speed increased, the crew experienced that the control columns oscillated back and forth and were heavy to operate.

The crew report states that they started on a visual turn to return to Flesland, but abandoned this when the aircraft entered clouds. The climb was then stabilizing, and the controls became gradually easier to move. When the aircraft emerged above the clouds, the crew continued to the destination without using autopilot. The flight controls were inspected after landing at Florø without anything abnormal being found. According to DAT Technical Flight Log, the aircraft was then returned to regular operations.

De-icing and anti-icing

The first stage of the treatment of OY-JRY before departure from Flesland was de-icing, consisting of the removal of ice and snow with warm water. According to the report from SAS SGS, a total of 193 litres of water was used for this. Then anti-icing was applied to prevent snow and ice from forming on the aircraft prior to flight. In this operation, 69 litres of type 2 anti-icing fluid at 100% concentration were applied. According to SAS SGS, 17 litres of type 1 at 28% concentration were used in addition on the underside of the tail surface. The final stage of this process (application of anti-icing fluid) started at 1558 hrs, according to the log kept by SAS Ground Services (SGS). Two de-icing vehicles participated in the treatment of OY-JRY. Based on the available information, the AIBN has estimated that HOT exceeded 30 minutes. Take-off was initiated 8 into the HOT.

Both the commander and SAS SGS have stated that Danish Air Transport's procedure for de/anti-icing of ATR 42/72 was used. This procedure, consisting of four items illustrated with photographs, was submitted to the AIBN by SAS SGS shortly after the incident:



De/anti-icing av halen på ATR 42/72 gjeldende for Cimber Air og DAT

1. **Alltid de-ice stabilizer som det er CLEAR ICE!**
2. **ELEVATORS OVERSIDE**
   Først de-ices elevator med **TRAILING EDGE i DOWN** position.
   Elevator down
3. **ELEVATORS UNDERSIDE**
   Kontakt Cockpit når klar til de-icing av undersiden.
   Elevator skal være i **TRAILING EDGE UP** position.
   Spray bakfra og ha spesiell fokus på området mellom elevator og stabilizer
   Elevator up
4. **ANTI - ICING med TYPE II -** (på request fra cockpit)
   SPRAY KUN OVERSIDEN

Figure 1: Danish Air Transport's procedure for de-icing and anti-icing of ATR 42.

In a comment to the draft report the manufacturer, ATR has suggested that anti-icing fluid appears to have been used too sparingly on OY-JRY. The manufacturer has commented as follows:

> *"Taking into account the amount of Type II fluid used for the second step seems to be low. Usually the anti-icing fluid is applied through a uniform layer of at least 2mm thick that would correspond to roughly 120 liters of type II fluid. The amount of type II used for this case seems to be low."*

<u>Experiences after the incident</u>

When asked by the Accident Investigation Board, DAT stated that the company had not experienced similar incidents in the years following the control problems during the take-off from Bergen Airport Flesland. The company have operated from Norwegian airports in all the winter seasons since the incident.

DAT also reported the incident to the manufacturer, which issued ATR Airworthiness Review Sheet 131/2007 concerning the incident (see Appendix A). The manufacturer concluded that:

> *"The event description fully matches with the behaviour an ATR would have in case of an improper de-icing of the horizontal stabilizer."*

ATR went on to refer to an information bulletin that the French accident investigation agency BEA (Le Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation civile) published in 2004 following a similar case. The bulletin describes how ice contamination can cause changes to the airflow causing an upward deflection of the elevator (see Appendix B).

COMMENTS FROM THE ACCIDENT INVESTIGATION BOARD

The Accident Investigation Board believes there was a real risk of a stall before the crew eventually regained control of the elevator function following take-off from Flesland. The fact that the aircraft's stall warning system (stick shaker and cricket sound) engaged, indicates that OY-JRY was close to stalling.

Taking into account the major problems with controlling the nose position of the aircraft, the Accident Investigation Board considers it uncertain whether the crew or the aircraft's automatic stall protection system (stick pusher) could have prevented a stall from occurring if the aircraft nose had risen further. It is also uncertain whether it would have been possible to recover in time if a stall had occurred at such a low altitude.

The AIBN has considered if other factors such as aft centre of gravity position, wrong trim setting or frozen (stuck) elevators could have caused this incident. Based on the available information, all these scenarios seem less probable than the ice contaminated horizontal stabilizer hypothesis.

The Accident Investigation Board has noted that de-icing of the stabiliser, and especially the rear sections in the transition between stabiliser and elevator, was given special attention in the tail surface de-icing procedure for ATR 42/72. This is to prevent the elevator from freezing, as has happened several times with this, and aircraft types of similar design. The procedure also explicitly states that the upper surface of the tail must be de-iced, but the AIBN still questions whether the special focus on clearance between the elevator and stabiliser on ATR, and other aircraft types with a similar tail design, may have caused the de-icing personnel to not be sufficiently attentive to the importance of also keeping the upper surface of the stabiliser and elevator completely free of ice and snow.

The Accident Investigation Board Norway

Lillestrøm, 23. January 2013

Appendix A

ATR AIRWORTHINESS REVIEW SHEET

TI : 131 / 2007 Page 1 sur 1
MODEL: ATR 42-300 **ENGINE:** PW120
SUBJECT: PITCH CONTROL ANOMALY
OPERATOR: DANISH AIR TRANSPORT **MSN:** 63 **REG.:** OY-JRY
EVENT DATE: 09/11/2007 **LOCATION:** Bergen (Norway) **FL. PHASE:** ROLLING
SAFETY CONCERN:
EASA CLOSURE STATEMENT: 87th ARM : EASA concurs with ATR position.
STATUS CLOSED

DESCRIPTION:

During ground stop on apron in ENBR snow accumulated on plane caused by the vicinity showers. The plane also had remained of accumulated clear ice on wings, stabilizer, nose & propeller spinners from previous flight. As precipitation was still present a one step type 1&2 de-icing was performed according to company procedures at remote de-icing apron. During take-off roll the plane lifted off without any inputs on the flight controls by the crew at a speed of approx. 10 Kts below rotation speed.
Airspeed indications were fluctuating due to gusting wind conditions and therefore difficult to determine exact readings. The plane maintained a steady shallow climb at low speed, despite both control columns were moved to the forward stop and extra power added. The stick shaker was activated and the cricket sound heard. Level 2 anti-icing was "ON" from before take-off. The plane maintained this altitude for a few seconds where the airspeed kept decreasing. Eventually the aircraft began leveling the nose and the airspeed increased slowly whereat the stick shaker also stopped. As the airspeed increased, the control columns were oscillating in pitch and were very heavy to move. A visual return to landing was attempted but discontinued when the flight entered in I.M.C conditions. The plane was now performing a steady climb and gradualy the flight controls become easier to move. V.M.C conditions on top was entered and flight continued to destination without the use of A/P.

ACTIONS:

During post flight inspection of the flight controls, no abnormalities were found.

SAFETY CONCERN COMMENTS AND AIRWORTHINESS IMPACT (IF ANY):

SIMILAR EVENTS:

TI 41/07

ANALYSIS/CONCLUSION:

87th ARM:
The event description fully matches with the behaviour an ATR would have in case of an improper de-icing of the horizontal stabilizer.
B.E.A has issued in January 2004 an information bulletin that explains this phenomenon.
Presence of frozen contaminants over the horizontal stabilizer and elevator, change the aerodynamic characteristics of this surface leading the elevator to a nose up tendancy.
To re-establish the balance it is thus necessary to put more trim to nose down, reducing the capacity of trim to stabilise the aircraft when the speed increases. Nevertheless upon natural ice shedding from the surface, an out of trim may suddenly appear.
The most probable scenario is that the plane was either badly de-iced on ground or that the holdover time was exceeded with subsequent contamination on the horizontal stabilizer/elevator.

ATR POSITION:

Operational issue. The ATR operational documentation already addresses adequately the issue

Appendix B

BEA Incidents en transport aérien Numéro 1 – janvier 2004 – version in English:

Incidents in Air Transport
Special Issue

ICING

CONTENTS

AIRCRAFT ICING

We must not underestimate the risk, on the ground as well as in flight. Snow and ice have been the cause of many accidents throughout the world.

Cases in point:

B737 Washington, USA, 13 January 1982
F28 Dryden, Canada, 10 March 1989
MD-81 Götrorra, Sweden, 27 December 1991
ATR 42 Roselawn, USA, 25 October 1998

Although the risks have been clearly identified and are widely known, some circumstances can lead to decisions influenced by under-assessments or confirmation bias, resulting in unexpected situations for the crew. This issue illustrates such situations.

ITA bulletins are available on the BEA site
www.bea.aero

Flaps blocked during approach

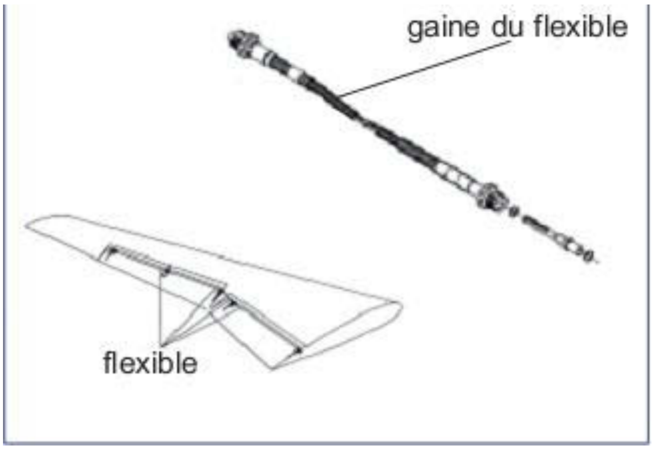
History of Flight

An Embraer 135 was performing a flight in winter. It was snowing and the temperature on the ground was 0°C. The aircraft was de-iced at the ramp with a solution composed of 75% type II fluid and 25% water. The aircraft was in contact with a walkway on the left side, and the de-icing vehicle moved to the rear side of the wing, which it sprayed starting from the trailing edge. The crew extended the flaps about five minutes after this operation, and took off. The flaps were retracted with no problems and the flight continued smoothly.
During the approach, a “FLAP FAIL” message reporting total loss of the flap system appeared on the EICAS when the crew commanded extension of the flaps. The corresponding checklist was run through. It was impossible to land during the first approach because this failure was being processed at the same time. The crew applied full throttle for another go-around, notified ATC about the failure and started a new approach followed by a landing with flaps retracted (0°).

Additional Information

The failure message was related to a failure in the mechanical flap system: hoses, worm screws, transmission brakes. The transmission of movement is made by hoses composed of steel / carbon cables passing through Teflon ducts.

Water had entered when these hoses were removed. This water froze during the flight, which took place entirely at negative temperatures, and caused blockage of the flap movement transmission. The operator launched an inspection campaign of all hoses in flap systems. Services responsible for monitoring of airworthiness were informed about this event and its circumstances.



Hose duct

Hose

Note: It is possible that high pressure injection of the de-icing fluid from the trailing edge facilitated this condition. The ICAO manual on ground de-icing and anti-icing operations describes the usual wing and stabiliser de-icing / anti-icing procedure that consists of spraying fluid from the leading edge to the trailing edge and from the highest point of the camber to the lowest point.

Icing of horizontal stabiliser and elevator control

History of Flight

A twin turboprop with a crew composed of an instructor in the right seat (TRE/TRI) and a Captain on line oriented flight training (LOFT) in the left seat, with a total of 1,100 hours combined experience on this type of aircraft, left the ramp at the beginning of the afternoon and taxied towards the holding point. There was a snow shower during taxiing, lasting for about five minutes. The pilots in the cockpit could see that the snow was melting and did not settle on the aircraft. After discussion, it was decided not to ask for de-icing of the aircraft and to continue taxiing. The crew changed the holding point due to congestion at the originally planned holding point. The snow shower stopped three to four minutes before arrival at the new holding point. After observing that the snow really was melting, the crew took off twelve minutes after leaving the ramp.

The instructor was the PF. The autopilot was engaged after the flaps were retracted at an altitude of 3,500 feet. The “Caution icing” message appeared as the plane climbed, shortly after reaching flight level 90. The crew performed the “De-icing” procedure and stabilised the plane at flight level 90. After being cleared to climb to level 110, climb was resumed less than one minute later. Then the “Pitch Mistrim” message appeared during level 100 actions, and the crew searched in vain for the “Pitch Mistrim” checklist in the flight control chapter in the Quick Reference Handbook (QRH). Since the aircraft did not stabilise at level 110, the PF disconnected the autopilot. He had difficulty in levelling the aircraft and had to apply strong nose-down forces on the elevator control, with the Pitch Trim at the "down" stop.
In order to get out of the icing conditions and with clearance from ATC to do so, the crew climbed to flight level 150. Since forces to be applied on the flight controls were still high, a request was made to return to the departure aerodrome. The descent took place with the Pitch Trim at the down stop and the same forces on the elevator control. It was planned to land with 15° flap deflection. The excessive forces reduced and disappeared on final approach when the speed dropped to 130 knots.
On the ground, it was found that there was a 0.5 cm layer of rime ice covering the upper part of the elevator and the horizontal stabiliser (no rime ice on the trim tab).

Additional information

Flight preparation
The crew had collected the following weather information during flight preparation 45 minutes before departure:

- risk of snow in Paris
- moderate to high risk of icing in Paris (end of SIGMET one hour and thirty minutes before the flight)
- three accessible aerodromes on arrival.

During the pre-flight inspection of the aircraft that had remained at the ramp for three hours, the instructor had observed that:

- there was no snow or ice on the aircraft,
- the ground and the aircraft were damp

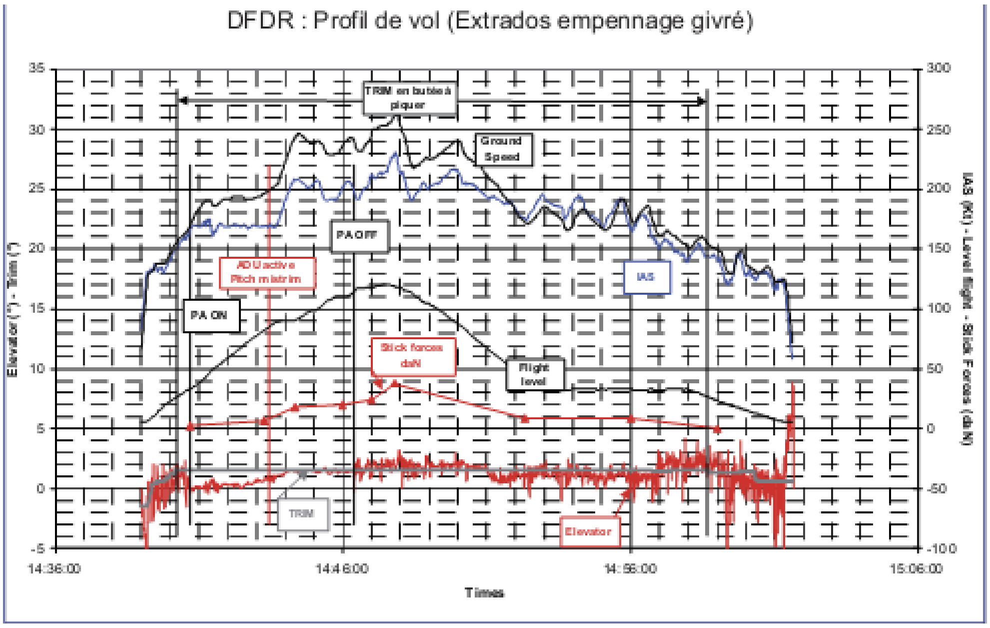
The crew had taken account of icing conditions in determining parameter limitations and for calculating parameters.

Interpretation of the Pitch Mistrim warning

An analysis of the parameters showed that the pitch trim had begun to move nose down at the beginning of the rotation. It reached the down stop before the flaps were retracted while climbing at a height of 2,500 feet. It stayed in this position until the speed was reduced for the approach.

The Pitch Mistrim message appears when the torque output from the elevator servomotor is greater than an equivalent force of 5 daN for more than ten seconds. It indicates that a “mistrim” situation will exist when the autopilot is disconnected. This can occur when the pitch trim is “mechanically” blocked, or when it has reached a stop (down or up) and its action is insufficient to compensate for forces applied on the elevator by the autopilot motor.

Aerodynamic explanation of the phenomenon
The FCOM (manufacturer’s operations manual) specifies that during a takeoff with residual ice or during severe icing, the elevator hinge moment may be affected. This is what happened during this flight, and the consequence was a mistrim of about 2°.
The analysis of flight parameters verified that the aircraft stability was not affected because the elevator deflections recorded showed no significant differences with deflections calculated for a non-contaminated aircraft, with identical mass and centre of gravity.



DFDR: Flight profile (tail assembly upper surface iced up)

Description of the phenomenon

The aircraft pitch is controlled by a horizontal stabiliser, an elevator and a trim tab.
To move or balance the elevator, the pilot or the autopilot needs to create a force which will be applied through the kinetic system to oppose the aerodynamic forces applied onto the elevator and the trim tab. This force is contrary to the elevator hinge moment.

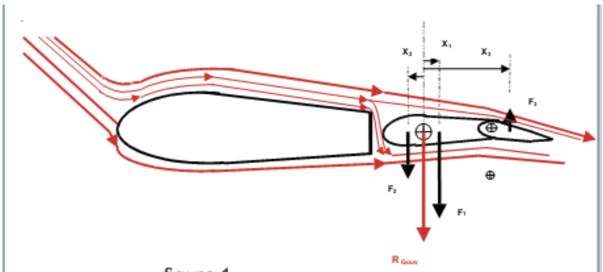


figure 1

If ice forms on the upper part of the horizontal stabiliser and the elevator, the boundary layer in the aft part of the profile is modified with the result that the elevator tends to pull up.

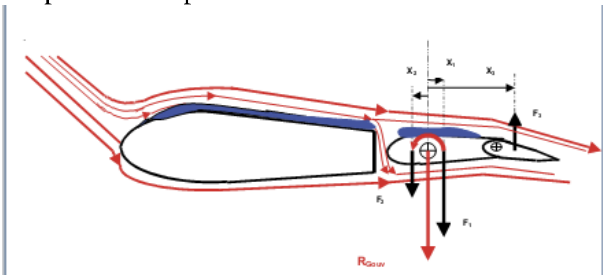


figure 2

Therefore, to restore equilibrium, the nose-down trim has to be increased which reduces the capacity of the trim to stabilise the aircraft when the speed increases. When the "down" trim stop is reached, the elevator hinge moment can no longer be compensated for, which increases the forces to be applied to reduce the aircraft's pitch attitude (see Figure 3).

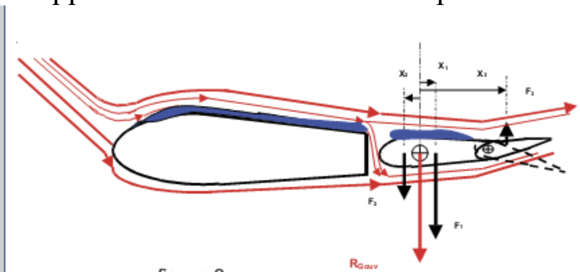


figure 3

Dangers of an elevator mistrim

Apart from the difficulties in piloting mentioned in the description of the event, a sudden disappearance of the cause of the elevator mistrim (for example if the ice on the upper part of the tail unit drops off suddenly), this will cause the elevator to pull down, thus increasing the aircraft speed. Recovery forces may be large and this situation can cause loss of control.

Note: The FCOM provides the following clarifications: the hinge moment on the elevator may be affected by external conditions. Experience shows that the most probable case is takeoff with residual ice on the aft part (de-icing/anti-icing fluid retention time exceeded). Icing may also be a factor.

Lessons learned

The operator implemented the following corrective action plan after this event:

- Reminders to crews about application of the de-icing / anti-icing procedure during snowfall or snow shower while parking or taxiing;

- Modification to Part B of the operations manual so that flight crews can easily find the checklist corresponding to the "Pitch Mistrim" message. The crew had looked for it in the flight controls chapter, although it was actually in the autopilot chapter. It was also noted that, for another aircraft in the same family but from a different series, this information was actually in the flight controls chapter;

- Increase awareness of flight crews on this type of event during recurrent training sessions.

Note: The operator also determined that the mass of rime ice on the horizontal stabiliser and on the elevator moves the centre of gravity in the aft direction by 5%, and the aircraft remains within the limits of the flight envelope.

Elevator control blocked by rehydrated residues of anti-icing fluid

This incident was the subject of an investigation report published by BEA (reference hb-r990129) and available on its internet site.

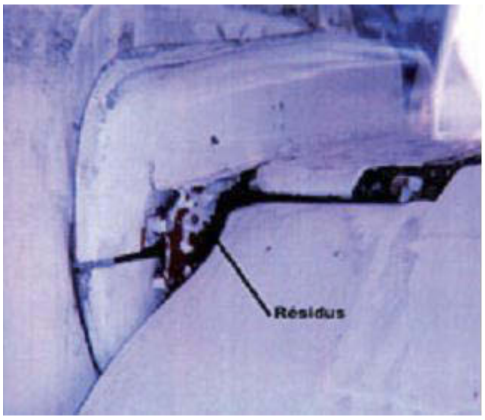
History of Flight

A twin-jet aircraft was making its first flight of the day on a winter morning. The temperature was 2°C and it was raining slightly. The Captain checked that there was no deposited rime ice or ice during the pre-flight inspection. After take-off, the aircraft went into the clouds at about 4,000 feet and came out at about 15,000 feet.
The autopilot "Pitch Trim" warning appeared when the aircraft reached level 250. The copilot was then PF.

The Captain changed the distribution of tasks in the cockpit. He took over piloting and navigation and asked the copilot to deal with radio communications.
The autopilot was disconnected; the elevator control column was very hard to manoeuvre. The column became completely blocked at level 240.

The crew notified ATC about the flight control problems and requested a return to the departure aerodrome.
The controller to whom the aircraft was transferred redirected traffic and told the crew not to hesitate to ask him for any assistance that they would like. The crew then requested priority for approach.
When control was transferred again, ATC asked the crew if they wanted to declare an emergency; the answer was yes; ATC then asked them to squawk 7700 on the transponder and once again asked the crew to change radio frequency.
The new controller proposed radar vectoring for an ILS and asked for the number of passengers on board. The crew replied stating that the emergency was due to blockage of the elevator and that the aircraft could only be controlled through the trim; in manual control, the Captain controlled the aircraft pitch using the trim tab. The crew suspected an icing problem, and performed several de-icing procedures during the descent.
Radar vectoring for a long final approach was suggested to the crew who then asked for line-up at 12 NM.

The crew recovered use of the elevator at about 1,000 feet and landed without damage 17 minutes after the warning appeared. On the ground, residues from the de-icing fluid that were still melting were found in the joints between the elevators and the control tabs.



Additional information

Elevator system

On the aircraft type considered, the two elevators are controlled by the displacement of the control tabs connected to the control columns via cables.

If these control tabs can no longer move freely, the control column can no longer be moved to control the pitch of the aircraft.

The change in the angle of attack of the trimmable stabiliser also provides the means of controlling the pitch of the aircraft. The control system of this trim is conventional and uses control column switches.

Since the primary pitch control was blocked, the crew could no longer control the pitch of the aircraft except by using the stabiliser trim.

Residue taken from the aircraft before and after hydration.

Type IV fluid before and after hydration

Characteristics of anti-icing fluids

The residues found were analysed. They comprised a gel originating from an acrylic polymer used as a thickener in type II and IV de-icing/anti-icing fluids and a very small quantity of propylene glycol (less than 1%), and paint debris and water (photo 1).

The process for formation of these residues was reproduced; type II and IV fluids lose 90% of their mass in 40 hours, by evaporation of water and glycols in a dry air stream at ambient temperature. The dry extract formed following this evaporation was composed predominantly of the acrylic polymer and the thickener.

When this dry extract is subsequently hydrated (for example by drizzle), it produces a large volume of gel (98% water, sponge effect photo 2). The freezing temperature of this gel is close to 0°C.

Maintenance operations

Note: Maintenance procedures drew attention to the possibility that this type of residue might be present, but can be so thin that it is difficult to detect it visually. It is also impossible to detect the dry extract formed during a pre-flight inspection using usual available means.

Lessons Learned

This incident was due to the presence of residues of anti-icing fluid thickeners in the hinges between the elevators and trim tabs. These residues had dried and were then rehydrated by rain, and then froze while climbing at negative temperatures, with the result that they blocked the elevators.

The operator modified the inspection procedure after the incident. The procedure consists of spraying water to rehydrate any residues that might be present so that they become more easily detectable, as can be seen in photo 1.

Intervals between inspections were reduced to make a periodic check that depends on the number of times that type II and IV fluids are applied.

The duration of the inspection is about 30 minutes and a two-step cleaning and de-icing / anti-icing procedure (which requires about 2 hours) will have to be undertaken if any residues are found.

Note: At the moment, there is no standard procedure for inspections related to the use of anti-icing fluids on aircraft guaranteeing the detection of dry residues (intervals between inspections, rehydration principle, detection methods, etc.).

Difficulties in controlling pitch axis due to ice around elevator control cables

History of Flight

The event took place in early April. After two legs, the crew of a twin-turboprop needed to make a very short leg starting from an aerodrome with very little assistance. A snow shower then fell on the aerodrome, and lasted for about an hour.

The wings and the airframe were covered with snow shortly before departure. The de-icing equipment had not been maintained in working order for the previous two weeks because the winter period was over. It was impossible to start it up quickly because it would require warming up for several hours. The airline operations service announced a delay. At the same time, a passenger put pressure on the crew to make the flight.

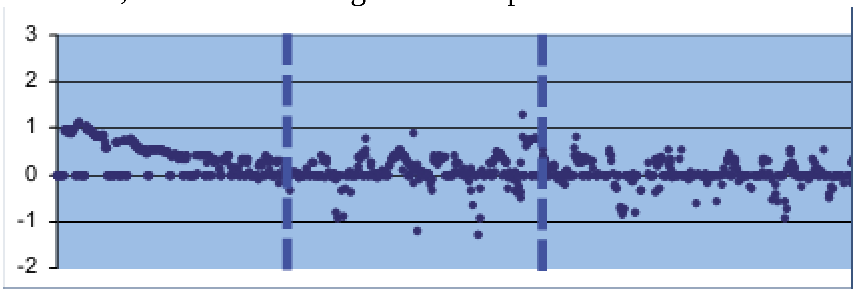
The crew searched for a way of removing snow from the aircraft. Snow was removed from the wings using a brush. The snow was thus cleared away and melted quickly. Since the aerodrome had so little equipment, there was not even a ladder because the only ladder was on the de-icing unit.

Since there was no station manager present, it was impossible to access this equipment. The method used to clear snow from the horizontal stabiliser that was at a height of 8 meters above the ground was to manoeuvre the elevator, making sure that the snow slid off and that water flowed between the horizontal stabiliser and the elevator.
Takeoff and climb took place normally in cloud cover. Once above 3,000 feet, the crew observed that rime ice was beginning to form on the aircraft. The autopilot was on and climb continued. 3 minutes after takeoff, the aircraft was in clear sky at approximately level 100. After commanding a modification to the pitch attitude to accelerate the aircraft, the copilot who was PF saw the elevator control move backwards towards him. The crew reacted by undertaking the pitch trim procedure. Once the autopilot was disconnected, the elevator control was difficult to move and the aircraft tended to climb. The crew issued a distress message and decided to descend to level 60. The meteorological analysis made before the flight had told them that the 0°C isotherm was at this level and that they would once again be in clear sky at a distance of about twenty nautical miles from the departure aerodrome. Therefore by choosing this altitude, they would be able to eliminate any rime ice deposit. Normal operation of the elevator control was in fact restored at about this level. The remainder of the flight proceeded normally and the landing was made without further incident. No malfunctions were found during an inspection of the aircraft elevator system on the ground. There were no longer any ice deposits. The flight recorders were removed.

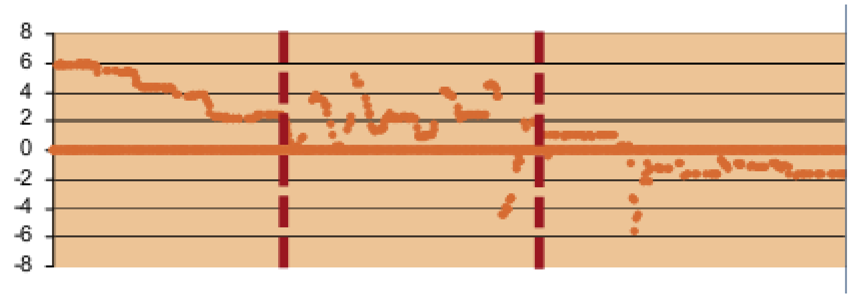
Additional information
A subsequent inspection of the area behind the pressurized bulkhead revealed the presence of debris (rivets) on the floor of the airframe. This is the area in which there are two water evacuation drains from this part of the aircraft.

Note: An airworthiness directive was made about the installation of a second drain following events in which freezing of stagnant water had caused blockage of elevator cable crossings. The maintenance manual also states that an inspection of this zone should be made. The pre-flight inspection also includes a check on the condition of the drains.

The following figure shows variations of FDR parameters at about the time of the event reported by the crew. The recording was not of very good quality, and there are several aberrant points. However, the trend in changes to these parameters can be seen.



Position of the elevator control



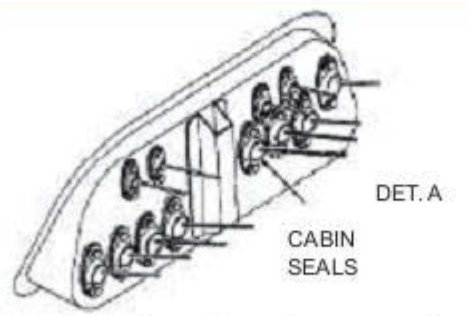
Position of the pitch trim

Three distinct sequences can be identified, as illustrated on the graphs by dashed separation lines:

- Initially, it can be seen that the positions of the elevator control and the trim vary in the same direction, tending to reduce the pitch attitude. This corresponds to the action of the autopilot to control the pitch attitude. Since climb thrust is applied during this phase, the speed increases.
- Subsequently, without any action by the crew, the autopilot commands a more pronounced nose-down action using the trim, but without any movement of the elevator control. Oscillations in the trim and elevator control then occur. These oscillations are characterised by phase opposition between the trim and the elevator control, in other words the trim appears to act first, followed by an opposite order from the elevator control.
- The third phase is characterised by relative stabilisation of the trim, while oscillations of the elevator control around the neutral are observed. Rapid displacement of the trim towards a nose-down position then occurs, immediately followed by a return to a slightly negative position.

The backward movement of the elevator control and the sensation of stiffness in the controls can be interpreted by considering a scenario determined after work done in cooperation with the manufacturer and the operator. Based on the parameters, system characteristics and reported or supposed actions by the crew (considering procedures and practices) and subsequent inspections made on the aircraft, the event can be explained as follows:

- The phenomenon occurred while the speed was increasing from 170 kts to 200 kts.
- The autopilot was activated in a pitch attitude hold mode. The autopilot was disconnected at a time that cannot be identified with any certainty. In attempting to control the pitch, the autopilot uses electric motors to control the position of the elevator control, immediately followed by trim compensation.



Passage des câbles des commandes de vol au niveau de la cloison de pressurisation arrière

Passage of flight control cables at the aft pressurized bulkhead

The snow covering the aircraft before departure was probably heavy and sticky. It stuck to the fuselage particularly and consequently to the horizontal stabiliser. As the outside temperature was increasing before takeoff, the snow was transformed into water which penetrated into the tail fin box, probably through the vent panel. This water could not all escape through the drains provided for this purpose before takeoff, because this area of the aircraft was more or less covered with debris. The climb under freezing conditions caused this stagnant water to freeze. Friction phenomena at the cable passage generated large forces on the elevator control. Consequently, operation of the autopilot was abnormal, creating particular difficulties in stabilising the aircraft, thus causing the oscillations observed in phase 2. Observing unusual movements of the elevator control, the crew disconnected the autopilot and performed the pitch trim procedure. The high forces felt on the controls could also be the result of this abnormal friction.

Lessons Learned

The descent to an altitude at which the temperature was positive explains the disappearance of this phenomenon.
The preponderant factor in this event is incomplete de-icing of the aircraft. The Captain decided to undertake the flight despite uncertainty about the condition of the horizontal stabiliser surface, due to the context. It was possible that flight conditions below 0°C IS0 would be encountered. However, the occurrence of unexpected phenomena put the pilots in an unusually stressful situation.
The presence of debris close to the drains contributed to the retention of water. The possible consequences of an obstruction illustrate the importance of being vigilant in these matters.
The operator took the following measures following the incident:

- The period during which de-icing equipment was available at this aerodrome was prolonged until the end of the month of April.
- A means of checking the condition of the elevator was installed in all stopover aerodromes.
- Crews were provided with information and more extensive knowledge about icing and de-icing.

Takeoff after incomplete de-icing of horizontal stabiliser

History of Flight
An ATR 42 was making its first flight of the day on a March morning. The temperature was close to 0°C and the dew point was – 1°C. It snowed moderately for about ten minutes, half an hour before the planned departure time[1] and the crew decided to have the aircraft de-iced. Passengers were allowed to board. The de-icing operation was performed by a runway agent, working for the service company, in about fifteen minutes [2] while the crew in the cockpit pushed the control column to the forward stop in accordance with the de-icing procedure. The equipment used was a mobile crane tanker with a tank containing a heated mix of type II fluid and water. The tanker was parked at the side of the aircraft between the trailing edge of the wing and the tail unit.
The ground operations coordinator was in contact with the runway agent using a walkie-talkie, and notified the crew when the operation was over, from the control station. The copilot noticed that the leading edges of the wings were still contaminated. He notified the coordinator who performed the remaining de-icing himself, but only on the wings. The crew did not perform the special flight control deflection test procedure after de-icing and before start-up.
The PF found the elevator control fairly heavy to manoeuvre during normal flight control tests at the holding point. He informed the Captain who did not feel the phenomenon. It was then concluded that the residues of de-icing liquid were the cause and that it would disappear with the relative wind during the takeoff roll.
The aircraft adopted a significant nose up attitude shortly after rotation. The crew had to bring the aircraft nose down to compensate for the nose up attitude. The maximum movement of the trim tab was reached and the crew had to push even more on the elevator control.
The crew stabilised the aircraft at FL 70 at a speed of 180 kts after several attempts, and diverted to its alternate field. The behaviour of the aircraft improved slightly. It landed with no further problems.

Additional information
Aerodynamic explanation of the phenomenon

[1] This was the only precipitation recorded before the aircraft took off.
[2] This was the first time that the agent had performed this operation.

The elevator hinge moment may be affected by the presence of residual ice or another contaminant on the tail. The boundary layer at the aft part of the profile is then modified. This phenomenon can force the elevator upwards. The crew must put the aircraft nose-down to restore equilibrium. If contamination is severe, the trim tab limit stop at the maximum nose down position can be reached before the elevator hinge moment is neutralised, and additional nose down forces have to be applied on the stick to reduce the aircraft attitude. More detailed explanations are given in the "Icing of fixed stabiliser and elevator" article in this issue.

De-icing procedures
The operator must define procedures to be followed for de-icing or anti-icing on the ground, and for checks of the condition of the aircraft after these operations. To achieve this, the instructions must be included in the operations manual.
The following procedures are extracted from separate parts of the operator's manual.
The General part contains the following:

"Responsibilities
The Captain is responsible for the decision to deice and / or anti-ice […].
The service provider responsible for de-icing and/or anti-icing (Airline runway agents, assistance contractor, CCI (Chambers of Commerce & Industry), other players, etc.) is responsible for:
- *making sure that the treatment is done properly and for the result obtained;*
- *training of assistance personnel […].*

The mechanic shall make a visual and tactile inspection of the two wings, or the Captain shall make it if there is no mechanic, particularly after the treatment has been applied and before starting up the engines […].
Checks
The person doing the work is responsible for checking the de-icing / anti-icing fluid and means (self-check) […].
The authorised mechanic or the Captain makes a visual and tactile inspection after the operations. This check can determine if the treatment was effective and if all critical areas of the aircraft are free of rime ice, ice or snow before the push-back or taxiing […].
After de-icing / anti-icing, the crew makes sure that all control surfaces deflect correctly, and it repeats this verification before the aircraft goes onto the runway."

The Utilisation part of the Operations Manual contains other instructions about de-icing:

"The elevator control must be held firmly to the front stop during application of the fluid […], so as to achieve the best possible de-icing / anti-icing of the horizontal stabiliser.
Forces higher than normal on the elevator control may be encountered after a de-icing / anti-icing procedure.

These forces can be twice as high as normal. This must not be interpreted as a blockage of the elevator control leading to an unnecessary decision to abort the takeoff beyond V1. Although this phenomenon is not systematic, it must be anticipated and it must be mentioned during the pre-takeoff briefing every time that a de-icing / anti-icing procedure has been applied. This increase in force on the elevator control is strictly restricted to the rotation phase [3] *and it disappears after takeoff."*

The assistance service provider

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[3] This phenomenon cannot explain a sensation of abnormal forces on the elevator control during deflection tests on this control.

Each service provider is responsible for training its own personnel. An annual audit is made by the Quality Assurance department of the air operator who hires this service provider.
In this particular case, agents who might be required to perform the de-icing / anti-icing operations had attended a training course at the end of which a global authorisation to initiate, perform and check these operations had been issued.
This training course lasts one day and is purely theoretical. No practical training is given.

Lessons Learned

There are still some uncertainties about the procedure used for de-icing. The runway agent performed the operation for the first time without having received any practical training. This is why it was not easy for him to realise that he had not done it correctly. Since then, the assistance company has set up practical training for its agents. The visual and tactile check required by the operator after de-icing was not performed. Firstly, the mechanic was not present. Secondly, if a pilot were to make this check, he would have to put on a safety harness to climb onto the crane, which is not very practical at the time of departure. It is thus obvious that procedures for making inspections are not appropriate for all situations that can occur during a stopover. Furthermore, the ground de-icing / anti-icing procedures are described in two different manuals [4], which can explain why not all of them were applied, particularly the tests on controls after de-icing.

[4] A simplified guide may be helpful for crews because these operations are not very frequent