SERIOUS INCIDENT

Aircraft Type and Registration:	ATR 72-212 A, G-COBO
No & Type of Engines:	2 Pratt & Whitney Canada PW127M turboprop engines
Year of Manufacture:	2009 (Serial no: 852)
Date & Time (UTC):	4 March 2016 at 09:15 hrs
Location:	On departure from Manchester Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 27
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	8,276 hours (of which 928 were on type) Last 90 days - 113 hours Last 28 days - 49 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft arrived at Manchester Airport from Guernsey and remained on the ground for more than an hour, while it was snowing and the temperature was 0ºC. The flight crew decided no de-icing or anti-icing treatment was needed, as they did not consider the snow was settling on the aircraft, and the aircraft subsequently departed to return to Guernsey.

During the takeoff, the commander exerted less aft pressure on the control column, to rotate the aircraft, than he expected and maximum nose-down pitch trim was then needed to maintain the appropriate climb attitude. The autopilot was engaged four times but on each occasion it disengaged, as designed, and the commander had to apply continuous forward pressure on the control column to retain the desired pitch attitude, as the climb proceeded.

Once at the cruising level, the commander decided he was having to exert excessive forward pressure on the control column and he elected to divert to East Midlands Airport (EMA). While descending, the aircraft flew out of icing conditions and the control difficulties dissipated. The crew assessed that ice contamination had caused the problem and they made a normal landing.

No ice was found on the aircraft during a post-flight inspection but analysis by the manufacturer concluded that, from the start of the flight until the latter stages of the descent, the airflow over the horizontal tailplane and elevator was disrupted by ice contamination.

Several safety actions have been taken to improve awareness of the hazards of not de-icing or anti-icing aircraft before flight.

Background

The crew reported for duty at Guernsey Airport at 0550 hrs and operated a passenger flight to Manchester. The co-pilot was Pilot Flying (PF) and he reported that the takeoff and climb were normal, with no unusual pitch trim indications. The aircraft cruised clear of cloud at FL170 and, before descending, the crew noted Manchester's Automatic Terminal Information System (ATIS) broadcast from 0720 hrs[1]. The reported air temperature was 1ºC and snow was falling. Consequently, because the aircraft was likely to encounter in-flight icing conditions, the crew increased the approach and landing speeds[2].

Early in the descent, the aircraft entered an extensive area of cloud. It then remained in cloud during the approach but only a thin layer of ice was seen to accumulate on the wing leading edges. This was less than the crew anticipated in the prevailing conditions. The ICING light on the ice detection panel illuminated when the aircraft was at a range of 3.5 nm on final approach. So, in accordance with Standard Operating Procedures (SOPs), the crew switched on the pneumatic anti-icing systems, before landing uneventfully at 0810 hrs.

While taxiing in, the crew's perception was that light, wet snow was falling and melting on the taxiways, although some was lying on adjacent grass areas. In addition, the co-pilot could see no ice on the airframe or on the Ice Evidence Probe (IEP) when he actioned the after-landing checklist. At 0814 hrs, the commander looked at the static air temperature gauge and observed that it was indicating between 1ºC and 2ºC. He then commented "IT DOESNT APPEAR TO BE STICKING…SO I THINK WE CAN GET AWAY WITHOUT DE-ICING", adding that he would "HAVE A GOOD LOOK". There was then a protracted delay before the aircraft could park, because another aircraft was being de-iced on their allocated parking stand. During this delay, the commander said he did not see any snow settling on the aircraft and suggested snow visible on other aircraft had probably accumulated overnight. The aircraft shut down at 0837 hrs, 23 min before it was scheduled to depart on a return flight to Guernsey.

The co-pilot later stated that he had no previous experience of ground operations in snow. He had been trained that an aircraft was clear of ice if none was visible on the IEP or on the leading edge de-icing boots or the propeller spinner and he saw no ice in these locations while taxing-in.

History of the flight

After shutdown, the pilots agreed that the commander would carry out an external inspection and then decide if de-icing was needed. They later stated they would have

Footnote

1 See *Meteorological information.*

2 Ice accretion can reduce the angle of attack at which an aircraft stalls and this increases the stall speed. For an approach in icing conditions or with ice accreted to the airframe, the standard operating procedure is to add an increment to the approach and landing speeds. Similar increments are required when taking off in icing conditions.

been prepared to delay the departure if they believed there was a need to de-ice (or anti-ice), despite commercial pressures to keep to the schedule. While parked, the aircraft was refuelled and the fuel quantity in the wing tanks was increased from 900 kg to 2,800 kg.

It was the commander's belief that the air temperature was just above freezing (approximately 1ºC) and he thought the falling snow was melting on the aircraft. He could not see the top of the horizontal tailplane[3] but, from the rear access step, he thought he saw most of the top of the wings and believed there was no frozen contamination. After completing his inspection he told the co-pilot, who had remained in the flight deck, that they could continue without de-icing. The co-pilot judged the commander's inspection to be thorough because it took a long time and he accepted this decision.

The two cabin crew members seldom saw snow in Guernsey, which has a relatively mild climate, and they took photographs while the aircraft was parked. These showed snow lying on the fuselage and on the Senior Cabin Crew Member's (SCCM) coat. She later recalled brushing snow from her coat when passengers began boarding.

Before departure, the crew noted the 0850 hrs ATIS which reported snow falling and a temperature of 0ºC. The commander, who was PF for this flight, informed a member of ground staff that no de-icing procedures were required and the aircraft was pushed back at 0910 hrs, 10 minutes later than scheduled. When the engines were started, the crew switched on the electric anti-icing systems, having already added the appropriate icing increments to the takeoff and climb speeds.

At 0919 hrs, the aircraft commenced takeoff. When rotation speed (V_R) was achieved, the commander found he needed to apply less aft pressure on the control column than he anticipated and, once airborne, had to push forward on the column to achieve the climb attitude. He used the electric pitch trim switch several times to trim in a nose-down direction, which caused an aural warning to be generated. This warning is triggered when the pitch trimmer is activated for more than one second.

The crew engaged the autopilot one minute after takeoff but it disengaged approximately two minutes later. In response, the crew re-engaged it but it disengaged again after one more minute and the co-pilot noticed the pitch trim indicator showed full nose-down deflection. A PITCH MISTRIM message was displayed on the Automatic Flight Control System (AFCS) display unit, so the crew actioned the '*Pitch Mistrim'* drill from the Quick Reference Handbook (QRH) which only stipulated that the autopilot be disengaged. The co-pilot suggested the problem might have been caused by contamination and the commander replied by saying the reason he had been happy to depart was that the snow was not sticking to the aircraft and, because it was wet, he expected it to have "blown off".

Footnote

[3] An access platform or ladder would have been required to inspect the aircraft's upper aerodynamic surfaces.

While still climbing, the crew again re-engaged the autopilot and this time it operated for approximately three minutes before disengaging once more. One further attempt was made to use the autopilot but, after less than two minutes, it disengaged again. By this time the commander had asked the co-pilot to check the load sheet and announced his intention to divert if he was still having control difficulties once they levelled-off.

The aircraft was levelled at FL170 and the co-pilot stated the load sheet looked very similar to the one from the previous flight. Shortly after this, the commander announced, "RIGHT I WANT TO DIVERT TO EAST MIDLANDS, BECAUSE I AM HAVING TO PUT FORWARD PRESSURE ON…" The co-pilot then asked ATC for a diversion to EMA due to a pitch trim problem. He later stated he did not query the commander's decision because it appeared the commander was having to exert a lot of forward force to maintain the required attitude. He agreed with the decision to go to EMA because he knew it was close by, he had seen it was clear of weather during the flight to Manchester and it was an airport they both visited regularly. The aircraft flew clear of cloud soon after the descent began.

This was the co-pilot's first diversion during commercial operations and he later said he experienced a very high workload while preparing for the landing and supporting the commander, who was flying the aircraft manually. Once the commander had told the SCCM they were diverting to EMA, the co-pilot informed the passengers. He then listened to the 0920 hrs ATIS broadcast for EMA, which reported Runway 27 was in use, the wind was from 260º at 14 kt, visibility 10 km or more, temperature 3ºC and dew point 0ºC.

While preparing to land, the commander said he was worried what would happen when FLAP 15 was selected. He suggested this might cause further control difficulty and warned the co-pilot to be prepared to re-select FLAP 0 if so instructed. A few seconds later, the commander announced the aircraft was becoming easier to fly and then stated, "I RECKON IT WAS ICE I'VE GOT THE PITCH TRIM BACK".

At 0954 hrs, the aircraft made a normal landing at EMA and, after shutdown, the horizontal tailplane was inspected. No ice was found, so the commander decided the problem might have been mechanical and placed the aircraft unserviceable.

Later that day an engineer inspected the aircraft and found no faults. The operator downloaded flight data from the Flight Data Recorder (FDR) and from the Cockpit Voice Recorder (CVR) before the aircraft was returned to service.

Neither the commander nor the operator immediately considered that a serious incident had occurred and there was a three day delay before the AAIB was notified. The AAIB then assessed the occurrence as one '*which could have caused difficulties controlling the aircraft*' so, in accordance with Regulation (EU) No 996/2010, it was classified as a serious incident.

Meteorological information

At 0900 hrs on the day of the flight, a slow-moving, occluded weather front affected the north of England, and radar imagery from the Met Office showed the associated cloud stretching east-west and extending approximately 30 nm south of Manchester. The Met Office reported thick cloud layers to a height of 15,000 ft amsl, or higher, near Manchester. EMA was south of the area of cloud, and little or no cloud returns were evident further south across England.

Manchester Airport experienced persistent snow or sleet through the morning and the air temperature was at or below freezing from the surface upwards. Further south and east the freezing level rose towards 2,000 ft amsl. Atmospheric data indicated to the Met Office that at 0800 hrs the air temperature at FL170 would have been approximately -33ºC.

The ATIS broadcast by Manchester at 0720 hrs gave the visibility as 800 m in snow, with few cloud at 400 ft agl, broken cloud at 1,000 ft, temperature 1ºC and dew point -1ºC. At 0740 hrs, the reported visibility had reduced to 600 m in heavy snow, with scattered cloud at 400 ft, broken cloud at 800 ft and temperature and dew point both 0ºC. The 0750 hrs ATIS was similar but with few cloud at 200 ft, broken cloud at 800 ft, temperature 0ºC and dew point -2ºC. For the aircraft's departure from Manchester, the 0850 hrs ATIS was current. It reported a surface wind of 230º at 4 kt, visibility 1,200 m in snow, with few cloud at 200 ft, broken cloud at 800 ft, the temperature and dew point both 0ºC and the QNH 988 hPa.

Recorded information

The downloaded FDR and CVR data was obtained from the operator. The FDR data for the flight was analysed by the aircraft manufacturer, along with comparative data from the previous flight, from Guernsey.

Previous flight

The aircraft took off at Guernsey at 0651:30 hrs with a recorded elevator trim of -0.82º nose-up, which is consistent with the manufacturer's recommended pitch trim for the weight and Centre of Gravity (CG), as shown on the load sheet. No significant pitch trim command was apparent after takeoff and, during the flight, the recorded pitch trim varied between -0.88º nose-up and +0.61º nose-down. The aircraft landed at 0809:40 hrs, two minutes after ice accretion was detected.

Incident flight

According to the data, the takeoff at Manchester commenced at 0918:50 hrs, with the elevator pitch trim set at –1.27º nose-up. This is also consistent with the manufacturer's recommended pitch trim for the figures from the load sheet. Rotation began at 0919:14 hrs and 14 seconds later a nose-down force of more than 10 decanewtons (daN)[4] was sensed on the commander's control column. (Discrete data inputs register when either a nose-down or a nose-up force greater than 10 daN is exerted by either pilot to move his control column.) After a further 3 seconds, nose-down pitch trim was manually applied.

Footnote

[4] 10.2 daN equates to approximately 10.2 kilogramme-force (kgf).

At 0920:05 hrs the autopilot was engaged and approximately 2 seconds later the pitch trim increased and moved to the nose-down stop. The position recorded was +1.76º-nose-down, which is beyond the normal stop of +1.5º in autopilot control (see *Pitch trim*).

The autopilot disengaged briefly at 0922:40 hrs and was then re-engaged for varying periods of time before finally disengaging approximately two minutes prior to the top of climb. A speed of 180 KIAS was maintained for the latter part of the climb and the aircraft reached FL170 at 0932:40 hrs, before commencing descent at 0934 hrs.

When the autopilot was disengaged, a nose-down force of more than 10 daN was frequently exerted on the commander's control column. However, as the aircraft descended this event was recorded less often and the final time such force was exerted was at 0950 hrs, prior to landing gear extension. Five minutes previously, at an altitude of approximately 5,000 ft amsl, in the descent, the pitch trim had started to decrease from its +1.76º nose-down position.

The aircraft landed at 0952:30 hrs with the pitch trim showing -0.1º nose-up, which was similar to the landing position for the previous flight.

Elevator hinge moment analysis

The aircraft manufacturer computed the elevator hinge moment for two different times during steady phases of each of the two flights. The recorded pitch trim at these times was compared against the pitch trim which the manufacturer calculated should be needed for trimmed flight, without any input on the control column. For the first flight, there was only a negligible difference (averaging 0.065º) between the recorded and the computed figures. For the incident flight, the computed pitch trim was -0.17º and -0.19º for the respective points but in each case the recorded trim was +1.76º, meaning the average difference was 1.94º. This would have been greater had the pitch trim not reached its stop, because an additional nose-down force was required on the control column to maintain the desired elevator position.

It was evident that for much of the flight the elevator had a tendency to deflect upwards and that the aircraft would have adopted an undesired nose-up attitude but for the maximum nose-down pitch trim which had been applied and the pilot's control input.

Aircraft information

The ATR-72-212A is a twin-engined, high-wing turboprop aircraft, with a horizontal tailplane mounted near the top of the tail fin (Figure 1).

Pitch control

Two elevators provide pitch control and both have associated trim tabs. The left horizontal tailplane assembly is shown at Figure 2 with the trim tab visible towards the rear of the elevator.

Figure 1
ATR 72-212A (photos courtesy of ATR Aircraft)

Figure 2
Left side of tailplane assembly showing trim tab (circled) on left elevator

Each control column mechanically drives the elevator on the associated side. The elevators are linked by an uncoupling mechanism, so that movement of one elevator moves the other and this causes the control column on the other side to move. In the event of a control jam, applying a force of approximately 50 daN[5] on the free control column will trigger the uncoupling mechanism, leaving each column only linked to its associated elevator (Figure 3).

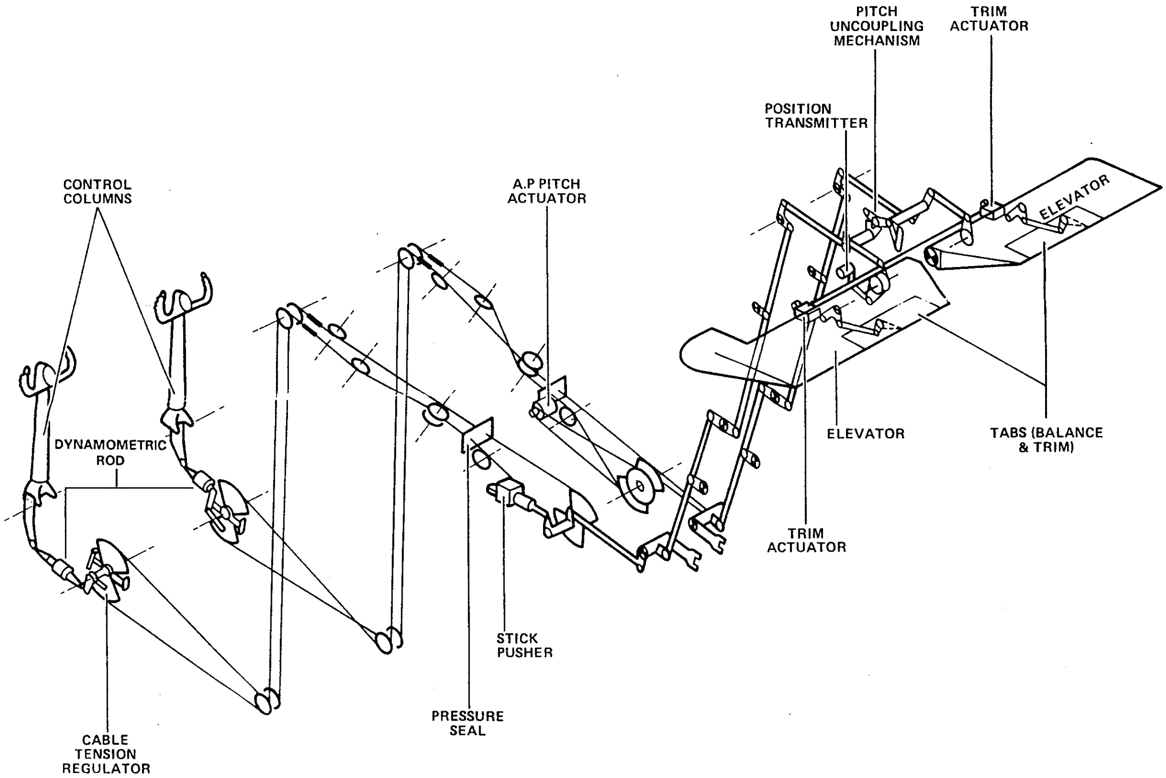

Figure 3

Schematic diagram of elevator control system

Pitch trim

The elevator trim tabs are linked mechanically to their associated elevator. When the elevator moves, they move in the opposite direction. For every 1º of elevator movement, its tab is adjusted 0.5º from its null, or neutral, position.

The null position of the pitch trim tabs can be further adjusted through actuation of the electrical pitch trim system, to offset any residual control force and reduce the elevator hinge moment. The tabs can be driven automatically by the autopilot system or manually by either pilot over a normal range of -5º (nose-up) to +1.5º (nose-down). A microswitch should prevent the tabs moving beyond +1.5º (+/-0.1º) under normal control.

Footnote

[5] 52 daN equates to approximately 53 kgf.

Each control wheel has a pair of pitch trim rocker switches to allow either pilot to electrically command the trim tabs up or down, under normal control. A further switch on the central console commands the tabs to move using standby control, which increases the range of movement of the trim tabs null position to +1.75º (+/-0 1º) (nose-down).

Actuation of the pitch trim for more than one second, manually or via the autopilot, generates an aural warning. This has a '*whooler*' sound intended to alert the pilots to prolonged movement of the pitch trim system. The achieved trim tab (null) position is shown on a pitch trim position indicator on the main instrument panel, with markings between -5º (nose-up) and +1.5º (nose-down).

Higher up the main instrument panel there is a display for AFCS messages. A PITCH MISTRIM message will illuminate if the autopilot operates the pitch trim and a pre-determined torque level is detected by the autopilot pitch servomotor. This can occur if the trim tabs reach the extent of travel or if an actuator jams, indicating the aircraft will be out of trim when the autopilot is disengaged.

Autopilot disengagement

Either pilot can manually disengage the autopilot via a button on their control yoke or via an AP pushbutton on the flight guidance control panel. It will also disengage if a manual pitch trim input is made (using the normal or standby control switches), if the stall warning activates or if either pilot exerts a pitch control input in excess of 10 daN (nose-up or nose-down).

A PITCH MISTRIM message is not directly associated with autopilot disengagement but it does indicate the autopilot pitch servomotor is experiencing a certain load. If the load increases further, it could lead to elevator movement which is inconsistent with the command from the autopilot. In this case, the autopilot will be disengaged by its internal monitoring circuitry.

Icing protection

The ATR-72-212A is certified for flight in icing conditions and is equipped with an illuminated Ice Evidence Probe (IEP), an ice detector, and electric and pneumatic systems to anti-ice and/or de-ice windshields, probes, engine intakes, propellers and the leading edges of the wing and horizontal stabiliser. When ice is detected by the detector, an ICING light illuminates on the main instrument panel to alert the crew.

For flight in icing conditions, but with no ice detected, the manufacturer's Flight Crew Operating Manual (FCOM) states the electrical anti-icing systems are to be switched on. This action also illuminates an ICING AOA pushbutton, positioned close to the ICING light, indicating that the angle of attack for stall warning and the angle of attack for stick pusher activation have been reduced. The FCOM then states the minimum manoeuvre / operating speeds defined for '*normal (no icing) conditions MUST BE INCREASED'.* The increased speeds are referred to as '*MINIMUM ICING SPEEDS'* and specific speeds for given aircraft weights are provided.

When the amber ICING light illuminates, or if ice is seen to accrete on the IEP, the FCOM states that the pneumatic de-icing systems are also to be switched on. Once clear of icing conditions and after the electrical anti-icing systems are switched off, the ICING AOA push button can be pressed to extinguish the light, provided the crew first make a visual check that the aircraft is free of ice. The safety speeds can then be reduced to '*normal*'.

Engineering actions

No faults were found during post-flight engineering checks of the aircraft's elevators and pitch trim tabs and no evidence of de-icing fluid residue was seen. After the aircraft had returned to service for 13 days, another commander, flying with the same co-pilot, thought he needed to apply less aft pressure to the control column during takeoff than he expected. The elevator control and pitch trim systems were checked but no discrepancies were evident, so a flight test was performed to check the pitch trim tab null, or neutral, position. It was found to be set within the manufacturer's required tolerances and the aircraft was assessed serviceable.

During the investigation it was evident the elevator trim tab was recorded as having run to +1.76º in normal control, whereas a microswitch should have limited it to +1.5º. Tests indicated that this was likely to have been caused by failure of the microswitch within the left trim tab actuator. Thus, during the incident, the pitch trim system assisted the pilot to a greater extent than would be expected under normal control; ie to the extent that could have been achieved if the pilot had used the standby trim switch on the central console.

Weight and balance

The aircraft operator is aware that small changes in CG can affect the pitch trim setting and that it is important to ensure aircraft loading for each flight accords with the prepared load sheet. For this reason, the crew checked the correct number of passengers were seated in each of three designated blocks of seat-rows. However, this check does not break down the number of females, males and children in each block. Different nominal weights are assigned to each of these groups and this can lead to slight differences between the calculated CG and the actual CG if the groups are not distributed uniformly within a block. To allow for this, the CG limits on the operator's load sheets are more limiting than the regulated limits. Consequently the operator accepts that in some cases pilots may detect a slight variation in the amount of effort required for aircraft rotation while taking off. Tables are used by crew to assess which pitch trim setting to use for takeoff at a specific mass and CG index.

For the departure from Guernsey the aircraft had a calculated takeoff mass of 18,393 kg and for the departure from Manchester it was 19,024 kg, with a regulated takeoff mass of 22,800 kg for both flights. The CG index on the incident flight was calculated at 26% of the Mean Aerodynamic Chord (MAC), almost midway between the forward and aft limits, while on the previous flight it was at 29.5%, approximately two-thirds of the way towards the aft limit. Before departure from Manchester, the crew confirmed the load sheet accurately recorded the baggage, cargo and fuel onboard, and cross-checked passenger seating in the manner previously mentioned.

Other aircraft

Aircraft handling companies at Manchester stated that all other commercial aircraft which departed on the morning of 4 March 2016 sought de-icing/anti-icing before start-up. The de-icing providers had difficulty coping with the demand for their services and some flights were delayed while others were subsequently cancelled.

Guidance material

De-icing/anti-icing requirements

The FCOM states:

> *'Atmospheric icing conditions exist when OAT on ground and for take-off is at or below 5°C or when TAT in flight is at or below 7°C and visible moisture in the air in any form is present (such as clouds, fog with visibility of one mile or less, rain, snow sleet and ice crystals).'*

and:

> *'Ground icing conditions exist when the OAT is at or below 5°C when operating on ramps, taxiways and runways where surface snow, standing water or slush is present.'*

It also states that even small quantities of ice accretion '*which may be difficult to detect visually*' can detrimentally affect aerodynamic efficiency of an '*airfoil*'. A cautionary note adds, '*Wing, tailplane, vertical and horizontal stabilizers, all control surfaces and flaps should be clear of snow, frost and ice before take off.*' Additionally there is a statement that '*elevator hinge moment may be affected by external conditions*' and that '*from experience, the most likely cause appears to be take off with ice remaining on the tail plane*'.

The manufacturer and the operator further define freezing conditions as existing when the air temperature is less than 3ºC and visible moisture in any form is present. In Part A of the Operator's Manual (OM), it states;

> *'Aeroplane commanders are to ensure that anti and de-icing operations appropriate to the conditions are carried out on the ground before departure, and that pre-flight inspection indicates that all remaining deposits and hoar frost, ice and snow have been removed before any attempt is made to take off.'*

and it includes the following definitions:

> '***Contamination*** *in this context, is understood as being all forms of frozen or semi-frozen moisture, such as frost, snow, slush or ice.*
>
> ***Contamination check*** *a check of aircraft for contamination to establish the need for de-icing.*

Anti-Icing *Precautionary procedure which provides protection against the formation of frost or ice and accumulation of snow or slush on treated surfaces of the aeroplane for a limited period of time (holdover time).*

De-Icing *Procedure by which frost, ice, slush or snow is removed from an aeroplane in order to provide clear surfaces.*

De-Icing/Anti-Icing *Combination of the procedures 'de-icing' and 'anti-icing'. It may be performed in either one or two steps.'*

Part A in the OM also mentions that, in rain or high humidity conditions, water may form into ice or frost on the surface of an aircraft wing that has been cold soaked below 0ºC.

Thickened fluids

Part A in the OM states that, following application of thickened anti-icing fluid[6] to an aircraft, '*maintenance action stipulated by the manufacturer should be conducted to detect and remove residues within three days*.' This is because some fluid can dry-out in aerodynamically quiet areas and later re-hydrate when the humidity increases. The resultant gel can reduce lift and increase drag or cause flight control restriction if it freezes. Regular inspections and cleaning are recommended[7] and the manufacturer had issued Service Letter No. ATR72-30-6006 which advises when and how this should be done. The Service Letter recommends, when thickened fluids are used, there should be a weekly inspection programme. This aircraft had been treated with thickened fluid once in that winter period, four days before the flight, but no residue inspection was carried out. However, the engineer who inspected the aircraft after the flight saw no evidence of residue on the tailplane.

For several years, the engineering requirement had been to check for residues after an airframe had received 10 applications of thickened fluid. This inspection regime was regarded as appropriate by the operator, because it seldom needed to use thickened fluids, but was at odds with the requirement in Part A of the OM for an inspection within three days of thickened fluid application.

Training

Licensing training

European flight crew licensing regulations require an understanding of the meteorological conditions affecting ice formation to be demonstrated, before pilots gain a commercial flight crew licence. The training syllabus for such licences also encompasses ground de-icing procedures. This includes types of de-icing fluid and how they should be used to ensure an aircraft's aerodynamic surfaces are clear of contamination for takeoff.

Footnote

6 Type II and Type IV fluids are referred to as thickened fluids and are in common use. They have a higher viscosity than Type I fluid, due to the addition of a pseudo-plastic thickening agent.

7 See UK Aeronautical Information Circular 88/2014, '*Recommendations for De-icing/Anti-icing of Aircraft on the Ground'* and Transport Canada publication TP 14052 'Guidelines *for Aircraft Ground – Icing Operations'*.

The ATR 42 and ATR 72 are aircraft variants. Thus, pilots' licences are endorsed with an ATR42/72 type rating on completion of type rating training, and differences courses must be completed when transitioning between the two variants. Each Approved Training Organisation (ATO) must prepare a syllabus for type rating training, in accordance with EASA's flight crew licensing requirements, and include any Training Areas of Special Emphasis (TASE) from the EASA Operational Suitability Data (OSD) report for the type. The TASE for ATR42/72 initial and differences training includes:

> *'Ice detection and management systems and displays*
>
> - *Knowledge of all ice detection including APM[8] systems and management of ice protection and prevention, procedural skills managing the consequences of icing;*
> - *Ground icing and effect of improper de-icing on different structural components and flight controls (eleva*tor) '

The pilots had completed type rating training for the ATR 42/72 at the same ATO. The ATO's training manual makes no specific mention of ground icing and the effect of improper de-icing but trainees were referred to a publication produced by the manufacturer, entitled '*Cold Weather Operations'*. This illustrated booklet includes meteorological notes about ice formation and recognition, as well as detailed procedures for ATR ground de-icing and anti-icing, aimed at ensuring clean aerodynamic surfaces for takeoff. The type's de-icing and anti-icing systems are also described in the booklet, along with the associated procedures and appropriate performance considerations for operation in snow and ice.

Operator's training

The operator is required to specify in its OM details of crew conversion training and recurrent training needed to comply with procedures for despatch and flight in icing conditions[9]. Pilot conversion training includes Line Flying Under Supervision (LIFUS), for which Part D in the OM includes a syllabus of topics that must be covered. Ground de-icing procedures are covered in this manner, by way of discussion if necessary.

Part D in the OM also states pilots should receive annual recurrent ground training and that this should include aircraft de-icing/anti-icing procedures and requirements. Consequently, the syllabus for recurrent proficiency checks and associated simulator training incorporates '*Winter Operations*' once per year.

Additionally, the operator distributes a '*Flying Staff Memo*' (FSM) to crews before each winter season, and both pilots had signed to acknowledge having read the FSM '*Winter Awareness 2015'*. This began by recommending that crew read the manufacturer's '*Cold Weather Operations'* booklet, with copies to be requested by any pilot who had not previously received one. The FSM re-iterated pertinent guidance from the OM concerning operation

Footnote

8 APM stands for Aircraft Performance Monitoring.
9 Refer to the Associated Means of Compliance for CAT.OP.MPA.255.

in icing conditions and referred pilots to some UK Aeronautical Information Circulars (AICs), including 88/2014 (‘*Recommendations for De-icing/Anti-icing of Aircraft on the Ground’*) and 98/1999 (‘*Turbo-Prop and Other Propeller Driven Aeroplanes: Icing-Induced Stalls*’). The operator stated that it had, in the past, circulated NASA-produced training material[10].

The operator’s expectation was that pilots would spend time on personal study of the recommended material to enhance their knowledge of winter operations. No classroom or computer-based training was provided and individuals’ knowledge levels were only tested within the scope of recurrent simulator/aircraft proficiency checks. When asked, neither pilot recalled having received or being referred to the manufacturer’s booklet.

Human factors

Crew Resource Management (CRM) training

The operator provides initial and recurrent CRM training to all crews and reinforces this during simulator exercises. The aim is to ensure good communication between crew members and to ensure all crew members work towards a common goal with an understanding of what their colleagues are doing. The Part B in the OM guides pilots to use a decision making process to manage abnormal occurrences. This is designed to ensure the crew work closely together to diagnose what has happened, then to generate options that suit the circumstances before deciding what to do. It is stressed that the decisions reached and action taken should constantly be reviewed so as to try and ensure that the best course of action has been taken or to modify it accordingly.

Crew experience

The commander joined this operator in January 2016. He was already in current flying practice on the ATR 42/72 and completed the operator’s conversion training before assuming command duties. This involved classroom, simulator and aircraft training and encompassed the operator’s CRM syllabus, as well as 20 sectors of LIFUS. Winter operations were discussed with a training captain who said the commander demonstrated good knowledge of de-icing/anti-icing procedures and was aware that the operator’s policy was to seek such treatment if there was any uncertainty.

The commander had gained most of his flying experience while based in Guernsey where, due to a mild climate, de-icing/anti-icing is seldom necessary and then usually only after overnight frost. Thus, although he had logged over 8,000 hrs, his experience of operating in freezing precipitation was not extensive.

This was the 30 year old co-pilot’s first airline position and his total flying experience was 920 hours, of which 620 had been flown on the ATR 72 with this operator. He had completed the operator’s CRM and winter operations training but he had no previous experience of flight in snow or of de-icing/anti-icing between flights.

Footnote

[10] NASA has an *Icing Branch* and the associated website includes material to help pilots train for flight in icing conditions, http://aircrafticing.grc.nasa.gov/

Cognitive biases

A pilot's decision making can be affected by various cognitive or heuristic biases[11] which can prevent their balanced consideration of all available evidence. Once an initial mental model of a situation is formed, a pilot can be prone to 'confirmation bias'. This can prevent him or her from accepting clear evidence that contradicts their initial understanding. Pilots are equally susceptible to 'optimism bias' which means they only envisage a positive outcome to a problem. It can be the subconscious result of overcoming previous difficulties and means that they tend to believe they are less prone to risk than others.

Previous similar events

Previous events, which shared some similarities with this incident, were reviewed during the investigation.

2003, ATR 72-212, France

In January 2004, France's Bureau d'Enquêtes et d'Analyses (BEA) published a bulletin of air transport incidents, including analysis of a serious incident involving an ATR 72-212 at Paris the previous year[12]. The aircraft was taxiing for departure without having de-iced/anti-iced when it was affected by a snow shower for approximately five minutes. It stopped snowing approximately four minutes before takeoff and the pilots decided the snow was melting and had not settled on the aircraft.

After taking off into icing conditions, a PITCH MISTRIM message was presented at FL 100. A large amount of pilot effort was needed in the nose-down sense to level the aircraft and the pitch trim indicator ran to the fully nose-down position. The aircraft returned to the airfield of departure, with the pilot having to exert excessive nose-down effort on the control column until the airspeed reduced below 130 kt on final approach. An immediate inspection found approximately 0.5 cm of rime ice on the upper surface of the horizontal tailplane and the elevator. It was calculated that this could have added 120 kg to the tailplane and, assuming no ice had formed elsewhere on the airframe, this could potentially have moved the CG aft by 5%[13].

The BEA reported that the pitch trim began to move nose-down as the aircraft started to rotate and was fully nose-down before the flaps were retracted. It stayed in this position until speed was reduced on final approach. The ice on the upper surface of the horizontal tailplane and elevator modified the airflow boundary layer causing the elevator's nose-down pitching force to reduce. The trim tab compensated until it reached full-travel and the pilot then had to exert continuous effort in the nose-down sense to maintain the desired attitude.

Footnote

[11] Academics and psychologists have identified numerous biases which affect human behaviour and actions. Captain Shem Malmquist FRAeS, summarised several biases which may have contributed to aircraft accidents in an internet article written in April 2014 https://airlinesafety.wordpress.com/2014/04/21/the-role-of-cognitive-bias-in-aircraft-accidents/

[12] The BEA bulletin provided anonymity to reporters and consequently the registration and date off the incident are not available but the report can be studied at https://www.bea.aero/fileadmin/documents/ita/pdf/ita.special.givrage.en.pdf

[13] If the CG of G-COBO had moved 5% aft it would have remained within the CG envelope.

VP-BYZ, 2 April 2012, ATR 72-201, Russia[14]

The aircraft was not de-iced/anti-iced and the upper wing and stabiliser surfaces were not inspected. There were sleet showers at the airfield, the air temperature was +2ºC and other departing aircraft did seek de-ice/anti-ice treatment. After takeoff, the pilot used extensive nose-down trim and then, after flap retraction, the aircraft stalled and crashed. An investigation into this fatal crash by the State accident investigation authority concluded the stall was caused by frozen contaminant on the aerodynamic surfaces, due to lack of de-ice/anti-ice treatment.

OY-JRY, 9 November 2007, Norway[15]

This ATR 42 became airborne, without pilot input, before reaching rotation speed. The pilots were unable to prevent the aircraft from pitching-up and the airspeed reducing, with the result that the stick shaker operated. Eventually, control was regained before the aircraft stalled. Prior to takeoff the aircraft had been de-iced and anti-iced but the manufacturer assessed that less fluid was used for anti-icing than usual and that the aircraft's behaviour indicated that the horizontal stabiliser had been '*improperly*' treated with fluid.

Manufacturer's analysis

The manufacturer analysed the FDR data and concluded that the aircraft's abnormal nose-up pitching tendency was consistent with the aerodynamic effects of upper surface icing on the horizontal tailplane. The manufacturer's explanation is summarised as:

Any aerodynamic load on the elevators will induce an elevator hinge moment which has to be balanced by applying an effort on the elevator through the control column or through the autopilot pitch actuator. In normal flight conditions, with a nominal aircraft and no ice contamination, the elevators will be deflected to a certain position to balance the aircraft.

If a downward aerodynamic force is applied to the elevator, the elevator deflection can be maintained by applying effort through the control column or through the autopilot pitch actuator. This effort can be cancelled through a pitch trim input which deflects the elevator trim tab downwards and creates an upward aerodynamic moment of equal magnitude to the downward moment on the elevator. In this condition, the elevator hinge moment resulting from elevator and tab aerodynamic forces is null and there is no residual effort on the control column or on the autopilot actuator (Figure 4).

Footnote

[14] A copy of the Russian State accident report in English is available at https://www.bea.aero/docspa/2012/vp-z120402/pdf/vp-z120402.pdf

[15] See Accident Investigation Board Norway Report SL 2013/03 at https://www.aibn.no/Luftfart/Rapporter/2013-03-eng

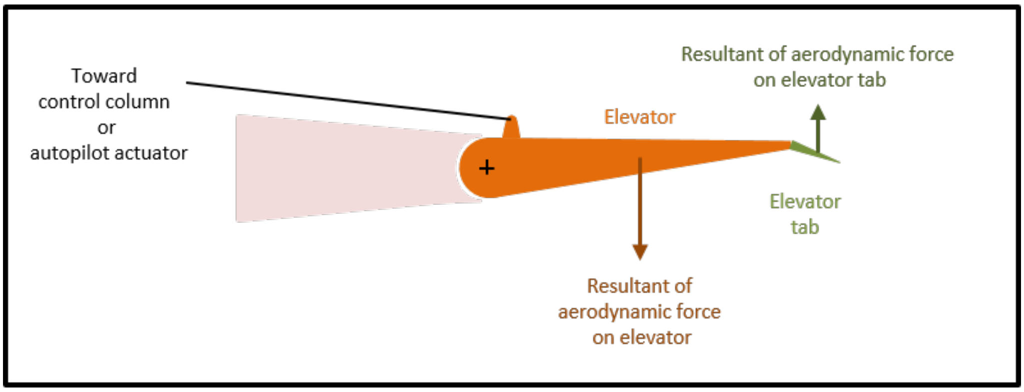

Figure 4

Manufacturer's diagram to illustrate aerodynamic forces in normal flight with pitch trim set

Comparison was made with a similar flight condition, with the elevator deflected the same way, but with ice contamination to the upper surface of the horizontal tailplane, which may also extend over the upper surface of the elevator (and possibly over the elevator tab as well). Numerical aerodynamic simulation, using a two-dimensional cross-section of the horizontal tailplane and elevator assembly, showed that a 5 mm layer of ice on the upper surface thickens the airflow boundary layer. The pressure distribution on the lower surface is virtually unaffected by this but the pressure on the upper surface is reduced. Thus, for a given deflection of the elevator, less downward aerodynamic force will result (Figure 5).

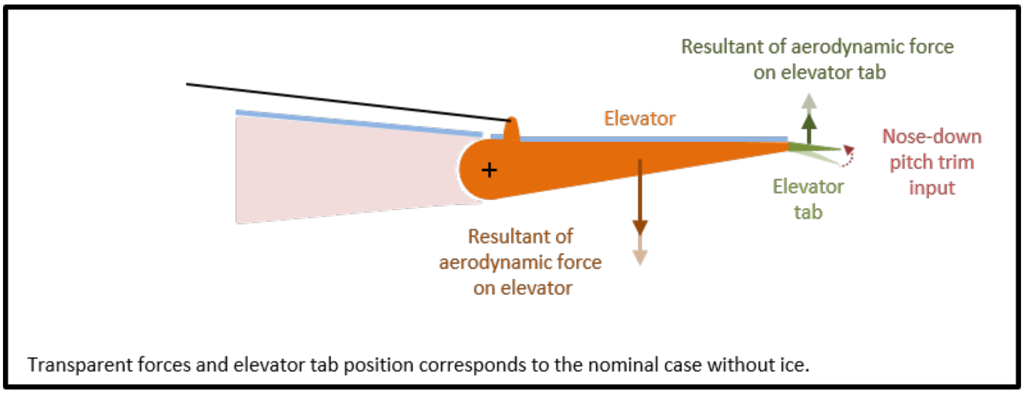

Figure 5

Manufacturer's diagram to illustrate aerodynamic forces with an ice-contaminated upper surface and the pitch trim set to compensate

To compensate, nose-down effort has to be applied through the control column or through the autopilot pitch actuator. This effort can be alleviated with a nose-down pitch trim input, which moves the elevator tab upwards, until autopilot pitch actuator or pitch control column efforts are cancelled, or until the elevator trim reaches its stop.

Simulated icing profile

The manufacturer indicated this event had similarities to the 2003 event at Paris. Following that event, a simulator profile was developed so pilots can experience the effect which ice contamination may cause after takeoff, if the horizontal tailplane has been '*badly de-iced*'. This simulation induces the pitch trim to run to the fully nose-down stop (elevator tab up) before the PITCH MISTRIM message appears on the ADU. As speed increases further, the pilot has to exert progressively more effort in the nose-down sense to maintain the desired attitude.

This profile is incorporated in the ATR 42/72 simulators used by the manufacturer's own ATO and forms part of the manufacturer's approved conversion course. It illustrates one potential repercussion of improper ground de-icing, in accordance with the TASE in the OSD. Pilots are taught to respond by slowing the aircraft to a safe speed, which reduces the nose-down effort needed, and then to descend and land. The profile is not incorporated in all ATR 42/72 simulators worldwide.

Analysis

De-icing/anti-icing

When flying the approach into Manchester in icing conditions, the crew saw little ice accreting on the aircraft. This may have led them to assume ice accretion was unlikely while on the ground. Also, the commander's declaration of the temperature being a little above 0ºC may have reinforced this belief. He told the co-pilot the snow did not appear to be "STICKING" and, before parking, he considered they could probably "GET AWAY WITHOUT DE-ICING".

The commander advised the co-pilot he would "HAVE A GOOD LOOK" during his external inspection but his early pronouncement may have made both pilots susceptible to 'confirmation bias'. From then on, they may have subconsciously tried to make the evidence available to them accord to the commander's original assessment. This was apparent when the commander saw snow on other aircraft and declared it must have accumulated overnight.

Neither pilot seemed to consider the possibility there might be unseen ice on the upper surfaces after landing, nor that the skin temperature would probably have been colder than 0ºC. The large quantity of fuel that was added might have caused the skin temperature of the wings to warm above 0ºC but the tailplane temperature would have remained at or below 0ºC.

Photographs taken on the ground at Manchester showed snow lying on the aircraft but the commander assessed it was not "sticking" and considered that any which remained would "blow off" during takeoff. He could not see all the upper surfaces and did not arrange a '*contamination check*'. However, even without such a check, it was apparent both '*atmospheric icing conditions*' and '*freezing conditions*' existed because the temperature was less than 3ºC, with visible moisture present. These were conditions in which the guidance is to de-ice/anti-ice an aircraft completely and check it afterwards. If the co-pilot had had previous experience of winter operations, he might have questioned the commander's decision not to de-ice/anti-ice.

The decision to depart without being certain the aircraft was free of ice, suggests the crew were affected by 'optimism bias' and only foresaw a positive outcome ie any snow 'blowing off'.

Nose-up pitch

The calculated CG on this flight was further forward than on the previous flight, on which the trim system had operated within the normal range. Therefore, the aircraft's nose-up pitching moment was not due to inappropriate loading. Also, no faults were found after the flight, indicating that there was no control malfunction or technical problem.

Thickened de-icing fluid had been applied to the aircraft four days before the flight. This fluid can dry out in aerodynamically quiet areas and subsequently re-hydrate and cause control restrictions. However, no evidence of fluid residue was found on the external surfaces of the tailplane after the incident and the problem experienced was that increasing effort was needed to push the nose down as the speed increased, rather than there being a control restriction. So the previous application of thickened fluid was not a factor in this serious incident.

The manufacturer's analysis was that the aircraft behaved in a manner consistent with the presence of ice contamination on the upper surface of the horizontal tailplane and the trim tab ran to the end of its nose-down travel while compensating.

It was concluded that the autopilot was disengaged by its internal monitoring circuitry, as a result of the load experienced by the autopilot pitch servomotor, or a manual pitch input.

Once the trim tab reached the stop, the commander had to apply an additional nose-down input on the control column to maintain the desired aircraft attitude. After levelling, he decided he would not be able to maintain the effort needed on the controls for the duration of the cruise, and made a decision to divert to EMA. The co-pilot accepted this because he believed the weather was good at EMA and both of them were familiar with this airport. As the flight progressed the crew realised that icing was the likely cause of their problems.

In the previous incident at Paris in 2003, when the tailplane had not been de-iced, it was possible to estimate the weight of ice that formed and the effect that weight would have had to the CG. It was not possible to estimate the weight of ice that formed on this flight but had it been similar to that in the 2003 incident, the aircraft's CG would have stayed within the CG envelope.

The control problem subsequently dissipated as the aircraft descended into warmer air, suggesting that ice on the tail detached or melted. Hence, no ice was found on the aircraft following its normal landing.

The evidence indicated the horizontal tailplane was affected by ice which formed while the aircraft was on the ground in freezing conditions and was not de-iced/anti-iced. The outcome was uneventful but there is evidence that failure to de-ice/anti-ice adequately could lead to a more serious outcome in certain conditions.

Training

The crew was based in Guernsey, where snow seldom falls and de-icing is seldom necessary. However, the pilots had been trained for conditions like those at Manchester, so a contributory factor in deciding not to de-ice may have been that their training was less effective than it might have been.

Their conversion course syllabus specifically covered ground de-icing and the effect of improper aircraft treatment but this may not have been emphasised sufficiently during the training. Neither pilot had read the manufacturer's '*Cold Weather Operations*' booklet, even though this was referred to during the conversion course and circulated by the operator.

Ground de-icing procedures had been discussed with the commander as part of his recent conversion training and both pilots had acknowledged the operator's extant FSM '*Winter Awareness* 2015'. The operator's recurrent winter training for its pilots relied on their self-study of this FSM and the reference material mentioned, in order to update their understanding of guidance in the OM and elsewhere. No recurrent classroom-based training was provided and the knowledge amassed from this self-study was not tested, other than through participation in recurrent simulator checks, which included a winter operations element.

The manufacturer's ATO includes a scenario for poor de-icing of the tailplane in its conversion course but not all ATR simulators incorporate this profile, which only represents one potential consequence of inadequate ground de-icing.

CRM issues

The co-pilot appears to have been excluded from some of the commander's decision making process. After the loadsheet had been checked for any CG issues, there was no further discussion of possible alternative reasons for the problem. No options were generated before actions were taken and there was no ongoing review of what had happened and what could be done. This was the co-pilot's first diversion during commercial operations and his workload in support of the commander felt very high.

Safety actions

> The ATO responsible for the pilot's type conversion training is adjusting its conversion course to align with the EASA Operational Suitability Data report. This is being achieved by incorporating the manufacturer's simulator profile for a badly de-iced tailplane.

The operator has enhanced its winter awareness training for pilots by purchasing a computer-based training module. All pilots will complete this before each winter season and their knowledge will be tested as part of the process.

The operator's conversion courses are being extended through the inclusion of a ground training day, with a training captain, prior to the start of Line Flying Under Supervision. This is to ensure time is spent discussing, in detail, technical issues relating to line operations. Winter operations and de-icing/anti-icing will be among the topics covered.

The operator provided the co-pilot with additional training before he was allowed to resume line flying duties.

The operator is reviewing its requirements for aircraft inspections following use of thickened de-icing fluids.

The operator intends to provide better guidance for the aftermath of a serious incident by making changes to its Operations Manual (Part A). This is likely to include a recommendation for a group debrief to take place as a matter of course, so the crew can discuss what happened and what they have learnt.

The manufacturer has stated it will contact all operators prior to the start of the next European winter, to promote awareness of the circumstances which led to this serious incident.

Conclusion

The investigation concluded that ice contamination affected the tailplane and caused pitch control difficulty after the aircraft rotated, on departure. The evidence indicated that this would have been avoided if the aircraft had been de-iced/anti-iced and then inspected carefully before flight.

The crew considered, before parking, that de-icing was probably going to be unnecessary. It may then have become difficult for them to change their assessment because of 'confirmation bias', even though they were in freezing conditions and snow was falling. A contributory factor may have been the crew's lack of experience operating aircraft in such conditions.

The commander optimistically thought that lying snow would blow off the aircraft before rotation; an assessment that was flawed and a possible reflection on the training the pilots had received for such winter conditions. The operator has recognised that recurrent winter training for pilots may have been over-reliant on self-study and has taken remedial action.