SERIOUS INCIDENT

Aircraft Type and Registration:	ATR 72-212 A, 500 Version, G-COBO
No & Type of Engines:	2 Pratt & Whitney Canada PW127M turboprop engines
Year of Manufacture:	2009 (Serial no: 0852)
Date & Time (UTC):	21 December 2016 at 1733 hrs
Location:	5 nm north of reporting point ORTAC
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 61
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	6,040 hours (of which 1,401 were on type) Last 90 days - 152 hours Last 28 days - 51 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was on a scheduled flight from Guernsey to Manchester. While climbing to a cruising level of FL170 the aircraft began to accrue airframe icing. The crew were presented with a DEGRADED PERF and an INCREASE SPEED caution. The appropriate checklists were not fully actioned and the correct climb speed was not maintained because the crew focused on climbing the aircraft clear of the cloud and icing conditions. The aircraft experienced an in-flight upset whilst levelling at FL130 (as requested by the pilots) and commencing a turn instructed by ATC. The aircraft was subsequently recovered to controlled flight, after which the crew elected to return to Guernsey. There were no injuries.

The loss of control resulted from airframe icing accrued during the climb and incomplete use of the appropriate checklists, leading to selection of an unsuitable speed followed by the use of the LNAV mode of the flight director to initiate a turn.

The operator and manufacturer took several safety actions, including an amendment to the aircraft's checklist and operating manuals.

History of the flight

The flight crew reported for a four-sector duty period involving flights from Guernsey to Bristol and return, and Guernsey to Manchester and return. The first two sectors were without incident.

During the turnaround at Guernsey, for the flight to Manchester, the crew had noted that a frontal weather system would be encountered during the flight over the English Channel, with associated cloud, precipitation and moderate icing conditions.

The aircraft took off at 1718 hrs with a takeoff mass of 21,937 kg. The co-pilot, who had recently qualified on type, was undergoing line training under the supervision of the commander, who was a line training captain. The commander was PF for this sector with the co-pilot PM.

Soon after takeoff HI[GH] bank[1] was selected, the autopilot engaged and the aircraft was cleared to climb to FL170. As the aircraft climbed at 170 kt on a northerly track it encountered the weather front and began to accrue airframe icing. Anti-icing systems were activated as the aircraft climbed through 5,300 ft, followed by de-icing systems when actual airframe icing was encountered as the aircraft climbed through FL090 (Figure 1). The aircraft was flown at or above the Minimum Icing Speed (this speed, known as the 'red bug' speed was 165 kt for the aircraft mass at the time). The crew conducted a review of the Quick Reference Handbook (QRH) 'SEVERE ICING'[2] procedure's memory items in the checklist (but not the notes on *Detection*) in case it became necessary to perform it later.

As the aircraft passed about FL110, DEGRADED PERF[3][ormance] and INCREASE SPEED[4] caution messages illuminated. Upon switching the external icing light to ON, to check the extent of the ice on the ice evidence probe, the commander commented "…WE'VE GOT A BIT [of icing] HAVEN'T WE". The commander made a reference to the QRH checklist for the caution, but it was not actioned; however, he did initially increase the target IAS to 175 kt (red bug +10 kt), during which the rate of climb reduced from 420 ft/min to about 25 ft/min and the caution extinguished.

The commander noted that the aircraft was "NOT CLIMBING VERY WELL" and acknowledged that the QRH procedure required an increase in speed to red bug +10 kt but he considered that, as the aircraft was at that moment flying level, it was safe to return the target IAS to 165 kt. This resulted in an increase in the aircraft's pitch attitude and a climb to the selected level. As he adjusted the speed he commented "…JUST SEE IF WE CAN GET ABOVE [THE CLOUDS]." The autopilot remained engaged in the IAS and heading capture modes.

About one minute later the INCREASE SPEED caution message illuminated again. At this point the commander commented "WE ARE PICKING UP QUITE A BIT OF ICE ACTUALLY", later adding that it was the first time he had encountered this [deterioration in climb performance]. At this point the aircraft's rate of climb was about 200 ft/min. The target IAS was again increased to 175 kt. To achieve this the aircraft initially descended, achieving a maximum rate of -540 ft min and descending almost to FL120, where the aircraft levelled off momentarily. The target IAS was then reduced back to 165 kt, which initiated a further climb.

Footnote

1 HI bank allows turns with up to 27° angle of bank, while LO[W] bank allows turns with up to 15° angle of bank and is the default setting in HEADING mode unless HI bank is selected.
2 See *Manufacturer's QRH procedures* section below for the 'SEVERE ICING' procedure.
3 A steady amber light with single audio chime and a master caution on the attention getter.
4 An amber flashing light with audio chime and a master caution on the attention getter. See *Manufacturer's QRH procedures* section below for the actions to be taken in the event these cautions illuminate.

As it was apparent that the aircraft had insufficient performance to reach its cruising level of FL170, the crew made a request to ATC to level off at FL130 so the aircraft could accelerate, before resuming the climb. ATC approved this and instructed the crew to proceed direct to reporting point NORRY, a change in heading of about 10°. This was achieved by re-programming of the Multifunction Control Display Unit and selecting LNAV[5]. The aircraft experienced an in-flight upset as it levelled off and turned towards NORRY. The autopilot had been engaged throughout the climb until that moment.

Recorded data[6] showed that at the point of the upset the aircraft initially rolled left to 32° the autopilot disengaged, before rolling right to 38°. It then rolled left again, reaching attitudes of 73° in roll and 16° nose-down in pitch.

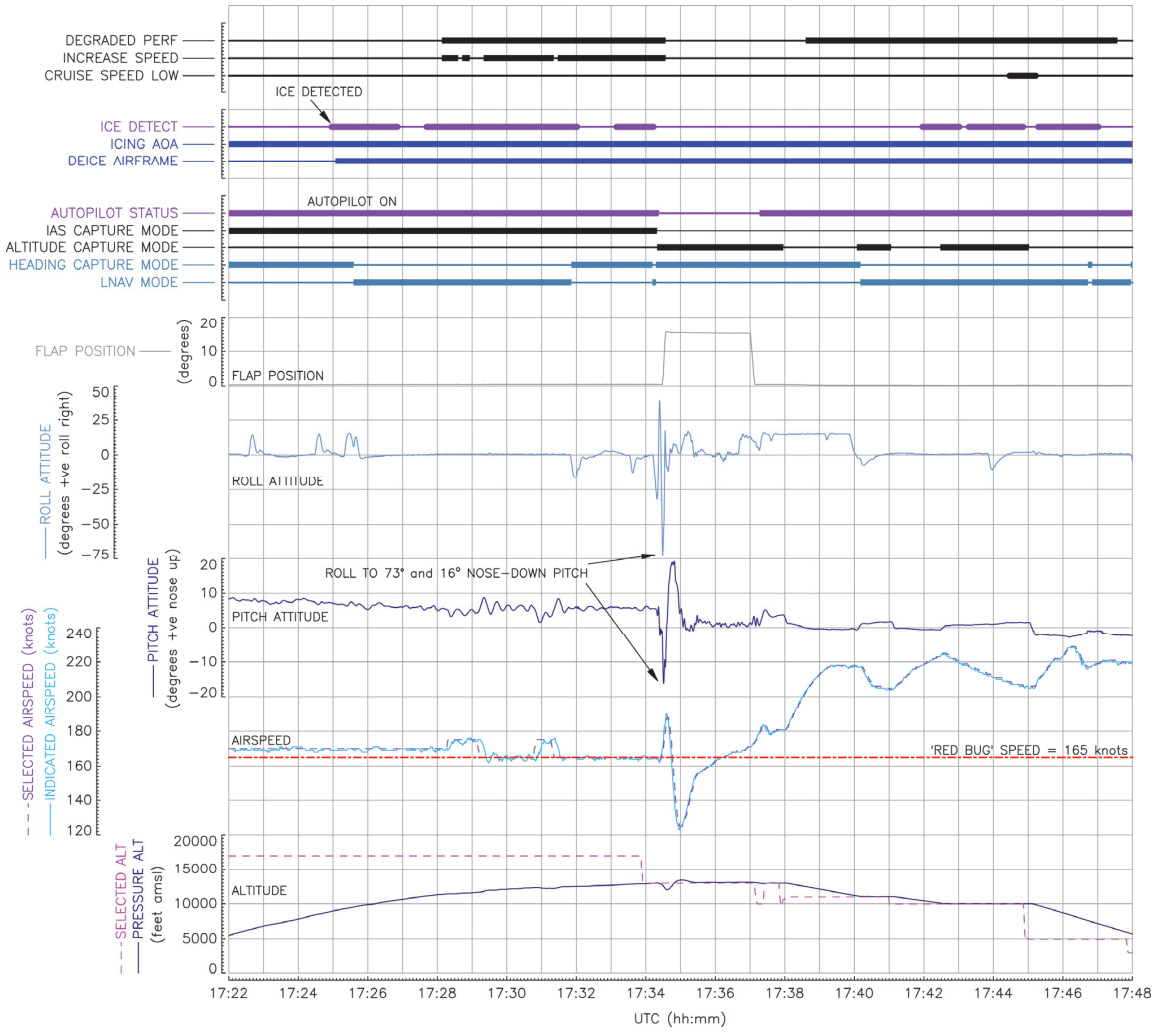

Figure 1

Salient data from the FDR and DAR

Footnote

5 Lateral Navigation. Selecting LNAV from heading mode deactivates the HI bank protection, if it had been selected.

6 Although not recorded on the FDR, the manufacture confirmed that the stick shaker would have activated during the event (resulting in the autopilot disengagement), and also the stick pusher. The crew had no recollection of these inputs, and neither of these was discussed or audible on the CVR.

Upon the commander's instructions the co-pilot actioned the upset recovery items when instructed to do so by the commander. These included extending the flaps to Flap 15[7]. The commander recovered the aircraft to controlled flight at FL130, having descended through about 1,000 ft. During the recovery, pitch increased from nose-down to a nose-up attitude of 19°, before reducing to a normal value. During these pitch and roll oscillations, the IAS varied between 190 kt and 123 kt.

During the manoeuvres the co-pilot transmitted a MAYDAY call and, once control had been regained and the situation assessed, the decision was made to return to Guernsey. The aircraft subsequently landed at Guernsey without further incident and no injuries were reported.

The aircraft was withdrawn from service pending a maintenance check. Functional tests were conducted on the aircraft's ice detection, anti-ice and de-ice systems as well as the Aircraft Performance Monitoring (APM) system. No abnormalities were found, but analysis of the FDR data indicated that, during the recovery manoeuvre, the extended flaps sustained an overspeed of 5 kt. The aircraft was subsequently returned to service.

Meteorological information

The vertical cross section and significant weather forecast charts issued to the crew for the flight to Manchester indicated that moderate icing was expected over the English Channel and southern England from below FL100 to FL190.

A summary of an aftercast produced by the Met Office included the comment that observed data verified there was an active frontal zone affecting southern England and the English Channel at the time of the incident. The aircraft would have flown through thick layers of frontal cloud during the climb, whose tops were at about FL190, which would have been expected to cause moderate icing. There was no evidence of cumulonimbus clouds or other data associated with severe icing.

Prolonged flight in moderate icing conditions could lead to an increasing amount of ice accretion that could result in severe ice accretion.

Aircraft technical information

Minimum manoeuvre speeds

Minimum manoeuvre/operating speeds are determined in order to provide sufficient margin above stall. They vary with icing conditions, mass, configuration and type of manoeuvre (HI or LO bank). They are defined by a minimum ratio to the appropriate stall speed or by V_2 when applicable. The minimum manoeuvre speed in icing conditions with HI bank selected is red bug + l0 kt.

Footnote

[7] With the flaps extended, the APM system does not generate data.

Aircraft Performance Monitoring

The aircraft was equipped with a Multi-Purpose Computer (MPC) which incorporated an Aircraft Performance Monitoring (APM) function. This was designed to monitor aircraft drag in icing conditions and alert the crew of a significant degradation of the aircraft performance, potentially associated with severe icing conditions. The APM also checked that the Minimum Severe Icing Speed[8] (MSIS) was respected.

The APM function was active in icing conditions (based on the status of the airframe de-icing system and ice detection, i.e. active when airframe anti icing was switched ON by the pilot or by automatic ice detection by the aircraft). It compared theoretical aircraft drag with actual in-flight drag, and MSIS with actual IAS. A DEGRADED PERF caution (a steady amber light with a single audio chime and a master caution on the attention getter) would illuminate when the actual drag was higher than the theoretical drag and the IAS greater than the MSIS. An INCREASE SPEED caution (an amber flashing light with audio chime and a master caution on the attention getter) would illuminate when actual drag was higher than theoretical one and IAS less than MSIS, within a threshold (Figure 2).

Figure 2

APM messages.
(Similar layout on left side of the cockpit)

Previous events

The previous day there had been an 'information' entry in the aircraft's technical log stating that the APM system had been giving spurious information. The system was subsequently checked and found serviceable.

The operator also provided the investigation with four additional reports in which flight crews believed APM cautions were spurious.

Operational ceiling

The extant regulation (CAT.POL.A.315) stated that an aircraft is deemed to have reached its operational ceiling when the rate of climb reduces to 300 ft/min.

Footnote

[8] The MSIS is Minimum Icing Speed+10 kt.

Effect of icing on performance

The manufacturer states, in its *Cold Weather Operations* publication, that the main effects of ice accretion are:

- A reduction of lift at a given angle of attack
- A reduction of maximum lift
- A reduction of maximum lift angle of attack
- Greater drag at a given angle of attack
- Greater drag at a given lift
- Best lift/drag ratio at a lower lift coefficient

Manufacturer's QRH

The aircraft manufacturer's QRH procedures for the cautions experienced by the crew were as follows:

DEGRADED PERF and INCREASE SPEED

DEGRADED PERF

Mainly appears in level flight after CRUISE SPEED LOW or in climb, to inform the crew that an abnormal drag increase induces a speed decrease or a loss of rate of climb

The most probable reason is an abnormal ice accretion

AIRFRAME DE-ICING ON.....CHECK
IAS > RED BUG + 10 KT.....MONITOR
AP (if engaged).....HOLD FIRMLY CONTROL WHEEL and DISENGAGE

■ **If SEVERE ICING conditions confirmed**
– or –
■ **If impossibility to maintain IAS > RED BUG + 10 KT in level flight**
– or –
■ **If abnormal aircraft handling feeling**

SEVERE ICING procedure (1.09).....APPLY

■ **If not**

SCHEDULED FLIGHT.....CONTINUE
ICING CONDITIONS and SPEED.....MONITOR

INCREASE SPEED

Appears after DEGRADED PERF to inform the crew that the drag is abnormally high and IAS is lower than RED BUG + 10 KT

■ **If abnormal conditions confirmed**

IMMEDIATELY PUSH THE STICK TO INCREASE SPEED
TO RECOVER MINIMUM IAS = RED BUG + 10 KT

SEVERE ICING procedure (1.09).....APPLY

Of note, the DEGRADED PERF checklist stated:

> *'The most probable reason is an abnormal ice accretion.'*

SEVERE ICING

SEVERE ICING

MINIMUM ICING SPEED ..... INCREASE by 10 kt
PWR MGT ..... MCT
CL 1 + 2 ..... MAX RPM
PL 1 + 2 ..... NOTCH
AP (if engaged) ..... FIRMLY HOLD CONTROL WHEEL and DISENGAGE
SEVERE ICING CONDITIONS ..... ESCAPE
ATC ..... NOTIFY

■ **If an unusual roll response or uncommanded roll control movement is observed :**

Push firmly on the control wheel
FLAPS ..... EXTEND 15

■ **If the flaps are extended, do not retract them until the airframe is clear of ice.**

■ **For the approach, If the aircraft is not clear of ice :**

GPWS ..... FLAP OVRD
STEEP SLOPE APPROACH (≥4.5°) ..... PROHIBITED
APP/LDG CONF ..... MAINTAIN FLAPS 15
APP SPEED ..... "REDUCED FLAPS 15 LDG icing speeds" + 5 kt
Multiply landing distance FLAPS 30 by 1.91.

DETECTION

Visual cue identifying severe icing is characterized by ice covering all or a substantial part of the unheated portion of either side window

and / or

Unexpected decrease in speed or rate of climb

and / or

The following secondary indications :

. Water splashing and streaming on the windshield
. Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice
. Accumulation of ice on the lower surface of the wing aft of the protected areas
. Accumulation of ice on propeller spinner farther aft than normally observed

The following weather conditions may be conducive to severe in-flight icing :

. Visible rain at temperatures close to 0°C ambient air temperature (SAT)
. Droplets that splash or splatter on impact at temperatures close to 0°C ambient air temperature (SAT)

Of note, the *Severe Icing* drill stated that:

> *'Unexpected decrease in speed or rate of climb' is one of the indicators of severe icing.'*

Flight crew training

The operator commented that, prior to this event, APM training was not included in the initial aircraft type rating but pilots were briefed on its use during follow-on line training using the manufacturer's *Cold Weather Operations* publication and its APM briefing package. The simulator used principally by the operator was not fitted with an APM, although it had been requested by several operators since 2013.

Other recent events

The Accident Investigation Board Norway (AIBN) investigated a similar event that occurred to an ATR 72-212A, registration OY-JZC, on 14 November 2016 while en route from Bergen to Ålesund in Norway[9]. The findings of this investigation have not been released at the time this AAIB Bulletin was published.

Analysis

The aircraft was climbed into a known area of frontal weather that was forecast to have moderate icing conditions. As the aircraft's altitude increased its performance decreased to a point where it had reached its operational ceiling due to the accretion of airframe icing. Although the DEGRADED PERF caution illuminated, the crew did not action the DEGRADED PERF check list or the SEVERE ICING procedure.

The forecast and aftercast icing conditions, and the visible extent of the icing encountered, were not entirely consistent. However, the poor climb performance was an indication to the crew of the severity of the ice accretion. Had the crew actioned the QRH procedure for the DEGRADED PERF they would have been directed to carry out the SEVERE ICING checklist. The crew had reviewed the memory items in the checklist, but not the notes on detection which listed '*Unexpected decrease in speed or rate of climb'* as being one of the indicators of severe icing.

The DEGRADED PERF checklist and SEVERE ICING memory procedure both required (among other things) that the speed be maintained at or above red bug +10 kt and that the autopilot be disconnected. The crew did not observe these actions, varying the speed instead between 165 kt (red bug) and 175 kt (red bug +10 kt). Consequently departure from controlled flight was more likely because the aircraft was flown slower than required. Also as the autopilot remained engaged, the crew would not have been aware of any handling indications of an imminent departure. With the controls in a dynamic condition, an extreme upset was more likely if the crew were not holding the controls firmly at that time.

The crew were focussed on climbing out of the icing conditions into VMC above the clouds, and in trying to achieve this, they had made speed selections which they knew were below that required by the DEGRADED PERF and SEVERE ICING checklists. An earlier level off or a descent would have been required, but this would have involved the

Footnote

[9] A summary on the AIBN's website can be found here: https://www.aibn.no/Aviation/Investigations/16-790

aircraft remaining in icing conditions, contrary to what the crew intended to achieve. High terrain was not a factor, and a descent, with the associated increase in IAS, would have avoided the occurrence.

Eventually, control of the aircraft was lost with extreme roll and pitch as a result of a combination of icing, an inappropriate speed, and a turn that was initiated by a change from HDG mode to LNAV which permitted a HI bank turn. The crew's actions enabled a recovery to normal flight and an uneventful landing at Guernsey.

There was evidence that pilots lacked confidence in the APM system, with technical log reports of spurious warnings including on the incident aircraft from the day before. This may have predisposed the commander to partially disregard the cautions and therefore not carry out the appropriate checklist appropriately. The APM system was subsequently checked and found serviceable.

The occurrence highlights that poor decisions are possible in stressful or otherwise high workload situations. In such circumstances, it may be necessary to abandon the immediate goal and pursue an alternative, safer course of action, even if that course of action is perceived as taking the aircraft further away from the desired state. In this case, the desired state was a climb out of icing conditions and thus a return to more normal performance, but the well-intentioned pursuit of the goal led directly to the upset.

Safety actions

Operator

The operator reviewed its ATR procedures and amended them to improve safeguards against similar occurrences. Flight crews were reminded of the required response to APM cautions, and the operator now replicates this incident, and APM messages, during pilots' flight simulator training. Several internal recommendations were made, addressing non-normal situation handling in general.

The following *FLYING STAFF INSTRUCTION – ATR* was issued on 28 December 2016, with an amendment to the ATR Operations Manual Part B, Section 2.4:

> *'2.4.16.2 Climb Speed*
>
> *Standard Climb Speed is 170 kts IAS or Red Bug + 10 kts, whichever is the higher, achieved using AFCS* [Automatic Flight Control System] *IAS mode.*
>
> *Climb speed may only be reduced below 170 knots if required for terrain clearance or mandatory ATC requirements. Under these circumstances the minimum IAS is White Bug + 10 kts in Normal Conditions and Red Bug + 10 kts in Icing Conditions.*
> *…*

If during climb at Standard Climb Speed the average rate of climb falls below 500 feet per minute, crews should request to stop climb at the next available level or advise ATC of the reduced climb capability. Speed must not be reduced to maintain a given rate of climb.'

The following memo was sent to all ATR pilots:

'APM / Reduced Performance

Crews are also reminded that Severe Icing may be encountered without the presence of the normally associated visual cues, and reduced rate of climb or cruise airspeed are sometimes the only indication of significant ice accretion. Whenever crews encounter or suspect severe icing, the full checklist at QRH page 1.09 [Severe Icing] *must be completed.*

…'

Aircraft manufacturer

The aircraft manufacturer stated that it is working to improve the APM to avoid the illumination of cautions that are perceived as spurious.

As a result of this occurrence and that investigated by the AIBN the manufacturer has amended the DEGRADED PERF and SEVERE ICING procedures.

The amended DEGRADED PERF procedure will state that the SEVERE ICING procedure should be actioned if the aircraft is unable to maintain a climb rate greater than 100 ft/min, when climbing at red bug +10 kt. The SEVERE ICING procedure will have fewer memory items and will state that, after IAS and engine power are increased and the autopilot is disconnected, a descent is to be initiated to escape the severe icing conditions.

The amendments, in the appropriate documents, are due to be distributed to all operators in January 2018.

The manufacturer of this aircraft, together with other aircraft manufacturers, has contributed to the update of the *Airplane Upset Prevention and Recovery Training Aid (AUPRTA),* Revision 3, which is available on ICAO website[10]. This update includes information specific to turboprop aircraft.

Footnote

[10] AUPRTA can be found here: https://www.icao.int/safety/LOCI/AUPRTA/index.html

Conclusion

The aircraft suffered an in-flight upset at FL130 after accruing airframe icing during the climb, resulting in the adverse aerodynamic effect of ice build-up on the wings. The crew were presented with a DEGRADED PERF caution but did not action the relevant checklist because they focused on climbing out of the icing conditions. The IAS was not maintained at or above red bug +10 kt and control of the aircraft was lost when a turn was initiated in the LNAV mode of the flight director.