SERIOUS INCIDENT

Aircraft Type and Registration:	Saab-Scania SF340B, G-LGNM
No & Type of Engines:	2 General Electric CO GE CT7-9B turboprop engines
Year of Manufacture:	1990 (Serial no: 340B-187)
Date & Time (UTC):	3 October 2014 at 0930 hrs
Location:	En route from Aberdeen to Sumburgh
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 25
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	9,168 hours (of which 6,283 were on type) Last 90 days - 87 hours Last 28 days - 37 hours
Co-pilot's Flying Experience:	2,340 hours (of which 928 were on type) Last 90 days - 105 hours Last 28 days - 44 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft's rate of climb deteriorated in icing conditions, while the aircraft was experiencing mountain wave effect during the latter part of a climb to FL130. Once level, the aircraft did not accelerate as expected and a descent was initiated, with the autopilot engaged using vertical speed mode. An unusual vibration was then experienced, followed by a stall warning system activation and the autopilot disengagement. The aircraft was recovered in a non-standard manner, a safe airspeed was achieved and the autopilot was re-engaged. Subsequently, a normal landing was made at the planned destination.

Unusual ice formation, seen on the wings, corroborated calculations by the manufacturer that the aircraft had encountered severe icing.

History of the flight

The aircraft was operating a scheduled passenger service from Aberdeen to Sumburgh. The crew, consisting of two pilots and one cabin crew member, reported for duty at 0440 hrs at Aberdeen and had already flown to and from Sumburgh, with passengers. During these flights, little cloud and no significant icing had been encountered.

On departure from Aberdeen at 0900 hrs, for the second flight to Sumburgh, there was a strong south-south-westerly airstream and severe mountain waves were forecast between FL40 and FL280. The takeoff weight was calculated to be 12,729 kg, 426 kg below the maximum certified weight, and the CG was in the normal operating range.

The planned cruising level was FL150 and ATC approved a climb to FL130. Close to FL65, the aircraft entered cloud and the crew switched on the engine anti-icing systems, together with the wing and stabiliser de-icing boots. Above FL110, the rate of climb reduced. A small amount of ice had formed around the windscreen wipers but the commander initially assessed that the reduced rate of climb was due to downdraughts caused by mountain wave effect.

Ice was seen to accrete on the propeller spinners, and propeller de-icing was selected to NORM when the OAT reached -5ºC. No propeller vibration was apparent and no ice from the propellers was heard to strike the fuselage. The commander, who was PF, used the autopilot's vertical speed (VS) mode and reduced the IAS from more than 160 KIAS, the normal minimum speed for climbing in icing, to 145 KIAS, which was the appropriate $V_{ERICING}$ speed[1] for use in exiting icing conditions. The half-bank mode and IAS (hold) mode were engaged and the aircraft continued to climb at 145 KIAS. The commander realised the aircraft was being affected by ice, as well as by mountain wave effect, but was confident that it was close to the cloud tops and would climb above the icing level.

The pilots later recalled that the indicated rate of climb varied from a maximum of about 800 ft/min to a slightly negative rate. Climb power was maintained and the propeller rpm were also kept at the normal setting of 1,230 rpm. The co-pilot later stated that he realised that the power and propeller rpm should have been increased when the speed was reduced below 160 KIAS, in accordance with standard operating procedures (SOPs), but he had not suggested this at the time[2]. Approximately ¾ inch of ice could be seen on the windscreen wipers, while the de-icing boots on the wing appeared to clear any ice that formed on them.

The aircraft reached FL130 (OAT -7ºC) at 0925 hrs but it only accelerated to 164 KIAS, rather than the expected 180 KIAS or greater. The commander's reaction was to climb the aircraft another 100 ft, then descend back to FL130 using VS mode. This was not a manoeuvre the commander had previously employed, but he had seen it used by another pilot. Before commencing it, he and the co-pilot had a brief discussion about what was intended. The commander thought that the angle of attack (AOA) and drag would reduce during descent and the aircraft would accelerate. Instead, during the short climb, the IAS reduced quickly towards 150 KIAS and did not increase in the descent.

On regaining FL130, the autopilot remained engaged and the active vertical mode was ALTS which is the altitude hold mode displayed when the aircraft is maintaining a

Footnote

[1] See *Procedures – Minimum IAS* later in this report.
[2] See *Crew comments – Reducing to minimum IAS* later in this report.

pre-selected altitude[3]. The pilots believed they were experiencing moderate icing and should descend to FL110 to increase airspeed. After ATC had approved the descent, the commander commented that the ice conditions were more than moderate and that the airframe was accumulating a lot of ice. FL110 was entered in the altitude pre-selector and the commander selected a rate of descent of 1,000 ft/min, using VS mode.

The commander noticed that, despite the selected rate of descent, the aircraft's pitch attitude remained high (around 5º nose-up) and he increased the selected rate to 2,500 ft/min. The airframe then started to vibrate and the commander said "FEEL THAT, THAT'S A STALL… I THINK… ICING STALL". (The co-pilot later likened the vibration to the sensation of driving a car over a cattle grid.) Approximately 10 seconds after the vibration started, at 09:28:49 hrs, the aural stall warning sounded for approximately one second, the stick shaker operated and the autopilot disengaged.

The commander took manual control and pitched the aircraft to 2º nose-down. He later reported that a little more force than usual had been required to lower the nose of the aircraft but it then responded normally as the speed increased to greater than 190 KIAS. The vibration ceased and the aircraft seemed to be in trim, without any pitch trim adjustment by the commander. The autopilot was re-engaged approximately 9 seconds after disconnection and, shortly afterwards, an elevator mis-trim annunciation was displayed on both Electronic Attitude Director Indicators (EADIs). It was acknowledged by the crew and cleared within a few seconds.

Thirty-five seconds after the stall warning, the ICE PROT caption illuminated on the Central Warning Panel (CWP), with an associated aural chime. This signified that a caution light relating to the ice protection system had come on and the co-pilot announced to the commander that the TIMER light on the Stabiliser and Wing De-Ice Panel had illuminated.

After levelling at FL110, the co-pilot followed the abnormal checklist procedure for '*TIMER light on'* and selected ONE CYCLE[4]. This cleared both the CWP caution and the TIMER light. The flight was continued to its original destination, without climbing again, and without further incident.

Recorded information

The aircraft's flight data recorder (FDR) and cockpit voice recorder (CVR) were downloaded and analysed at the AAIB. The salient FDR data (see Figures 1 and 2) present an overview of the incident period.

Figure 2 starts at 09:28:00, with the aircraft descending to FL130 (from FL131), which it reached 11 seconds later. As the aircraft levelled off, the airspeed began to reduce to less than 150 KIAS, gradually at first and then more rapidly. Consequently, with the aircraft now in ALTS mode, the pitch attitude increased in order to maintain altitude.

Footnote

3 See *Flight guidance and autopilot vertical modes* later in this report.
4 See *Ice protection systems* later in this report.

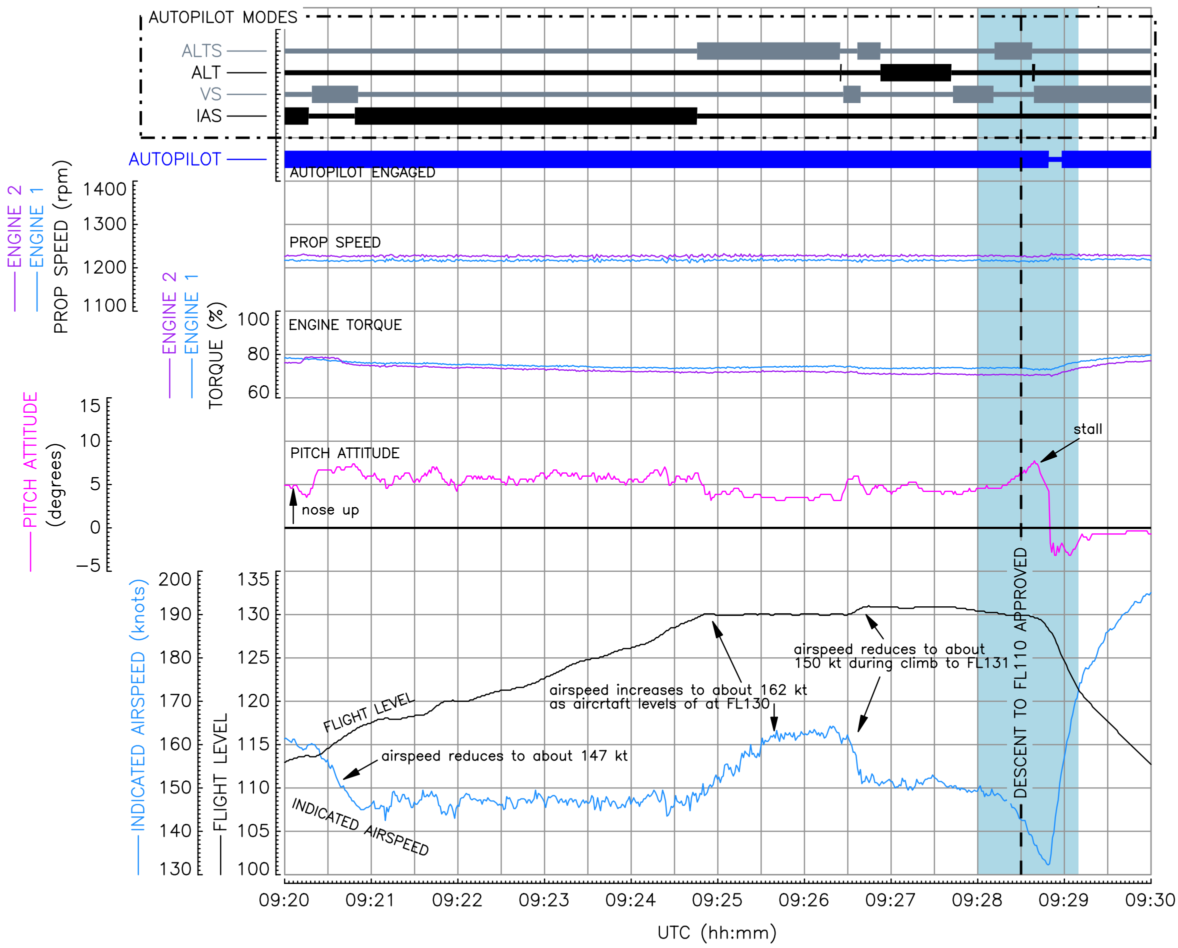

Figure 1

FDR data overview of event
(shaded area to the right is detailed in Figure 2)

At 09:28:26, the airspeed had slowed to 145 KIAS, reaching 140 KIAS 10 seconds later as the increasing angle of attack (AOA) exceeded 5.9º. The shaded blue area under the AOA curve illustrates the period when the AOA was 5.9° or more, when a stall warning would have occurred if the '*Ice Speed function*' had been operative[5].

The radio transmission to ATC, requesting descent, began at time 09:28:23 and approval for descent was given six seconds later. During this period the airspeed continued to reduce and the pitch attitude to increase. At 09:28:38, the autopilot mode changed to VS. About this time, the crew experienced vibration (buffet) and the AOA reached 8º.

When the buffet was first experienced, the pitch attitude, having peaked at between 7° and 8° nose-up, began to reduce steadily at a rate of 0.5°/s. However, the AOA continued to increase, as the aircraft started to descend and the airspeed decreased at a rate of 0.5 kt/s.

Footnote

5 See *Stall warning system* later in this report.

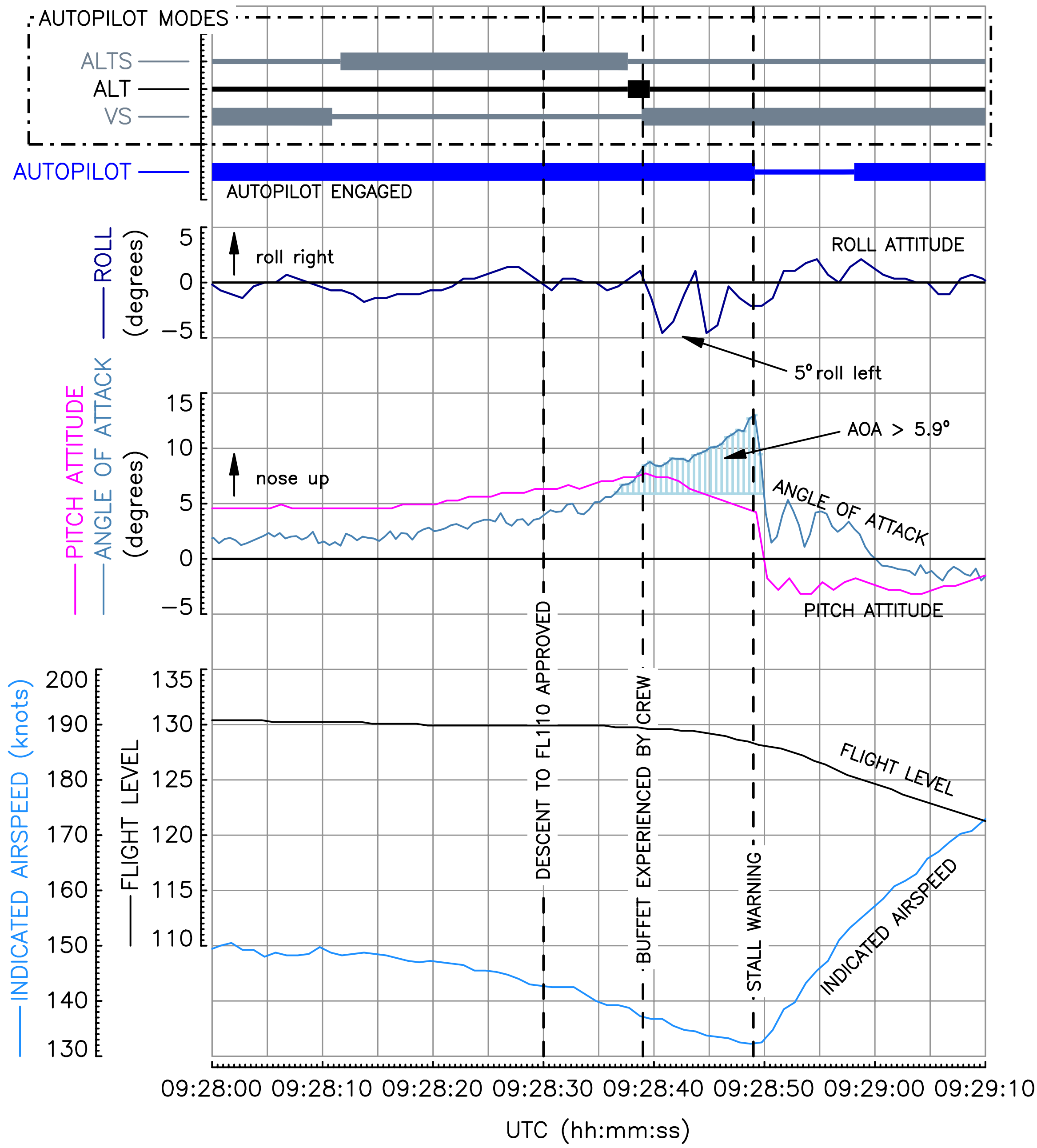

Figure 2

FDR data at the time of the event

The aircraft also rolled left, twice in quick succession, to 5° angle of bank (AOB). At 09:28:49, as the AOA reached 13° (with the pitch attitude at 4°), the stall warner sounded and the autopilot disengaged. The airspeed at this point was 132 KIAS. Subsequently, the AOA reduced, the airspeed increased and the autopilot was re-engaged.

Aircraft information

The Saab-Scania SF340B is a twin turboprop aircraft which can seat up to 36 passengers. It was certified in 1984 in compliance with Appendix C of Federal Aviation Regulation (FAR) and Joint Aviation Regulation (JAR) 25, with regard to icing conditions. The aircraft's stall characteristics in icing conditions were demonstrated during test flights, with simulated ice-shapes attached to the airframe to represent a build-up of ½ inch of ice on protected surfaces[6] and 3 inches on unprotected surfaces. These tests showed that this amount of simulated ice increased the clean stall speed by 10%. Later, during certification tests to Canadian standards, a build-up of 1 inch of ice on protected surfaces was simulated. The manufacturer subsequently informed operators that, in this case, the stall speed could increase by 15 to 20 KIAS, compared to an increase of around 10 KIAS for the JAR-certified ½ inch shape.

Ice detection

G-LGNM was not fitted with an ice detector. The manufacturer's Aircraft Operations Manual (AOM) states:

> *'The windshield wiper arms give a visual cue of ice accumulation, although airframe ice can be present without any build-up on the wiper arms. Even though the wiper arms are the primary visual cue, accumulation of ice shall be monitored on all visible surfaces.'*

A note in the manufacturer's Airplane Flight Manual (AFM) warned that ice can build-up on the aircraft without being visible.

Ice protection systems

The Saab 340B has systems to anti-ice the engines, de-ice the airframe and propellers, as well as systems to heat the windshields, pitot tubes, OAT probe and AOA sensors. Icing conditions are considered to exist for the engines and the airframe when the temperature is +5ºC or colder and any visible moisture is present. Engine anti-icing is to be turned ON prior to entering icing conditions.

De-icing of the leading edges of the wings and stabiliser is achieved through the inflation and deflation of pneumatic boots, using engine bleed air. The associated controls and indicators are on the left side of the cockpit overhead-panel and this system is to be switched to CONT when entering icing conditions, without waiting for any visual signs of ice formation. In CONT mode, one complete cycle of the system takes place every third minute and involves inflating the boots on the horizontal and vertical stabiliser surfaces for 6 seconds, inflating the boots on the outboard wings for 6 seconds, inflating the boots on the inboard wings for 6 seconds and finally inflating the stabiliser boots again for 6 seconds. When pressurised engine air is not being fed to the boots, suction is applied to keep them deflated. Sensors monitor boot inflation and deflation and, if a fault is

Footnote

6 The leading edges of the wings and stabiliser have de-icing boots for protection, see *Ice protection systems*.

detected, a TIMER light on the overhead panel illuminates, together with an ICE PROT caption on the CWP. A single cycle of the boots can be initiated by manually selecting the system to ONE CYCLE, instead of CONT or OFF.

The propellers are electrically heated, with power applied to two blades, on opposite sides of the hub, at the same time. The control switch should be moved from OFF to NORM when ice accretion is observed on any part of the aircraft and the temperature is between -5ºC and -12ºC. This initiates a continuous cycle, with power on for 11 seconds and then off for 79 seconds. In temperatures below -12ºC the switch should be moved to MAX, in order to cycle the power on for 90 seconds and then off for 90 seconds. The operator noted that, when the system is operated, there can be intense vibration through the airframe as each pair of blades sheds ice, in turn.

Stall warning system

The AOA sensors, on either side of the aircraft, feed data to two independent stall warning computers that alert pilots to an impending stall. There is no indication in the flight deck of the AOA but if an AOA of 12.1° is detected by either computer, when the flaps are up and the de-icing boots are turned on, a stick shaker will operate, together with a sharp, continuous aural warning. Also, the autopilot will simultaneously be disengaged (if engaged at the time). Should one computer sense an AOA greater than 18.6º then, provided the other computer senses an AOA of at least 12.1°, the stick push system will apply a force to the control column to achieve 4º of down-elevator. According to the AFM, 105 KIAS would be the stick push speed for a clean aircraft weighing 12,500 kg (the estimated weight of G-LGNM at the time it approached the stall).

A modification to the stall warning system introduces an '*Ice Speed Function'.* This is activated with either engine anti-ice switch set to ON, once the aircraft has been airborne for six minutes or more. A blue ICE SPEED push button on the instrument panel illuminates when the system is active and the AOA at which the stall warning (stick shaker) will operate is reduced from 12.1° to 5.9º. Although G-LGNM had this modification incorporated, permission to use the system on Saab 340s had been temporarily withdrawn by EASA[7]. The reason for the modification is that a wing will tend to stall at a lower AOA, and therefore at a higher IAS, when it is contaminated. The AOA of the stick pusher was not changed by the modification. No tables were provided for the stall speed in JAR-certified icing conditions but, applying the likely 10% increase in IAS from flight trials, the stall speed of an aircraft weighing 12,500 kg would be 115.5 KIAS.

Elevator trim

Elevator trim is commanded using the MAIN trim switches on the pilots' control wheels, or the STDBY trim switch on the centre console if there is a failure of the main system. Trim commands are added in parallel to the control column commands for manual flight.

Footnote

[7] After this incident EASA approved an updated modification and all the operator's aircraft were expected to have the system operational by August 2015.

When the autopilot is engaged, the system uses an auto-trim function to maintain a trimmed flight position. The auto-trim monitors torque on the control servo motor and makes trim corrections to relieve high torque forces. An elevator mis-trim annunciator shows on the EADIs when the torque forces exceed a preset threshold. If the autopilot is engaged when the aircraft is out-of-trim, the torque threshold may be reached and the annunciator may show until the auto-trim has operated to offload the servo. This can occur during normal flight conditions.

Flight guidance and autopilot vertical modes

When the aircraft captures and maintains a pre-selected altitude, the active vertical mode, as displayed on the PFD, becomes ALTS. Alternatively, at any time the ALT button is pressed, the aircraft will maintain its current altitude and ALT is displayed on the PFD. When ALTS is displayed and the altitude pre-selector is moved, the aircraft will continue to hold the current altitude but the displayed mode will change to ALT until a new vertical mode (such as VS) is engaged. There is no overspeed or under-speed protection when the vertical mode is VS, ALT or ALTS.

Propeller spinners

Both spinners on G-LGNM's propellers, in common with those on many of the operator's other aircraft, were painted with black rings (see Figure 3). The rings were not mentioned in any guidance material and the manufacturer stated that they had been incorporated on certain aircraft as part of a trial. The intention, which was not advised to operators, was that if ice was seen to accrete aft of this line it could indicate that the conditions were beyond the aircraft's certified limits ie a severe icing encounter. However, the manufacturer later determined that this was not an accurate cue for severe icing and was more conservative than the certified visual cue (see *Ice detection* section earlier in this report). The manufacturer has stated that no guidance about the use of the black lines was ever provided to pilots and that spinners with black lines are interchangeable with those without lines.

Figure 3

Propeller spinner showing black-painted ring

Meteorological information

The crew's meteorological forecast indicated that a cold front, orientated north-east to south-west, would pass through the planned route around mid-morning and that either side of the front there would be broken or overcast altocumulus cloud, with a base of 8,000 ft and tops above 10,000 ft. The forecast warned of associated moderate icing and moderate turbulence in this cloud. Ahead of the front, the freezing level was estimated to be at 9,000 ft and at least 3,000 ft lower behind the front. Mountain waves, with a maximum vertical speed of 900 ft/min at 9,000 ft, were forecast over a large area either side of the front. Turbulence in the mountain waves was forecast to be moderate or occasionally severe. A SIGMET[8], valid between 0600 hrs and 1000 hrs, forecast that severe[9] mountain waves could affect the area in which the aircraft would be flying between FL040 and FL280.

An aftercast from the Met Office estimated that the incident occurred in the air mass just ahead of the cold front, with a particularly moist layer above the freezing level which was at 9,000 - 9,500 ft. The best estimate for the wind velocity at FL130 was from 200º at 70 - 75 kt. It was calculated that downdraughts of 100 - 150 ft/min, caused by mountain wave effect, might have been encountered at FL130 in G-LGNM's position. The severe mountain waves mentioned in the forecast, and in the SIGMET, were confined to an area closer to the Grampian Mountains, to the southwest of G-LGNM's position.

It was calculated that the aircraft would have encountered a layer of altocumulus cloud layer about 7,500 ft in depth, with tops at FL150, and with conditions conducive to moderate or severe icing. The water droplets in the cloud at FL130 were likely to have been of mid to large size. A mid-size droplet has a diameter of 0.015 to 0.05 mm, while a large-size droplet has a diameter of 0.05 to 1 mm.

Moderate and severe icing

The accepted aeronautical terms for describing icing intensity are 'trace', 'light', 'moderate' and 'severe' but there is no internationally recognised definition of icing severity, as there is for turbulence or mountain waves. The UK Aeronautical Information Publication (AIP) states that, from a reporting perspective, moderate icing exists when the rate of accumulation is such that even short encounters are potentially hazardous and the use of de-icing/anti-icing equipment, or diversion, is necessary. In comparison, severe icing exists when the rate of accumulation is such that de-icing/anti-icing equipment fails to reduce or control the hazard and immediate diversion is necessary. The term 'diversion' in this context implies a diversion from the intended routing and not necessarily a diversion to an alternative airfield.

There are no absolute parameters used by the Met Office to forecast moderate or severe icing conditions. Forecasters are encouraged to consider a number of parameters together, including the type and extent of cloud, as well as its depth, temperature and relative

Footnote

8 SIGMET messages are issued by the Met Office when significant meteorological conditions are forecast.
9 ICAO Annexe 3 defines severe mountain waves as those where downdraughts exceed 600 ft/min.

humidity. The forecasters are aware that severe icing can occur with short exposure to deep, convective clouds but that it may also occur with prolonged flight in stratiform cloud at temperatures just below 0ºC. When preparing forecasts, they appreciate that aircraft of different shapes and speed accrete ice at differing rates.

Procedures

The operator's Operations Manual (OM), issued in accordance with EASA regulations, is split into several parts and is supplemented by various external publications. OM, Parts B1 and B2 summarise the procedures to be used for operation of aircraft but the manufacturer's AFM, AOM and the abnormal and emergency checklists are also contained in the OM. The operator states that the AFM and the AOM are to be treated as the definitive guides, unless specific instructions to the contrary appear in the Part B1 and Part B2 (collectively referred to hereafter as Part B).

Flight in icing conditions

OM Part B repeats much, but not all, of the guidance given in the AFM and the AOM concerning flight in icing conditions. The AOM includes a Supplement that focusses on operations in cold weather and icing conditions but this is not comprehensive. Some of the guidance that relates to icing conditions is contained elsewhere within the AFM and the AOM.

The first chapter of the AOM Supplement is titled '*Aspects of Operation in Icing Conditions*'. It states that the Saab 340 is certified for operation in icing conditions, in accordance with Appendix C of FAR/JAR 25. It also explains that this regulation specifies two criteria, an '*Intermittent Maximum Condition*' in cumuliform cloud and a '*Continuous Maximum Condition'* in stratiform cloud. This information is repeated in OM Part B. Both manuals state that '*Moderate icing conditions equals the Appendix C definition of intermittent or continuous icing*', while the Limitations Section of OM, Part B states additionally: '*The aeroplane is approved for icing conditions forecast to be not greater than moderate*'.

OM, Part B and the AOM both include a graph of liquid water content against droplet diameter, to illustrate that 50 microns[10] is considered to be the maximum diameter of mean water droplets in intermittent conditions, reducing to 40 microns in continuous conditions. It is stated that larger droplets are commonly called Supercooled Large Droplets (SLD) and that '*such conditions are often called freezing rain and freezing drizzle*'.

A later section in the first chapter of the AOM Supplement is titled '*SLD detection*'. It states:

> *'Substantial ice build-up on the spinner further aft than normally observed might be an indication of freezing rain / drizzle. If observed, increase scanning of the wing leading edge and if accumulation of ice on the upper surface aft of the protected surface is observed, exit these conditions immediately to avoid*

Footnote

[10] Under Met Officer categorisation, a droplet measuring 50 microns (0.05 mm), is a large-size droplet.

> *extended exposure. If the autopilot is engaged, hold the control wheel firmly and disengage the autopilot. Keep the autopilot disengaged until the upper wing surface is free from ice. If an unusual roll response or uncommanded roll control movement is observed, reduce the angle of attack.'*

Diagrams indicate how ice spreading back on the spinner towards the propeller blade roots could indicate the possible presence of SLD. No mention is made of the black-painted rings on the spinner.

In addition to the instruction to disengage the autopilot, should ice be seen on the un-protected upper surface of the wings, the AOM includes an instruction to disengage the autopilot if there is a significant performance loss in icing conditions. This instruction is not repeated in OM, Part B.

The OM makes few references to severe icing and this condition is only mentioned twice by the manufacturer's manuals, in relation to the de-ice boots and to propeller rpm. The de-ice boots may have to be operated manually in severe icing, between automatic cycles, to minimise ice accumulation. While use of maximum propeller rpm is to be considered if severe icing conditions are '*experienced or expected*'. Increasing the propeller rpm helps to shed ice from the blades.

Minimum IAS

The OM states that in icing conditions, for '*climb above MSA, cruise, descent, holding and approach*', the minimum IAS is V_{CM} (the conservative manoeuvring speed). A table provides the V_{CM} appropriate to each flap setting. With flaps set to zero, the V_{CM} is 160 KIAS and this increases by 10 KIAS for each 10º of bank above a bank angle of 30º. As a proviso, the OM states that a lower speed, known as $V_{CLEAN+15}$ (referred to as $V_{ERICING}$ by the operator), may be used for a flaps 0 climb to exit icing conditions, when above MSA.

V_{CLEAN} is the speed quoted by the manufacturer for the final stage of a single-engine climb or for drift-down. It provides a margin of at least 1.25 to the stall speed, up to 15º angle of bank. By adding 15 KIAS, this speed becomes $V_{CLEAN+15}$ or $V_{CLEAN-ICE}$, the '*Enroute Climb Speed – with residual airframe and propeller ice'.* This gives a margin of 1.4 to the clean stall speed, with a maximum of 15º angle of bank. Crews use reference cards to check the relevant speed for a specific aircraft weight and configuration. The OM states that this speed offers optimum climb performance and '*gives the required margin to stall with ice on the wings for straight flight*'. It also indicates that use of this speed allows the aircraft to climb through a layer of ice clouds in the shortest distance. At this speed, half bank mode is recommended to improve the margin to the stall.

Power setting

The OM notes that, in icing conditions, engine performance should be carefully monitored to ensure proper climb performance. Both OM, Part B and the AOM state:

> *'If experiencing extreme icing conditions and safe speed and/or climb rate can not be maintained, do not hesitate to temporarily set TAKEOFF PWR/MAX CONTINUOUS PWR, if that is required to escape from the situation. Extreme icing conditions do not necessarily imply a large amount of ice but ice accumulation causing a large impact on performance making airspeed decrease towards the minimum safe speed in icing conditions'.*

No other explanation or definition is provided for the term 'extreme icing.'

Setting of normal climb power is carried out in accordance with torque setting charts, using 1,230 propeller rpm. Charts carried on the aircraft show that, at FL130, the climb power appropriate for G-LGNM, at 140 KIAS and a temperature of -7ºC, was 73% torque. It is noted that for each 40 KIAS increase in speed, the indicated torque would increase by 1%. The torque figures recorded on G-LGNM at the top of climb were: 74% for the left engine and 72% for the right engine. Throughout the latter stages of the aircraft's climb, its level off and the subsequent descent, the torque figures remained between 70 and 80%, the variation being a function of altitude and airspeed changes (torque reducing with increasing altitude and reducing airspeed).

The AOM states that Maximum Continuous Power (MCP) is available for two engine operation '*in extreme icing conditions*' and is not intended for use during '*normal icing conditions*'. OM, Part B substitutes the phrase '*extreme icing conditions*' with '*severe icing conditions*' and notes that MCP, with a propeller rpm of 1,384, may be used to ensure safe obstacle clearance or maintain a safe flying speed. The charts show that MCP for 150 KIAS, at FL130 and -7ºC, is 77% torque, with 1,384 propeller rpm. Therefore, use of MCP, with 1,384 propeller rpm, would have increased G-LGNM's power by approximately 18% at FL130.

Stalling

Guidance in the OM states:

> *'With ice on the wing stall might be encountered before, or at, stick pusher activation. In some adverse cases stall may even be encountered before the artificial stall warning is activated.*
>
> *Natural stall warning in the form of buffeting, caused by partial separation over the wing may be experienced at a speed of up to 25% above the ice free stall speed.*
>
> *This might however be mistaken/hidden by the "vibration" caused by the uneven shedding of ice from the propellers.'*

Should unusual vibrations be experienced, the Emergency Checklist states:

> *'If in any doubt whether it is a natural pre-stall warning in the form of buffeting, or an unusual vibration, always perform stall recovery.'*

The stall recovery procedure is included in the AOM, in the chapter entitled '*Flight Procedures, Training.*' Here, alongside guidance and hints for instructors, is a list of the recovery procedures for recovery from a stall warning (stick shaker or natural buffeting) or from a stall. The PF is instructed to call "STALL - MAX POWER", immediately decrease the pitch by about 5° (to trade altitude for airspeed), press the autopilot disconnect and simultaneously use all power available, even at high altitude. A note states:

> *'In a real situation with an iced up aircraft stall warning can be in the form of buffeting and the same stall recovery procedure shall be carried out. This cannot be simulated in a simulator as ice buildup is not accompanied by buffet in the simulator.'*

The AOM states that stall onset is recognised by light buffeting just prior to the stall, followed by a nose-down movement and a possible roll to the left or right, which cannot be controlled until the AOA is reduced. An iced-up aircraft may roll past 90º and the nose may drop '*excessively*'.

Winter operations brief

The operator issues a Notice to Aircrew (NOTAC) to promulgate changes to the OM or to remind crew about specific procedures. NOTACs have a limited validity period before they have to be re-issued or incorporated in the OM. Prior to this incident, the operator circulated a NOTAC each autumn to remind pilots about important aspects relating to flight in icing conditions. NOTAC 66/13, '*Winter Operations Brief (Revised), Winter 2013 -2014*', had expired five months before the incident but both pilots said they were familiar with its content. The NOTAC drew together various procedures from different parts of the OM and offered some guidance that was not covered by the AFM, the AOM or the Part B.

Specifically, the NOTAC associated the setting of MCP with an election by the pilots to reduce speed to $V_{CLEAN+15}$ in icing conditions. It stated that, if an adequate rate of climb could not be achieved at 160 KIAS, the pilots should assess if the best course of action was to continue climb or to initiate descent, to escape icing conditions. If the climb was continued, the initial recommended actions were to move the condition levers to the MAX position, set MCP according to the appropriate chart, select half bank and climb straight ahead at a speed not below $V_{CLEAN+15}$.

In cruise flight, there was a recommendation to exit icing conditions if 180 KIAS could not be maintained and a statement that a minimum of 160 KIAS should be maintained at all times after the top of climb. In a reference to the detection of SLD, the notice stated, '*Typically these large droplets (SLD) give a thin layer which covers a large area and can lead to* ***Severe Icing***'.

One section of the NOTAC was devoted to icing-induced stalls. It pointed out that these have occurred on several occasions to Saab 340s being operated at less than 160 KIAS. The following points were noted:

'• *Loss of performance (reducing airspeed, increasing nose up attitude, poor rate of climb) in icing conditions may be indicative of serious airframe icing, even if it is not observable*

- *Build up of ice can cause aircraft to stall at speeds 30% above normal stall speed*[11]

- *The stall warning/protection system may not activate due to the higher stall speed. A light buffet may be an early indication of impending stall*

- *There may be little or no pitch change in an icing induced stall, first indication may be a roll which oscillates from side to side with increasing severity*

- *If corrective action is not taken at an early stage the aircraft may enter an extreme rate of descent situation*

- *If the crew suspect an icing induced stall has developed, or is developing then recovery action should be taken immediately as follows:*

Disconnect autopilot

Lower nose approximately 5 degrees

Apply maximum climb power

Minimum speed should be 1.4 x Vs (Ver icing), preferably Vcm

Beware of pulling up too quickly following recovery to prevent secondary stall

- *Stall recovery from an icing induced stall is not about losing the minimum amount of altitude, it is about ensuring the aircraft recovers from the stall, altitude may have to be traded for airspeed.'*

Training

Operator training for icing conditions

The operator's syllabus for type rating training encompasses aircraft operation in icing conditions. Winter operations training is also provided to pilots and a presentation is given during annual classroom training, which, in recent years, has included a video about flight in icing conditions, either one produced by NASA or one from the manufacturer. Pilots are also expected to refer to the 'W*inter Operations Brief'* NOTAC each autumn, in preparation for flight in icing conditions during winter.

Simulator training

Icing conditions had been incorporated into recurrent simulator training details for both pilots. However, the operator reported that it had not previously been possible to simulate severe icing or the pre-stall buffet.

Footnote

[11] The figure of 30% appears to have been taken from the manufacturer's ice awareness video. This mentions that as a general rule, minimum speeds should be increased by about 30% to allow for ice accumulation.

Stall awareness and stall recovery were covered during type rating training and testing. Thereafter, stall training was one of a number of abnormal and emergency items that were regularly included in recurrent simulator details. The commander and the co-pilot had received stall training about one year before the incident. Their last simulator checks took place one month and two months, respectively, before the incident.

Crew comments

The commander was a line training captain with around 10 years' experience flying the Saab 340. He stated that his duty on 3 October 2014 involved his third consecutive early report time but that he did not consider his performance was negatively affected. The co-pilot, who had been flying the Saab 340 for two years, stated that this was his first duty with an early report time, following days off. He said that, as a result, he had not achieved a full night's sleep and that, as often happened on his first early-start duty, he felt a little tired and perhaps not as alert as he would have liked. Both pilots were based at Aberdeen and were familiar with the Sumburgh route.

The OM was regarded by both pilots as their prime point of reference for Saab 340 operation. They had access to the AFM and the AOM but the electronic format, in which these manuals were presented, made them difficult to browse on a computer and search for specific text. They only tended to refer to these manuals if they could not find what they were looking for in OM, Part B.

Weather

As no significant icing was encountered on the first return flight to Sumburgh, the pilots were not expecting problems with icing on this sector. They regarded forecasts of icing conditions and mountain wave effect as routine for that area. Both of them thought that they had seen severe icing once or twice in the past but it had been a transient experience, when ice had built-up quickly rather than gradually. They knew severe icing was not always associated with the identification of freezing rain or drizzle but they only expected to encounter it in cumuliform clouds and they thought that on this occasion they were flying in stratus-type[12] cloud.

Ice detection

The pilots stated that they used the wiper arms, in conjunction with looking at the wings, to check for ice accretion. They said that ice did not show up well if it was behind the boots on the wings or on the spinner because those areas had light-coloured paint. They observed that most of the aircraft they flew had a black line painted on the spinner. The co-pilot believed that if ice was observed aft of this line then the propeller heating should be turned on. The commander believed that if ice accreted aft of this line it indicated severe icing. He could not recollect seeing any undue ice accretion while they were climbing. The co-pilot recalled that he saw ice about two thirds of the way back towards the black line on the spinner when they turned on the propeller de-icing, between FL110 and FL120. Neither

Footnote

[12] The cloud they were flying in was altocumulus, see *Meteorological information*.

of the pilots were aware of any vibration from ice being shed by the propellers, or any noise from ice hitting the fuselage, when the de-icing was activated.

Once the aircraft levelled off, the pilots believed there was about ¾ inch of ice on the wipers. Later, after descending, the co-pilot deduced that the bottom part of the windshield may have iced-up without him noticing because it blended with the white backdrop formed by the cloud outside. When this ice melted, he estimated there was 1 - 2 inches of ice on the underside of the wipers. The co-pilot also reported that, about the time the airframe vibration began, he had observed a ridge of ice about ½ inch high on the de-ice boots, to the rear of the area that inflated. He did not bring this to the commander's attention because they had already requested descent. Neither he nor the commander saw more than ¼ inch of ice elsewhere on the boots at any time, nor could they see any ice behind the boots. The commander reported that after they had descended he saw a broken ridge of ragged ice about ¾ of an inch high along the rear edge of the boots. At this time there seemed to be ice on the spinner about three quarters of the way back towards the black line. Neither pilot saw ice aft of the black line at any stage.

Reducing to minimum IAS

When the commander reduced the airspeed to less than 160 KIAS in the climb, he did not think that this had to be accompanied by an increase in power to MCP. His understanding was that maximum propeller rpm was only appropriate to assist in the shedding of propeller ice, which he did not regard as an issue. The co-pilot was aware that the SOP was to increase power to MCP, if the speed was reduced below 160 KIAS due to icing. However, on two previous occasions he had flown with commanders who had not increased power to MCP in these circumstances. He did not advocate it on this occasion because this commander was a senior line-training captain who, in the recent past, had not been open to a suggestion the co-pilot had made, concerning an unrelated SOP.

Both pilots believed it acceptable to fly at less than 160 KIAS when level, with a minimum of $V_{CLEAN+15}$, provided they were trying to vacate icing conditions. However, they did not regard a speed of less than 160 KIAS as acceptable for cruise flight.

Stall warning and recovery

The decision to descend was made once it became apparent that, whilst level, the airspeed would not return to 160 KIAS. The co-pilot was not initially aware of the airspeed reducing below 145 KIAS, as he was busy obtaining ATC permission to descend and writing down the approved level. The commander recalled that his concentration was focussed on setting the new level into the autopilot controller and initiating a descent using VS mode. After he had commanded a 1,000 ft/min rate of descent, he noticed that the aircraft's pitch attitude still exceeded 5°, which was higher than he expected. He did not appreciate that the AOM included an instruction to disengage the autopilot if there was a significant loss of performance due to icing conditions.

In order to reduce the pitch, the commander adjusted the commanded vertical speed to 2,500 ft/min and it was while he was doing this that he started to feel the aircraft vibrate. He did not recall identifying the vibration as pre-stall buffet but was aware of the need to increase the airspeed. He believed the descent, in commanded vertical speed, would achieve this by pitching the nose down. Eventually, as he reached for the controls to disengage the autopilot, because of the high nose attitude, the stall warning activated.

The co-pilot's recollection was that he had been looking out of the window when he experienced the unfamiliar vibration. It was high-frequency and more violent than the irregular propeller vibration he had experienced in the past, when ice was shedding. His recollection was that the aircraft also rolled slightly from side to side. When he looked back inside, he noticed that the airspeed had reduced to less than 145 KIAS. He was about to warn the commander when he saw him reaching for the controls.

The commander observed that, although, initially, more force than normal was needed to pitch down, he did not need to trim the aircraft and it felt in-trim when the autopilot was re-engaged. He was, therefore, surprised to see the elevator mis-trim annunciation.

Previous accidents and incidents

Flight in icing conditions, worse than those prescribed in certification standards, was studied in 1994. This followed a fatal accident investigation to an ATR-72 at Roselawn, Indiana, USA, which concluded that a ridge of ice accreted beyond the de-ice boots, leading to loss of control. This ice was attributed to the presence of SLD with a diameter larger than the 0.05 mm considered in Annex C to FAR/JAR 25.

On 2 January 2006, a Saab 340B (N306AE) stalled at 11,700 ft while climbing in icing conditions. The airspeed reduced during the climb and at 144 KIAS a roll anomaly was experienced. As was the case with G-LGNM, the autopilot arrested this slight rolling motion through a correcting aileron deflection. The crew saw little evidence of ice prior to the stall but they reported experiencing a heavy vibration. Recorded data showed that the IAS decayed quickly in the 10 seconds before a sharp wing-drop and departure from controlled flight at 130 KIAS. This led to descent through 4,000 ft before control was regained.

On 18 May 2011, a Saab 340A (LV-CEJ), at a similar weight to G-LGNM, crashed in Argentina, fatally injuring all 22 people on board[13]. Icing conditions prevented the aircraft from climbing to FL190 and MCP was not selected. To vacate the conditions, the aircraft descended to FL140 but the icing became severe and, in level flight, the AOA increased and IAS decayed. Pre-stall buffet commenced at 145 KIAS but this was mis-identified as propeller vibration and propeller rpm was set to MAX. The stall warning activated and the autopilot disengaged at 138 KIAS, 13 seconds after the onset of the buffet. The aircraft initially pitched 22º nose-down and rolled left to approximately 82º AOB. The stick pusher operated several times but the pilots did not regain control from the upset that occurred following the stall warning.

Footnote

[13] See Argentinian Civil Aviation Accident Investigation Board (JIAAC) Technical Report 096/2011, published 11 March 2015.

Prior to 2006, there had been other stall events to Saab 340 aircraft, in icing conditions, and changes were made to the manufacturer's guidance. In some incidents, pre-stall buffet was not correctly identified and a sharp wing drop occurred, leading to unusual attitudes and significant loss of altitude.

Manufacturer's assessment of the data

The manufacturer compared the DFDR data from the G-LGNM incident with nominal performance data[14] at seven points before and after the stall warning. It was calculated that, as the aircraft passed FL125 in the climb and also later, while at FL130, it experienced aerodynamic drag forces more than three times the datum level recorded during certification trials in simulated icing conditions. At the time of the stall warning, these drag forces had increased to almost four times the datum level. Once the aircraft had descended to FL110, they had reduced to twice the datum level.

After allowing for downdraughts of 300 ft/min, twice the strength of those calculated by the Met Office, the calculated drag forces were still greater than expected. The most likely reason for this was that the aircraft had accumulated severe icing. The manufacturer considered that the ice the pilots saw behind the inflatable area on the de-icing boots was also an indication of severe icing. The manufacturer noted the instruction in the AOM to exit the conditions immediately and disengage the autopilot, if ice accumulated '*aft of the protected surface*'.

Calculations by the manufacturer indicated that if MCP had been applied when IAS was first reduced to 145 KIAS, the aircraft would have been capable of continued climb to FL170, to vacate the icing conditions. Alternatively, an increase to MCP, after levelling at FL130, would have ensured that the IAS remained above 160 KIAS for a considerable period, despite the conditions.

The manufacturer analysed the aircraft's response to the VS command input prior to the stall warning. The conclusion was that the autopilot system responded normally and gradually increased the rate of descent to achieve a smooth transition from level flight. Flight trials confirmed that it could take between 10 and 15 seconds, from initiation of a descent using VS mode, to achieve a steady rate of 1,000 ft/min. During this incident, the stall warning activated 11 seconds after VS mode was engaged.

A diagram (Figure 4) produced by the manufacturer indicates why an aircraft's AOA can be much greater than its pitch angle, when descending.

Footnote

[14] The manufacturer's nominal data had been validated through flight test calibration.

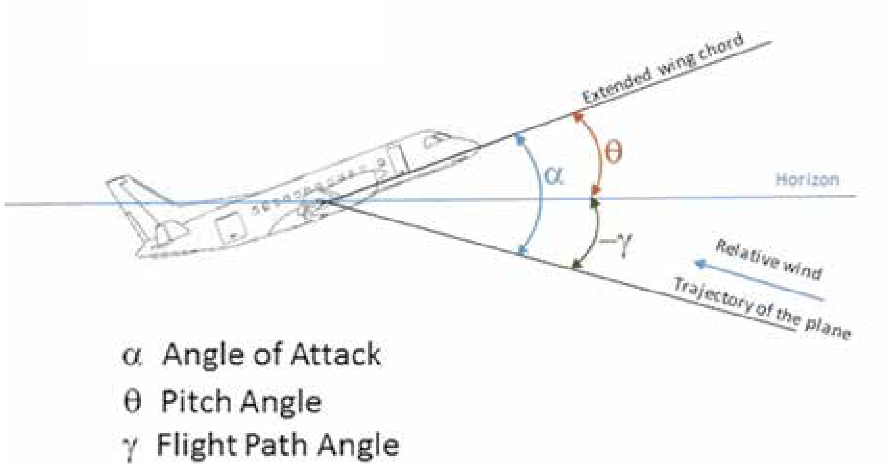

Figure 4

Manufacturer's illustration of AOA greater than pitch angle in descent

Operator's review of the event

A report by the operator stated that many of its pilots regarded an IAS of $V_{CLEAN+15}$ as acceptable to vacate icing conditions in straight and level flight. This was attributed to lack of clarity in the OM. The operator also noted that its pilots did not recognise the need to set MCP in a low speed situation when straight and level.

Consideration was given to the way in which stall recovery had been taught in the simulator. The operator identified that it had been usual to initiate recovery from idle power. In this incident, the aircraft already had a relatively high power setting and the commander believed that a pitch reduction alone was appropriate. The operator concluded that clarification was needed about the manner in which maximum power should be achieved during stall recovery.

The review also noted that many of the operator's pilots perceived that the aircraft would achieve a commanded rate of descent using VS mode more quickly than it actually does (see *Manufacturer's assessment*).

Analysis

Mountain wave

The critical portion of the flight took place in altocumulus cloud, downwind of a mountain range and near a cold front. Moderate icing and severe mountain waves, with downdraughts of up to 900 ft/min, were forecast but subsequent Met Office analysis suggested that the downdraughts experienced in G-LGNM's position should not have exceeded 150 ft/min. The pilots reported that the VSI showed large variations in the rate of climb, which could have indicated the presence of updraughts or downdraughts exceeding 150 ft/min. However, with IAS mode engaged during the latter part of the climb, any tendency for the airspeed to increase or decrease would also have caused an attitude change that would have affected the VSI reading. Hence, the observed variations in the rate of climb were not directly representative of the rate of updraughts or downdraughts.

Severe icing conditions

The conditions at FL130 were capable of supporting SLD greater than 0.05 mm (50 microns) in diameter which can lead to the formation of severe icing. Analysis by the manufacturer concluded that the aircraft was affected by a large increase in aerodynamic drag. This could have been due to ice or downdraughts or a combination of the two. Even if the downdraughts had been twice as great as the Met Office calculated, the increase in aerodynamic drag indicated that the aircraft had probably encountered severe icing conditions.

The manufacturer also noted that the ice ridges, which the pilots saw behind the inflatable area of the de-icing boots, corroborated the presence of severe icing. The co-pilot observed this about the time the airframe vibration began, but he did not discuss it with the commander because they were in the process of descending, to vacate the icing conditions. Also, the OM did not state that this was an indication of severe icing.

The lines painted on the aircraft's spinners caused confusion. The manufacturer had painted them as a trial but there was no written information about them and both pilots had a different understanding of their significance.

The evidence suggested that severe icing conditions were encountered by G-LGNM by the time it passed FL125, in the climb, and that it remained in severe icing after levelling.

Procedures

The OM states that MCP should be used if ice accumulation due to '*extreme icing conditions*' causes a *'large impact on performance'* and the IAS decreases towards the minimum safe speed. The OM, as extant at the time of the incident, also stated that a speed reduction to $V_{CLEAN+15}$ may be used for flaps 0 climb to exit icing conditions, when above MSA. However, it did not link this to an increase in power to MCP and the setting of maximum propeller rpm. Nevertheless, the pilots were familiar with NOTAC 66/13, which recommended that, if the climb were continued, the initial actions should be to move the condition levers to the MAX position, set MCP according to the appropriate chart, select half bank and climb straight ahead at a speed not below $V_{CLEAN+15}$.

The commander did not set MCP when reducing the IAS below V_{CM} because he thought that downdraughts were primarily responsible for the reduction in the rate of climb, not icing. Furthermore, he believed that propeller rpm only needed to be increased to aid the shedding of propeller ice if severe icing conditions had been identified. The co-pilot did not advocate the setting of MCP because he considered that the commander would not value such a suggestion. The manufacturer's analysis determined that, if MCP had been set, the aircraft could have been climbed to FL170 and vacated icing conditions.

After levelling off, and an unsuccessful attempt to increase IAS using a non-standard technique, the crew concluded that they should vacate icing conditions by descending. In level flight, the minimum approved speed is 160 KIAS (V_{CM}) but the pilots believed 145 KIAS ($V_{CLEAN+15}$) was acceptable, if they were attempting to vacate icing conditions. As ice accumulation was having an impact on the aircraft's performance, and reducing airspeed, the SOP to use MCP in such circumstances was applicable, even though, the SOP included the potentially confusing reference to '*extreme icing conditions*'. Had MCP been set, it was calculated that the aircraft would have achieved a speed in excess of 160 KIAS for a considerable period.

In the event, while the commander was programming the autopilot and setting a descent rate to increase airspeed, the IAS reduced below 145 KIAS. During the time that it took to make the flight guidance inputs and for the system to react, IAS reduced at a rate of 1 kt every two seconds and the AOA increased. The pitch attitude reduced by 2º in response to the descent rate commanded (1000 ft/min), but it was still 5º nose-up. IAS continued to decrease and the AOA increased even further.

It was stated in the OM that the stall protection systems would operate at a pre-determined AOA and that, in icing conditions, a stall could precede the activation of these systems. There were notes to the effect that, in icing, a stall would occur at higher airspeeds than with a clean wing. Accordingly, the AOM mentioned that the autopilot should be disengaged in response to a significant performance loss in icing conditions. Had this been done, the aircraft could have been pitched down more quickly and the speed decay arrested. This requirement was not included in the Part B or in the operator's expired NOTAC 66/13.

Stall indications and recovery

The AOM stated that in (certified) ice conditions, buffeting might be experienced at an IAS up to 25% above the clean stall speed. This equated to 131 KIAS at G-LGNM's weight. However, the aircraft apparently encountered severe icing, which placed it outside certified conditions, and a strong vibration (the pre-stall buffet) was noticed at 137 KIAS. The co-pilot was not sure of the significance of the vibration, while the commander was attempting to use the autopilot to lower the nose and increase airspeed. The Emergency Checklist states that if there is any doubt about the source of an unusual vibration or buffeting, a stall recovery must be performed.

As the IAS decreased, a roll to the left was corrected by the autopilot. This reflected a previous investigation, concerning N306AE, which noted a similar rolling motion prior to the stall of that aircraft. The OM recommends a reduction in AOA in the event of an uncommanded roll movement. This appears in a section relating to '*SLD Detection*'.

Of note, the stall warning would have been set to a lower AOA if the '*Ice Speed Function'* had been operational. If so, the warning would have operated at an IAS of about 140 KIAS, before the pre-stall buffet and the uncommanded roll.

When the stall warning activated and the autopilot dis-engaged (at 132 KIAS, with an AOA of 13º), the commander effected a recovery by pitching the nose down to accelerate the aircraft. However, he did not call 'STALL - MAX POWER' and use all available power, as specified in the AOM.

The pilots' previous stall training had commenced from an approach configuration, with a low power setting and with the propeller rpm already at MAX. The pilots had practised carrying out a stall recovery by advancing the power levers but not the condition levers. This anomaly was highlighted during the investigation and has been addressed by the operator in a new training schedule (see *Safety Actions* later in this report).

ICE PROT caution

No definitive explanation could be given for the illumination of the ICE PROT caution and the TIMER light as the airspeed increased. It was likely to have been caused by a discrepancy in one of the sensors in the de-ice boot system but, as it cleared when the abnormal checklist actions were taken, there is no evidence that it was a contributory factor in the incident.

Guidance material

The OM refers to '*normal icing condition'* and to '*extreme icing conditions*' as well as to *'moderate'* and *'severe icing'* conditions. Only the latter two terms are accepted aeronautical terms and compatible with the UK AIP. G-LGNM is not certified for the severe icing conditions it experienced and OM, Part B states that the aircraft is not approved for icing conditions forecast to be worse than moderate. The AFM and the AOM include two separate actions to be taken if severe icing is encountered, while there are several other instructions linked to '*extreme icing conditions*'. The only clear instruction to vacate specified icing conditions is linked with the observation of ice accretion on the upper surfaces of the wings, aft of the protected surfaces, but this does not take account of a statement elsewhere that ice can build-up without being visible.

The manufacturer is reviewing the manuals to address these observations (see *Safety Actions* later in this report).

Conclusion

G-LGNM probably encountered both severe icing conditions and mountain wave effect while climbing. The crew reduced the airspeed to $V_{CLEAN+15,}$ for optimum climb performance, but the propeller rpm and power were not increased to MCP. The co-pilot perceived that the command gradient between himself and the commander was too steep for him to feel comfortable advocating such a procedure, even though he believed it appropriate.

After levelling-off, airspeed initially increased before reducing back towards $V_{CLEAN+15}$, a speed that was only intended for use when climbing out of icing conditions, and in combination with MCP. It was apparent that the aircraft's performance was being impaired by ice and it would have been appropriate to set MCP, as well as disengage the autopilot.

Pre-stall buffet was experienced and the recovery was delayed until after the stall warner had activated. Not all the stall recovery vital actions were implemented, although control was regained before a wing drop developed, as had happened in previous Saab 340 stall events.

The manufacturer is reviewing the guidance in the AFM and AOM, relating to flying the Saab 340B in icing conditions, and the operator has updated its advice to crews on the same subject.

Safety actions

The operator

- After the event, the crew received extra simulator training. The instructor was able to simulate a vibration which was similar, although not identical, to the pre-stall buffet that the pilots had experienced.
- During this simulator training the crew practised stall recovery when at cruise altitude. This differed from their previous stall training, which was practised from an approach configuration, with the propeller levers already set to MAX and with the power levers at a low setting. This had not prepared them for the situation at cruise altitude where the power levers were at a high setting and the propeller levers needed to be moved to MAX during stall recovery.
- The operator has since developed a recurrent simulator training package that encompasses performance degradation in icing conditions, leading to pre-stall buffet, with associated stall recovery practice. This training, which all the operator's pilots are scheduled to receive, began in Spring 2015.
- The operator produced an updated NOTAC about Saab 340B operations in icing conditions and intends to incorporate this information in Part B of its OM. The NOTAC offers more detail about severe icing conditions, instructs crews to aim for a minimum cruise IAS of 180 KIAS and to disconnect the autopilot and descend immediately if IAS decays below V_{CM}. The NOTAC also lists the stall recovery actions because they do not feature in the abnormal or emergency checklists for the aircraft.
- The operator has ensured its crews can access bookmarked, electronic versions of the AFM and AOM and intends to liaise with the manufacturer to improve the available search functions.
- The operator acknowledged the crew resource management issues which were raised by the co-pilot's reluctance to advocate his position. These issues were addressed as part of the re-training which both pilots received before returning to line operations.
- A modification which re-instates the 'Ice Speed Function' has been approved by EASA and is to be installed in all the operator's aircraft by August 2015.

The manufacturer

- The manufacturer is reviewing the guidance provided in the AFM and the AOM that relates to operation of the Saab 340B in icing conditions. This review includes crew actions to be taken on identifying specified icing conditions, using accepted aeronautical terminology compatible with the UK AIP.

- An Operational Newsletter has been issued to inform operators that the black lines on the propeller spinner have no operational significance.
- The manufacturer and the operator have begun a dialogue on the simulation of pre-stall buffet in icing conditions, so that other operators can use this training technique.