INCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash 8 Q400, G-JEDM
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2003
Date & Time (UTC):	3 March 2009 at 1820 hrs
Location:	10 nm north-east of Southampton Airport, Hampshire
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:	Air Transport Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	4,100 hours (of which 413 were on type) Last 90 days - 100 hours Last 28 days - 27 hours
Information Source:	AAIB Field Investigation

Synopsis

During an approach to Southampton in moderate turbulence the aircraft decelerated below its minimum manoeuvring speed and the flight crew received a momentary stick shake warning, indicating a low speed condition. The autopilot disengaged automatically and the aircraft reached 12.5° nose-up and rolled 43.5° to the left, albeit not concurrently, before the flight crew regained full control.

Background to the investigation

The aircraft operator became aware of the incident on 6 March 2009 through its flight data monitoring programme. Since the event was classified as an incident reportable to the Civil Aviation Authority (CAA)[1], the aircraft commander submitted an air safety report, which was received by the CAA on 25 March 2009.

The Civil Aviation (Investigation of Accidents and Incidents) Regulations 1996 empower the Chief Inspector of Air Accidents (CIAA) to determine whether or not an investigation is to be carried out into an occurrence, whether or not it qualifies for reporting to the AAIB. The CIAA ordered such an investigation to be conducted into this incident.

Footnote

[1] As described in the CAA's Civil Aviation Publication (CAP) 382 – '*The Mandatory Occurrence Reporting Scheme'.*

History of the flight

The aircraft was operating a scheduled passenger service from Edinburgh to Southampton, with four crew and 61 passengers on board. The flight was the second of a four sector duty for the crew. The duty originated at Southampton and involved a planned aircraft change to G-JEDM at Edinburgh after the first sector. The aircraft departed stand at Edinburgh at 1701 hrs for the flight to Southampton, with the co-pilot handling the aircraft.

The weather at Southampton was wet and blustery and, although the aircraft's descent would be through an area of potential icing, icing conditions were not expected during the final approach. Therefore, when the co-pilot gave her approach and landing briefing, she briefed that 'non-icing' (ie non-adjusted) reference speeds would be used for the final approach.

As the aircraft descended, it was routed overhead Southampton Airport before being turned left onto a downwind heading for Runway 20. The aircraft entered cloud at about 8,000 ft, and information from the flight data recorder (FDR) showed that it encountered some airframe icing. The aircraft was in an 'icing configuration' at this point, in which activation speeds for the stall warning and protection systems were increased to allow for the possible adverse aerodynamic effects of ice on the airframe.

There was a strong wind blowing from the south and considerable turbulence at lower levels. As the aircraft turned downwind under instructions from Southampton Air Traffic Control (ATC), its groundspeed increased rapidly due to a 50 kt tailwind, prompting the controller to instruct the crew to slow the aircraft to 160 kt in order to ensure separation from an aircraft ahead. As it neared the end of the downwind leg, G-JEDM had slowed to about 174 kt IAS. The autopilot remained engaged in the heading and vertical speed modes.

The aircraft then commenced a turn to the left towards a base leg. Shortly after being established in the turn, it entered an area of increased turbulence and the stall warning stick shaker activated for a brief period, at a recorded aircraft speed of 161 kt. This caused the autopilot to disconnect automatically. Almost coincident with this, the trailing edge flaps were selected from 0° to the intermediate approach setting of 5º. The aircraft then pitched up slowly, reaching a maximum of 12.5º pitch angle and a minimum speed of 147 kt. It rolled further left and, with increasing bank angle, the pitch attitude started to reduce. The aircraft reached a recorded 43.5º of left bank before the co-pilot made any significant control inputs. Normal control was then regained. The speed subsequently increased to about 175 kt and the autopilot was re-engaged.

According to crew accounts, the commander was unaware that the stick shaker had activated, and the co-pilot was unsure whether she had mentioned it at the time. As the surface wind for landing was in excess of the company limits for a co-pilot to land, the commander assumed control for the final approach. Turbulence and windshear were also encountered during this period, and at one point the autopilot again disconnected, but there were no further stick shaker activations.

Meteorological information

A cold front crossed the south of England during the day, giving rise to a band of heavy rain which continued into the evening as wintry showers. For the approach into Southampton, the airport was reporting a surface wind from 170°M at 16 to 47 kt, a visibility of 6,000 m in rain, and broken cloud cover at 1,200 ft aal. The flight crew reported that the aircraft was in cloud and

rain at the time of the incident, with moderate to severe turbulence. The aircraft's FDR recorded an outside air temperature of +2°C at the moment the stall warning stick shaker activated and the autopilot disengaged.

Crew information

The commander joined the operator from the RAF in May 2008, having previously flown the Lockheed Martin C130J Hercules. At that time he had about 3,800 flying hours, including about 1,100 hours in command on the C130J. He completed all the required aircraft conversion training and testing and had been flying the Dash 8-Q400 as commander since 30 July 2008. The duty period in which the incident occurred was the commander's first period at work after 10 days leave.

The co-pilot commenced her commercial flying career in 2001. She joined the operator in 2008 after a two year break from flying. She completed a final line check on 6 January 2009 and at the time of the incident had a total of about 3,500 flying hours, with 88 hours on type. Her commercial flying prior to joining the operator was mainly on the Dash 8-300, on which she had about 570 hours, and the Embraer 145. The co-pilot worked a part-time roster and had also just taken annual leave. The duty period in which the incident occurred was her first period at work after 18 days off.

Aircraft information

The Dash 8-Q400 is a high wing, two pilot, transport category aeroplane, with seating for up to 78 passengers. It is powered by two turboprop engines, each driving a six bladed propeller, and is approved for flight into known icing conditions.

Ice detection system

An automatic ice detection system provides early indication of aeroplane icing conditions. The flight crew are alerted to the presence of airframe icing by an ICE DETECTED message which appears on their engine display.

Stall protection

A stall protection system warns the crew when the aircraft is in a near stall condition. It calculates when to start and cancel stick shaker and stick pusher operation. Operation of one or both stick shakers causes the control columns to vibrate. In addition to this tactile warning, the stick shaker motor and the rattling of the mechanism on the control column creates a loud noise. If only one stick shaker is operating, its vibration is transmitted through the control linkage to the other column. When the stall protection system signals a stick shaker to operate, it also sends a signal to the automatic flight control system to disengage the autopilot.

Activation of stick shaker and stick pusher systems is triggered at a relatively lower angle of attack when in icing conditions, because of the reduced performance limits of the aircraft. This change is signalled to the system by the flight crew setting a REF SPEEDS switch on the ice protection panel from OFF to INCR. The minimum operating speed, depicted on the speed tape of each pilot's primary flight display (PFD), is increased accordingly.

Aircraft performance

The calculated mass of the aircraft at the time of the incident was 26,200 kg; maximum landing mass was 28,009 kg. Reference stall speeds (Vsr) from the manufacturer's Aircraft Operating Manual (AOM) were given as: 122 kt in Flap 0 configuration and 113 kt in

Flap 5 configuration. The operator's in-flight data card for 26,500 kg gave minimum manoeuvring speeds[2] for Flap 0 and Flap 5 configurations as 150 kt and 138 kt respectively.

Icing procedures

Icing procedures were contained in the AOM and the operator's Operations Manual (OM). The AOM instructed that the REF SPEEDS switch should be set to INCR either before entering icing conditions or when an ICE DETECTED message appeared on the engine display. With the REF SPEEDS switch at INCR, the minimum clean speed (Flap 0) was to be increased by 25 kt, equivalent to 175 kt for G-JEDM at the time of the incident. This advice was reproduced in the OM. To ensure limiting speeds were not exceeded, the OM recommended selecting Flap 5 at 180 kt when decelerating, irrespective of icing conditions. It also listed an icing increment of 20 kt to the Flap 5 minimum speed, giving a minimum Flap 5 speed of 158 kt at the time of the incident.

Stall recovery

Stall entry and recovery procedures were also contained in the AOM and reproduced in the OM, although the procedures were oriented towards the training environment rather than inadvertent stall encounters during line operations. In summary, the required crew response was for the handling pilot to announce the stall and set the power levers forward to the normal takeoff power setting, while relaxing control back pressure and levelling the wings. The monitoring pilot would set the condition levers to maximum. The OM stated:

> *'Once stick shaker has ceased and aircraft is safely established in a recovery, climb to and maintain the altitude at which the stall was entered or as briefed. Adjust power so as not to exceed 160 KIAS. Stall recovery is complete and the aircraft should be configured as required for continued flight.'*

Automatic flight indications and displays

The autopilot couples the flight director commands to the flight control surfaces using pitch and roll servos for automatic control of the aircraft's flight path. Autopilot engagement is indicated by two lit arrows on the flight guidance control panel, which is mounted centrally on the glareshield. Engagement is also indicated by a green A/P legend on each pilot's PFD.

Automatic autopilot disengagement is signalled to the crew by a flashing red warning light on the glareshield in front of each pilot and by a flashing amber AP DISENGAGED legend on each PFD. It is also accompanied by an aural tone which sounds continuously until acknowledged by the flight crew by pressing either of two disengage switches mounted on the control wheels.

Operational notices to crew

In 2005, the operator had identified that a number of recorded low speed events had been due to the REF SPEEDS switch being at an incorrect setting (ie at INCR) when 'non-icing' speeds were being used, resulting in an increased stick shaker activation speed. A notice to flight crews stressed the importance of having the switch in the correct position for the prevailing conditions. It also stressed that crews must respond to any stick shaker warning by carrying out the stall recovery actions; they were not to react by setting the REF SPEEDS switch OFF in an assumption that the switch must be incorrectly set.

Footnote

[2] Minimum manoeuvring speed in this case equates to Vsr, in the relevant configuration, multiplied by a factor of 1.23.

The stalling information in the AOM and OM, together with the minimum operating speeds in icing conditions, was reiterated to the operator's flight crews in an operational notice dated 16 February 2009, shortly before the incident.

Recorded flight data

FDR information for the whole flight had been downloaded by the aircraft operator and was available for analysis. Figure 1 shows relevant flight data from the time of the incident.

Initial manoeuvring

As the aircraft passed 6,000 ft, descending through cloud with an outside air temperature of -0.25°C, the ice detection system generated an ICE DETECTED message, which lasted one minute. The REF SPEEDS switch was already at INCR, having been selected to that position during the climb after the aircraft departed from Edinburgh. The aircraft continued to descend on the downwind leg for Runway 20, towards a cleared altitude of 3,000 ft. The autopilot was engaged in vertical speed mode, with a rate of descent of 500 ft/min selected. The power levers were retarded and the engines were developing approximately zero torque. Airspeed, which had been decreasing steadily, was about 200 kt and the wind, as sensed by the aircraft, was from 210°M at 50 to 55 kt.

When the aircraft turned left towards base leg, the airspeed was 174 kt and the engine power lever positions were unchanged, giving zero to -3% torque. The aircraft was descending at 500 ft/min through 4,300 ft. The bank angle subsequently stabilised at 23°, with the same power setting and steadily reducing airspeed.

Stick shaker activation and attitude excursion

About five seconds after the turn was established, there was an increase in the level of turbulence, indicated by increasingly large normal 'g' spikes. Near the peak of one such fluctuation, which recorded 1.36 'g', both stick shakers activated and the autopilot disengaged. Airspeed was 161 kt and the angle of attack, which had been at about 7° immediately beforehand, rose to between 10 and 12° for between one and two seconds. The aircraft's pitch attitude was 6° nose up.

The power levers had been advanced to a mid-range setting just before the stick shakers activated but the engine torques had not increased before the warning was triggered. The engine torques then rose momentarily to about 40%, reduced to between 25 and 30%, before increasing again to 56.5%, where they remained for the remainder of the event. Flap 5 was selected within about a second of stick shaker activation.

The angle of bank remained unchanged for about five seconds, as the aircraft began to pitch further nose up at a rate of approximately one degree/second. Bank angle then began to increase, and was increasing through 34° as a maximum pitch of 12.5° was reached. The angle of bank reached a recorded maximum of 43.6°, coincident with the lowest recorded airspeed of 147 kt. The REF SPEEDS switch was selected OFF at between 153 kt and 147 kt[3], shortly before the minimum speed was reached and approximately 10 seconds after the stick shaker had activated.

The exact moment and duration of stick shaker activation could not be determined precisely because the data sampling rate was once every four seconds.

Footnote

[3] The recorded data update rate for this item was relatively slow, at once per four seconds.

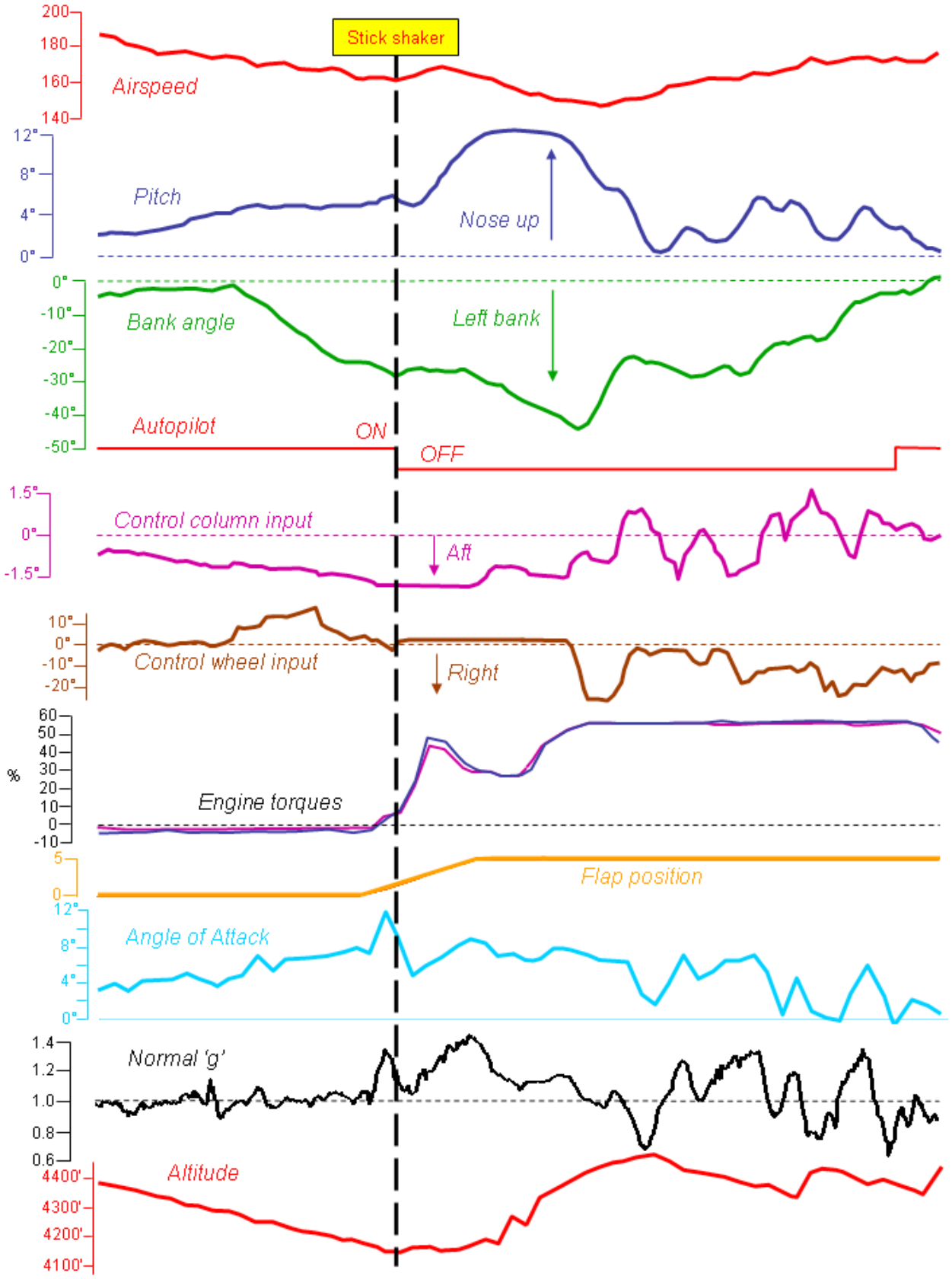

Figure 1

Relevant FDR parameters over a 65 second period surrounding the stick shaker event (simplified)

However, from the angle of attack and other data with a higher sampling rate, it is likely the stick shaker was active for only about one second, possibly less. The airspeed continued to reduce below that at which the stick shakers activated but, by then, the flaps had travelled to 5° and the angle of attack, although still fluctuating, was less.

Flight control inputs

Lateral control wheel displacements of up to 17° were recorded as the aircraft rolled left, in response to autopilot commands, returning to almost zero as the aircraft was stabilised in the turn. The control columns gradually moved aft as the speed reduced but this movement ceased when the autopilot disengaged, although the aircraft continued to pitch up and roll further left. Pitch trim, which had been increasing under autopilot control, remained unchanged after the autopilot was disengaged.

As the pitch approached its maximum value, about four seconds after autopilot disengagement, there was a small forward movement of the control column, which was soon removed, with no wheel displacement. Only when the bank angle increased beyond 40° was a large lateral control wheel input made, which corrected the overbanked condition. This was about 13 seconds after autopilot disengagement.

The aircraft returned to a steady turn condition, banked left at about 25° with a pitch attitude near 0°. It completed its turn onto a westerly heading and the airspeed recovered to 175 kt. Having gained about 350 ft during the event, the aircraft was established in a descent, once again, and the autopilot was re-engaged in the heading and vertical speed modes.

Flight crew accounts

The incident was initially investigated by the aircraft operator under its existing flight safety scheme. Consequently, both pilots had discussed the event at some length with company management and were aware of the FDR data. Thus, when they were interviewed as part of the AAIB investigation, nearly a month after the incident, it is probable that their recall of the event was influenced somewhat by the earlier investigation process.

The aircraft commander said that the flight crew had been expecting icing conditions during the descent, but the reported conditions at Southampton allowed for the final approach and landing to be made using normal speeds, ie without icing increments. Neither pilot recalled receiving an ICE DETECTED message at any stage of the flight. Both reported that cockpit conditions became difficult as the aircraft descended and encountered cloud, with heavy rain and turbulence causing considerably raised noise levels in the flight deck.

The commander recalled the ATC instruction to reduce speed to 160 kt. Although the REF SPEEDS switch was set to INCR, and he knew that non-icing speeds would be used for the final approach, he was undecided as to when he would or should put the switch to OFF. He was aware of the Flap 5 minimum manoeuvring speed of 138 kt and the 20 kt icing increment with the REF SPEEDS switch at INCR. He thought that the speed had reduced to 160 kt and the co-pilot had called for Flap 5 when the autopilot disengaged, although he did not recall the stick shaker activating. The co-pilot had her hands clear of the controls but placed them on the controls at that time.

The commander considered that he may have been partly distracted by the radio and imminent flap selection at about the time that the stick shaker went off. However, he recalled seeing the airspeed just above the point on the speed tape at which stick shaker activation was predicted. He called something like "CAUTION, SPEED – REFS GOING OFF" and set the REF SPEEDS switch to OFF. This immediately increased the speed margin above stick shaker activation.

The co-pilot recalled thinking that the 160 kt instruction was achievable with Flap 5 and, essentially, conformed to a normal speed profile. She reported being aware that the autopilot had disconnected, which she attributed to the turbulence. As it did so, she placed her hands on the control wheel and felt the stick shaker for a brief moment. She attributed the subsequent attitude excursions to the severity of the turbulence. She did not recall the commander mentioning the REF SPEEDS switch but was aware that he set it to OFF.

During interview, both pilots expressed some reservations about the complexity of the icing procedures, as they appeared in their company's documentation, and felt that simulator training in this regard tended not to reflect real world situations in which changes from icing to non-icing procedures often entailed changing the REF SPEEDS switch during speed transitions.

Safety actions

Following the incident, the aircraft operator introduced or planned a number of safety measures:

1. A further notice to flight crews on the subject of low speed events was issued, incorporating information gleaned from a company analysis of such events over the preceding two years. The notice further stressed to crews the importance of the correct operation of the REF SPEEDS switch and of awareness of its position, particularly during the approach phase when a transition from 'icing' to 'non-icing' speeds was planned. The analysis identified a number of cases in which the REF SPEEDS switch had been set to OFF as an early action on encountering stick shaker, so it was again stressed that crews were to carry out standard stall recovery actions before making any attempt to identify the reason for a stick shake warning.

2. A standard speed profile was introduced. Using this profile, the aircraft would reduce to a Flap 0 speed of 210 kt by 12 nm to touchdown, thence to 180 kt with Flap 5 by 8 nm to touchdown. Further speed reduction, initially to 160 kt, would normally only occur within 8 nm of touchdown.

3. An evaluation would be made of the quality of the initial type rating training given to company pilots regarding the correct use of the REF SPEEDS switch, with a view to amending the training if deemed necessary.

4. Further amendments to winter operations documents were planned, to reinforce the correct procedures in icing conditions.

5. A review would be made of the stall recovery training given during initial type rating training to ensure such training reinforced the correct initial response to a stick shake warning.

6. Low speed awareness training was to be included in recurrent simulator training programmes.

7. Takeoff and landing data cards were to be introduced, to provide reference speeds for flight crews on the flight deck.

8. In a subsequent revision to the OM, the operator removed the requirement not to exceed 160 kt during stall recovery, replacing it with the phrase *"not to exceed any airframe limitations."*

In May 2009 a meeting was held between the AAIB and the CAA, at which the operator's response to the incident was discussed. The CAA was satisfied that appropriate and measured steps were being taken by the operator and undertook to monitor the areas of concern at future audits. No further actions or recommendations were deemed necessary.

Analysis

Stick shake encounter

The aircraft was descending with the autopilot engaged in vertical speed mode, with a low rate of descent and at low power. Although this configuration suited the planned descent path and resulted in a desired reduction in airspeed, it required that the crew closely monitor airspeed to ensure it did not fall below the minimum for the configuration, particularly given the turbulent conditions.

Had the aircraft been flying in smooth, straight and level flight, there would have been a margin above the stick shaker speed, even with the REF SPEEDS switch at INCR. However, the aircraft was in a decelerating turn at low power, and in moderate turbulence. In this case, the reduction below the minimum Flap 0 speed, together with these other factors, reduced the margin to zero for a brief time, causing the stick shaker to activate.

Both pilots were apparently aware of the minimum Flap 5 speed of 158 kt, but on this occasion seem to have regarded this as a target speed with Flap 5 rather than a minimum speed. This may have been influenced by the knowledge that the REF SPEEDS switch was soon to be set OFF, or may be indicative of a less than full understanding of the speed schedule in icing conditions. The late flap selection resulted in a significant excursion below the minimum Flap 0 speed of 175 kt which, with the aircraft in a turn and in moderate turbulence, caused the stick shakers to activate.

Attitude excursion

FDR data showed that no effective control inputs were made after the autopilot had disengaged, although the co-pilot had placed her hands on the controls at that point. As the aircraft subsequently reached exaggerated attitudes in both pitch and roll, it appears that the co-pilot did not in fact realise that the autopilot had disengaged until the increasing roll attitude had become a concern. Her belief at interview that the attitude excursion was brought on by turbulence supports this supposition. The commander saw the co-pilot put her hands on the control wheel and probably thought she had assumed manual control.

Flight crew performance

Each pilot was correctly trained and qualified, and had demonstrated their competence to the required standards. However, on this occasion they did not operate effectively, either individually or as a crew, in that they first allowed the aircraft to reach an undesirable situation and then did not deal with the situation in an entirely appropriate manner.

Neither pilot had flown for a period of time due to annual leave and their normal roster patterns. Although this did not contravene any regulation, it was not an

ideal situation. Early in their first duty period after leave, they were required to fly an approach at night in difficult circumstances, albeit the approach was at their home airfield and not procedurally demanding.

The presence of a significant tailwind on the downwind leg may have combined with the pilots' relative lack of currency and difficult cockpit conditions to produce a situation where they were not thinking as far ahead as they normally would. The tailwind necessitated ATC's instruction to reduce speed to 160 kt at an unusually early stage in the approach and was followed quickly, again because of the tailwind, by the instruction to turn left onto base leg. As this coincided with the aircraft speed reducing to the point that flap extension was required, the crew's workload would have increased rapidly and probably unexpectedly, which would have increased the likelihood of them making procedural and cognitive errors.

The lack of a positive reaction by the co-pilot to the stick shaker, and the commander's response to the low speed situation of putting the REF SPEEDS switch to OFF, shows that neither pilot considered the aircraft to be in immediate danger of an actual stall. This was an accurate assessment, but one which is difficult to make at a time of increased stress and workload, hence the requirement to carry out positive stall recovery actions upon stick shaker activation.

The co-pilot was faced with an unusual situation, in which her procedures and training required a definite response (the stall recovery actions). Yet the aircraft had effectively recovered itself and already met most of the criteria for recovery: speed was in excess of (or not far below) 160 kt, the altitude was about that at entry, and the aircraft was by now configured for continued flight. Crucially though, the aircraft was not wings level, and positive action from the co-pilot on the controls at this stage to level the wings, or at least reduce the existing bank angle, would have prevented the subsequent attitude excursion.