BUFFET ON APPROACH IN ICING CONDITIONS

• History

Boeing has received 15 reports over the last few years from 4 Boeing 767 operators of higher than "normal" airframe buffet occurring after flap extension to Flaps 30 while on approach in icing conditions. Several of these reports originated from KLM. A few reports also included observation of the Vref bug being inside the EFIS speed tape amber band.

Boeing analyzed Flight Data Recorder (FDR) data from 3 KLM flights where buffet had been reported. Furthermore an extensive flight test program was conducted by Boeing to investigate and resolve this issue.

The first part of this bulletin briefly describes this investigation and Boeing's conclusions and gives operational information. This first part is "Need to Know".
The second part of this bulletin gives more background information, primarily focused on the flight test results and may be considered "Nice to Know".

• Need to Know

Boeing's investigation of the Flight Data Recorder (FDR) data of the three KLM flights confirmed higher than-normal buffet. levels for two of the three flights. The data for the two higher-buffet approaches also indicated that reduced maneuver capability due to lift losses at Flaps 30 could be associated with ice accretion. To further investigate this issue Boeing conducted a flight test program on a B767-300 in which several artificial-ice configurations were tested. During these tests artificial-ice shapes were Installed on the leading edges of the horizontal tail and on the wing leading-edge sections that are not protected by the thermal anti-ice system. Furthermore tests were performed where artificial-ice shapes were also installed on the inboard and outboard flaps.

Findings

The FAA participated in the flight test program and the results were reviewed with representatives of both the FAA and JAA. It was concluded that there are no safety issues related to flight in icing for the 767-300. No changes to operating procedures or Airplane Flight Manual (AFM) parameters are required by either Boeing or the authorities. Testing did confirm that ice accretion may cause an increase in airframe buffet levels under some operating conditions.
The airframe buffet can be described as having characteristics similar to buffet associated with speedbrakes extension at flaps 20 or greater. The buffet becomes more noticeable with increasing flap deflection and at forward centers of gravity. In addition, ice accretion on extended trailing edge flaps may result in increased airframe buffet, decreased lift and increased stall speeds at landing flaps.

These effects are dependent on the amount of ice adhering to the flaps. Normal operating procedures for flight in icing conditions can accommodate these performance effects.

Boeing has demonstrated adequate stall warning margin and manoeuvering capability for all tested configurations.

There were no adverse handling capabilities noted.
Boeing's information indicates that the Wing anti/de -ice system performs as per design.

Guidelines

In some more extreme cases an increase in EFIS speed tape amber band speed may be noticeable. In these circumstances R is advised to raise the approach speed as necessary to stay "out of the amber bond".

Explanation: The top of the amber band is based on measured angle of attack. Reduced performance of the wing due to ice accretion, results in flying at a higher - angle of attack than with a clean wing at the same speed this higher angle of attack will then result in a higher amber band speed.

In order to minimize the impact of ice accretion on airplane performance and buffet levels, avoid holding with flaps extended when in icing conditions.

Furthermore prolonged operation in moderate-to severe icing conditions should be avoided when possible.

This bulletin discusses the effects of ice build-up during flight in icing conditions.
It should be stressed that this information does in no circumstances alleviate the requirement for a clean aircraft before take-off . Under ground icing conditions ice may build-up on wing, tail and other aircraft surfaces which have a detrimental effect on aircraft lift, performance and handling capabilities.

- ## Nice to know

As mentioned Boeing conducted a flight test program to try to resolve the issue. These tests were conducted on a new 767-300 during May of 1999. Several artificial-ice configurations were tested. The baseline configuration consisted of 3-inch artificial ice shapes installed on the horizontal tail and on the wing leading-edge sections that are not protected by the thermal anti-ice system. These ice shapes were representative of ice accretion during a Flaps Up hold and were used as part of the original 767 flight-in icing- certification. While retaining the 3-inch baseline ice shape installation, two different artificial flap ice shapes, "small flap ice" and "large flap ice", were tested. The "small flap ice" represented a thin, frost-like ice accumulation, which was considered to be representative of the configuration experienced in many of the in-service reports.

The "large flap ice", a more substantial ice shape with a 1.2-inch horn, represented extended exposure to icing, such as during a flaps-down hold, and was considered a conservative configuration. The flap ice shapes were installed on the leading edges of the inboard and outboard trailing edge flaps. Tests were conducted at both forward and aft centers of gravity (cg's).

Flight Test Results

- Buffet

With the baseline 3-inch shapes, buffet levels increased with increasing flap deflection and were consistent with the 767-200 buffet levels with ice at equivalent flap deflection angles. The increased flap deflections at Flaps 30 with the improved -300/-300 ER flap system resulted in higher buffet levels than seen on the 767-200 at its Flaps 30. The buffet increase was primarily driven by the horizontal tail and increased at more forward cg's. Elevator and stabilizer effectiveness were thoroughly tested and found to be satisfactory.

With flap ice there was an additional buffet increase, again growing larger as flap deflection increased. The same flap ice configuration at Flaps 30 exhibited the highest buffet levels generated during the flight test program. It was similar to the buffet level for a non-iced airplane at Flaps 30 with the speedbrakes up. Flow visualization data suggested that the cause of the increased buffet was intermittent flow separation on the outboard flap upper surface. With large flap ice shapes, buffet increased at Flaps 25 and 30 although not quite as much as with the small flap ice. The flow visualization data indicated nearly complete flow separation on both the inboard and outboard flap upper surfaces at Flaps 30. The buffet levels for all ice configurations were found to be acceptable and did not interfere with operation of the aircraft.

The buffet levels are mainly caused by ice accretion on the horizontal stabilizer and the trailing edge flaps. The performance loss at landing flaps is mainly caused by ice accretion on the trailing edge flaps. The effects of ice accretion on both the protected (by thermal anti-ice) and unprotected leading edge slats is far less pronounced. Boeing's information indicates that the Wing anti/de-ice system performs as per design.

- Lift at Normal Operating Speeds

There was no effect on lift at normal operating speeds with the 3-inch ice shapes on the wing and empennage, nor with either flap ice shape at detents less than Flaps 25. There was a lift decrement with both small, and large flap ice at Flaps 25 and small flap ice at Flaps 30, equivalent to a change in airspeed of 1 to 4 knots. Flaps 30 with the large flap ice had a somewhat more significant lift loss, equivalent to approximately 12 knots, consistent with separated flow on the flaps.

- Stall Speeds & Stall Warning Margin

The baseline 3-inch ice shapes on the wing leading edge caused an increase in stall speeds relative to the clean airplane for all flap detents except Flaps Up. Relative to this level, there was an additional increase in landing flap stall speeds with both small and large flap ice.

Adequate stall warning margin was demonstrated for all configurations Maneuvering Capability. There was no reduction of maneuvering capability to stall warning at Flaps Up through Flaps 20 for any of the ice configurations tested. The large flap ice resulted in a 3- to 4-degree reduction in Flaps 25 maneuver capability at a speed of Vref 25, the bank angle capability for this configuration exceeding 40 degrees. With small flap ice at Flaps 30, Vref 30, 40-degree maneuver capability to stall warning was demonstrated. With large flap ice at Vref 30, the demonstrated maneuver capability was slightly reduced to approximately 35 degrees, consistent with the lift loss. At Vref 30+5, Flaps 30 bank-angle capability in excess of 40 degrees exists for all ice configurations.

- Drag

The drag increase due to the 3-inch ice shapes was in agreement with the certified drag levels. There was no appreciable drag increase with either the large or small flap ice configurations. For all configurations, the incremental Ice drag was less than or equal to the increment currently accounted for in the AFM.

- Landings

Both manual and automatic landings were performed at Flaps 25 and 30 with the conservative configuration of 3-inch baseline ice shapes plus large flap ice. Flaps 30 touchdown speeds ranged form Vref 30 to Vref 30+1 1. Adequate margin to tail-skid contact was demonstrated in all cases. During some Flaps 30 approaches, the Vref bug was inside the speed tape amber band, which is consistent with the reduction in lift and maneuvering capability with the large flap ice. On average, the Vref bug was several knots inside the amber band and for brief periods a difference exceeding 1 0 knots was seen. With autothrottle on, approach speeds were maintained above the amber band. During automatic approaches, oscillation or *pulsing" of the control column was experienced. The oscillation appeared to be caused by excitation of the natural frequency of the control-column cable system in response to the airframe buffeting. The control-column oscillation was not driven by the autopilot and had no effect on autopilot or elevator performance. The control-column movement is considered to be a normal characteristic of the 767 under these flight conditions. There were no adverse handling characteristics noted.

Remark :

Some B767 operators have experienced stiff aileron controls due to ice accumulation on the aileron cable system. Ice accumulation has occurred due to operation in moderate to heavy rain, plugged drains, potable water line rupture, air conditioning water separator leakage, overflowing lavatories, etc. Aileron control wheels are linked together through override devices. If one control wheel or aileron cable system jams, it can be overridden by applying sufficient force to the other wheel. However, water freezing on the aileron cable system in both wings can prevent operation of the ailerons even through actuation of the override system. It sufficient force, including maximum simultaneous effort on both control wheels is applied, the cables can normally be freed from the ice and normal roll control regained. Boeing states in its report that a cable breakage will not occur as a result of a maximum two-pilot effort on the control wheels.