STAR 009 V2 – December 2014	Winter Operations – Tailplane and Engine Fan Blade Icing

Introduction

FAR/JAR Part 25 transport airplanes are equipped and certified to operate in known icing conditions. While the certification standards provide protection for the majority of atmospheric conditions encountered, this is not valid for freezing rain, freezing drizzle or conditions with a mixture of super cooled droplets (SLD) and snow or ice particles. Flight into severe icing areas must therefore be avoided.

The purpose of this STAR is to provide an understanding of severe icing conditions when they are encountered and propose ways of reducing associated risks.

Severe Icing Conditions - Air Safety Report Example

Following is an incident described by the crew operating a CRJ on an early morning winter flight.

"*It was a smooth flight that went on as planned, and the atmosphere on board was relaxed. When arriving at the destination approach sector we received a clearance to enter holding. While holding in VMC conditions at first, we were later cleared descend to FL 150 which was in IMC. Shortly after entering the clouds aircraft icing began to develop rapidly, being clearly visible at the wiper posts and cockpit window frames. Engine vibration was felt immediately. As we expected another 40 minutes of holding time we requested ATC for an immediate re-climb into a higher VMC level.*

At first we only received a climb to FL 160. The ATC controller promised us a higher climb and started to find out the next available flight level that was in VMC. Shortly after, the engine vibration increased rapidly, and after a few moments ice particles separated from engine no.1, audible all over the airplane. This made our request more urgent: "We have severe icing, our engines start to vibrate and we need the climb now!" We promptly received clearance to climb. At the same time there was a loud noise, the aircraft was vibrating heavily and the VIB indication for engine no. 1 exceeded the maximum instrument value. We reduced thrust on that engine to idle and decided to request priority. Vibrations also started on engine no.2 and were increasing.

We expected an approach to runway 26 (no autopilot), in IMC and icing conditions. We were both convinced that the vibrations were caused by fan blade icing and not by damage, so we decided to leave engine no.1 running at idle thrust instead of shutting it down. ATC was informed accordingly, and we received a direct approach vector to the runway. In order not to make the cabin crew anxious we just informed them that one engine was vibrating due to icing and that we had already started the approach.

During the approach the vibrations reduced and instruments showed normal values. We then increased thrust on the engine, but the VIB indication went up into "yellow" range. On short final the ice seemed to have dissipated and we were able to use both engines in a normal way.

The landing was normal."

Source: ASR from an ERA member airline.

"Remarks by Flight Safety Officer:

At the time of the incident Munich weather was light snowfall and the OAT at –1° C (26016KT 7000 -SN FEW006 SCT012 BKN050 M01/M02 Q1016).

During the interview the crew reported that the aircraft wing/cowl anti-ice system had been switched on long before entering the upper cloud layer. At the time when icing conditions were encountered the engine thrust setting was N2 79% and higher because the crew deliberately wanted to operate in the "green arc". With the first sign of vibrations the crew also noticed a significant elevator control pulsing (4-5 cm fore and aft).

The CRJ was examined by our local technicians immediately after arrival. There was no mechanical damage or fan imbalance on the engines. We do therefore suspect fan blade icing that was blown off during approach due to inadvertent engine rpm changes . We must also suspect that tail plane icing was present."

Understanding Icing Conditions

[*The following information has been extracted from the BAE 'Think Ice 2007' Document*]

Definition of Icing Conditions:

- The Flight Manuals include a definition of icing conditions for both ground and in-flight operations. These are based on the Total Air Temperature (TAT) or Outside Air Temperature (OAT) along with the prevailing atmospheric and ground conditions. The Flight Manual definitions of icing conditions vary for the different aircraft manufacturers and according to specific Airworthiness Authority requirements. Whether ice accretion will actually occur or not depends upon many factors and therefore flight crews must be vigilant at all times, both on the ground and in the air. In flight, airframe ice accretion will normally be limited to forward facing surfaces, most significantly the leading edges of the aerofoil surfaces. The ice accretion can have a large variety of shapes and textures ranging from clear, thin ice (which can be difficult to detect) to coarse rime and glaze ice forms with single or double horns. The effects of such accretions on the operation of the aircraft are assessed during the certification process.

Aircraft Ice Accretion:

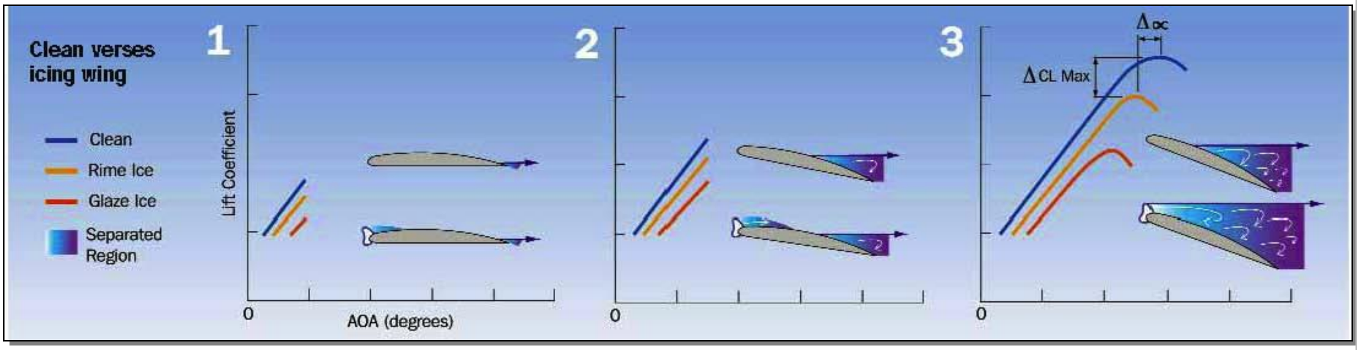
- Ice forms in-flight on leading edges and frontal areas of the airframe, engine intakes and spinners/propellers by a complex process involving both meteorological and aerodynamic factors. Meteorological factors include the liquid water and ice crystal content of the clouds, outside air temperature, droplet and crystal size and distributions. Aerodynamic factors include aircraft speed, configuration, surface geometry and temperature, and efficiency of catch of droplets and crystals.

Aerodynamic Degradation Due to Ice Accretion:

- Even slight surface roughness, often referred to as 'sandpaper' ice, can result in large lift and drag penalties. The majority of maximum lift degradation often occurs with the first ¼ to 1/2 inch of ice accretion (6 to 13mm). Further increase in ice depth and surface roughness has a less dramatic degradation of lift but will produce additional drag. Lift degradation is associated with an increase in stall speed and decrease in stall AOA. With significant ice accretion, the stall speed is increased substantially and pre-stall buffet may precede the activation of the stall warning system, particularly on aircraft with an airframe de-icing system.
- Control and trim effectiveness may be reduced. Aileron, rudder and elevator control systems can be prone to freeze if water deposits, snow or ice are not properly drained from critical areas. Control surfaces may freeze or jam with external ice accumulation.

- The power required to achieve or sustain a flight path can be increased significantly due to ice formation on the unprotected surfaces including areas of the airframe not visible from the cockpit. For turboprops, ice accretion on the propellers can significantly decrease the available thrust.

Asymmetric ice shedding from propellers or jet engine fans can also give rise to vibration.



- With ice accretion on the wing leading edges, the mechanism of stall development remains the same but starts at a lower AOA and therefore higher speed. In addition the airflow does not have the same level of energy around vortex generators (if fitted) for them to delay progression of the stalled area as effectively as on a clean wing.

- The overall effect of ice accretion on the stalling characteristics is also dependent on the type of airframe ice protection system installed. In general, the effect of ice accretion on aircraft with leading edge deicing systems installed is more adverse due to the ice accretion required prior to operation of the system and inter-cycle ice build-up.

- Where airframe anti-icing systems are installed as on the BAE 146 and Avro RJ, the protected areas of the airframe will in general be clear of ice and so the effect of ice on stalling characteristics can be less pronounced. However, with some of the more adverse ice shapes the stall warning may be preceded by airframe buffet and the stick pusher (when fitted) may be preceded by some lateral instability, wing rock, pitch nodding or ‘g’ breaks. This is more probable on the aircraft types with wing mounted lift transducers, due to ice accretion around the protected area of the vanes. With ice accreted on the leading edges, high rates of descent can develop at high flap angles. It does not require an excessive level of ice accretion to generate these wing stalling characteristics, accretions of just 1/2 inch can be sufficient.

- The phenomenon of tailplane stall is of considerable interest, particularly within the regional aircraft industry. It is one that has affected aircraft throughout the history of flight, including modern turboprop and jet aircraft. In order to increase the general awareness and understanding of its mechanism, an explanation of the causes is given below.

✈ A tailplane stalls when the maximum angle of attack for the tailplane, either positive or negative, is exceeded. The following discussion addresses the more common negative tailplane stall and is concentrated on aircraft with un-powered mechanical elevator controls and airframe de-icing systems.

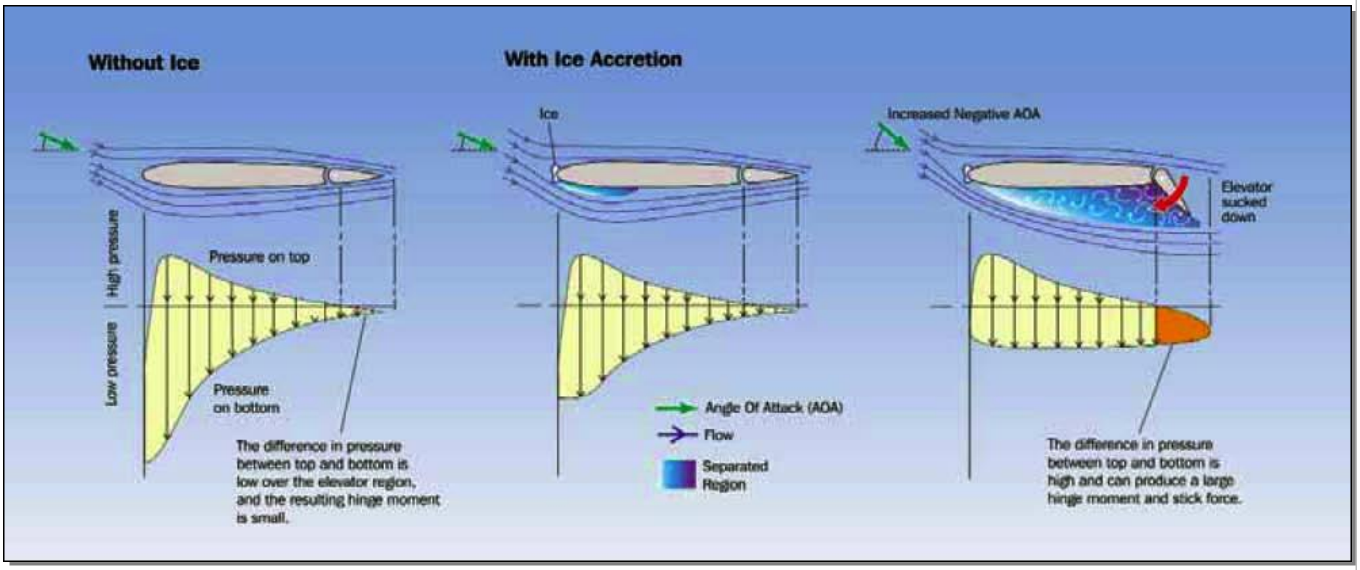
✈ Normally, the tailplane creates a force (lift) in the downward direction to balance wing and fuselage pitching moments. Under normal conditions, without ice accreted, aerodynamic pressures above and below the elevators are roughly equal and thus create no significant control surface hinge moment (see illustration below).

- With ice accreted on the tailplane, flow separation may develop on the lower surface, which will limit the maximum amount of downward lift the tailplane can generate and cause the tail to stall at a lower AOA.

- The development of flow separation will also result in an adverse change in the relative pressure distribution over the upper and lower surfaces. Since the forces about the elevator hinge and the resultant stick forces sensed by the pilot are balanced by aerodynamic and mechanical system forces, any change to the airflow can affect the stick forces.

✈ Tailplane stall *may* therefore be sensed by the pilot as a control anomaly (e.g. stick lightening), pitch instability or nose down trim change. For unpowered mechanical elevator controls, the magnitude and direction of stick force anomalies will depend upon the size and configuration of the elevator control system and the difference in pressure between the upper and lower surfaces.

✈ In the worst case, the elevator would be forced to the nose down stop if unrestrained, and the aircraft would respond accordingly by pitching nose down, often rapidly. This would be in addition to the aircraft's natural nose down pitching tendency as the tailplane loses downward lift effectiveness, and could require an extremely high pull force on the control column to recover.

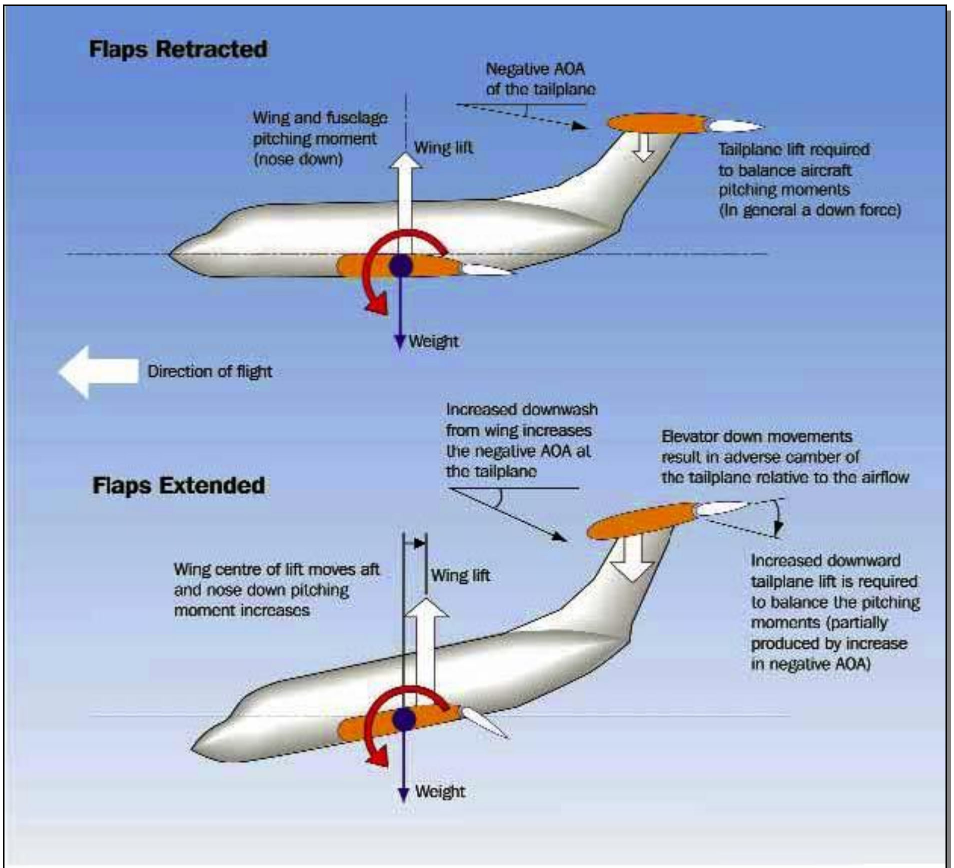


✈ Extending the flaps increases the airflow downwash angle from the wing and the tailplane negative AOA (see figure below). For a given flap setting, the AOA on the tailplane becomes more negative with increasing speed because of the reduced AOA of the wing (more nose down, more tail up). Therefore, at higher flap angles and airspeeds the wing stall margin is increased, but the tailplane stall margin is further reduced.

- The occurrence of stall on any aerofoil contaminated by ice almost always occurs at a lower angle of attack than a clean aerofoil; hence any ice accretion reduces the tailplane stall margin further. It is worth emphasizing that ice can form on the tailplane at a greater rate than the wing, primarily due to its relative small size and smaller leading edge radius. This can lead to a significant build up of ice which is not evident from observation of ice accretion on other areas of the airframe.

- In general, the most adverse combination of factors for tailplane stall is ice accretion of critical shape, roughness and location, maximum flap extension, forward centre of gravity, high power and nose down elevator control inputs (which result in a tailplane camber adverse to the airflow). On the certain turboprop types, higher airspeeds close to the maximum flap extension speed are also adverse, although flight testing of the HS748 demonstrated that speeds close to the normal landing speeds can also be critical.

✈ However, it should be understood that tailplane stall factors can be complex, and consequently symptoms for crew recognition and appropriate recovery actions are specific to the aircraft type and configuration.



Effect of flap angle on tailplane angle of attack.

Source: BAE Systems 'Think Ice! 2007'

Encountering Severe Icing Conditions:

✈ **Flying in severe icing is to be avoided where ever possible. When encountering such conditions steps must immediately be made to move out of that environment.**

Engine fan blade icing

- First symptoms of icing can be detected by observing ice build-up on small objects like wiper posts.
- Sudden icing of the window frames is a sign for severe icing.
- Engine fan blade icing is often announced with engine vibrations.
- Due to ice shedding, the vibrations may be accompanied by a sharp metallic noise as ice impacts the inside of the nacelle.

✈ Check the published procedure for N1 vibration. Most manufacturers make a distinction between non-icing conditions and icing conditions.

- In icing conditions, thrust increase is required to increase fan rpm in order to shed the ice. A higher fan speed reduces the risk of blade icing.

✈ **Unless there is another indication of a severe engine abnormality, i.e., high oil temperature, high oil pressure, or abnormal vibration being felt through the airframe, it is not recommended to shut down the engine.**

- Fan blade icing directly reduces the aerodynamic effectivety of the fan rotor, leading to significant performance degradation although the gas generator is at full thrust.

Tailplane Icing

- The quantity of ice collected on the aircraft is determined by the amount of liquid water in the cloud and the duration of exposure to icing. In addition, the amount of ice depends upon a factor called the “collection efficiency”: the higher the efficiency the greater the amount of ice collected.
- Because of their smaller leading edge radius and chord length, tail surfaces have higher collection efficiencies than wings and can collect two to three times greater ice thickness. Because the horizontal stabilizer has a sharper leading edge than the wing, it becomes a more efficient collector of ice as speed and droplet size increase.
- With flap extension and decreasing airspeed, the wing centre of lift moves aft, downwash is increased and the stabilizer, as a result, must provide greater downward lift while its stall margin is further reduced. Ice contamination on the leading edge of the stabilizer reduces the stall margin even further.
- Most incidents involving tailplane icing has happened during the landing phase, at very low altitude and when the final segment of flaps were extended.

✈ The symptoms for tailplane stall are: elevator control pulsing, oscillations or vibrations; unusual pitch anomaly; abnormal nose down trim change; reduction or loss of elevator force; sudden change in elevator force; and sudden un-commanded nose down pitch.

Operator/Manufacturer Procedure

✈ **The performance of aircraft types in icing conditions vary a great deal. It is therefore advisable to regularly consult and follow operators and manufacturer procedures and recommendations. As these are regularly updated.**

Reference:
Think Ice! 2007 - BAE SYSTEMS Regional Aircraft - E-mail: raengliaison@baesystems.com