POSITION & HOLD
an editorial opinion

Tailplane icing—too much data, not enough knowledge

Clear guidance and realistic training are key to avoiding inappropriate crew response when encountering in-flight icing.

Photo courtesy NASA/Chris Lynch

NASA's icing research aircraft is this modified de Havilland Canada DHC6 Twin Otter. Flow probes and a clear-ice simulation casting are attached to the leading edge of the left horizontal stabilizer.

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Pressures of modern operations, advances in technology—which often dilute airmanship skills—and improved cockpit facilities all encourage penetration into weather conditions far worse than our predecessors would have attempted. The dangers are still there—we have just learned to navigate them differently.

Icing conditions have been regarded as hazardous virtually since the beginning of flight. Ice buildup (accretion) results in degraded aircraft performance, flight characteristics and systems operation. Interestingly, modern aircraft designs, in achieving greater efficiency, may also be better icing collectors than previous designs.

Aerodynamic, stability or control events resulting from structural icing include stall, loss of control, high sink rate, loss or degradation of performance, and flight control degradation. Outcomes include ground or water collision, hard landing, inflight breakup/structural failure, landing short or precautionary landing. The especially insidious ice-contaminated tailplane stall (ICTS) is identified as causal in at least 16 corporate and air carrier mishaps, involving 139 fatalities.

Since critical icing conditions occur infrequently, crewmembers may become complacent about the potential for critical ice accretion in certain operating areas or conditions.

Each atmospheric icing condition is different, and flightcrews may occasionally encounter severe conditions beyond the capabilities of the aircraft protection systems.

However, totally effective anti-icing systems are—and will remain —beyond economic realization for the foreseeable future, and the threat of tailplane icing will remain a major cause for concern among flightcrews.

Developed in the 1990s, the landmark NASA/FAA Tailplane Icing Program (TIP) improved understanding of tailplane (empennage) icing but yielded comparatively little in the way of assessing design susceptibility to ICTS or developing related detection or unambiguous mitigation strategies of use to corporate and regional pilots.

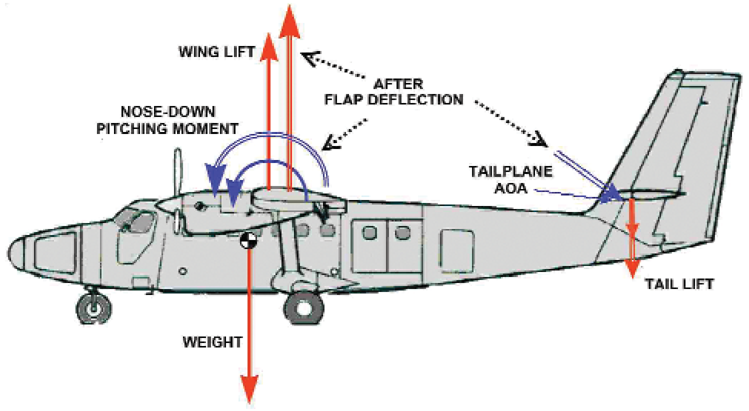
Regardless of the final report findings, the recent crash of a Bombardier DHC8-Q400 near BUF (Buffalo NY) renewed widespread interest in the dangers of inflight icing and, more particularly, ICTS.

Ice accretion

Ice adheres to all forward-facing surfaces of an aircraft in flight, often accumulating with surprising speed.

The tailplane, generally having a sharper leading-edge section and shorter chord than the wings, can accrete ice before it is visible on the wing—and at a greater rate. Pilots have reported ice accretion on the empennage 3–6 times thicker than ice on the wing and about 2–3 times thicker than on the windshield wiper arm. On turboprops, propwash cooling effect may further encourage ice formation on the tailplane.

The aerodynamic effect of a given thickness of ice on the tail will generally be more adverse than the same thickness of ice on the wing. This is due to the ratio of thickness to chord length and leading-edge radius.



Tailplane counters the nose-down pitching moment caused by the center of gravity (CG) being forward of the center of pressure.

Ice-induced stall

In worst cases, ice allowed to accumulate will disrupt airflow over the wings and tail, causing a stall and loss of control. In some cases, only a few seconds elapse between normal flight and ground impact.

Wing stall normally results from flow separating from the top surface. This usually starts at the inboard wing trailing edge or at the wing/fuselage and wing/nacelle junctions. Stall identification is notified to the pilot either through the inherent aerodynamic characteristics of the airplane or by a stick shaker/pusher incorporated in the elevator control circuit. A stick pusher induces an abrupt nose-down pitch change.

ICTS occurs when, as with the wing, the critical angle of attack (AOA) is exceeded. Since the horizontal stabilizer acts to counter the natural nose-down tendency caused by the wing lift moment, the airplane reacts by pitching down—often abruptly—when the tailplane is stalled.

Flap extension can initiate or aggravate the stall. With flaps extended, the center of wing lift moves aft and downwash is increased, requiring the horizontal tail to provide greater downward lift. Similarly, as the center of gravity (CG) moves forward, the tail may be near its maximum AOA, meaning that a small amount of ice contamination could cause it to stall. In either case, the result may be a rapid and unexpected loss of control with little or no margin for recovery.

A significant number of events occur during the landing phase, resulting in a hard landing. This may be associated with a loss of performance during the approach, forcing descent below the glidepath.

Recognizing ICTS

If the stabilizer is not visible from the cockpit, pilots may be unaware of ice accretion and may fail to operate deicing equipment correctly.

ICTS factors are complex and exhibit symptoms unique to aircraft type and configuration. These factors can cloud crew recognition and obscure appropriate recovery actions. It is important that symptoms of ICTS are recognized correctly and not confused with those of the more familiar wing stall.

Perhaps the most important characteristic of a tailplane stall is the relatively high airspeed at the onset and, if it occurs, the suddenness and magnitude of the nose-down pitch with the control column moving toward the forward limit. ICTS is more likely to occur when flaps approach full extension or during flight through wind gusts.

In general, the combination of factors favoring tailplane stall is ice accretion of critical shape, roughness and location, maximum flap extension, forward center of gravity, high power and nose-down elevator control inputs.

Symptoms of ICTS include:

- Elevator control pulsing, oscillations or vibrations
- Abnormal nose-down trim change
- Other unusual or abnormal pitch anomalies (possibly resulting in pilot-induced oscillations)
- Reduction or loss of elevator effectiveness
- Sudden change in elevator force (control would move nose-down to the limit if unrestrained)
- Sudden uncommanded nose-down pitch

Avoiding ICTS

Tailplane icing is a capricious killer, but steps can be taken to defend against its hazards, the foremost of which is to maintain vigilance and be ready to undo configuration and power changes if ICTS is suspected. At all times, ice protection systems should be used as the AFM suggests.

Certification rules for aircraft operations in icing conditions were never intended to endorse flight of unlimited duration in severe icing conditions. The safest action is to avoid prolonged operation in moderate to severe icing conditions. Prolonged operations in altitude bands where temperatures are near freezing and heavy moisture is visible on the windscreen should be avoided.

Flap extension should be limited during flight in icing. For turboprops, the use of flaps is prohibited in icing conditions when enroute or holding.

Autopilot use during flight in severe icing conditions is discouraged since (within its capabilities) it will correct anomalies and divergences that signal ICTS onset, thus almost certainly masking these symptoms by not

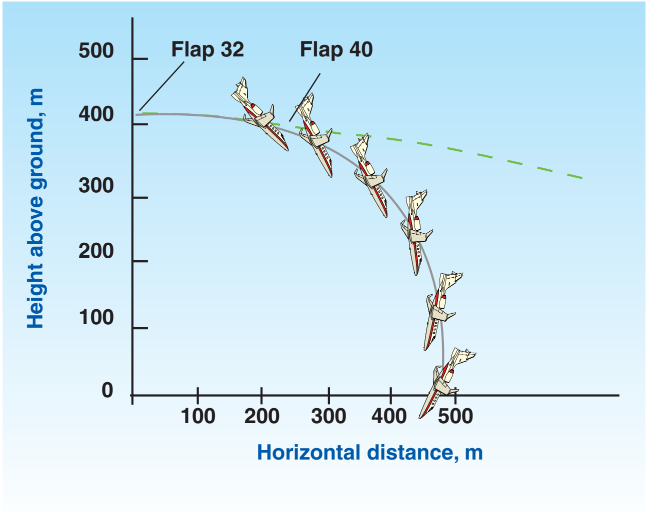


Illustration courtesy DGAC (France)

This diagram illustrates how severe nose-down pitch attitude and loss of control may become following tailplane stall.

allowing the pilot to receive tactile feedback from the controls.

	WING STALL	TAIL STALL
Recovery actions	• Full power • Relax back pressure or lower nose • Actions i a w AFM	• Immediate hard pullback • Retract flap to previous setting • Apply power judiciously and maintain precise control

Some stall symptoms may not be detected by the pilot if the autopilot is engaged.

Table courtesy BAE, NASA/FAA

FAA advises pilots to use caution when applying flaps during an approach if tailplane icing is possible. Selecting final flap earlier in the approach should be considered to use the greater height margin in case ICTS recovery is needed.

Uncoordinated flight (side or forward slips) which can adversely affect pitch control should be avoided.

Landing with reduced flap setting, accounting for the greater landing distance required, is encouraged if allowed by the AFM.

Crosswind landing should be avoided, since ice accumulates not only on the horizontal stabilizer but also on the vertical stabilizer, reducing directional control effectiveness.

Landing with a tailwind component should also be avoided, because of the possibility of more abrupt nose-down control inputs.

Recovery from ICTS

Available statistics show that an ICTS rarely occurs until approach and landing. However, the odds of recovery from uncontrollable nose pitch-down in this flight regime are poor, especially if the cause is misdiagnosed, since recovery procedures for wing stall will aggravate ICTS and vice versa. For example, adding airspeed in this case may actually reduce the margin of safety.

Because of the reduced maneuvering height margin available, increased stall speed and altered stall characteristics, recovery actions must be correct, immediate and aggressive. (One ICTS event during the NASA/FAA TIP required 170 lb of elevator force to recover!)

A good recovery strategy involves early detection and restoring the aircraft configuration just prior to the ICTS.

Training needs

Corporate and regional crews may not receive much unusual attitude training and rarely experience full stalls and recovery in the aircraft they are flying. Without this training, they may misdiagnose aerodynamic buffeting as due to other causes, such as ice on propeller blades.

Typically, flightcrews are trained down to stick shaker and taught to power out of the stall warning with minimal altitude loss. These pilots may not recognize an ICTS that occurs before stick shaker activation and may not be sufficiently aggressive in recovery action even if they do recognize the situation.

A hard way forward

The likelihood of a flightcrew experiencing a full stall is much lower than the probability of a stick shaker encounter. As useful as a stick pusher is in avoiding wing stalls, it offers no comfort regarding an ICTS.

Dangers of ICTS begin with the absence of visible or tactile stall cues for which pilots are usually trained. The empennage giving rise to the ICTS event is not usually visible from the cockpit. Recovery from the event—if allowed to develop fully—is counterintuitive to conventional pilot training and may require physical strength exceeding the pilots' capability.

The certified primary means of ice detection is visual inspection of the airframe by the flightcrew, including observation of areas such as the windshield, windshield pillars, windshield wiper bosses, wing leading edges, and propeller or engine fan spinners. The admonition against autopilot engagement in icing conditions requires a subjective assessment of current weather conditions in which the empennage may already have been contaminated.

For pilots unfamiliar with stick pusher action beyond the classroom, it may be difficult to distinguish a valid wing stall warning from an ICTS-initiated elevator snatch.

A decision to land, in which a pilot elects to divert and make an unscheduled landing due to ice accretion, is effective in fewer than 25% of cases classified as either an accident or incident.

Conclusions

More rigorous operating criteria and training requirements are needed to prevent ICTS-related accidents.

Aircraft permitted flight into known and forecast icing conditions are only approved and certified for flight in supercooled water droplet conditions, as defined in FAR/CS/ JAR-25 Appendix C.

Reportedly, the current Appendix C chart and standard come from 1951–52 USAF icing research data showing that a Douglas C54 (DC4) could survive for approximately 8 min while descending 6500 ft, covering a distance of 20 sm at 150 mph. It was adopted by FAA's predecessor—the Civil Aviation Administration—in 1955 following the 1950 crash of a Northwest Airlines DC4 into Lake Michigan.

This may be an appropriate time to revisit this design standard in light of technological advances and improved understanding of icing since its promulgation.

In the same way as training and recovery techniques were developed for jet upset recovery, current tailplane icing data must be distilled into a universal system for detection, avoidance and recovery.

Finally, operators are encouraged to give pilots the realistic training they need. Don't require them to become test pilots each time they encounter ice.

Don Van Dyke is an 18,000-hr TT pilot and instructor with extensive experience in charter, business and airline operations. A former IATA ops director, he has served on several ICAO expert panels and is a Fellow of the Royal Aeronautical Society.