U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Ice Contaminated Tailplane Stall (ICTS) **Date: 12/20/01**
Initiated By: ACE-100 **AC No: 23.143-1**

1. Purpose. This advisory circular (AC) sets forth an acceptable means, but not the only means, of demonstrating compliance with the longitudinal (pitch) axis flight characteristics requirements of Title 14 of the Code of Federal Regulations (14 CFR) part 23 when ice has accreted on the airframe. The FAA developed this AC to give more detailed and uniform guidance in showing compliance with the control and maneuver requirements of § 23.143.

- This guidance addresses methods that can be used to show compliance with the pitch axis controllability requirements of § 23.143 when ice accretions are present on the horizontal tailplane.

- The Federal Aviation Administration (FAA) will consider other methods of demonstrating compliance that an applicant may elect to present.

- This material is neither mandatory nor regulatory in nature and does not constitute a regulation.

2. Cancellation. Not applicable.

3. Applicability. The guidance material in this AC applies to airplanes approved for flight into known icing conditions and certificated to the requirements of Part 3 of the Civil Air Regulations (CAR) and part 23 of the Federal Aviation Regulations, including:

- New Type Certificates (TC's).

- Supplemental Type Certificates (STC's).

- Amendments to existing TC's.

This AC applies to airplanes equipped with aft-mounted, horizontal tail, pitch control surfaces. However, the AC does not apply to foreplane pitch control surfaces such as canards.

Note: Additional primary pitch axis control tests may be required for aircraft with all-movable stabilizers.

---

4. Related Regulations and Documents.

a. Regulations. 14 CFR part 23, § 23.143.

b. Advisory Circulars. You may get the following publications free of charge from the U.S. Department of Transportation, Subsequent Distribution Office, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785:

AC 20-73	Aircraft Ice Protection
AC 23.1419-2A	Certification of Part 23 Airplanes for Flight in Icing Conditions

You may buy the following publication from the Superintendent of Documents, Post Office Box 371954, Pittsburgh, PA 15250-7954:

AC 23-8A	Flight Test Guide for Certification of Part 23 Airplanes

c. Related Reading Material. NASA/FAA Tailplane Icing Program: Flight Test Report. NASA/TP—2000-209908, March 2000. This document is for reference only. Assumptions, ice shapes, and certain other data are not necessarily representative or appropriate for use with other projects. Available from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100

The above report and other reference material on ice contaminated tailplane stall (ICTS) are available at the NASA Glenn Research Center Icing Branch website: icebox.grc.nasa.gov.

5. Background.

When the leading edge of a horizontal tailplane becomes contaminated with ice accretions, control of the aircraft may be severely affected. The ICTS phenomenon in its extreme form may result in an uncontrollable nose-down pitching event. Pilots may sense ICTS or impending ICTS as one or a combination of:

- difficulty to trim in the pitch axis;
- a pulsing or buffeting of the longitudinal control; or
- a lightening of longitudinal control push force (or an increase in pull force) necessary to command a new pitch attitude.

ICTS typically occurs either while extending the wing trailing edge flaps to the landing position or with the flaps already extended to that position when operating in, or departing from, icing conditions. The flap extension increases the wing airflow downwash angle, reduces the aircraft angle-of-attack (AOA) for the same lift coefficient, and increases nose-down pitching moment which requires more tail download, all of which in turn result in an increased negative AOA at the horizontal tailplane.

This increased negative AOA coupled with an ice contamination on the horizontal tailplane leading edge causes turbulent or separated airflow, or both, on the undersurface of the horizontal tailplane, which can result in reduced or reversed elevator hinge moment, or a complete stall of the tailplane, or both. Since flaps are normally only extended to the landing position during final approach to landing, an ICTS event under these conditions has a high probability of being catastrophic due to the associated low ground clearance.

> Note: Full flap extension is generally the only case that results in ICTS but this may not be true for all designs, particularly those with closely spaced flap settings.

Tailplane stall has been reported on several airplane type designs with small quantities of ice observed on the airplane. In some cases, the critical ice accretion for susceptibility to ICTS has been a thin rough layer of ice on the protected and unprotected portions of the leading edge that accretes during the time that:

1. The airplane enters icing conditions.
2. The flightcrew recognizes the icing conditions and activates the ice protection system.
3. The ice protection system performs its intended function.

On airplanes with reversible control systems, the high trailing-edge-down elevator hinge moment translates to a forward motion of the longitudinal control and may result in recovery forces beyond the flightcrew's strength capabilities. ICTS reduces tail lift or diminishes the effectiveness of the primary and secondary control surfaces.

Diminished control effectiveness ranges from reduced elevator authority to sudden, large and unexpected changes in required control forces. Tab driven reversible pitch control designs may have insufficient authority to overcome the elevator hinge moments resulting from ICTS.

Tailplane stall can occur when:

- wing flaps are extended;
- engine power is increased;
- the pilot makes a nose-down control input;
- the airplane increases speed or encounters gust conditions; or
- a combination of these factors with flaps extended.

Pitch trim difficulty, forward pitch control force lightening or increased pull force to maintain pitch attitude, and pulsing or buffeting of the longitudinal control may not be recognized as cues of ICTS. The pilot may incorrectly interpret these cues as aerodynamic warning of an impending wing stall and perform the wrong, possibly catastrophic, corrective action since recovery techniques for a wing stall are opposite those of an ICTS. It is critical for the pilot to promptly and correctly diagnose the abnormal condition and apply the right corrective measures.

In 1991, the FAA reviewed the pitch control and stability factors of various airplanes to determine the susceptibility of those airplanes to ice contaminated tailplane stall. The review included discussions with manufacturers of airplanes certificated for flight in known icing, analysis of stall margin design parameters, and methods used to show compliance with 14 CFR 23.143, Controllability and Maneuverability. Findings included:

- Lack of clear understanding and uniformity in applying the regulations due to complexity of the issue.
- Need for uniform and detailed guidance.
- Shortage of basic data on the subject.

Before 1994, no uniform quantitative criteria or standardized acceptance procedures were available to show compliance with Title 14 CFR part 23, § 23.143 or its predecessor, Civil Air Regulations Part 3, § 3.106. In 1994, after examining available engineering data and its own guidance on this subject, the FAA decided to give more detailed and uniform guidance on demonstrating compliance. The FAA issued policy letters applicable to all airplanes and sponsored research with NASA to understand better ice contaminated tailplane stall.

Based on the results of the data and guidance review, and with input from the joint FAA/NASA research project, the FAA determined that guidance would be helpful for two steps in the process leading to certification. The first step is the design phase when the preliminary design parameters of the airplane are determined. The second step is the method of evaluation of compliance with the regulations.

1. During the design process, the manufacturer can evaluate airplane response characteristics and efficiently resolve serious problems using various modeling tools such as wind tunnel testing and computational fluid dynamics analysis. This AC does not address this process.

2. Susceptibility of an airplane design to ICTS should be considered when demonstrating compliance to the pitch control requirements of CFR 23.143. The demonstration should include:

- flight at the critical airspeed;
- artificial ice accretions on the horizontal tailplane; and
- flight testing in the critical trailing edge flap and power configuration.

For airplanes with irreversible, powered pitch control systems the flight tests described in this AC may not be necessary to show compliance to 14 CFR § 23.143. However, a detailed analysis, as a minimum, should show that:

- the airplane has adequate (consult Small Airplane Directorate) margin to tail stall angle of attack; and
- airplanes of similar size, configuration and operating envelope have demonstrated an acceptable service history with respect to ICTS.

A flight test demonstration is normally required for showing compliance with the controllability tests of CFR § 23.145, Longitudinal control, with ice accretions on the horizontal tail.

6. Objectives. To remove the risk of contaminated tailplane stall from the operating envelope of the airplane, the applicant should demonstrate by tests or a combination of analyses and tests, that the airplane is safely controllable and maneuverable during all phases of flight including:

- Level Flight.
- Descent.
- Go-around.
- Landing (power on and power off) with the wing flaps extended and retracted (if landing is possible with zero flaps).

Appendix A lists various items that affect safety when operating with ice accretions on the horizontal tail of the airplane. Tailplane stall could occur when the wing flaps are extended or during extension, or combined with other configurations, pilot inputs, and environmental factors.

7. Demonstration of Compliance by Flight Test.

The zero-g pushover maneuver and steady heading sideslip can be used to demonstrate compliance with the pitch axis controllability requirements of § 23.143. Appendix B describes these maneuvers.

WARNING

Some hazard is associated with ICTS flight testing. It is important that the applicant take appropriate precautions in the conduct of these tests and the flight test crew very carefully considers risk mitigation that includes defining minimum altitudes, conducting tests in a build-up manner, and providing emergency escape and parachute provisions.

It should be noted that longitudinal controllability during flap extension, power application and nose-down control at airspeeds down to stall, with artificial ice shapes, are also evaluated during the testing done to show compliance to § 23.145, Longitudinal control.

Michael Gallagher
Manager, Small Airplane Directorate
Aircraft Certification Service

Appendix A

Factors Affecting Susceptibility of an Airplane to Ice Contaminated Tailplane Stall (ICTS)

1. Airplane Design Variables. The aft location of the tailplane relative to the wing, the lift generated by the wing, and the spanwise lift distribution of the wing will affect the wing downwash induced tailplane angle-of-attack (AOA). Lift generated by wings with airfoils capable of high lift and equipped with efficient trailing edge flaps may induce a significant increase in the tailplane AOA. The airplane AOA, the wing downwash induced AOA, the tailplane fixed incidence angle, the tailplane design stall AOA, and the adverse effects of surface roughness on the tailplane stall AOA all influence the tailplane AOA margin and susceptibility to stall.

2. Tail Design Variables.

- Vertical position of the horizontal tail and the aerodynamic effects of the surfaces forward of the horizontal tail. ("T", cruciform, conventional).
- Fixed incidence tailplane with elevator and trim tab.
- Variable incidence tailplane (VIT) with elevator.
- All-moving tailplane (stabilator) with and without a trim-servo tab.
- Characteristics of vertical stabilizer interaction with T and cruciform tails.
- $C_{L_{Max}}$, Coefficient of Maximum Lift of wing and tailplane.

3. Center of Gravity. Most forward center of gravity (CG) loading conditions are usually most adverse to 1-g tailplane stall because of the greater balancing down load required by the tail. A greater download on the tail is developed by either increased incidence on a VIT, or greater trailing edge up deflection of the elevator.

4. Flap Extension. Extension of flaps increases the downwash at the tail and moves the wing center of lift aft, increasing nose-down pitching moment and requiring more tail download. In addition, the AOA of the airplane is reduced for the same lift. The tail is subjected to a negative increase in local AOA. The extension of wing flaps, therefore, brings the horizontal tail closer to its stall AOA.

Extending flaps from the retracted position may involve an increase in effective wing chord as well as an increase in camber. These changes in wing geometry:

- shift the center of pressure aft;
- increase the nose-down pitching moment;
- increase the wing lift coefficient at the same AOA; and
- likely increase the local airflow downwash angle aft of the flaps (even for T-tail configurations).

Because of these tests, maximum landing flap extension may be defined at an intermediate position, which then must become an airplane limitation for flights into icing conditions. In this instance, landing gear position warnings as a function of flap position and degraded landing performance data should be considered.

5. Speed/Load Factor. In 1-g flight, higher airspeeds result in reduced aircraft AOA and a more negative tailplane AOA. For the same reasons as described in paragraph 4. above, higher speed is more adverse to ICTS in 1-g flight. However, for variable incidence tailplane (VIT) stabilizers, slow airspeed requires more negative tailplane angles (leading edge down) for trim and therefore a more negative tail AOA and higher susceptibility to ICTS. Also, during dynamic maneuvers (such as pushovers), lower speeds put the tailplane at a more critical state (more negative AOA) due to the ability to generate higher pitch rates.

6. Engine Power. The effects of power or thrust on ICTS susceptibility are airplane specific. Increasing engine power on high thrust line aircraft (thrust line above the CG) requires more nose-up trim. This raises the risk of ICTS. In addition, increasing engine power on propeller-driven airplanes tends to be adverse to ICTS due to increases in strength and angle of wing downwash, especially with flaps extended.

7. Maneuvering. There are two elements of maneuvering that increase vulnerability to ICTS: nose-down pitch control input, and for some configurations, sideslip.

a. Nose-down pitch control input. When the elevator is deflected to the nose-down position, horizontal tail camber is changed and tail lift is reduced. Since a nose-down pitching moment exists that is not completely balanced by the tail, the airplane will pitch nose-down and there will be angular rotation rate about the CG. The resultant aerodynamic effect on the horizontal tailplane due to this rotation rate in the nose-down direction is an increased negative AOA which may increase susceptibility to tailplane stall.

b. Side slip. On “T” and cruciform tail configurations, local flow separation on the tailplane can start with sideslip due to initiation of separation at the junction of the horizontal and vertical stabilizer. This condition is worsened by ice accretions on the vertical stabilizer or structure forward of the horizontal stabilizer even if, in some cases, the horizontal tail leading edge is uncontaminated. The effects of a contaminated vertical stabilizer should also be considered when evaluating the susceptibility of a contaminated horizontal tailplane to ICTS in a sideslip.

On low tail configurations, impingement of flap tip vortices on the empennage may result in elevator self deflection and lead to similar control problems in the pitch axis. Sideslip can also result in asymmetric conditions on the horizontal stabilizer due to prop wash effects. Airplanes without counter-rotating propellers produce asymmetric local flow conditions. The steady heading sideslip should evaluate the effects of both left and right sideslip conditions.

8. Gusts and Turbulence. Gust or airplane gust response may contribute to ICTS. Gusts may occur parallel to any airplane axis. The direct effect of a gust on the resultant airflow may be adverse. The flight tests should be robust enough to evaluate the characteristics of the tail for various combinations of conditions.

Appendix B

Pushover and Steady State Sideslip Flight Test Maneuvers

1. Purpose. This appendix describes two flight test maneuvers that may be used to determine the susceptibility to Ice Contaminated Tailplane Stall (ICTS).

2. General.

a. Ice Shapes. The applicant should specify the critical ice accretion case(s) to be investigated in terms of location, shape, thickness, and texture, and obtain Federal Aviation Administration concurrence with the ice shape(s) to be investigated. The critical shape(s) should contribute to the largest adverse hinge moment, lowest stall angle, greatest tail lift loss, and lowest control surface effectiveness.

More than one shape may require testing. If a clean wing (no ice accretion) can result in increased negative angle-of-attack (AOA) on the horizontal tail, ice shapes on the wing should be removed. The critical ice accretion case(s) should include an allowance for the ice shape accreted during any time delays in activation of the ice protection system associated with ice detection or observation systems, intercycle and residual ice, runback ice, or the accretion that may be reasonably expected in service. Intercycle ice is the ice accretion between cycles of deicing system and residual ice is the ice remaining immediately after a deicing system cycle.

It should be noted that ice accreted with the flaps retracted might result in a more critical condition than ice accreted with the flaps extended. Ice accretion shape and thickness need not be greater than that resulting from exposure to the icing conditions defined in Appendix C to Part 25 or the 45 minute hold condition of AC 23.1419-2A, whichever is more critical.

Ice on the vertical stabilizer should also be considered for the sideslip case.

A thin ice layer simulated by sandpaper has been found to be critical on some aircraft and should be included on tests with a reversible longitudinal control system.

Failure conditions of the ice protection system should also be addressed. Maximum landing flap extension with a failed ice protection system may be defined at an intermediate position. This should become an airplane limitation for a failure.

b. Maneuvers. The following procedures produce a large negative AOA on the horizontal tail to evaluate any susceptibility to tailplane stall. The first maneuver is the "zero-g pushover maneuver." This is essentially a nose-down pitching maneuver that results in the normal force on the airplane center of gravity (CG) reaching zero. The second maneuver is the "steady state sideslip maneuver." This determines if ICTS may occur from detached flow on the horizontal tail due to sideslip.

3. Risk Mitigation. Risk mitigation should include:

- considerations of emergency egress and use of parachutes under 14 CFR 21.35(d), Flight tests;
- flight tests with a build-up of ice shapes;
- maneuvers beginning at no lower than altitudes above ground level used for stall characteristics flight tests of the subject airplane; and
- buildup using specific process of control inputs, with progressive evaluations, to reach the test airspeed and g target.

In crew served airplanes, a non-flying pilot should be ready to retract the flaps to reduce downwash over the tail, and help overcome large nose-down stick forces should they occur. Airplanes with powered or non-reversible pitch control surfaces may still be subject to large pitching moments and changes to control effectiveness.

WARNING

The maneuvers described below may result in a sudden loss of pitch control due to an aerodynamic stall condition on the horizontal stabilizer, or elevator singly, or in combination. In addition to reduction of tail lift, large control forces may make recovery difficult.

4. Tailplane Stall Investigation with Ice Accretion.

Note: A flight test data acquisition system (DAS) recording control positions, control forces, and g at the CG, and a camera recording an airflow visualization method (tufts) on the underside of the horizontal tailplane is desirable. However, this test is designed to evaluate susceptibility to ICTS without a DAS.

a. Configuration.

(1) All combinations of wing flaps and landing gear should be tested beginning with zero flaps up to the maximum flap setting to be approved for landing following an icing encounter. Since increased flap extension will increase the potential for ICTS, flight testing should proceed cautiously as the flaps are further extended.

(2) Critical weight and CG position (normally full forward at light weight).

(3) Speeds from 1.2 V_{S_1} or V_{REF}-5 knots, as appropriate to the wing flap position, up to the maximum speed to be encountered operationally in a given flap or gear configuration that will not result in exceeding V_{FE} or V_{LE}, as applicable, during the maneuver. The speeds V_{S_1} and V_{REF} may have to be redefined with critical ice shapes.

(4) Power or thrust: flight idle to maximum go-around.

(5) Ice Shapes: The applicant specifies the critical ice case(s) for investigation in terms of location, shape, thickness, and texture, and obtains FAA concurrence for the ice shape(s) to be investigated as described in paragraph 2.a. of this appendix.

b. Zero-g pushover maneuver test procedure: This is essentially a nose-down pitching maneuver. Before the maneuver, the test pilot determines initial entry speeds and pitch attitudes to achieve the target load factor and target airspeed as the airplane pitches through approximately level flight. The airplane should be fitted with the ice shapes defined in paragraph 2.a. above.

(1) The objective of the pushover maneuver is to push the pitch control in the nose-down direction to obtain the test load factor (g level) and be at the test airspeed as the nose passes through the horizon. Note any lightening of the pitch control push force during the build-up to the test end. Begin the maneuver with the airplane trimmed or trimmed as nearly as possible at the test power, configuration, and test (target) speed. The airplane is dived to gain sufficient airspeed above the test airspeed to allow a pull-up (nose above the horizon), followed up by a rapid pitch over as the test airspeed is approached to achieve the test load factor and airspeed as the nose passes through the horizon.

(2) The pushover series begins by moving the control column forward while evaluating for any reduction of required control force or force reversal. Continue the test points incrementally by increasing the amplitude of forward control inputs to obtain lower target load factors until a zero-g flight condition is obtained or, if limited by elevator power, to the lowest load factor attainable. The target load factors need to be maintained long enough to allow an evaluation of the longitudinal force required. During the pitch down maneuver, the test pilot should not change the rate of longitudinal control or reverse control movement as this may alter pitch rate and tail surface geometry to disqualify that test point.

(3) A push longitudinal control force should be required throughout the test maneuver. Stop the test if a control force lightening to less than zero, or a pull pitch control force is required to achieve the test load factor (g level).

(4) The airplane should demonstrate suitable controllability and maneuverability throughout the maneuver, including recovery, with no tendency to diverge in pitch or other indications of a stalled tailplane.

(5) During the pitch-down maneuver, any pilot produced change in elevator deflection toward the nose-up direction disqualifies that test point.

c. Steady state sideslip maneuver: For the test conditions described above in paragraphs 4.a.(1) through (5), establish the airplane incrementally in a straight, steady heading sideslip, up to the sideslip angle appropriate to normal operation of the airplane used to demonstrate compliance with § 23.177, Static directional and lateral stability.

The airplane should demonstrate suitable controllability and maneuverability throughout the maneuver with no tendency to diverge in pitch.

5. Other Parameters that May Indicate a Stalled Tailplane.

If the test aircraft is instrumented, the following parameters may indicate a stalled tailplane:

- The relationship of pitch rate (q) vs. elevator deflection (δ_E) after the elevator is returned trailing edge-up (TEU). If stalled, the elevator could deflect substantially before the airplane pitch rate starts to return to zero. This also appears as reduced elevator effectiveness, $C_{m\delta E}$.

- If the elevator stalls, the aircraft will continue toward zero-g regardless of the force applied by the pilot to return to one-g flight. This may be determined by examining the slope of the plot of vertical load factor (N_z) vs. pitch control force ($F_{ELEVATOR}$) after the elevator is returned TEU.

- Flow visualization methods (tufts) will usually indicate the onset of destabilization by flow reversal over a substantial portion of the suction (lower) surface of the horizontal tail. This indication often appears slightly before pilot tactile force cues. Critical tests would have to be repeated without the tufts to demonstrate the tufts have no effect on tail stall.