U.S. Department
of Transportation

**Federal Aviation
Administration**

Advisory Circular

Subject: **EFFECT OF ICING ON AIRCRAFT CONTROL AND AIRPLANE DEICE AND ANTI-ICE SYSTEMS**

Date: **7/17/96**
Initiated by: **AFS-820**

AC No: **91-51A**
Change:

1. PURPOSE. This advisory circular (AC) provides information for pilots regarding the hazards of aircraft icing and the use of airplane deice and anti-ice systems.

2. CANCELLATION. AC **91-51**, Airplane Deice and Anti-ice Systems, dated September **15, 1977**, is cancelled.

3. RELATED READING MATERIAL. The information contained in this AC complements the documents listed below.

a. Current editions of the following AC's may be obtained at no cost by sending a written request to U.S. Department of Transportation, Subsequent Distribution Center, **Ardmore** East Business Center, **3341** Q **75th** Avenue, Landover, MD **20785**:

(1) AC **20-117**, Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing.

(2) AC **135-16**, Ground Deicing and **Anti**-icing Training and Checking.

(3) AC **135-17**, Pilot Guide, Small Aircraft Ground Deicing.

b. Current editions of the publications below may be purchased from: New Orders, Superintendent of Documents, **P.O.** Box **371954**, Pittsburgh, PA **15250-7954**.

(1) AC **00-6**, Aviation Weather.

(2) AC **00-45**, Aviation Weather Services.

(3) AC **61-21**, Flight Training Handbook.

(4) AC **61-23**, Pilot's Handbook of Aeronautical Knowledge.

4. BACKGROUND. A review of aircraft accident and incident reports indicates that pilots may not be fully aware of the effects of icing on aircraft control. The review also indicates that pilots may be unaware of the limitations of aircraft deice and anti-ice systems and the conditions under which those systems are approved for flight into icing conditions.

5. DISCUSSION. One of the hazards to flight is aircraft icing. Pilots should be aware of the conditions conducive to icing, the types of icing, the effects of icing on aircraft control and performance, and the use and limitations of aircraft deice and **anti**-ice equipment.

a. It is important that a pilot understand the conditions which are conducive to icing. An understanding of these conditions allows the pilot to evaluate the available weather data and make an educated decision as to whether an intended flight should be made. One of the best sources of available weather data is pilot reports. The Federal Aviation Administration (FAA) encourages all pilots to report their flight conditions when warranted.

(1) For ice to form, there must be moisture present in the air and the air must be cooled to a temperature of **0°C (32°F)** or less. Aerodynamic cooling can lower the temperature of an airfoil to **0°C** even though the ambient temperature is a few degrees warmer. However, when the temperature reaches **-40°C (-40°F)** or less, it is generally too cold for ice to form. Ice is identified as clear, **rime**, or mixed. Rime ice forms if the droplets are small and freeze immediately when contacting the aircraft surface, This type of ice usually forms on areas such as the leading edges of wings or struts. It has a somewhat rough looking appearance and is a milky white color. Clear ice is usually formed from larger water droplets or freezing rain that can spread over a surface. This is the most dangerous type of ice since it is clear, hard to see, and can change the shape of the airfoil. Mixed ice is a mixture of clear ice and rime ice. It has the bad characteristics of both types and can form rapidly. Ice particles become **imbedded** in clear ice, building a very rough accumulation.

(2) The following table lists the temperatures at which the various types of ice will form.

Table 1: Temperature Ranges for Ice Formation

Outside Air Temperature Range	Icing Type
0°C to -10°C	Clear
-10°C to -15°C	Mixed Clear and Rime
-15°C to -20°C	Rime

b. There are two kinds of icing that are significant to aviation: structural icing and induction icing. Structural icing refers to the accumulation of ice on the exterior of the aircraft; induction icing affects the powerplant operation. Significant structural icing on an aircraft can cause aircraft control and performance problems. The formation of structural icing could create a situation from which the pilot might have difficulty recovering and, in some instances, may not be able to recover at all. To reduce the probability of ice buildup on the unprotected areas of the aircraft, a pilot should maintain at least the minimum airspeed for flight in sustained icing conditions. This airspeed will be listed in the airplane flight manual **(AFM)**.

(1) Structural icing can block the **pitot** tube and static ports and cause the breakage of antennas on the aircraft. This can cause a pilot to lose or receive erroneous indications from various instruments such as the airspeed indicator and **altimeter** and can cause a loss of communications and radio navigation capabilities.

(2) The most hazardous aspect of structural icing is its aerodynamic effects. Ice can alter the shape of an airfoil. This can cause control problems, change the angle of attack at which the aircraft stalls, and cause the aircraft to stall at a significantly higher airspeed. Ice can reduce the amount of lift that an airfoil will produce and increase drag several fold. Additionally, ice can partially block or limit control surfaces which will limit or make control movements ineffective. Also, if the extra weight caused by ice accumulation is too great, the aircraft may not be able to become airborne and, if in flight, the aircraft may not be able to maintain altitude. For this reason, Title **14** of the Code of Federal Regulations **(14 CFR)** prohibits takeoff when snow, ice, or frost is adhering to wings, propellers, or control surfaces of an aircraft. This clean aircraft concept is essential to safe flight operations.

(3) Another hazard of structural icing is the possible **uncommanded** and' uncontrolled roll phenomenon referred to as roll upset that is associated with severe in-flight icing. Pilots flying airplanes certificated for flight in known icing conditions should be aware that severe icing is a condition that is outside of the airplane's certification icing envelope. Roll upset may be caused by airflow separation (aerodynamic stall) inducing self-deflection of the ailerons and loss of or degraded roll handling characteristics. This phenomena can result from severe icing conditions without the usual symptoms of ice accumulation or a perceived aerodynamic stall.

(4) The term "severe icing" is associated with the rapid growth rate of visible ice shapes most often produced in conditions of high liquid water content and combinations of other environmental and flight conditions. Severe icing is often accompanied by aerodynamic performance degradation such as high drag, aerodynamic buffet, and premature stall.

(5) In addition, ice associated with freezing rain or freezing drizzle can accumulate on and beyond the limits of an ice protection system. This kind of ice may not produce the familiar performance degradation; however, it may be potentially hazardous. Freezing rain and freezing drizzle contain droplets larger than the criteria specified by certification requirements. Temperatures near freezing can produce severe icing.

(6) Another hazard of structural icing is the tailplane (empennage) stall. Sharp-edged surfaces are more susceptible to collecting ice than large blunt surfaces. For this reason, the tailplane may begin accumulating ice before the wings and can accumulate ice faster. Because the pilot cannot readily see the tailplane, the pilot may be unaware of the situation until the stall occurs. There have been reports of ice on the tailplane without any visible ice on the wing. This can occur if the tailplane has not or cannot be deiced.

(7) A tailplane stall occurs when, as with the wing, the critical angle of attack is exceeded. Since the horizontal stabilizer counters the natural nose down tendency caused by the center of lift of the main wing, the airplane will react by pitching down, sometimes uncontrollably, when the tailplane is stalled. Application of flaps can aggravate or initiate the stall. The pilot should use caution when applying flaps during an approach if there is the possibility of icing on the tailplane.

(8) 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. A stall is more likely to occur when the flaps are approaching the fully extended position, after nose down pitch and airspeed changes following flap extension, or during flight through wind gusts.

c. Small aircraft engines commonly employ a carburetor fuel system or a pressure fuel injection system to supply fuel for combustion. Both types of induction systems hold the potential for icing which can cause engine failure.

(1) The pilot should be aware that carburetor icing can occur at temperatures between **-7°C (20°F)** and **+21°C (70°F)** when there is visible moisture or high humidity. This can occur in the carburetor **because** vaporization of fuel, combined with the expansion of air as it flows through the carburetor, causes sudden cooling, sometimes by a significant amount within a fraction of a second. Carburetor ice can be detected by a drop in **rpm** in fixed pitch propeller airplanes and a drop in manifold pressure in constant speed propeller airplanes. In both types, usually there will be a roughness in engine operation. Some airplanes are equipped with carburetor heat for use in both prevention and removal of ice. The pilot should consult the **AFM** or the pilot's operating handbook for the proper use of carburetor heat.

(2) Fuel injection systems are less susceptible to icing than the carburetor system. Ice, which can partially or totally block the air from entering the engine, forms on the air intake of the engine. The usual indication of icing in a fuel injection system is the same as in a carburetor system. An alternate air source located inside the engine cowling is used to provide air to the engine to continue combustion. Usually, this source is operated automatically and has a manual backup system that can be used if the automatic system malfunctions.

d. Ice detection is very important in dealing with icing in a timely manner. A careful preflight of the aircraft should be conducted to ensure that all ice or frost is removed before takeoff. This is especially true in larger aircraft where ice is difficult to see in some locations. Also, it is more **difficult** to detect ice during flight on such areas as the tail, which may be impossible to see. At night, aircraft can be equipped with ice detection lights. which will assist in detecting ice. Being familiar with the airplane's performance and flight characteristics will also help in recognizing the possibility of ice. Ice buildup will require more power to maintain cruise airspeed. Ice on the tailplane can cause diminished nose up pitch control and heavy elevator forces, and the aircraft may buffet if flaps are applied. Ice ***on the rudder or ailerons can cause control oscillations or vibrations.***

e. When operating in icing conditions on the ground or in flight, a pilot must have knowledge of aircraft deicing and anti-icing procedures. Deicing is a procedure in which frost, ice, or snow is removed from the aircraft in order to provide clean surfaces. Anti-icing is a process that provides some protection against the formation of frost or ice for a limited period of time. There are various methods and systems which are used for deicing and anti-icing. A pilot must be knowledgeable regarding the systems and the procedures to be used on the specific aircraft before operating in icing conditions.

(1) There are numerous methods which are capable of removing ice from an aircraft surface. One