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Advisory Circular

Subject: Pilot Guide: Flight In Icing Conditions

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FOREWORD

This advisory circular (AC) contains updated and additional information for the pilots of airplanes under parts 91, 121, 125, and 135 of Title 14 of the Code of Federal Regulations (14 CFR). The purpose of this AC is to provide pilots with a convenient reference on the principal factors related to flight in icing conditions and the location of additional information in related publications. This AC does not authorize deviations from established company procedures or regulatory requirements.

ORIGINAL SIGNED by
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CHAPTER 1. INTRODUCTION

1-1. This advisory circular (AC) updates the previous version and contains essential information concerning safe flight in icing conditions, what conditions should be avoided, and information on how to avoid or exit those conditions if encountered. The information provided is relevant to fixed-wing aircraft, including those operating under Title 14 of the Code of Federal Regulations (14 CFR) parts 91, 121, 125, and 135. The general guidance provided here in no way substitutes for aircraft type specific information in a particular Airplane Flight Manual (AFM) or specific Pilot's Operating Handbook (POH).

1-2. This material is not regulatory, nor does it establish minimum standards. Where the term "must" is used in this AC, such use reflects actual regulatory requirements; where the term "should" is used, such reflects recommendations from the Federal Aviation Administration (FAA).

1-3. Aircraft icing remains a key aviation safety issue. Accident data has shown that pilots are (advertently and inadvertently) flying aircraft not certificated for flight in icing conditions into such conditions, often with fatal results. Even more disturbing are the numbers of accidents involving aircraft that are certificated for flight in icing conditions. Such accidents are often the result of pilot complacency, poor technique, poor understanding of the airplane's limitations, and performance in icing conditions, misconceptions of airplane and system icing certification, and a misunderstanding of icing terminology. Education is the first step in reducing aircraft icing accidents.

1-4. Pilots must determine whether the aircraft to be flown is certificated for flight in icing conditions. An aircraft that is certificated for instrument flight rules (IFR) is not necessarily certificated for flight in icing conditions. To determine whether an aircraft is certificated for flight in icing conditions, the AFM or specific POH must be consulted. It is imperative that the pilot ensures that the aircraft is certificated to fly in icing conditions and that the appropriate deicing/anti-icing equipment is installed and operational. It is also of critical importance that the pilot understands and complies with the aircraft manufacturer's limitations and procedures when operating in icing conditions.

1-5. If an aircraft is not certificated for flight in icing conditions, each flight should be planned carefully so that icing conditions are avoided. Chapter 3 provides information on when and where icing conditions may occur and Chapter 5 discusses flight planning. The flight should be planned to avoid clouds or precipitation where temperatures are near or below freezing. During flight, the pilot should monitor the information available (see Chapter 6 on in-flight operations) and be aware of conditions that might require a change of flight plan to avoid icing conditions. In the event of an inadvertent icing encounter, the pilot should take appropriate action to exit the conditions immediately, coordinating with air traffic control (ATC) as necessary, and declaring an emergency. In a recent study (AIAA 2006-82, "A Study of U. S. Inflight Icing Accidents and Incidents, 1978 to 2002"), conflicts with ATC are very prevalent. Very often, this was because the pilot deviated from an IFR clearance and failed to declare an emergency or otherwise clarify the situation with the controller. In a subset of these cases, the controller actually offers to declare an emergency for the pilot, but the pilot declines. In another subset, the frequency is too busy for communications, often because the controller is overwhelmed with traffic. A number of pilots expected an immediate response from ATC when they reported difficulties after encountering ice and expected a blanket clearance to escape icing without first declaring a state of emergency. In many cases, such assumptions proved to be not only false, but also fatal.

1-6. This AC also includes information on a recently identified icing threat, high altitude ice crystal ingestion into turbine engines. Turbine engine upsets have occurred from ice accreting within the engine at altitudes up to 42,000 feet and temperatures colder than -45°C (-50°F). These high altitude ice crystals in large concentrations, typically found near convective weather systems, do not accrete on external airframe surfaces, and may not be visible on current technology airborne radar systems.

1-7. Many pilots of aircraft certificated to operate in icing conditions have had numerous icing encounters in which the aircraft systems coped effectively with the icing conditions — in some cases, even with a substantial ice buildup. However, a pilot should not relax his/her vigilance in icing conditions because of such experiences. A thin ice accretion on critical surfaces, developing in a matter of minutes, can have dramatic effects on stall speeds, stability, and control. Wind tunnel testing indicates that if such accretions are particularly rough, they can have more adverse effects than larger accretions that are relatively smooth.

CHAPTER 2. TERMINOLOGY, ACRONYMS, AND ABBREVIATIONS

2-1. DEFINITIONS.

a. Adiabatic Cooling. A process by which a parcel of air cools. When a parcel of air is lifted, pressure is reduced due to the elevation increase. This reduction in pressure causes the parcel of air to expand in volume and in turn, the parcel cools to maintain an energy balance because no energy is added to the parcel.

b. Airman's Meteorological Information (AIRMET). In-flight weather advisories concerning weather phenomena of operational interest to all pilots and especially to pilots of aircraft not approved for flight in icing conditions. AIRMETs concern weather of less severity than that covered by significant meteorological information (SIGMET) or Convective SIGMET. AIRMETs may include moderate icing.

c. Automated Surface Observing System (ASOS)/Automated Weather Observation System (AWOS). A suite of sensors that measure, collect, and disseminate weather data to help meteorologists, pilots, and flight dispatchers prepare and monitor weather forecasts, plan flight routes, and provide necessary information for correct takeoffs and landings. There are many differences between these two automated weather systems and it is important for pilots to understand the strengths and limitations of the various configurations. The ASOS is comprised of a standardized suite of weather sensors and is a product of a National Weather Service (NWS), Department of Defense (DOD), and FAA joint venture. One of ASOS's most important features is its ability to detect precipitation including intensity of rain, snow, and freezing rain. One ASOS limitation that currently exists is its inability to detect and report freezing drizzle without human augmentation. Pilots should be aware of this limitation at airports deemed service level C or D, as described in the Aeronautical Information Manual (AIM). A detailed description of ASOS's capabilities can be found at the NWS ASOS Homepage: http://www.nws.noaa.gov/asos/index.html.

d. The AWOS is a suite of weather sensors that are procured by the FAA or purchased by individuals, groups, airports, etc. There are seven different configurations of AWOS: AWOS A, AWOS I, AWOS II, AWOS III, AWOS III-P, AWOS-T, and AWOS P/T. Precipitation identification is only available with AWOS III-P or higher. It is important to note that the absence of reported precipitation does not mean that such conditions do not exist. The AWOS may not be configured to report this information. A detailed description of AWOS's capabilities can be found in FAA AC 150/5220-16C, Automated Weather Observing Systems (AWOS) for Non-Federal Applications. The AIM also contains useful information on both ASOS and AWOS.

e. Aviation Weather Service Program. Aviation weather service provided by the NWS and the FAA that collects and disseminates pertinent weather information for pilots, aircraft operators, and ATC. Available aviation weather reports and forecasts are produced at NWS offices and displayed at FAA Flight Service Stations (FSS).

f. Center Weather Advisory (CWA). An unscheduled weather advisory issued by NWS meteorologists for use by ATC in alerting pilots of existing or anticipated adverse weather conditions within the next two hours. A CWA may modify a SIGMET.

g. Clear Ice. A glossy, clear, or translucent ice formed by the relatively slow freezing of large supercooled water droplets. The terms “clear” and “glaze” have been used for essentially the same type of ice accretion, although some reserve “clear” for thinner accretions which lack horns and conform to the airfoil.

h. Cold Front. Any nonoccluded front that moves in such a way that colder air replaces warmer air.

i. Convection. An atmospheric motion that is predominantly vertical, resulting in the transport and mixing of atmospheric properties.

j. Cumulus Clouds. Clouds in the form of detached domes or towers and are usually well defined. Cumulus clouds develop vertically in the form of rising mounds of which the bulging upper part often resembles a cauliflower; the sunlit parts of these clouds are mostly brilliant white. Their bases may be relatively dark and nearly horizontal.

k. Current Icing Product (CIP). A graphical planning product that combines sensor and numerical model data to provide a three-dimensional diagnosis of the probability and severity of icing, plus the potential for the presence of supercooled large drops (SLD). CIP is an unrestricted supplementary weather product.

l. Forecast Icing Product (FIP). The FIP examines numerical weather prediction model output to calculate the probability of encountering in-flight aircraft icing conditions. This icing product demonstrates the confidence that an atmospheric location, represented by a three-dimensional model grid box, will contain supercooled liquid water that is likely to form ice on an aircraft.

m. Freezing Drizzle. Drizzle is precipitation at ground level or aloft in the form of liquid water drops that have diameters less than 0.5 mm and greater than 0.05 mm. Freezing drizzle is drizzle that exists at air temperatures less than 0°C (supercooled), remains in liquid form, and freezes upon contact with objects on the surface or airborne.

n. Freezing Rain. Rain is precipitation at ground level or aloft in the form of liquid water drops which have diameters greater than 0.5 mm. Freezing rain is rain that exists at air temperatures less than 0°C (supercooled), remains in liquid form, and freezes upon contact with objects on the ground or in the air.

o. Front. The boundary between two air masses. A front can be classified as cold, warm, occluded, or stationary.

p. Hazardous Weather Information. Summary of SIGMETs, Convective SIGMETs, urgent pilot weather reports, CWAs, AIRMETs, and any other weather, such as isolated thunderstorms rapidly developing and increasing in intensity or low ceilings and visibilities becoming widespread, that is considered significant and is not included in a current hazardous weather advisory.

q. Heavy Icing. The rate of ice accumulation requires maximum use of the ice protection systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is more than 3 inches (7.5 cm) per hour[1] on the outer wing. Consider immediate exit from the conditions.[2]

r. Icing Conditions.

(1) Potential Icing Conditions. Atmospheric icing conditions that are typically defined by airframe manufacturers relative to temperature and visible moisture that may result in aircraft ice accretion on the ground or in flight. The potential icing conditions are typically defined in the airplane flight manual or in the airplane operation manual.

(2) Forecast Icing Conditions. Environmental conditions expected by a NWS or an FAA-approved weather provider to be conducive to the formation of in-flight icing on aircraft.

s. Ice Crystals. Ice crystals, often found in high concentrations near convective weather systems, can accrete within turbine engines and cause power loss. Ice crystals are not typically detected by either conventional ice detectors or airborne radar, and typically do not accrete on external airframe surfaces. Ice crystals found in stratus and cirrus clouds are usually in relatively low concentrations, and do not represent a threat to turbine engines.

t. Icing Envelopes. These icing envelopes, found in 14 CFR part 25, appendix C, are used for the certification of aircraft for flight in icing conditions. They specify atmospheric icing conditions in terms of altitude, temperature, liquid water content (LWC), and droplet size represented by the median volume diameter (MVD). (The envelopes use the term mean effective diameter (MED), but this equates to the median volume diameter for the instrumentation and assumptions current at the time the envelopes were established). There are two classes of icing envelopes: continuous maximum and intermittent maximum. The continuous maximum is for stratus-type clouds, and the intermittent maximum is for cumulus-type clouds.

u. Impinge. The striking and adherence of a droplet on an aircraft surface. The impingement rate is the rate at which droplets of a given size impinge a particular surface. In general, impingement rates are higher for larger droplets and smaller components, such as antennae.

v. Known, Observed, or Detected Ice Accretion. Actual ice that is observed visually to be on the aircraft by the flight crew or identified by onboard sensors.

w. Light Icing. The rate of ice accumulation requires occasional cycling of manual deicing systems [3] to minimize ice accretions on the airframe. A representative accretion rate for

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[1] These rates can be measured by a suitable icing rate meter.

[2] It is expected that deicing or anti-icing systems will be activated and operated continuously in the automatic mode, if available, at the first sign of ice accumulation, or as directed in the AFM. Occasional and frequent cycling refers to manually activated systems.

[3] See footnote number 2

reference purposes is 1⁄4 inch to one inch (0.6 to 2.5 cm) per hour [4] on the outer wing. The pilot should consider exiting the condition.[5]

x. Liquid Water Content (LWC). The total mass of water in all the liquid cloud droplets within a unit volume of cloud. LWC is usually discussed in terms of grams of water per cubic meter of air (g/m^3).

y. Median Volume Diameter (MVD). The diameter is such that half the liquid water in a region of cloud is contained in smaller drops, and half in larger drops.

z. Mixed Ice. Simultaneous appearance of rime and clear ice or an ice formation that has the characteristics of both rime and clear ice.

aa. Moderate Icing. The rate of ice accumulation requires frequent cycling of manual deicing systems[6] to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is 1 to 3 inches (2.5 to 7.5 cm) per hour [7] on the outer wing. The pilot should consider exiting the condition as soon as possible.[8]

bb. Occluded Front. The front formed by a cold front overtaking a warm front and lifting the warm air above the earth's surface. An occlusion (or frontal occlusion) forms when an air mass is trapped between two colder air masses and is forced to higher and higher levels.

cc. One-Minute Weather. The most recent 1-minute update weather broadcast based on ASOS/AWOS measurements and available to a pilot from an uncontrolled airport ASOS/AWOS.

dd. Orographic Cloud. A cloud that usually results from air flowing upslope from terrain and being cooled adiabatically.

ee. Outside Air Temperature (OAT). The measured or indicated air temperature (IAT) corrected for compression and friction heating. Also referred to as true air temperature.

ff. Pilot Briefing. A service provided by a Flight Service Station (FSS) to assist pilots with flight planning. Briefing items may include weather information, notices to airmen (NOTAMs), military activities, flow control information, and other items, as requested.

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[4] See footnote number 1.

[5] It is assumed that the aircraft is approved to fly in the cited icing conditions. Otherwise, immediate exit from any of these intensity categories is required by regulations (14 CFR §§ 91.13(a), 91.527, 121.341, 125.221, and 135.227).

[6] See footnote number 1.

[7] See footnote number 2.

[8] See footnote number 3.

gg. Pilot Report (PIREP). A report from a pilot of meteorological phenomena encountered by aircraft in flight, usually transmitted in a prescribed format. The letters "UA" identify the message as a routine PIREP while the letters "UUA" identify an urgent PIREP.

hh. Rime Ice. A rough, milky, opaque ice formed by the instantaneous freezing of small, supercooled water droplets.

ii. Runback Ice. Ice that forms from the freezing or refreezing of water leaving protected surfaces and running back to unprotected surfaces.

jj. Severe Icing. The rate of ice accumulation is such that ice protection systems fail to remove the accumulation of ice and ice accumulates in locations not normally prone to icing, such as areas aft of protected surfaces and any other areas identified by the manufacturer. Immediate exit from the condition is necessary.[9]

kk. Significant Meteorological Information (SIGMET). Information about in-flight weather of operational significance to the safety of all aircraft. SIGMETs may include severe icing. (See CWA and AIRMET.)

ll. Stagnation Point. The point on a surface where the local air velocity is zero. The region of maximum icing collection efficiency is near this point.

mm. Stationary Front. A front that has little or no movement because the opposing forces of the two air masses are relatively balanced.

nn. Stratus Clouds. Clouds that form layers with a uniform base. Stratus clouds can appear in ragged patches and may produce drizzle, rain, or snow.

oo. Sublimation. A process where ice turns directly into water vapor without passing through a liquid state.

pp. Supercooled Large Drop (SLD). A supercooled droplet with a diameter greater than 50 micrometers (0.05 mm). SLD conditions include freezing drizzle drops and freezing raindrops.

qq. Supplemental Weather Service Location. An airport facility staffed with contract personnel who take weather observations and provide current local weather to pilots via telephone or radio.

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[9] Severe icing is aircraft dependent, as are the other categories of icing intensity. Severe icing may occur at any ice accumulation rate when the icing rate or ice accumulations exceed the tolerance of the aircraft. Icing certification implies an increased tolerance to icing intensities up through heavy.

rr. Telephone Information Briefing Service (TIBS). A telephone recording of meteorological and/or aeronautical information obtained by calling an FSS.

ss. Total Air Temperature (TAT). Kinetic heating causes the Total (or Ram) Air Temperature (TAT) to be warmer than the Static Air Temperature (SAT). TAT is close to the temperature of the wing leading edge, which also experiences ram rise.

tt. Trace Icing. Ice becomes noticeable. The rate of accumulation is slightly greater than the rate of sublimation. A representative accretion rate for reference purposes is less than 1/4 inch (6 mm) per hour on the outer wing. The pilot should consider exiting the icing conditions before they become worse. Pilots should be aware that any ice, even in trace amounts, could be potentially hazardous.

uu. Warm Front. Any nonoccluded front that moves in such a way that warmer air replaces colder air.

vv. Weather Advisory. In standard aviation weather forecast terminology, a warning of hazardous weather conditions not predicted in the forecast area that may affect air traffic operations. These reports are prepared by the NWS.

CHAPTER 3. ATMOSPHERIC CONDITIONS ASSOCIATED WITH ICING

3-1. AIRCRAFT ICING CONDITIONS.

a. Nearly all aircraft icing occurs in supercooled clouds. Liquid droplets are present at outside air temperatures below 0°C (32°F) in these clouds. At outside air temperatures close to 0°C (32°F), the cloud may consist entirely of such droplets, with few or no ice particles present. At decreasing temperatures, the probability increases that ice particles will be found in significant numbers along with the liquid droplets. In fact, as the ice water content increases, the liquid water content tends to decrease since the ice particles grow at the expense of the water particles. At temperatures below about -20°C (-4°F), most clouds are made up entirely of ice particles.

b. The general rule is that the more ice particles and the fewer liquid droplets that are present, the less ice accumulation on the airframe. This is because the ice particles tend to bounce off an aircraft surface, while the supercooled droplets freeze and adhere. As a result, ice accumulation is often greatest at temperatures not too far below 0 °C (32°F), where liquid water content can be abundant, and is usually negligible at temperatures below about -20°C (-4°F).

c. An exception to the general rule just stated may be made for surfaces heated by a thermal ice protection system (or by aerodynamic heating near the stagnation point of an aircraft component at speeds in excess of perhaps 250 knots). For such surfaces, ice particles may melt upon impact and then run back to colder aft regions and refreeze.

d. The higher liquid water content associated with temperatures near freezing is not the only concern. Tests have shown that at outside air temperatures near freezing, the total air temperature may be above freezing. The result is no ice accretion near the stagnation, but the refreezing of the water running back on the airfoil, causing runback ice accretions, possibly behind the protected areas. The formation of a ridge is possible. Pilots should be vigilant at total temperatures (TAT) between -5°C (23°F) and +2°C (35°F). Pilots should know whether the temperature instrument they are reading in the cockpit is outside air temperature (OAT) or TAT.

e. The greater the liquid water content of the cloud, the more rapidly ice accumulates on aircraft surfaces. The size of the droplets also is important. Larger droplets have greater inertia and are less influenced by the airflow around the aircraft than smaller droplets. The result is that larger droplets will impinge on more of the aircraft surface than smaller droplets.

f. Every supercooled cloud contains a broad range of droplets, starting from between 1 and 10 micrometers (millionth of a meter) and usually not exceeding 50 micrometers (by comparison, the thickness of the average human hair is approximately 100 micrometers). A single droplet size must be chosen as representative, and in icing terminology this is the MVD, the diameter such that half the liquid water is in smaller drops, and half in larger drops. An icing-certificated aircraft is certificated for flight in stratus-type clouds with MVDs up to 40 micrometers and for cumulus-type clouds with MVDs up to 50 micrometers. The MVD distribution is such that aircraft that undergo icing certification are not evaluated for operations in clouds with a significant amount of liquid water in droplets with diameters larger than 100 micrometers. Such conditions are sometimes encountered, and accidents and incidents in such conditions have been documented. These conditions are referred to as freezing drizzle aloft in cloud or SLD in cloud. Table 1, Evolution of Icing Certification Standards, discusses some cues developed for aircraft with unpowered controls and pneumatic deicing boots, mainly relating to the location of the airframe ice, which the flightcrew can use in attempting to determine if such droplets may be present in a cloud.

g. An aircraft can also encounter SLD conditions in freezing drizzle (droplets with a diameter of 50 to 500 micrometers) or freezing rain (droplets with a diameter of 500 micrometers and larger) below a cloud deck. These droplets are, by definition, larger than those for which any aircraft is certificated, and accidents and incidents have occurred following flight in freezing drizzle or freezing rain. The larger drops can cause ice accretion behind the protected leading edge.

3-2. CLOUD TYPES AND AIRCRAFT ICING.

a. Air can rise because of many factors, including convection, orographic lifting (i.e., air forced up a mountain), or lifting at a weather front. As the air rises, it expands and cools adiabatically. If a parcel of air reaches its saturation point, the moisture within the parcel will condense and the resulting droplets form a cloud. Cloud water droplets are generally very small, averaging 20 micrometers in diameter, and are of such small mass that they can be held aloft by small air currents within clouds.

b. If rising air is moist (water vapor plentiful) and lifting is vigorous, the result can be clouds with substantial liquid water content and, sometimes, large droplets. The greater the liquid water content, the more rapid the icing; and the larger the droplets, the greater the extent of icing. Tops of clouds often contain the most liquid water and largest droplets, because the droplets that reach the tops have undergone the most lifting. If the temperatures are cold enough at the tops (below around -15 °C (5 °F)), however, ice particles will usually start to form, which tends to deplete the liquid water.

c. Several types of clouds and the hazardous aircraft icing conditions that may be associated with them are discussed below.

(1) Stratus Clouds.

(a) Stratus clouds, sometimes called layer clouds, form a stratified layer that may cover a wide area. The lifting processes that form them are usually gradual, and so they rarely have exceptionally high liquid water contents. Icing layers in stratus clouds with a vertical thickness in excess of 3,000 feet are rare, so a change of altitude of a few thousand feet may take the aircraft out of icing.

(b) Lake-effect stratus clouds are exceptional in that they may have very high liquid water content because of the moisture available when they form over lakes. In the continental United States, lake-effect stratus clouds are most common in the Great Lakes region, particularly in early winter when cold northwesterly winds blow over the unfrozen lakes.

(c) Drizzle-size drops occasionally occur in stratus clouds, and pilots should always be on the lookout for cues that might indicate the presence of these drops (see Table 1 for a list of cues developed for aircraft with unpowered controls and pneumatic deicing boots).

(2) Cumulus Clouds.

(a) Cumulus clouds, which often form because of vigorous convection, can have high liquid water content. If an aircraft traverses them, the icing can be rapid. Because they tend to be of limited horizontal extent, it may be possible to avoid many of them. Because of the vertical development of cumulus clouds, icing conditions can be found in layers thousands of feet in depth, but with much less horizontal development than in stratus clouds.

(b) This class of clouds includes the cumulonimbus, or thunderstorm, clouds. Updrafts in such clouds can be great and result in very large liquid water contents. Thus, a large icing threat can be added to the other excellent reasons to stay out of such clouds. The thunderhead anvil can spread out from the core for several miles and is composed mainly of ice crystals. These crystals will not adhere to unheated surfaces when they hit, but they may melt on a heated surface, run back, and refreeze. The ice content in the anvils can be high, and ingestion of the ice crystals has resulted in uncommanded thrust reductions.

(3) Orographic Clouds, Wave Clouds, and Cirrus Clouds.

(a) Orographic clouds form when moist air is lifted by flowing up the side of a mountain. As the parcel of air is lifted, it cools and forms a cloud. Such clouds can contain a large volume of water, and in some cases, large droplets.

(b) Wave clouds, recognized by their “wavy” tops, can have high liquid water contents. Continued flight along a wave may result in airframe icing.

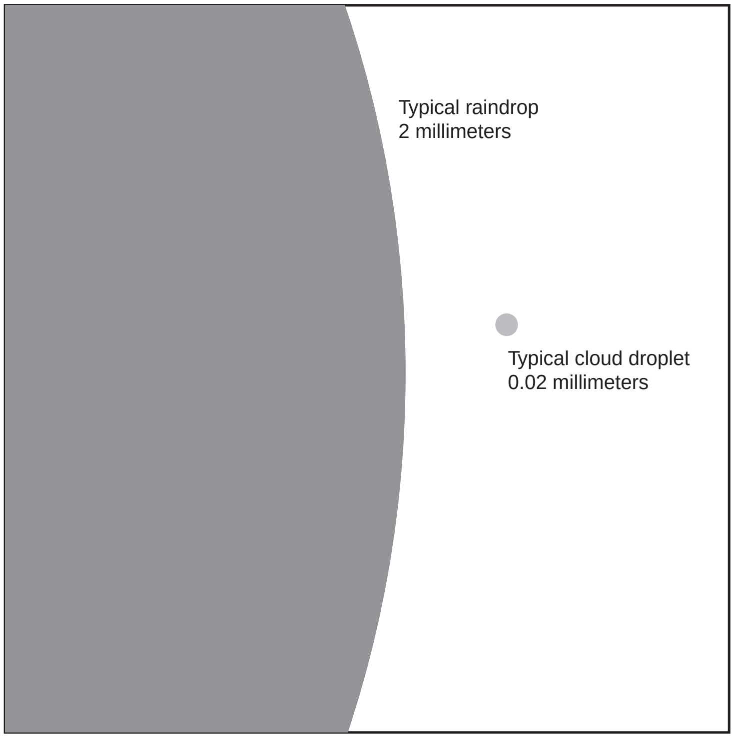
(c) Cirrus clouds, found at very high, cold altitudes, are composed entirely of ice particles. Flight through these clouds should not result in structural icing, although the possibility exists for runback icing from the refreezing of particles that melted on thermally or aerodynamically heated surfaces.

d. Freezing Rain and Freezing Drizzle.

(1) Freezing rain forms when rain becomes supercooled by falling through a subfreezing layer of air. Ordinarily, air temperatures decrease with increasing altitude, but freezing rain requires a temperature inversion, which can occur when a warmer air mass overlies a colder air mass. This situation can occur along a warm front, where a warm air mass overruns a cold air mass. When flying in freezing rain, normally there is warm air (above 0 °C (32 °F)) above.

(2) Freezing raindrops are defined as drops of 500 micrometers (0.5 mm) diameter or larger. A typical diameter is 2 mm, and the few that grow much larger than about 6 mm tend to break up. Using 20 micrometers (0.02 mm) as a typical diameter for a cloud droplet, the diameters of rain and cloud drops differ by a factor of approximately 100, and the volume and mass differ by a factor of about 1,000,000. The size difference is shown in Figure 1. Droplet mass affects how far aft of the stagnation point (leading edge surfaces) droplets will strike the aircraft. The mass of freezing rain is typically 1,000,000 times that of cloud droplets. Because of this, freezing rain will result in ice forming in areas far aft of where it would form in ordinary supercooled clouds.

FIGURE 1. DROPLET SIZE COMPARISON



(3) Freezing drizzle also can form through the same process. It consists of supercooled liquid water drops that have diameters smaller than 500 micrometers (0.5 mm) and greater than 50 micrometers (0.05 mm).

(4) However, freezing drizzle is perhaps more commonly formed by a different process, known as the collision-coalescence process. When, through condensation, some droplets in a cloud grow to approximately 30 micrometers in diameter, they begin to settle, falling fast enough so that they collide with some smaller droplets. If the droplets coalesce, the result is a larger droplet, which now has an even better chance of capturing smaller droplets. Under favorable conditions, this process can produce drizzle-size drops in a supercooled cloud, usually near the top, where the larger droplets generally are found in any cloud. Statistics vary, but some studies have reported that freezing drizzle aloft forms more than 80 percent of the time by the collision-coalescence process in non-convective clouds. Thus, in freezing drizzle, the pilot cannot assume that a warm layer (above 0°C (32°F)) exists above the aircraft.

(5) The diameters of representative cloud and drizzle drops differ by a factor of about 10 and the volume and mass by a factor of about 1,000. The greater inertia and impingement efficiency of the drizzle drops will result in icing beyond the usual icing limits for typical cloud droplets. When drizzle drops are found within a supercooled cloud, they can result in accretions that cause very rapid and dangerous stall speed and drag increases for some aircraft and roll control anomalies for others. These situations may be caused by the roughness, shape, and extent of the accretion that forms. This is an instance of SLD icing as discussed earlier in this paragraph. (See Table 1 for a list of cues developed for aircraft with unpowered controls and pneumatic deicing boots.)

3-3. FRONTS.

a. When air masses of differing temperatures, pressures, or relative humidity meet, a front is formed. If the front moves so that warmer air replaces colder air, it is called a warm front; if it moves so that colder air replaces warmer air, it is called a cold front. An occluded front forms when an air mass is trapped between two colder air masses and is forced to higher and higher levels. In all three cases, significant lifting occurs. If sufficient moisture and subfreezing temperatures are present, icing conditions are created.

b. Along a warm front, the warmer air tends to slide gradually over the cold front, forming stratus clouds conducive to icing (see Figure 2). In a cold front, the cold air plows under the warm air, lifting it more rapidly and resulting in the formation of cumulus clouds with high liquid water content if the lifted air is moist (see Figure 3). SLD in the form of freezing rain and freezing drizzle are sometimes found near fronts, as explained above.

FIGURE 2. WARM FRONT

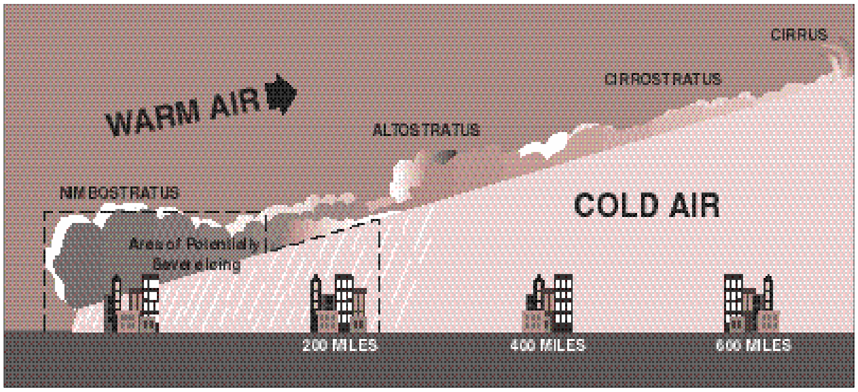
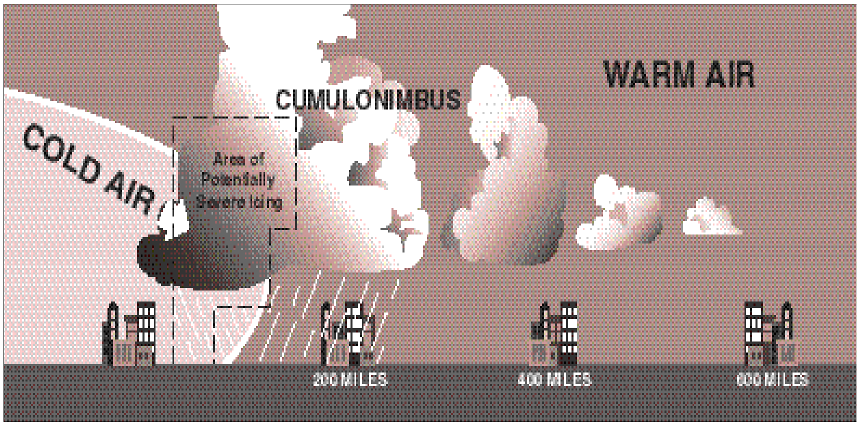


FIGURE 3. COLD FRONT



c. Because of the icing and other hazards associated with fronts, they are best avoided, if possible. When flying through a front, the shortest route through the front should be taken, instead of flying along the front, to reduce the time spent in potential icing conditions.

3-4. CONVECTIVE WEATHER AND ICE CRYSTALS.

a. Some turbine engine designs have shown a susceptibility to ice crystals that form in the atmosphere because of convective weather activity. Deep lifting (thousands of feet) and condensation of water vapor in an unstable atmosphere characterize convective weather. Some or all of the following can be found in areas of convection: strong wind shear, turbulence, lightning, and high-condensed water or hail. Convective weather can range from isolated thunderstorms or cumulonimbus clouds, to convective complexes or squall lines to tropical storms or hurricanes. It can extend hundreds of miles laterally and above 50,000 feet vertically. Convective weather systems, especially, those associated with tropical weather fronts can pump large quantities of moisture to high altitudes that freezes into ice crystals that can remain aloft. These ice crystals can remain as a cloud well after the convective system has decayed.

b. These clouds of ice crystals may not be detectable on conventional airborne radar. Although these ice crystals do not typically accrete on airframe surfaces or trigger ice detectors, when present in high concentrations they can still accrete on warm surfaces within the flow-path of turbine engines. This accretion can ultimately result in engine upset, engine damage from shedding, or power loss.

c. Dry ice crystals, particularly those found above 25,000 feet altitude, do not provide good radar reflectivity. Dry ice particles have about 20 times less radar reflectivity than rain droplets, and therefore are difficult to detect. Clouds and temperatures less than ten degrees centigrade are better indicators of the possible presence of ice crystals when near convective weather. Follow AFM procedures.

CHAPTER 4. ICING EFFECTS, PROTECTION, AND DETECTION

4-1. FORMS OF ICING. Aircraft icing in flight is usually classified as being either structural icing or induction icing. Structural icing refers to the ice that forms on aircraft surfaces and components, and induction icing refers to ice in the engine's induction system.

a. Structural Icing. Ice forms on aircraft structures and surfaces when supercooled droplets impinge on them and freeze. Small and/or narrow objects are the best collectors of droplets and ice up most rapidly. This is why a small protuberance within sight of the pilot can be used as an "ice evidence probe." It will generally be one of the first parts of the airplane on which an appreciable amount of ice will form. An aircraft's tailplane will be a better collector than its wings, because the tailplane presents a thinner surface to the airstream. The type of ice that forms can be classified as clear, rime, or mixed, based on the structure and appearance of the ice. The type of ice that forms varies depending on the atmospheric and flight conditions in which it forms.

(1) Clear Ice. A glossy, transparent ice formed by the relatively slow freezing of supercooled water (see Figure 4). The terms "clear" and "glaze" have been used for essentially the same type of ice accretion. This type of ice is denser, harder, and sometimes more transparent than rime ice. With larger accretions, clear ice may form "horns" (see Figure 5). Temperatures close to the freezing point, large amounts of liquid water, high aircraft velocities, and large droplets are conducive to the formation of clear ice.

FIGURE 4. CLEAR ICE

FIGURE 5. CLEAR ICE BUILDUP WITH HORNS

(2) Rime Ice. A rough, milky, opaque ice formed by the instantaneous or very rapid freezing of supercooled droplets as they strike the aircraft (see Figure 6). The rapid freezing results in the formation of air pockets in the ice, giving it an opaque appearance and making it porous and brittle. For larger accretions, rime ice may form a streamlined extension of the wing. Low temperatures, lesser amounts of liquid water, low velocities, and small droplets favor formation of rime ice.

FIGURE 6. RIME ICE

(3) Mixed Ice. Mixed ice is a combination of clear and rime ice formed on the same surface. It is the location, size, shape, and roughness of the ice that is most important from an aerodynamic point of view. This is discussed later in this chapter, on effects of icing.

b. Induction Icing.

(1) Ice in the induction system can reduce the amount of air available for combustion. The most common example of reciprocating engine induction icing is carburetor ice. Most pilots are familiar with this phenomenon, which occurs when moist air passes through a carburetor venturi and is cooled. As a result of this process, ice may form on the venturi walls and throttle plate, restricting airflow to the engine. This may occur at temperatures between 20°F (-7°C) and 70°F (21°C). The problem is remedied by applying carburetor heat, which uses the engine's own exhaust as a heat source to melt the ice or prevent its formation. Fuel-injected aircraft engines usually are less vulnerable to icing, but still can be affected if the engine's air source becomes blocked with ice. Manufacturers provide an alternate air source that may be selected in case the normal system malfunctions.

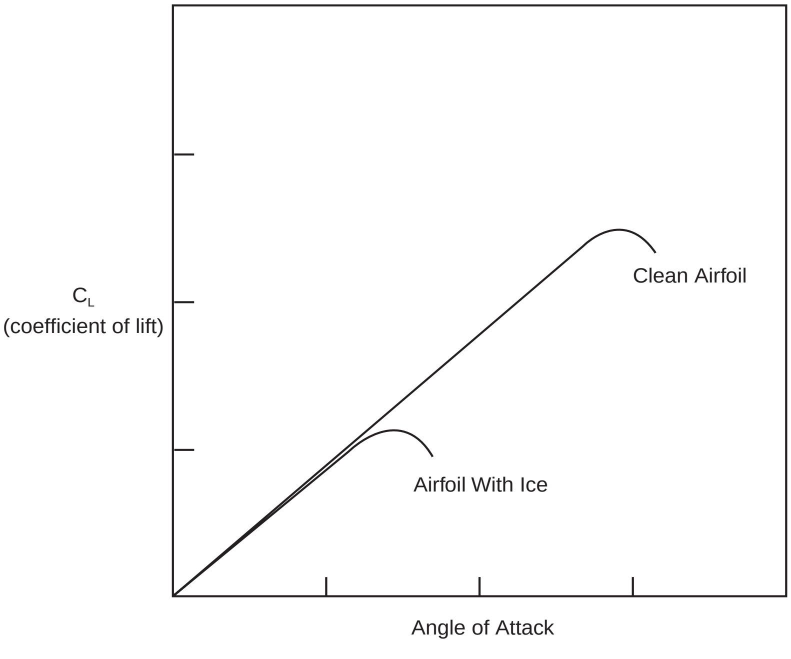
(2) In turbine engine powered aircraft, air that is drawn into the engines creates an area of reduced pressure at the inlet, which lowers the temperature below that of the surrounding air. In marginal icing conditions (i.e., conditions where icing is possible), this reduction in temperature may be sufficient to cause ice to form on the engine inlet, disrupting the airflow into the engine. Another hazard occurs when ice breaks off and is ingested into a running engine, which can cause damage to fan blades, engine compressor stall, or combustor flameout. When anti-icing systems are used, runback water also can refreeze on unprotected surfaces of the inlet and, if excessive, reduce airflow into the engine or distort the airflow pattern in such a manner as to cause compressor or fan blades to vibrate, possibly damaging the engine. Another problem in turbine engines is ice, particularly snow and ice crystals accumulating on the engine probes used to set power levels (for example, engine inlet temperature or engine pressure ratio (EPR) probes), which can lead to erroneous readings of engine instrumentation (see the description of the Air Florida B-737 accident in Appendix 1, paragraph 2).

(3) Ice also may accumulate on both the engine inlet section and on the first or second stage of the engine's low-pressure compressor stages. This normally is not a concern with pitot-style engine airflow inlets (that is, straight-line-of-sight inlet design). However, on turboprop engines that include an inlet section with sharp turns or bird-catchers, however, ice can accumulate in the aerodynamic stagnation points at the bends in the inlet duct. If ice does accumulate in these areas, it can shed into the engine, possibly resulting in engine operational difficulties or total power loss. Therefore, with these types of engine configurations, the use of anti-icing or deicing systems per the AFM is very important. Supercooled water droplets tend to form ice on the turbine engine inlet, fan, and first few stages of the compressor. Ice crystals, when present in high concentrations, tend to form ice deeper in the turbine engine's compressor section. Ice accretions can ultimately shed and damage the compressor, or cause engine surge or flameout. These conditions are analyzed and tested during original engine airworthiness approvals. These tests are conducted to demonstrate the turbine engine's tolerance to these conditions.

4-2. GENERAL EFFECTS OF ICING ON AIRFOILS. The two figures in this chapter depict important information on the effects of ice contamination on an airfoil. (For this AC, an airfoil is a cross-section of a wing or tailplane.)

a. Figure 7 shows how ice often affects the coefficient of lift for an airfoil. Note that at very low angles of attack, there may be little or no effect of the ice on the coefficient of lift. Thus when cruising at a low angle of attack (AOA), ice on the wing may have little effect on the lift. However, note that the maximum coefficient of lift (C_{Lmax}) is significantly reduced by the ice, and the AOA at which it occurs (the stall angle) is much lower. Thus when slowing down and increasing the AOA for approach, therefore, the pilot may find that ice on the wing that had little effect on lift in cruise now causes stall to occur at a lower AOA and higher speed. Even a thin layer of ice at the leading edge of a wing, especially if it is rough, can have a significant effect in increasing stall speed. For large ice shapes, especially those with horns, the lift may also be reduced at a lower AOA as well. Depending on the airfoil section, the lift loss may even be larger if ice accretes behind areas normally protected, such as due to large drop impingement and runback.

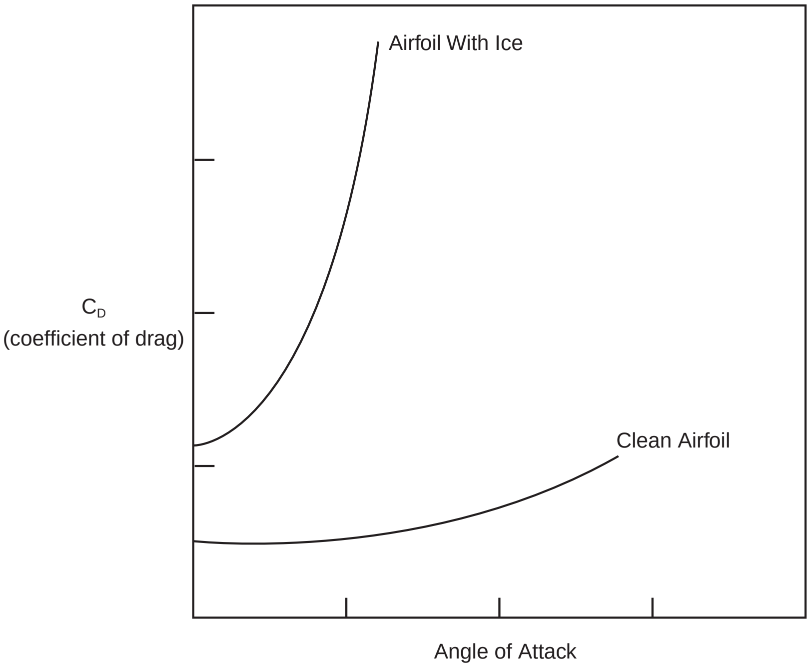
FIGURE 7. LIFT CURVE



b. Figure 8 shows how ice affects the coefficient of drag of the airfoil. Note that the effect is significant even at very small AOAs.

(1) A significant reduction in C_{Lmax} and a reduction in the AOA where stall occurs can result from a relatively small ice accretion. A reduction of C_{Lmax} by 30 percent is not unusual, and a large horn ice accretion can result in reductions of 40 percent to 50 percent. Drag tends to increase steadily as ice accretes. An airfoil drag increase of 100 percent is not unusual, and, for large horn ice accretions, the increase can be 200 percent or even higher.

FIGURE 8. DRAG CURVE



(2) Ice on an airfoil can have other effects not depicted in these curves. Even before airfoil stall, there can be changes in the pressure over the airfoil that may affect a control surface at the trailing edge. Furthermore, on takeoff, approach, and landing, the wings of many aircraft are multi-element airfoils with three or more elements. Ice may affect the different elements in different ways and affect the way in which the flows over the elements interact.

4-3. EFFECTS OF ICING ON WINGS. The effect of icing on a wing depends on whether the wing is protected and the kind and extent of protection provided.

a. Unprotected Wing. An aircraft with a completely unprotected wing will not be certificated for flight in icing conditions, but it may inadvertently encounter icing conditions. Since a cross-section of a wing is an airfoil, the remarks above on airfoils apply to a wing with ice along its span. The ice causes an increase in drag, which the pilot detects as a loss in airspeed. An increase in power is required to maintain the same airspeed. (The drag increase is also due to ice on other parts of the aircraft). The longer the encounter, the greater the drag increase; even with increased power, it may not be possible to maintain airspeed. The ice on the wing also causes a decrease in C_{Lmax}, possibly about 30 percent, for an extended encounter. The rule of thumb is that the percentage increase in stall speed is approximately half the decrease in C_{Lmax}, so the stall speed may go up by about 15 percent. If the aircraft has relatively limited power (as is the case with many aircraft with no ice protection), it may soon approach stall speed and a very dangerous situation. A similar scenario applies to aircraft that are certificated for flight in icing conditions if the wing ice protection system fails in icing conditions.

b. Deiced Wing. The FAA recommends that the deicing system be activated at the first indication of icing. Because some residual ice continues to adhere between pneumatic boot system cycles, the wing is never entirely "clean." The amount of residual ice increases as airspeed or temperature decreases. At airspeeds typical of small airplanes (demonstrated in tunnel tests at airspeeds below 145 knots calibrated airspeed (KCAS)), it may take many boot cycles to effectively shed the ice. It may appear that the boots are not having any effect at all until shedding occurs.

(1) Use of ice adhesion inhibitors on pneumatic deicing boots is highly recommended; consult the AFM or maintenance manual for the recommended product and application interval. The ice that can build between boot cycles, called intercycle ice, can be significant. On many icing accidents and incidents, loss of airspeed and stall can occur in a span of minutes. Ice accretion will decrease C_{Lmax}, which will translate into an increase in stall speed.

(2) The increase in stall speed becomes more of a concern at the higher AOAs characteristic of approach and landing because the aircraft is operating closer to C_{Lmax}. Thus the pilot should consider continuing activation of the deicing system for a period after exiting the icing conditions so that the wing will be as clean as possible and any effect on stall speed minimized. If the icing conditions cannot be exited until late in the approach or significant icing appears to remain on the wing after activating the system, an increase in the aircraft's stall speed is a possibility and adjustment of the approach speed may be appropriate. Consult the AFM or POH for guidance.

(3) Intercycle ice will also accrete on airplanes with electrothermal deicing systems. It is typical for these systems also to produce runback ice behind the protected area.

c. Anti-Iced Wing.

(1) An anti-icing system is designed to keep a surface entirely free of ice throughout an icing encounter. Anti-icing protection for wings is normally provided by ducting hot bleed air from the engines into the inner surface of the wing's leading edge and thus is found mainly on transport turbojets and business jets, but not on turbopropeller or piston airplanes. Even on transport and business jets, there are often sections along the span of the wing that are not protected. An important part of icing certification for these planes is checking that the protected sections are extensive enough and properly chosen so that ice on the unprotected areas will not affect the safety of flight.

(2) Anti-icing systems can be evaporative or running wet. On newer designs, the wing anti-ice system may be running wet by design, forming runback ice accretions. The effects of these accretions are evaluated during certification, but only in part 25, appendix C icing conditions. Runback ice can serve as accretion sites for additional accumulations.

4-4. EFFECTS OF ICING ON ROLL CONTROL.

a. This chapter is in effect a continuation of the previous one, since ice on the wings forward of the ailerons can affect roll control. The ailerons are generally close to the tip of the wing, and wings are designed so that stall starts near the root of the wing and progresses outward. In this way, the onset of stall does not interfere with roll control of the ailerons. However, the tips are usually thinner than the rest of the wing, and so they most efficiently collect ice. This can lead to a partial stall of the wings at the tips, which can affect the ailerons and thus roll control.

b. If ice accumulates in a ridge aft of the boots, but forward of the ailerons, possibly due to flight in SLD conditions, this can affect the airflow and interfere with the proper functioning of the ailerons, even without a partial wing stall at the tip.

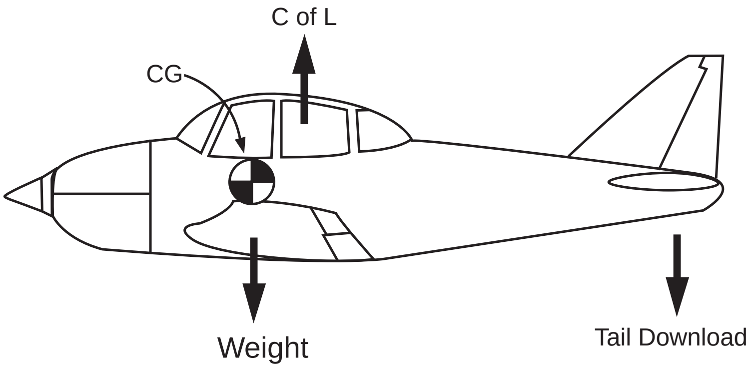
(1) This is the phenomenon that the National Transportation Safety Board (NTSB) found to be responsible for the accident of an ATR-72 turbopropeller aircraft in Roselawn, Indiana in October 1994 (see Appendix 1, paragraph 1). Flight test investigations following the accident suggested two ways in which the ailerons might be affected by ice in front of them.

(2) One has been termed “aileron snatch,” in which an imbalance of forces at the aileron is felt by the pilot of an aircraft without powered controls as a sudden change in the aileron control force. Provided the pilot is able to adjust for the unusual forces, the ailerons may still be substantially effective when they are deflected. The other is that ailerons may be affected in a substantial degradation in control effectiveness, although without the need for excessive control forces.

4-5. TAILPLANE ICING.

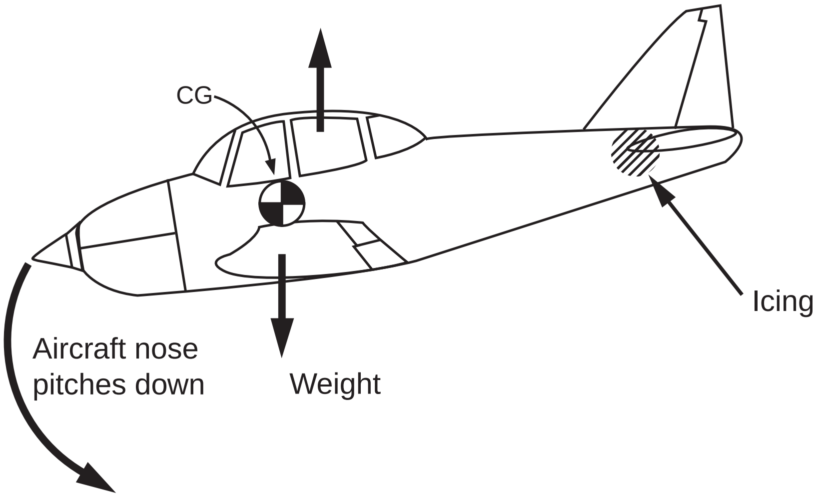
a. Most aircraft have a nose-down pitching moment from the wings because the center of gravity (CG) is ahead of the center of pressure. It is the role of the tailplane to counteract this moment by providing “downward” lift (see Figure 9). The result of this configuration is that actions that move the wing away from stall, such as deployment of flaps or increasing speed, may increase the negative AOA of the tail. With ice on the tailplane, it may stall after full or partial deployment of flaps (see Figure 10).

FIGURE 9. TAIL DOWN MOMENT



b. Since the tailplane is ordinarily thinner than the wing, it is a more efficient collector of ice. On most aircraft, the tailplane is not visible to the pilot, who therefore cannot observe how well it has been cleared of ice by any deicing system. Thus, it is important that the pilot be alert to the possibility of tailplane stall, particularly on approach and landing. A no-flap landing should be considered to avoid a tailplane stall, consistent with AFM procedures. Tailplane stall is discussed in detail in Chapter 7, paragraph 7-9.

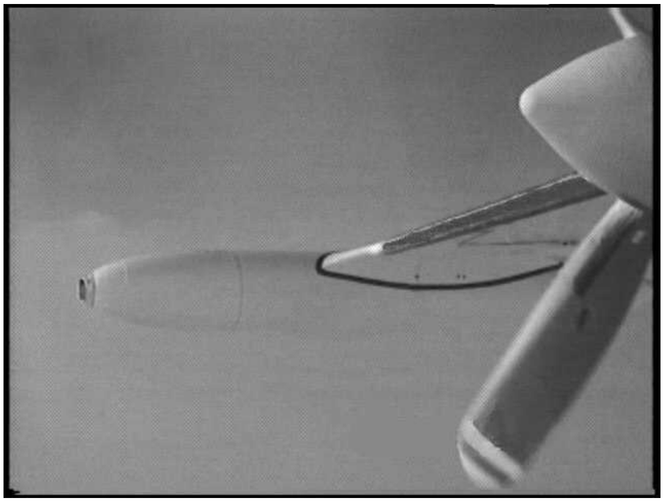
FIGURE 10. PITCHOVER DUE TO TAIL STALL



c. On some transport turbojets, the tailplane has no ice protection. However, the tailplanes on these aircraft are usually quite thick and therefore, are a less efficient collector of ice. Furthermore, these aircraft are subjected to extensive certification testing and analysis to ensure that the tailplane will not be placed at such an extreme angle in actual operations to experience a stall, even with a large ice accretion.

4-6. PROPELLER ICING. Ice buildup on propeller blades reduces thrust for the same aerodynamic reasons that wings tend to lose lift and increase drag when ice accumulates on them. The greatest quantity of ice normally collects on the spinner and inner radius of the propeller. However, in one suspected large drop icing during a flight test (Figure 11), ice was experienced along the entire span of the propeller blades. This resulted in a 50-knot loss of airspeed in one minute, 25 seconds. There was little airframe ice and no indication of propeller icing. As ice accretes on the propeller blades increasing blade drag, the propeller governor of the constant speed propeller flattens the blade pitch to maintain revolutions per minute (RPM). In the cockpit, the pilot sees no change in RPM or torque.

FIGURE 11. PROPELLER ICE ACCRETION DURING AN SLD ENCOUNTER WITH THE PROPELLER ICE PROTECTION SYSTEM OPERATING



4-7. ANTENNA ICING. Because of their small size and shape, antennas that do not lay flush with the aircraft’s skin tend to accumulate ice rapidly. Furthermore, they often are devoid of an internal anti-icing or deicing capability for protection. During flight in icing conditions, ice accumulations on an antenna may cause it to begin to vibrate or cause radio signals to become distorted. Besides the distraction caused by vibration (pilots who have experienced the vibration describe it as a “howl”), it may cause damage to the antenna. If a frozen antenna breaks off, it can damage other areas of the aircraft in addition to causing a communication or navigation system failure.

4-8. COOLING INLET ICING. Some types of electronic equipment generate significant amounts of heat and require independent sources of cooling, which often use external air scoops. These cooling inlets are susceptible to icing and may or may not be heated as part of the airplane’s icing protection system. Pilots should check their airplane’s AFM to determine if the cooling inlets are protected from ice.

4-9. EFFECTS OF ICING ON CRITICAL SYSTEMS.

a. Pitot Tube. The pitot tube is particularly vulnerable to icing because even light icing can block the entry hole of the pitot tube where ram air enters the system. This will affect the airspeed indicator and is the reason most airplanes are equipped with a pitot heating system. The pitot heater usually consists of coiled wire heating elements wrapped around the air entry tube. If the pitot tube becomes blocked, and its associated drain hole remains clear, ram air no longer is able to enter the pitot system. Air already in the system will vent through the drain hole, and the remaining will drop to ambient (outside) pressure. Under these circumstances, the airspeed indicator reading decreases to zero, because the airspeed indicator senses no difference between ram and static air pressure. If the pitot tube, drain hole, and static system all become blocked in flight changes in airspeed will not be indicated, due to the trapped pressures. However, if the static system remains clear, the airspeed indicator would display a higher-than actual airspeed. At lower altitudes, the airspeed indicator would display a lower-than-actual airspeed.

b. Static Port. Many aircraft also have a heating system to protect the static ports to ensure the entire pitot-static system is clear of ice. If the static port becomes blocked, the airspeed indicator would still function; however, it would be inaccurate. At altitudes above where the static port became blocked, the airspeed indicator would indicate a lower-than-actual airspeed. At lower altitudes, the airspeed indicator would display a higher-than-actual airspeed. The trapped air in the static system would cause the altimeter to remain at the altitude where the blockage occurred. The vertical speed indicator would remain at zero. On some aircraft, an alternate static air source valve is used for emergencies. If the alternate source is vented inside the airplane, where static pressure is usually lower than outside static pressure, selection of the alternate source may result in the following erroneous instrument indications:

(1) The altimeter reads higher than normal,

(2) The indicated airspeed reads greater than normal,

(3) The vertical-speed indicator momentarily shows a climb.

c. Stall Warning Systems.

(1) Stall warning systems provide essential information to pilots. A loss of these systems can exacerbate an already hazardous situation. These systems range from a sophisticated stall warning vane to a simple stall warning switch. The stall-warning vane (also called an “AOA sensor” since it is a part of the stall warning system) can be found on many aircraft. The AOA provides flightcrews with an AOA display or feeds AOA data to computers that interpret this information and provide stall warning to the crew when the AOA becomes excessive. These devices consist of a vane, which is wedge-like in shape and has freedom to rotate about a horizontal axis, and is connected to a transducer that converts the vane’s movements into electrical signals transmitted to the airplane’s flight data computer. Normally, the vane is heated electrically to prevent ice formation. The transducer is also heated to prevent moisture from condensing on it when the vane heater is operating. If the vane collects ice, it may send erroneous signals to such equipment as stick shakers or stall warning devices. Aircraft that use a stall horn may not give any indication of stall if the stall indicator opening or switch becomes frozen.

(2) Because contamination of the wing reduces lift, even an operational, ice-free stall warning system may be ineffective because the wing will stall at a lower angle of attack due to ice on the airfoil. The stall onset will therefore occur prior to activation of the stall warning devices, leading to a potential pitch or roll upset. It is imperative that pilots monitor airspeed closely when in icing conditions. On airplanes recently certificated for icing conditions, stall warning systems may have been demonstrated to provide adequate warning within the icing conditions required for certification (part 25, appendix C) once certain ice protection systems were activated. However, the adequacy of stall warning systems in conditions outside appendix C, such as SLD, has not been demonstrated.

d. Windshields.

(1) Anti-icing generally is provided to enable the flightcrew to see outside the aircraft in case icing is encountered in flight. On high-performance aircraft that require complex windshields to protect against bird strikes and withstand pressurization loads, the heating element often is a layer of conductive film or thin wire strands through which electric current is run to heat the windshield and prevent ice from forming.

(2) Aircraft that operate at lower altitudes and lower speeds generally have other systems of window anti-icing/deicing. One system consists of an electrically heated plate installed onto the airplane’s windshield to give the pilot a narrow band of clear visibility. Another system uses a bar at the lower end of the windshield to spray deicing fluid onto it and prevent ice from forming.

e. EPR Probe (turbine engines).

(1) Ice crystals can clog and freeze over turbine engine pressure ratio (EPR) probes as well, resulting in unreliable and misleading power indications. These indications may lead a pilot to believe that an engine is producing more or less power than it actually is, and may result in improper throttle adjustments.

(2) There have been several instances where EPR probes became clogged with ice crystals during climb or cruise (see Air Florida accident in appendix 1. Pilots of turbojet aircraft should calculate a backup N1 setting for takeoff/go-around in icing conditions as a crosscheck for EPR. In flight actuating engine nacelle anti-ice when in heavy clouds usually prevents ice blockage.

f. TAT Probe.

(1) Ice crystals can clog and freeze over the TAT probe on some aircraft. This tendency to freeze over appears to be sensitive to the location of the probe on the airframe. If the TAT freezes over, the indicated temperature will erroneously rise to zero degrees C and hold. In this situation, some aircraft systems will alert the flightcrew that there is a disagreement between various ambient temperature sensors, thus indicating the presence of ice crystals.

(2) Freezing of the TAT probe has been a precursor in many of the turbine engine power loss events occurring in the area of convective weather systems.

4-10. CERTIFICATION FOR FLIGHT IN ICING CONDITIONS. An aircraft which is “certificated for flight in icing conditions” goes through an extensive procedure intended to ensure that it can safely operate throughout those icing conditions encompassed by the icing envelopes specified in 14 CFR part 25, appendix C. This process typically includes extensive analysis (done today with sophisticated computer modeling), tunnel testing, dry-air testing, testing behind an icing tanker, and flight in natural icing conditions. Its objective is not only to verify that the aircraft has functioning ice protection, but also to verify that the aircraft will have acceptable performance and handling qualities in all the environmental conditions covered by the icing envelopes.

a. What is Covered.

(1) The icing envelopes are mainly based on various types of stratus and cumulus supercooled clouds. The envelopes specify maximum amounts of liquid water and drop sizes expected at certain temperatures and altitude ranges. The envelopes were formulated during the 1950s, based on contemporary research, and research that is more recent generally is consistent with the envelopes.

(2) It has been estimated that these envelopes encompass 99.9 percent of all conditions encountered in research programs in stratus and cumulus clouds.

b. What is Not Covered.

(1) First, the pilot should bear in mind that 99.9 percent is not 100 percent, and so vigilance in exceptional conditions is always wise.

(2) Second, the cloud measurements on which the envelopes were based generally did not include SLD conditions. Recent research shows that SLD (in particular, freezing drizzle aloft within cloud) is more common in supercooled clouds than had been thought (see Table 1 for some cues of SLD conditions).

(3) Third, freezing rain or freezing drizzle may be encountered beneath the clouds. Neither of these icing conditions is included in the icing envelopes.

(4) Finally, ice crystals may be encountered in high concentrations at higher altitudes in the area of convective weather systems. Currently these conditions are not included in the icing envelopes, although new envelopes have been preliminarily developed.

4-11. SIGNIFICANCE OF ICING CERTIFICATION.

a. Icing certification is an extensive process. It includes testing and analysis to check that aircraft can operate safely for extended periods in the conditions covered by the icing envelopes. For example, certification includes testing and analysis to show that an aircraft can hold in significant icing conditions for up to 45 minutes. Nonetheless, pilots of certificated aircraft should not be casual about operations in icing conditions, particularly extended operations. It is always possible to encounter an unusual condition for which the aircraft has not been certificated, such as liquid water content outside the envelopes, which is sometimes indicated by a very rapid rate of accumulation. This can result in runback and ice accumulation aft of protected surfaces.

b. SLD may result in droplets impinging aft of protected surfaces and causing ice accumulation. These surfaces may be very effective ice collectors, and ice accumulations may persist as long as the aircraft remains in icing conditions. Note also that icing conditions can develop very quickly and may not be immediately recognized. For example, even though the rate of accumulation may be quite gradual, a thin, extremely rough accretion can develop on a critical surface in minutes**.** This can be very hazardous, particularly on approach and landing.

NOTE: Not all icing certification is the same.

c. Prior to 1973, small airplanes were approved for flight in icing if they were equipped with a minimum suite of ice protection equipment. For example, see Bureau of Flight Standards

Release 434. No analysis or testing to show safe operation in the part 25, appendix C icing envelopes was required.

d. Many small airplanes flying today fall in this category. In 1973, at Amendment 23-14, 14 CFR part 23, § 23.1419 was amended to require analysis and testing to demonstrate that the airplane can operate safely in the part 25, appendix C icing envelopes.

e. In 1993, at Amendment 23-43, § 23.1419 was amended to require small airplanes, certificated for known icing, to comply with performance, stability, controllability, and maneuverability regulations in icing. There were no quantitative criteria for performance prior to Amendment 23-43.

f. Keep in mind, even though the small airplane icing certification regulations changed in 1973 and 1993, the means of showing compliance have changed continuously, as shown by the example in Table 1. Table 1 compares the current means of compliance in AC 23.1419-2C (2004) to the guidance that existed prior to 1993.

TABLE 1. EVOLUTION OF ICING CERTIFICATION STANDARDS

	Criteria prior to 1993	**Current Criteria**
Simulated ice shapes tested	Unprotected areas only	Unprotected and protected (e.g., intercycle ice on boots)
Performance criteria	Qualitative	Must meet Subpart B minimum climb gradients
Stall warning	Can use different type in icing (e.g., buffet versus stall warning system)	Stall warning type in icing should be same as in non-icing and margin should meet Subpart B
Maneuver margin	No policy	There should be no buffet or stall warning during maneuvering at operating airspeeds
Autopilot	No policy	Evaluate operation, disconnect at stall warning
Propeller icing performance	No policy	Evaluate performance in natural icing
Use of ice adhesion inhibitors	No policy	Cannot use for certification

g. How can I tell how my airplane was certificated for icing?

(1) The airplane was certificated to 14 CFR § 23.1419 at Amendment 23-14 or later if your AFM or POH references "part 25, appendix C" icing conditions, or "14 CFR § 23.1419" at Amendment 23-14 or later.

(2) The "Certification Basis" section of your airplane's type certification data sheet (TCDS) may reference "14 CFR § 23.1419" at Amendment 23-14 or higher, or "SFAR 23." The TCDS can be found in the FAA's on-line Regulatory and Guidance Library at http://rgl.faa.gov.

(3) If there is only a minimum equipment list (MEL) for icing conditions in the AFM or POH, the certification basis of your airplane is prior to Amendment 23-14 (1973). Some pilots mistakenly believe IFR certificated airplanes are analyzed or tested for inadvertent icing encounters—they are not.

h. How is certification related to the operating rules?

(1) Section 34 of Special Federal Aviation Regulation (SFAR) 23, and § 34 of part 135, appendix A.

(2) These are referenced in the part 91 and part 135 operating rules, respectively, and are equivalent to 14 CFR § 23.1419 at Amendment 23-14.

4-12. ICE PROTECTION EQUIPMENT ON AIRPLANES NOT CERTIFICATED FOR ICING.

a. All aircraft are required to have ice protection for their propulsion systems in case of an inadvertent icing encounter, and nearly all aircraft have pitot heat and an alternate source of static air.

b. Some general aviation aircraft, that are not certificated for flight in icing conditions, also have ice protection systems on their wings and tailplane, providing an additional safety margin should an inadvertent encounter with icing occur. These systems are for emergency use only.

c. The FAA recommends that aircraft not certificated for flight in icing conditions, but that are equipped with these "non-hazard" deicing/anti-icing equipment exit those conditions as expeditiously as possible, coordinating with ATC as necessary.

d. The differences between these systems and fully certified systems are significant. Airplane performance is unknown, stall warning in icing conditions most likely will not activate prior to stall, controls may jam due to ice accretion, and system features required for known icing may not be present in these "non-hazard" systems.

4-13. ANTI-ICING SYSTEMS. Anti-icing systems operate on the principle that ice should not be allowed to accumulate on the aircraft or certain aircraft systems when flying through icing conditions. Usually, anti-icing is accomplished using electric heat, hot air, or chemicals. While an aircraft's AFM or POH is the ultimate authority on the operation of anti-icing systems, a good rule of thumb is to activate anti-icing systems at the first signs of visible moisture encountered during conditions conducive to icing. This will prevent the buildup of any appreciable amounts of ice.

a. Electric Systems. Electric systems normally are used for smaller areas such as antennas, static ports, air temperature probes, pitot tubes, and windshields.

b. Hot Air Systems.

(1) Hot air systems are used for larger areas of the aircraft, such as engine nacelles and wing leading edges. Bleed air from turbine engines is the most common type of anti-icing protection for engine nacelles and wings of transport and business turbojets. Hot air is distributed to “piccolo tubes,” which consist of a perforated pipe installed directly behind the airplane’s skin. Such hot-air systems are quite effective in preventing the formation of ice.

(2) One drawback of a hot air system is that tapping air from the engine to anti-ice large surfaces reduces the amount of available thrust, which may have a significant effect on climb performance (especially one engine inoperative climb performance in multiengine turboprops, turbojets, and turbofans.) This performance loss is the reason this system is not common on smaller turbine powered airplanes.

(3) Pilots should keep in mind that while cruising or descending with anti-ice systems on, higher than normal power settings may be required to ensure sufficient bleed air is being supplied to the anti-ice system, and to prevent engine surges/stalls (see the particular AFM for the appropriate settings.)

(4) In addition, in some situations on some airplanes, the hot air system may not fully evaporate all impinging water drops, resulting in runback ice. This may occur with an inoperative engine, and may be the reason your AFM requires a minimum engine power setting on descent.

c. Chemical Systems.

(1) Chemical systems apply a chemical agent that lowers the freezing point of water found on aircraft surfaces and decreases the friction coefficient of those surfaces to prevent ice from adhering to the surfaces. Examples of such chemical agents are isopropyl alcohol and ethylene glycol.

(2) While an aircraft’s AFM or POH is the ultimate authority on the operation of anti-icing systems, a good rule of thumb is to activate anti-icing systems at the first signs of visible moisture encountered during conditions conductive to icing. This will prevent the buildup of any appreciable amounts of ice.

4-14. DEICING SYSTEMS.

a. The operating philosophy behind deicing systems differ from that of anti-icing systems because deicing systems permit a certain amount of ice accumulation before they can be activated. Because ice is permitted to accrete between cycles, and because after each cycle there is some residual ice, the wing or the tailplane is never entirely “clean.” If the systems are operated properly, however, the intercycle ice buildup on the airfoil should be limited, along with the accompanying drag increases.

b. Because other parts of the aircraft, including part of the span of the wing, are not protected from ice, a drag increase from those areas will still be present. This is accounted for in the icing certification process, and the pilot can fly the aircraft safely by following the operating procedures in the AFM or POH. Residual ice and the ice that accumulates between deicing cycles can be expected to have some effect on C_{Lmax}, but note that this effect is significant only at higher AOA.

(1) At the AOA typical of cruise, this ice should have very little effect on lift. At the higher AOA characteristic of approach and landing, the decrease in C_{Lmax} will translate into an increase in stall speed. Thus, the pilot should cycle the deicing system on approach after exiting the icing conditions so that the wing will be as clean as possible and any effect on stall speed minimized.

(2) If the icing conditions cannot be exited until late in the approach, or if significant icing appears to remain on the wing after cycling the system, the pilot should assume an increase in the aircraft’s stall speed and adjust the approach speed accordingly. Pilots should consult the AFM or POH for guidance. Usually, deicing is accomplished using an electroimpact system, an electrothermal system, or a pneumatic boot system.

c. Electroimpact System.

(1) The electroimpact system deices a surface using pulses of energy to produce rapid flexing movements of the airplane’s skin surface, which break the bond of accumulated ice.

(2) The shattered ice is then carried away by the airflow.

d. Electrothermal System.

(1) The electrothermal system deices a surface by heating the surface to a temperature above freezing to break the bond of accumulated ice. The shattered ice is then carried away by the airflow. The surface is allowed to cool to allow ice to form, and the heat is activated again to shed the ice, the cycle being repeated. Such systems are common on propellers and helicopter main rotors, and have been recently introduced on wing and tail leading edges.

(2) Propellers are deiced using rubber boots with embedded heater wires to break the adhesion of ice to the propeller blades. Sometimes the blades are heated alternately in sections due to limits of available electrical power. The alternate sections are heated symmetrically to avoid an imbalance of the propeller while sections of ice are being removed and dislodged from the propeller by centrifugal force. Often, on aircraft that have such systems, the skin surrounding the airframe is reinforced with doublers to strengthen the skin where ice is most likely to be flung from the propellers. However, the initial imbalance caused by ice accumulation and the loud noise created by ice shedding and hitting the airframe can be unsettling to passengers and distracting to flightcrews.

e. Pneumatic Boots.

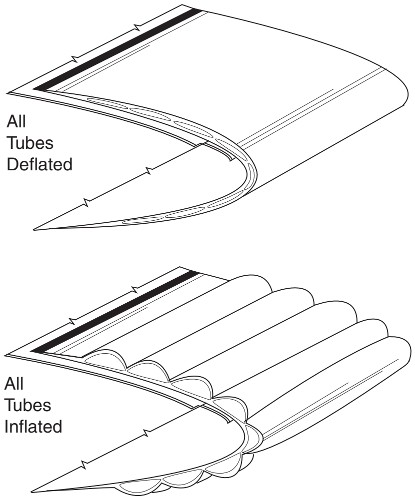
(1) Pneumatic boots, pictured in Figure 12, consist of rubber tubes attached to critical aircraft surfaces, such as the leading edges of wings and horizontal and vertical stabilizers. The tubes may be either chordwise or spanwise. The pneumatic boots are collapsed during normal operations, with suction provided by a vacuum pump to avoid disruption of airflow over the wings. When the system is activated in flight, a timer-operated valve selectively inflates all tubes or half of the tubes intermittently to crack the ice and then allow the airflow over the wings to blow off the broken ice.

(2) A traditional concern in the operation of pneumatic boots has been “ice bridging.” This is attributed to the formation of a thin layer of ice, which is sufficiently plastic to deform to the shape of an expanded deicing boot without being fractured or shed during the ensuing tube deflation. As the deformed ice hardens and accretes additional ice, the boot may be ineffective in shedding the “bridge” of ice. Traditional advice on avoiding this problem has been to wait for a layer of ice of a predetermined thickness to form before cycling the boot. This thickness has been variously prescribed as 1/4 inch, 1/2 inch, and even 1 inch.

(3) Studies done in the late 1990’s have established that there are few, if any, documented cases of ice bridging on modern boot designs. In addition, several icing tunnel tests sponsored by the FAA since 1999 showed no ice bridging on modern boot designs. Known cases are confined to boots of designs dating back a quarter century or more. Furthermore, it is recognized that a layer of ice 1/2 inch thick, especially if rough, can have a significant effect on aircraft performance, stability, and control. Consequently, some manufacturers now advise that the boots be cycled as soon as icing is encountered, rather than waiting for a prescribed thickness to accrete. More recent studies in 2005 have shown that at airspeeds typical of general aviation airplanes with modern boot designs, ice will not shed at every boot inflation.

(4) Depending on the icing conditions and airspeed, it could take anywhere from 4 to 25 minutes to shed ice (perhaps longer at the extremely cold temperature of -30°C (-22°F), even when boots were activated at the first sign of icing and cycled every minute thereafter. Cycling early and often provided a small improvement over waiting until 1/4 or 1/2 inch of ice has accreted before activating the boots. Residual and intercycle ice are inherent in the use of any available deicing system, including pneumatic boots. Proper operation of the boots is necessary to minimize the effect of this ice. It is essential that the pilot consult the AFM or POH (the POH must be consistent with the operating limitations section of the AFM) for guidance on proper use of the system. The 2005 testing did show that the proper application of ice adhesion inhibitors improved ice shedding at colder temperatures. The FAA strongly encourages the use of the manufacturer’s recommended ice adhesion inhibitors.

FIGURE 12. WING BOOT



4-15. MAINTENANCE CONSIDERATIONS. Some anti-icing and deicing systems are known to be very reliable, while others may require a lot of maintenance to remain effective. Pneumatic boots, for example, are known for their susceptibility to damage from many sources and should be inspected carefully. The rubber used for the boots is subject to degradation from atmospheric pollution, which results in the rubber cracking and losing some of its elastic properties. An ice adhesion inhibitor should be applied to pneumatic deicing boots in accordance with the maintenance manual. Any product that is not recommended by the airplane or boot manufacturer should be approved by the FAA. Other problems are defects, delaminations, or tears in the rubber caused by the impact of objects, such as foreign matter found on airport ramps. Pinholes or tears in pneumatic deicing boots will draw in moisture when system vacuum is supplied, and subsequent freezing of this moisture can render the system ineffective. Pilots should have maintenance personnel evaluate any defects in the boots when they are found.

(1) Flightcrews always should ensure their airplane’s anti-icing and deicing equipment is in a serviceable condition.

(2) The airplane’s MEL should be consulted for details on what is permitted to be inoperable and what equipment deficiencies constitute “no go” items.

4-16. ICE DETECTION.

a. Electronic.

(1) Many modern aircraft come equipped with electronic ice detectors. A common in-flight ice detector consists of a probe that vibrates at a specific frequency. When ice begins to form on the probe, the frequency of the probe’s vibration will change because of the increased mass of ice on the probe, and an indicator will light in the cockpit. These detectors are activated for a short time period, generally one minute, after which the probe is heated electrically to melt the accreted ice. The process is then repeated. If the aircraft is flying in continued icing conditions, ice will continue to form on the probe, and the light in the cockpit will remain on.

(2) Pilots should consult their AFM or POH to determine if their ice detection system is an “Advisory” or “Primary” system. The difference between the systems is the redundancy of the system and testing required for certification. The majority of airplanes have an “Advisory” system, which means the pilot is responsible for detecting ice and ensuring ice protection systems are activated. This is true even for ice protection systems that are automatically activated when the ice detection system detects ice.

(3) Currently, there are no electronic detection systems that can reliably detect ice crystals, although new systems are under development.

b. Visual. Strategically located protuberances also may serve as ice indicators. There is usually some unprotected protuberance or surface visible to the crew, such as windshield wipers, pod pylons, or landing lights that can serve as an icing reference because they tend to build up ice first. If there is no such protuberance visible to the crew, manufacturers may provide one for this purpose. These ice detectors, referred to as “ice evidence probes,” are typically in plain view of the cockpit and normally collect ice more readily than larger components or surfaces. If ice begins to accumulate on such an ice detector, the flightcrew should assume the rest of the aircraft also is accumulating ice and take appropriate action. These detectors only serve their purpose if pilots include them in their scan during flight in potential icing conditions. Pilots should monitor critical surfaces at temperatures near freezing, since ice may form on critical surfaces prior to forming on visual ice indicators.

4-17. VISUAL CLUES OF SLD CONDITIONS. If SLD is known to be present, most aircraft with unpowered controls and airframe deicing systems should request a route or altitude change to exit the conditions. This action may be prudent for other aircraft as well. The cues listed below were developed for aircraft with unpowered controls and pneumatic deicing boots as indicative of SLD conditions. Of most concern is the accretion of ice in areas aft of where it would usually be found. Such “aft accretions” could sometimes be the result of runback due to high liquid water rather than SLD. Excessive runback icing, however, may have effects similar to SLD, so similar pilot action may be appropriate. The cues are:

a. Ice may become visible on the upper or lower surface of the wing, aft of the active part of the deicing boots. Pilots should look for irregular or jagged lines of ice or for pieces of ice shedding off the airplane. During night operations, adequate illumination should be used to observe all areas. On most airplanes, the last inch of the deicing boot is inactive.

b. The aft limit of ice accumulation on a propeller spinner that is not heated will reveal ice extending beyond normal limits, typically back to the blades.

c. Unheated portions of side windows may begin to accumulate granular dispersed ice crystals or a translucent or opaque coating over the entire window. This icing may be accompanied by other ice patterns on the windows, such as ridges. These patterns may occur from within a few seconds to half a minute after exposure to SLD conditions.

d. Ice coverage may become unusually extensive, with visible ice fingers or feathers on parts of the airframe that normally would not be covered by ice. The aircraft’s performance may degrade. Pilots should remain vigilant when icing conditions are present, and any alteration of the aircraft's performance should be monitored closely as a sign of icing on the airplane.

NOTE: Pilots should be vigilant for the ice accretions listed above when the following are observed:

- **Visible rain or drizzle at temperatures below +5°C outside air temperature (OAT).**
- **Droplets that splash or splatter on impact at temperatures below +5°C OAT.**

(1) Vigilance for SLD ice accretions should also be exercised when flying into or over areas reporting precipitation at the surface, such as rain, freezing rain, sleet, ice pellets, drizzle, freezing drizzle, or snow, where temperatures are near freezing. However, pilots should be aware that SLD could occur aloft without any SLD precipitation on the surface. Current weather information can miss SLD, so it is important to know and watch for cues on the airplane.

(2) While the pilot should be aware of these general cues, there may be specific cues that are characteristic of SLD icing on particular aircraft types. The pilot should consult the aircraft AFM or POH for descriptions of any such cues.

CHAPTER 5. FLIGHT PLANNING

This chapter describes sources of flight planning information as well as elements pilots can identify from the material made available to them to adequately manage their in-flight icing risk.

5-1. GENERAL AVIATION RESOURCES.

a. The primary means available to general aviation pilots for obtaining preflight planning information is the FSS. An FSS briefer is available via telephone by dialing 1-800-WX-BRIEF (1-800-992-7433). The briefer will provide weather information that may include the location of frontal systems, available PIREPs, cloud coverage, temperatures, and wind direction and speed.

b. Another source of information is the Direct User Access Terminal (DUAT), which is an information system that enables pilots to conduct their own weather briefings. The computer-based system acquires and stores a number of NWS and FAA products commonly used in pilot weather briefings and can be accessed through the World Wide Web. Pilots also can file and amend flight plans while logged into the system. Further information about DUAT can be obtained from any FSS, Flight Standards District Office (FSDO), or on the Web.

5-2. AIR CARRIER DISPATCH SERVICES.

a. U.S. air carriers that are authorized to conduct domestic or flag operations must have professional dispatch services that provide their pilots with relevant weather data for each flight.

b. Sometimes, these dispatchers rely on forecasts developed by the NWS, but some air carriers have an expanded capability, with their own meteorologists on staff who analyze raw data in addition to available forecasts to build a more detailed picture of existing and predicted weather conditions, including icing conditions.

NOTE: Title 14 CFR part 121 supplemental and part 135 commuter/on-demand operations do not require dispatchers.

5-3. PIREPs.

a. PIREPs are the only direct evidence of aircraft icing in a given area. They constitute an extremely valuable source of information for flight planning.

b. The AIM lists the following essential elements for all PIREPs: message type, location, time, flight level, type of aircraft, and at least one weather element encountered. When not required, elements without reported data are omitted. All altitudes are referenced to mean sea level unless otherwise noted. Distances are in nautical miles and time is in Coordinated Universal Time. The phenomenon is coded in contractions and symbols. A PIREP usually is transmitted as an individual report but can be appended to a surface aviation weather report or placed into groups of PIREPs.

c. To report the intensity of icing in a PIREP, the following descriptions should be used (refer to Chapter 2 for complete definitions.):

(1) Trace Icing. Ice becomes noticeable. The rate of accumulation is slightly greater than the rate of sublimation. A representative accretion rate for reference purposes is less than 1/4 inch (6 mm) per hour on the outer wing. The pilot should consider exiting the icing conditions before they become worse.

(2) Light Icing. The rate of ice accumulation requires occasional cycling of manual deicing systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is 1⁄4 inch to 1 inch (0.6 to 2.5 cm) per hour on the outer wing. The pilot should consider exiting the condition.

(3) Moderate Icing. The rate of ice accumulation requires frequent cycling of manual deicing systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is 1 to 3 inches (2.5 to 7.5 cm) per hour on the outer wing. The pilot should consider exiting the condition as soon as possible.

(4) Heavy Icing. The rate of ice accumulation requires maximum use of the ice protection systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is more than 3 inches (7.5 cm) per hour on the outer wing. Immediate exit from the conditions should be considered.

(5) Severe Icing. The rate of ice accumulation is such that ice protection systems fail to remove the accumulation of ice and ice accumulates in locations not normally prone to icing, such as areas aft of protected surfaces and areas identified by the manufacturer. Immediate exit from the condition is necessary.

5-4. PIREP CAUTIONS. Although PIREPs are excellent sources of information on in-flight icing, there are situations when these reports can be misleading. Two possibilities are discussed below.

a. An aircraft encounters icing conditions in an area where there were no recent icing PIREPs. There are several possible reasons for this:

(1) No aircraft recently flew in the area.

(2) Some aircraft recently flew in the area but did not encounter the icing conditions. This is a common occurrence, especially if the area has limited air traffic. Icing conditions are extremely variable in both space and time. A slight change in altitude or flightpath or the passage of just a few minutes can mean the difference between encountering and not encountering icing. There are many documented cases of aircraft flying through approximately the same area at similar altitudes at approximately the same time with one aircraft experiencing substantial icing and the other experiencing none.

b. An aircraft encountered icing, but the pilot did not report it. An aircraft encounters icing conditions that are more serious than those are reported in any recent PIREPs in the given area.

c. Again, there are several possible reasons for this.

(1) Icing conditions are extremely variable in space and time, as previously noted. PIREPs depend on the type and ice protection of the reporting aircraft. If the pilot's aircraft is smaller, has less power, or has less ice protection than the reporting aircraft, it may experience more serious icing than the reporting aircraft in the same exact meteorological conditions. For example, a Boeing 747 may report light icing when flying through conditions that would cause a Mooney to experience severe icing.

(2) PIREPs are subjective, depending on the pilot's observations, how the pilot operates the ice protection on the aircraft, and the pilot's experience level with in-flight icing. For example, there are documented cases of pilots reporting "light" icing conditions when ice was accreting on an ice evidence probe at a rate of approximately 1 inch per minute. In addition, observation and assessment of icing is more difficult at night.

(3) Although PIREPs from similar aircraft are most relevant to the pilot's aircraft, direct translation to the pilot's aircraft may still present difficulties. In addition to pilot subjectivity, other relevant questions are: Was the reporting aircraft flying slowly, or climbing, at a high AOA (which is conducive to accumulation over a larger area of the aircraft)? What kind of ice protection does the reporting aircraft have, and is it functioning properly?

(4) When icing conditions exist, reporting may alert other crews to maintain vigilance. Flightcrews should ensure that when submitting a PIREP of observed icing conditions, they accurately state the conditions and effects of the icing observed and report them in a timely fashion to make the PIREP as useful as possible.

5-5. ICING FORECASTS.

a. Aviation meteorologists at the NWS Aviation Weather Center (AWC), local NWS Field Offices, major airlines, and private companies prepare icing forecasts. In addition, guidance products are available on the Web. Icing AIRMETs, prepared at AWC, cover a 6-hour forecast window and are updated four times daily. Because they cover an extended time and may cover an area of several states, they are necessarily somewhat broad. Consulting a local FSS or NWS for a more specific preflight briefing will provide more detail and allow interaction with the briefer for more specific questions.

b. Technologies for forecasting icing are undergoing rapid development. PIREPs remain the major source of information for icing location and severity. The forecaster matches the PIREP to local weather features, assesses where those features will be moving during the forecast period, and estimates areas of expected icing, assigning their type and severity in this manner. Automated methods for assessing these icing attributes have been developed and are now available. (See the discussion on Current and Forecast Icing Product (CIP and FIP) later in this section.)

5-6. TERMINOLOGY USED IN ICING FORECASTS.

a. The AWC uses the same terms for icing intensity in its forecasts as those given in the AIM for use in PIREPs. These forecasts are based on:

(1) Weather analysis, using both traditional tools and those developed in recent years by the research community.

(2) PIREPs.

b. Since icing intensity is aircraft-dependent, a standard needs to be adopted by the NWS for all icing forecasts. Currently, there is one standard for AIRMET in which light or moderate icing is related to anticipated operational effects on a reciprocating engine, straight wing aircraft of intermediate size. Nevertheless, pilots of other aircraft are expected to familiarize themselves with AIRMETs also. However, there is no similar standard for severe icing in SIGMETs. Therefore, any SIGMET for severe icing must be interpreted as forecasting severe icing for all classes of aircraft.

c. Icing PIREPs are valuable to forecasters for the same reasons they are valuable to pilots. The PIREPs constitute the only direct observation of the phenomenon that is forecast. Thus the weather forecasters carefully evaluate the results of their weather analysis against the PIREPs for the forecast area and modify their forecasts if necessary. SIGMETs for severe icing are rarely issued unless there has been a PIREP of severe icing in the forecast area. PIREPs are also used in the CIP algorithm, described in the next chapter.

d. Icing forecasts also use the previously defined terms clear, rime, and mixed to describe types of ice. A convention that has evolved in forecasting practice is to associate ice type mainly with cloud drop size, essentially ignoring other factors such as temperature, liquid water content, drop size, and aircraft velocity. Thus a forecast of rime icing (RIME ICG) indicates smaller drop sizes, whereas a forecast of mixed (MXD ICG) or clear (CLR ICG) indicates larger drop sizes, with the line of demarcation not firmly established.

5-7. CURRENT AND FORECAST ICING PRODUCTS (CIP AND FIP).

a. There is a new Web-based preflight planning tool available to pilots that gives a graphical presentation of the current and forecast potential for icing. The URL for this product is http://adds.aviationweather.gov/icing/.

b. The CIP represents the latest analysis of possible icing regions. CIP combines weather sensor and numerical model data, as well as PIREPS, to provide a three-dimensional diagnosis of the icing environment.

(1) The new version of CIP output consists of a probability of icing and a severity of icing, as well as an indication of the possible presence of SLD.

(2) Water drops larger than 50 micrometers (diameter), which includes freezing drizzle and freezing rain aloft characterize SLD icing conditions. It has been demonstrated that these conditions, which are outside the icing certification envelopes (part 25, appendix C) can be particularly hazardous to some aircraft. Thus the information can be valuable for flight planning.

c. The FIP is an automatically generated forecast of the potential for icing 2, 3, 6, 9 and 12 hours in the future. This icing potential demonstrates the confidence that an atmospheric location, represented by a three-dimensional model grid box, will contain supercooled liquid water that is likely to form ice on an aircraft. The algorithm analyzes the model output from a vertical column, determines the cloud top and base heights, checks for embedded cloud layers, and identifies a precipitation type. Once the likely locations of clouds and precipitation are found, the physical icing situation is determined, and a physically-based, fuzzy logic method is used to determine the icing potential. The fuzzy logic interest maps are based on clues from the model output reflecting relevance to the presence of icing. After the information is extracted, the interest maps are combined in a manner that reflects their significance for icing, given the physical situation present. The entire model domain is examined and the result is a three-dimensional depiction of the potential for icing and SLD at the model valid time. Note that plans are for FIP to depict icing probability and severity, similar to CIP, in mid-2008.

5-8. PREFLIGHT PLANNING INFORMATION. All pilots, whether they are general aviation (GA) or air carrier pilots, are responsible for obtaining as much information as possible about all meteorological conditions, including icing conditions, before departure. Some important meteorological facts that pilots should be aware of with respect to icing are described below.

a. Location of Fronts. Fronts play an important part in the formation of icing conditions. Pilots should be aware of a front’s location, type, speed, and direction of movement. Pilots should try to keep a mental picture of where the front is moving and look for indications of frontal activity or frontal passage, such as a wind shift or temperature change.

b. Cloud Layers. While information on the types of clouds present may not be available without direct observation, the bases and tops of clouds might be known. This information is valuable because pilots need to know whether they will be able to climb above the icing layers of the clouds or descend beneath those layers into warmer air if icing is encountered.

c. Freezing Levels. It is critically important for pilots to obtain the freezing levels for the areas in which they will be flying to be able to make educated decisions on how to exit icing conditions if they are encountered. It is also important for pilots to know if there are any temperature inversions aloft that might alter the normal relationship between altitude and air temperature. Pilots should be aware of multiple freezing levels and their locations. The National Weather Service Aviation Digital Data Service (ADDS) Web site at http://adds.aviationweather.gov/icing/ provides a graphical depiction of the freezing level.

d. AIRMET and SIGMET. An AIRMET is information of significant weather phenomena, but describes conditions at intensities lower than those described that trigger a SIGMET. An AIRMET is intended for dissemination to all pilots in the preflight and en route phase of flight.

- SIGMETs and Convective SIGMETs advise of weather that is potentially hazardous for all aircraft, such as severe icing. A SIGMET for severe icing applies to all aircraft, from small GA aircraft to transport jets (see also the discussion in paragraph 5-6, Terminology Used in Icing Forecasts).

- The ADDS Web site at http://adds.aviationweather.gov/airmets provides a graphical depiction of the areas covered by AIRMETS and SIGMETS.

e. Air Temperature and Pressure. Icing tends to be found in low-pressure areas and at temperatures at or around freezing. For areas of low pressure, pilots can scan the surface analysis charts, and for freezing levels, the winds aloft chart can be used because the wind direction and speed grouping also provide air temperature at that altitude.

f. Alternatives. When contemplating flight into possible icing conditions in an aircraft approved for flight in icing conditions, a major consideration of preflight planning is to have alternative courses of action if conditions are worse than expected. These alternatives could be a change in altitude, heading, airspeed, or an alternate airport with adequate runway length.

g. It is important to note that aircraft that are approved for instrument flight rules (IFR) operations but not certified for known icing conditions are not testing during the certification process for inadvertent icing encounters. Therefore, pilots in such aircraft should emphasize ice avoidance during preflight planning and pay special attention to planning an alternate course of action in case actual icing is encountered.

CHAPTER 6. IN-FLIGHT OPERATIONS

6-1. AVAILABLE IN-FLIGHT INFORMATION.

a. Flight Watch. There are numerous sources of meteorological information available to pilots while in flight. A principal source of this information is Flight Watch. Flight Watch is an FSS-provided en route flight advisory service designed to provide, upon request, timely weather information pertinent to the type, route, and altitude of flight. Flight Watch is available from 6 AM to 10 PM local time at altitudes generally above 5,000 feet above ground level (AGL). For weather information at other times or at lower altitudes, contact an AFSS via radio on a nearby frequency outlet as depicted on aeronautical charts. The FSSs providing this service are listed in the Airport/Facility Directory and can be contacted on radio frequency 122.0 MHz.

b. Hazardous In-flight Weather Advisory Service. The Hazardous In-flight Weather Advisory Service (HIWAS) provides continuous, recorded hazardous in-flight weather forecasts over selected VHF omnidirectional radio (VOR) outlets within the HIWAS broadcast area. This broadcast area is a geographical zone of responsibility, including one or more HIWAS outlet areas (defined as the area within a 150-nautical mile radius of the HIWAS outlet) assigned to an FSS for hazardous weather advisory broadcasting.

c. Transcribed Weather Broadcast. The Transcribed Weather Broadcast (TWEB) is a continuous recording of meteorological and aeronautical information broadcast on low/medium frequencies and VOR facilities for pilots. The TWEB is based on a route-of-flight concept that, among other information, includes adverse conditions, route forecasts, outlooks, and PIREPs that may contain useful icing-related information.

d. Air Carrier Dispatch. Air carrier flightcrews normally can contact their dispatch facilities on specified company frequencies or through their airplane’s onboard Aircraft Communications Addressing and Reporting System (ACARS). Dispatch can then relay icing information, changes in front movement or speed, or recent icing PIREPs.

e. Weather Radar. Since airborne weather radar detects raindrops, cells painted on radar should be avoided when the temperatures are at or near freezing. Airborne weather radar cannot, however, detect drizzle-size drops or cloud-size drops, and therefore should not be relied upon to detect icing in clouds or freezing drizzle. It also lacks the ability to detect small dry ice crystals that can be in heavy concentrations near convective weather systems.

f. Datalink/Satellite Radio.

(1) Pilots now have the option to subscribe to and receive real-time weather and airspace information via Sirius and XM satellite radio to their panel-mounted or handheld avionics. For a fee, these services provide graphical METARs, TAFs, SIGMETs, and AIRMETs, updated pilot reports, updated winds and temperatures aloft, information on severe thunderstorms, icing levels, and graphical displays of temporary flight restrictions.

(2) Such up-to-date information can assist pilots in avoiding hazardous weather, and identifying potentially hazardous areas of unforecast weather.

6-2. PILOT STRATEGIES. Flight into icing conditions is to be avoided if the aircraft is not certificated for flight into such conditions or otherwise equipped in accordance with § 91.527 (b). However, even if the aircraft can, by regulation, operate into icing conditions; it should not be regarded by pilots as blanket authority to fly through any weather conducive to aircraft icing.

a. Icing in Stratiform Clouds. Because the icing conditions in stratiform clouds often are confined to a relatively thin layer, either climbing or descending may be effective in exiting the icing conditions within the clouds.

(1) A climb may take the aircraft into a colder section of cloud that consists exclusively of ice particles. These generally constitute little threat of structural icing because it is unlikely that the ice particles will adhere to unheated surfaces.

(2) The climb also may take the aircraft out of the cloud altogether to an altitude where the ice gradually will sublimate or shed from the airframe depending on the conditions. A descent may take the airplane into air with temperatures above freezing, within or below the cloud, where the ice can melt.

b. Icing in Cumuliform Clouds. Hazardous icing conditions can occur in cumulus clouds, which sometimes have very high liquid water content. Therefore, it is not advisable to fly through a series of such clouds or to execute holds within them. However, because these clouds normally do not extend very far horizontally, any icing encountered in such a cloud may be of limited duration; it may be possible to deviate around the cloud.

c. Snow.

(1) Normally snow itself is not a hazard with respect to icing, unless it begins to adhere to aircraft surfaces. If snow does begin to stick, it should then be treated as an icing encounter because ice may begin to form under this accumulation of snow. No aircraft is evaluated in the icing-certification process for this rare situation. If it occurs, the aircraft should exit the conditions as quickly as possible, coordinating with ATC as necessary.

(2) However, as discussed in paragraph 4-17, Visual Cues of SLD Conditions, freezing drizzle can co-exist with snow. If you are flying into or over areas reporting snow, it is important to understand that the presence of snow does not necessarily mean that icing conditions are not present. See following paragraph for further information.

d. Freezing Rain and Drizzle.

(1) Freezing rain forms when rain becomes supercooled by falling through a subfreezing layer of air. Thus, it may be possible, to exit the freezing rain by climbing into the warm layer.

(2) Because freezing drizzle often forms by the collision-coalescence process, the pilot should not assume that a warm layer of air exists above the aircraft. A pilot encountering freezing drizzle should exit the conditions as quickly as possible either vertically or horizontally. The three possible actions are to ascend to an altitude where the freezing drizzle event is less intense, to descend to an area of warmer air, or to make a level turn to emerge from the area of freezing drizzle.

e. Ice Pellets. Ice pellets by themselves are not a hazard to the airframe with respect to icing. However, a ground observation of ice pellets could indicate SLD aloft, so avoid such areas.

f. Ice Crystals. Ice crystals can exist in high concentrations at high altitudes near convective weather systems. Turbine engines can ingest and accrete some ice crystals that can ultimately cause power loss. Therefore, flying through clouds near convective weather should be avoided and engine nacelle anti-ice systems should be activated. Refer to your airplane’s AFM for specific information.

g. Communications with ATC. If an aircraft that is not approved for flight in icing conditions inadvertently encounters ice, controllers will not know if the aircraft is certificated or equipped for icing, the severity of the conditions, or what anti-icing or deicing equipment is installed on the aircraft. Therefore, it is imperative that ATC be thoroughly informed and a change in altitude or heading requested as soon as possible in order to exit the icing conditions.

(1) Communications from the pilot should focus on the icing conditions, whether an alteration of the current course and altitude is required, and, if necessary, an alternate landing site selected. In the congested airspace that exists in some parts of the country, along with the intensity of radio communications in such areas, it is possible that a pilot who encounters icing will not receive a clearance in time to exit the conditions before the safety of the flight is compromised.

(2) In such cases, pilots should declare an emergency to ATC and inform the controller of what actions are being taken by the pilot to cope with the emergency. If an aircraft certificated for flight in icing conditions encounters freezing rain or freezing drizzle, flightcrews should advise ATC and should not attempt sustained flight in these conditions. Final authority and responsibility for the safety of a flight rests with the pilot in command.

(3) Therefore, the pilot should not hesitate to reject a controller’s instructions if, in the judgment of a pilot, those instructions would result in an unsafe condition. To make correct decisions, pilots should have at their disposal as much information as possible, including the capability of the aircraft and its systems, and an awareness of the current and evolving weather situation.

CHAPTER 7. ICING CONSIDERATIONS FOR THE PHASES OF FLIGHT

The following is a description of icing considerations as they apply to the phases of flight. This chapter focuses primarily on how to safely fly an aircraft certificated for flight in icing conditions, and when it is advisable to exit those conditions. The following is only a sampling of icing-related items to consider when planning a flight. Pilots should consult the aircraft's AFM or POH for approved checklists.

7-1. PREFLIGHT. The first step in preparing for any flight is to obtain a thorough weather briefing. This becomes especially crucial when icing conditions are likely. When obtaining a weather briefing, make special note of the following items:

a. Freezing Level. Pilots should locate freezing levels on forecast maps. This will assist in developing a contingency plan in the event icing is encountered.

b. AIRMET and SIGMET. These advisories will alert a pilot to areas of moderate and severe icing. AIRMET "Zulu" is the classification of AIRMET issued for icing. SIGMETs are issued to indicate severe icing not associated with a thunderstorm. Anytime a Convective SIGMET is issued, expect severe icing.

c. PIREPs. PIREPs are an excellent source of information on icing location and type.

d. Precipitation. Knowing the location and type of precipitation forecast will assist in avoiding areas conducive to severe icing.

e. Graphical Data. Supplement your briefing by checking theADDS at: http://adds.aviationweather.gov. (This site depicts all of the above data in easy to read color graphics, and has the CIP and FIP. The CIP and FIP are updated every hour.)

f. Icing conditions require some additional considerations.

(1) When determining routes of flight, make note of airports along the way and highlight them on the chart for easy identification in case an alternate is needed.

(2) When determining routes, consider the climb performance of the airplane and the route's minimum altitude, particularly in mountainous terrain. Because the airplane's climb performance will be degraded in icing conditions, consult the AFM to see if there is degradation data.

(3) Determine icing exit strategies during preflight. Determine if climbing or descending will be viable options.

(4) When choosing alternate airports, remember that if structural icing occurs, higher approach speeds and, consequently, longer runways may become necessary.

(5) Consider carrying a high intensity flashlight for use in locating ice accumulation on the aircraft at night or in low visibility conditions.

(6) Consider using a transceiver as a backup radio in case of a communications loss caused by an antenna icing up and/or breaking off.

(7) If the aircraft is loaded near maximum gross weight, climb performance will be degraded, possibly increasing time spent in icing conditions.

(8) Extra fuel may be necessary because excess drag caused by ice formation may require extra power, increasing fuel consumption.

(9) When performing an aircraft preflight inspection, remove all frost, snow, and ice from the aircraft surfaces because even very small amounts may adversely affect the aerodynamic properties of a wing. Placing an aircraft in a heated hangar is a good method of removing frost, snow, and ice; however, a pilot should ensure the aircraft is dry before removing it from the hangar to prevent the moisture from refreezing on the surface.

g. Frost may appear on an aircraft even if the air temperature is well above freezing. This can occur if the airplane is flown in temperatures below freezing, causing the fuel to become cold-soaked. In flight or after landing, ice and frost can form on the wing in the same fashion that condensation forms on a cold soft drink can. Certain airplanes may be more vulnerable to ice formation from cold-soaked fuel than others may. An airplane sitting outside on a clear night may cause the airplane’s skin temperature to fall below freezing due to radiation cooling. If there is moisture present, frost can form on the airplane skin.

h. Frost, snow, or ice also can be removed with freezing-point depressant fluids. See AC 120-58, Pilot Guide Large Aircraft Ground Deicing, or AC 135-17, Pilot Guide Small Aircraft Ground Deicing, for discussion of the proper use of the fluids and protection provided under various environmental conditions as summarized in holdover timetables. Anti-icing fluids are designed to be shed by the time the aircraft reaches rotation speed; consequently, they provide no protection once the aircraft is airborne. Even though holdover times for freezing drizzle and light freezing rain exist, aircraft certificated for flight in icing conditions are not evaluated for flight in freezing drizzle or freezing rain.

i. Caution should be exercised when choosing an anti-icing fluid because Type II and IV fluids are not appropriate for use on aircraft with a rotation speed of less than 110 knots due to incomplete flowoff and resulting lift losses and control problems. Check the AFM to see if the use of Type II, III, or IV fluids is approved. In some cases, there may be limitations on takeoff procedure or minimum outside air temperature. If fluids are not mentioned in the AFM, consult with airplane manufacturer.

j. Ensure there is no ice that may interfere with control surface movement, braking, or steering. Check the pitot heat, pitot tube opening, and stall warning system. Check for proper functioning of any anti-icing or deicing systems. For fluid systems, make sure you see fluid along the entire leading panels. It may take several minutes to “prime” the fluid system, particularly if it has not been used in a while. Do not assume that any contamination, even snow, will blow off during takeoff. Wet snow may not blow off, and there may be a layer of ice under the snow.

7-2. TAXI. Always perform a pretakeoff check of the anti-ice/deice systems in accordance with the AFM or POH prior to takeoff.

a. While taxiing in snow or ice, leave extra space around your aircraft and taxi at a slower rate. Be careful when braking to prevent the wheels from skidding.

b. When stopping, begin to brake earlier than normal because the aircraft may require more distance to stop. Leave additional space in front of the aircraft during an engine run-up; the aircraft may begin to slide on ice. Carefully check the braking action of the aircraft to ensure that snow or ice is not building up on any of the components of the brake system.

c. If the aircraft is equipped with wheel fairings, be aware that snow may accumulate in the wheel fairings and freeze during flight. Make sure that all controls have full range of motion, and, if applicable, check that the carburetor heat is working.

d. If the aircraft is not equipped with windshield anti-icing or deicing system, turn the defroster on high and leave it on. This may help to prevent ice from forming on the windshield during flight.

7-3. TAKEOFF AND CLIMBOUT. Depending on the recommendations of the manufacturer, the POH, or the AFM, on small aircraft and on certain light aircraft, it may be advisable during climbout to apply the brakes and cycle the landing gear to break loose any snow, slush, or ice that may have accumulated during taxi and takeoff.

a. Verify that the airspeed indicator is working properly and that the pitot heat is on. Because of ATC restrictions and other traffic, climbout may not always be expeditious.

b. Airplanes are vulnerable to ice accumulation during the initial climbout in icing conditions because lower speeds often translate into a higher AOA. This exposes the underside of the airplane and its wings to the icing conditions and allows ice to accumulate further aft than it would in cruise flight.

c. Consequently, any ice that forms may be out of the pilot’s view and go undetected. Extreme vigilance should be exercised while climbing with the autopilot engaged. Climbing in Vertical Speed (VS) mode in icing conditions is highly discouraged.

d. As ice accretes on aircraft without autothrottles, the autopilot will attempt to hold a vertical speed without regard for airspeed, leading to a potential stall situation. It is critical that the pilot monitor airspeed to assure that at least the minimum flight speed for the configuration and environmental conditions is maintained.

7-4. CRUISE. An aircraft that is certificated for flight in icing conditions will be able to cope with most icing encounters provided that its ice protection systems are operating properly and that the exposure is not extended beyond their capabilities. However, if it is possible to exit the icing conditions by a change in altitude or a minor change in flight path, this is certainly advisable. During any icing encounter, the pilot should carefully monitor the behavior of the aircraft.

a. The aircraft will have some unprotected areas that will collect ice. Although ice in such areas should not compromise the safety of flight, it may cause enough increase in drag to require the pilot to apply more power to maintain flight speed.

b. Residual or intercycle ice on deiced areas can have a similar effect. Typically, adding power is the recommended action, since reduction in flight speed is associated with an increase in AOA, which on many aircraft will expose larger unprotected areas on the underside of the aircraft to the collection of ice. If for any reason (ice protection failure, improper use of protection system in extreme icing conditions, etc.) the point is reached where it is no longer possible to maintain airspeed through addition of power, the pilot should exit icing conditions immediately.

c. On an aircraft equipped with in-flight deicing systems, there will at all times be residual or some stage of intercycle ice on the wings.

d. Airspeed in cruise can have a significant effect on the nature of an icing encounter. An aircraft that cruises at a fast airspeed will increase the rate of ice accumulation. However, if the airspeed is sufficiently fast, surface heating due to compressibility effects may melt some of the ice and prevent accumulation in those areas. Generally, only very high-performance aircraft can attain such speeds. During the flight, periodically verify that all anti-icing and/or deicing systems are working. During the en route portion of the flight, have an exit plan that is regularly reevaluated as necessary.

e. Even if the encounter is short and the icing not heavy, the pilot should exercise particular awareness of the behavior of the airplane. Configuration changes following cruise in icing conditions, such as spoiler/flap deployment, should be made with care. This is because ice on the aircraft that had little effect in cruise may have a much different and potentially more hazardous effect in other configurations. Remember that for normal cruise configurations and speeds, both the wing and tailplane are ordinarily at moderate AOA, making wing or tailplane stall unlikely. After configuration changes and in maneuvering flight, wings or tailplane (especially after flap deployment) may be at more extreme AOA, and even residual or intercycle ice may cause a stall to occur at a less extreme angle than on a clean aircraft.

f. Again, care should be exercised when using an autopilot in icing conditions, while in cruise, just as in other phases of flight. When the autopilot is engaged, it can mask changes in handling characteristics due to aerodynamic effects of icing that would be detected by the pilot if the airplane were being hand flown. In an aircraft that relies on aerodynamic balance for trim, the autopilot may mask control anomalies that would otherwise be detected at an early stage. If the aircraft has non-boosted controls, a situation may develop in which autopilot servo-control power is exceeded. The autopilot disconnects abruptly, and the pilot is suddenly confronted by an unexpected control deflection.

g. Pilots may consider periodically disengaging the autopilot and hand flying the airplane when operating in icing conditions. If this is not desirable because of cockpit workload levels, pilots should monitor the autopilot closely for abnormal trim, trim rate, or airplane attitude. As ice accretes on aircraft without autothrottles, the autopilot will attempt to hold altitude without regard for airspeed, leading to a potential stall situation.

h. It is critical that the pilot monitor airspeed to assure that at least the minimum flight speed for the configuration and environmental conditions is maintained. There have been events in which the airspeed loss from cruise to stall occurred in a matter of minutes.

i. Care should be exercised when operating turbine engine powered aircraft in or around convective weather systems. Ice crystals can be accreting in the engine even though the airframe and ice detectors may not show any indications of an icing environment. This can occur at very low ambient temperatures and high altitudes. Nacelle and engine anti-ice systems should be activated if the presence of ice crystals is suspected.

7-5. DESCENT.

a. Pilots should try to stay on top of a cloud layer as long as possible before descending into the clouds. This may not be possible for an aircraft that uses bleed air for anti-icing systems because an increase in thrust may be required to provide sufficient bleed air. This increased thrust may reduce the descent rate of high-performance aircraft whose high-lift attributes already make descents lengthy without the use of aerodynamic speed brakes or other such devices. The result may be a gradual descent, extending the aircraft’s exposure to icing conditions.

b. If configuration changes are made during this phase of flight, they should be made with care in icing conditions, noting the behavior of the airplane. See the discussion in the preceding chapter.

c. When leveling off, especially with the autopilot engaged, ensure that sufficient power is applied to maintain proper airspeed.

7-6. HOLDING.

a. During holding, an airplane may be more vulnerable to ice accumulation because of the slower speeds and lower altitudes during this phase of flight.

b. Caution concerning the use of the autopilot, as described above, is also applicable to holding during or after flight in icing conditions.

c. If configuration changes (such as deployment of flaps) are made before or during the hold and after or during flight in icing conditions, the pilot should be prepared for any unusual behavior of the airplane during or after the change. If the aircraft reacts adversely to a change of configuration, the pilot should return the aircraft to its original configuration. See the discussion above.

d. Consult the AFM for use of flaps. Many AFMs prohibit use of flaps for extended periods in icing conditions.

7-7. APPROACH AND LANDING.

a. During or after flight in icing conditions, when configuring the airplane for landing, the pilot should be alert for sudden aircraft movements. Often ice is picked up in cruise, when the aircraft's wing and the tailplane are likely at a moderate AOA, making a relatively ice-tolerant configuration. If effects in cruise are minor, the pilot may feel comfortable that the aircraft can handle the ice it has acquired.

(1) Extension of landing gear may create excessive amounts of drag when coupled with ice. Flaps and slats should be deployed in stages, carefully noting the aircraft's behavior at each stage.

(2) If anomalies occur, it is best not to increase the amount of flaps or slats and perhaps even to retract them depending on how much the aircraft is deviating from normal performance.

(3) Additionally, before beginning the approach, deicing boots should be cycled because they may increase stall speed and it is preferable not to use these systems while landing. Once on the runway, pilots should be prepared for possible loss of directional control caused by ice buildup on landing gear.

b. Another concern during approach and landing may be forward visibility. Windshield anti-icing and deicing systems can be overwhelmed by some icing encounters or may malfunction. Pilots have been known to look out side windows or, on small GA aircraft, attempt to remove ice accumulations with some type of tool (e.g., plotter, credit card, etc.)

c. Pilot workload can be heavy during the approach and landing phase. Autopilots help to reduce this load. The advantages of a reduced workload must be balanced against the risks associated with using an autopilot during or after flight in icing conditions. An unexpected autopilot disconnect because of icing is especially hazardous in this phase of flight due to the airplane being flown at a low altitude.

d. Accident statistics reveal that the majority of icing-related accidents occur in the final phases of flight. Contributing factors are configuration changes, low altitude, higher flightcrew workload, and reduced power settings. Loss of control of the airplane is often a factor. The ice contamination may lead to wing stall, ice-contaminated tailplane stall (ICTS), or roll upset.

e. Wing stall and roll upset may occur in all phases of flight. However, available statistics indicate that ICTS rarely occurs until approach and landing. Many AFMs will have a limitation on the maximum flap use approved in icing conditions due to ICTS susceptibility. If your airplane does not have such a limitation, and it was certificated prior to 2000, it may be best to perform a no-flap landing at a higher than normal approach speed if the airplane has accumulated ice on the wings and tailplane. However, because of the higher approach speed, longer runways may be needed for this procedure.

f. During the landing flare, carry higher than normal power if there is ice on the airplane. Many non-fatal icing accidents have been attributed to stall during the flare.

7-8. WING STALL.

a. The wing, when contaminated with ice, will ordinarily stall at a lower AOA, and thus at a higher airspeed. Even small amounts of ice, particularly if rough, may have some effect. An increase in approach speeds may be advisable if any ice remains on the wings. How much of an increase depends on both the aircraft type and the amount of ice. The pilot should consult the AFM or POH.

b. An increased landing speed will mean a longer landing roll; so if possible, the pilot may want to consider a longer runway for increased rollout distances.

c. This discussion of ice-contaminated wing stall is considerably shorter than the discussion of ICTS that follows. This is not because the latter is more frequent. Statistics indicate that incidents or accidents due to ice-contaminated wing stall are the more common result of flight in icing conditions. However, pilots have extensive training in recognizing and coping with wing stalls, but little or no training for tailplane stalls, which are very unusual on most designs when the tailplane is clean. It is also important to recognize that although pilots have extensive training in recognizing and coping with stalls of clean wings, the stall of an ice-contaminated wing will often be markedly different and may call for aggressive pitch down inputs quite unlike those used in the case of a clean wing stall. The stall characteristics of an aircraft with ice-contaminated wings may be markedly degraded, and serious roll control problems are not unusual.

d. As explained in Chapter 4, Icing Effects, Protection, and Detection, the accretion may be uneven between the two wings; therefore, the outer part of a wing, which is ordinarily thinner and thus a better collector of ice, may stall first rather than last. The effectiveness of ailerons may be reduced due to ice formations in front of them on the wing.

7-9. ICE-CONTAMINATED TAILPLANE STALL (ICTS).

a. The basic aerodynamics of ICTS was described briefly in Chapter 4, Icing Effects, Protection, and Detection. ICTS occurs when a tailplane with accumulated ice is placed at a sufficiently negative AOA and stalls.

b. This angle would not be expected to be reached without at least partial deployment of the flaps. There are few, if any, known incidents of ICTS in cruise (when flaps would not ordinarily be deployed). However, when the flaps are deployed, tailplane ice, which previously had little effect other than a minor contribution to drag, now can put the tailplane at or dangerously close to stall.

c. While preparing for the deployment of flaps after or during flight in icing, the pilot should carefully assess the behavior of the aircraft for any buffet or other signs of wing stall. The initial deployment of the flaps should be only partial. Vibration or buffeting that follow deployment is much more likely to be due to incipient tailplane stall than wing stall if there was no vibration buffet before deployment. The reason is that after deploying the flaps, the wing will be at a less positive angle, and so farther from stall, while the tailplane will be at a more negative angle, and so closer to stall. There are a number of specific cues associated with ICTS to which a pilot should be sensitive, particularly during this phase of flight. Most of these cues are less readily detected with the autopilot engaged.

- Elevator control pulsing, oscillations, or vibrations,
- Abnormal nose-down trim change,
- Any 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 if unrestrained), and
- Sudden uncommanded nose-down pitch.

NOTE: The pilot should observe the following guidelines for action if these cues are encountered:

- Flaps tend to alter the airflow reaching the tailplane and should be retracted immediately to the previous setting, and the appropriate nose-up elevator pressure should be applied.
- Airspeed should be increased appropriately for the reduced flap extension setting.
- Sufficient power should be applied for the airplane’s configuration and conditions. (High engine power settings may adversely affect the response to ICTS conditions at high airspeed in some aircraft designs. Manufacturer’s recommendations in the AFM or POH should be observed regarding power settings.)
- Nose-down pitch changes should be made slowly, even in gusting conditions, if circumstances allow.
- If a pneumatic deicing system is used, the system should be cycled several times to clear the tailplane of ice.

d. Note that some of the measures for recovery from ICTS are the opposite of those for recovery from wing stall. Thus distinguishing between the two is very important. If for any reason there is a large or rough ice accretion on both the wing and tailplane (perhaps because of ice protection system failure), manage approach and landing with great care.

e. Deployment of flaps permits the aircraft to be flown with wings at a less positive attack, decreasing the probability of wing stall. However, the AOA at the tailplane is more negative, putting it closer to stall. Similarly, at any particular flap setting, lower speeds put the aircraft closer to wing stall and higher speeds put it closer to tailplane stall. Thus, there is a restricted operating window with respect to use of the flaps and to airspeed.

f. The pilot should be familiar with any guidance provided in the AFM or POH. If the AFM does have a maximum flap limitation in icing, it is usually because of ICTS susceptibility. A wing stall would be more common than an ICTS if the flap limitation was followed.

g. Increased power increases susceptibility to ICTS in some designs (depending on configuration), but not in others. Again, the pilot should consult the AFM or POH.

h. When ICTS or wing stall is a possibility, uncoordinated flight such as side or forward slips should be avoided and, to the extent possible, crosswind landings should be restricted because of their adverse effect on pitch control and the possibility of reduced directional control.

i. Landing with a tailwind component may result in more abrupt nose-down control inputs and should be avoided if possible. If an airplane has ice on the wings and tail, the pilot may be wise to exercise limited or no deployment of flaps, which will likely result in a higher than normal approach speed. Because of the higher speed approach, longer runways may be needed for this procedure.

7-10. ROLL UPSETS.

a. Roll upsets caused by ice accumulations forward of the ailerons also are possible during an icing encounter, particularly in SLD conditions. During the slow speeds associated with approach and landing, such control anomalies can become increasingly problematic. Pilots can remedy roll upsets using the following guidelines:

- Reduce the AOA by increasing airspeed or extending wing flaps to the first setting if at or below V_{FE} (maximum flap extension speed.) If in a turn, the wings should be rolled level.

- Set the appropriate power, and monitor the airspeed and AOA.

- If the flaps are extended, do not retract them unless it can be determined that the upper surface of the airfoil is clear of ice. Retracting the flaps will increase the AOA at a given airspeed.

- Verify that the wing ice protection is functioning normally and symmetrically through visual observation of each wing. If there is a malfunction, follow the manufacturer’s instructions.

NOTE: These procedures are similar to those for wing stall recovery, and in some respects opposite from those for recovery from the ICTS.

b. Application of the incorrect procedure during an event can seriously compound the upset. Correct identification and application of the proper procedure is imperative. It is extremely important that the pilot maintain awareness of all possibilities during or following flight in icing.

CHAPTER 8. SUMMARY

a. Ice-contaminated aircraft have been involved in many accidents. Takeoff accidents have usually been due to failure to deice or anti-ice critical surfaces properly on the ground. Proper deicing and anti-icing procedures are addressed in two other pilot guides, AC 120-58 and AC 135-17. This Pilot Guide focuses on ice that forms in flight, and should be useful to all pilots of fixed-wing aircraft. Any ice encountered in flight, even in trace amounts, can be dangerous. This guidance should help educate pilots about the potential hazards of in-flight icing, ways to avoid such hazards, and how to cope with potential hazards effectively.

b. The pilot of an aircraft that is not certificated for flight in icing conditions should avoid all icing conditions. This guide provides guidance on how to do this, and on how to exit icing conditions promptly and safely should they be inadvertently encountered.

c. The pilot of an aircraft that is certificated for flight in icing conditions can safely operate in the conditions for which the aircraft was evaluated during the certification process but should never become complacent about icing. Even short encounters with small amounts of rough icing can be very hazardous.

d. The pilot should be familiar with all information in the AFM or POH concerning flight in icing conditions and follow it carefully. Of particular importance are proper operation of ice protection systems and any airspeed minimums to be observed during or after flight in icing conditions. Airspeed loss can be very rapid, and without an autothrottle, the autopilot will not maintain airspeed. Monitor airspeed and do not rely on the airplane’s stall warning system in icing conditions. There are some icing conditions for which no aircraft is evaluated in the certification process, such as SLD conditions within or below clouds, and flight in these conditions can be very hazardous. The pilot should be familiar with any information in the AFM or POH relating to these conditions, including aircraft-specific cues for recognizing these hazardous condition.

APPENDIX 1. AIRCRAFT ACCIDENTS RELATED TO ICING

1. American Eagle ATR-72 (Roselawn, Indiana).

a. Of the recent air carrier accidents, the one with arguably the most significant implications regarding in-flight icing is the October 31, 1994, crash of an ATR-72 turbopropeller transport aircraft. The aircraft was on a flight from Indianapolis, Indiana, to Chicago's O'Hare International Airport, flying with the autopilot engaged and in a holding pattern, descending to 8,000 feet through supercooled clouds and SLD. Later analysis by the NTSB estimated that the supercooled drops in the area ranged between 0.1 mm and 2 mm in size.

b. Before the aircraft entered the hold, its engine RPM was increased to 86 percent as called for in the ATR-72's AFM for flight in icing conditions (specified as true air temperature (TAT) of less than 7°C in the presence of visible moisture). As the aircraft began holding, the flaps were extended to 15 degrees to lower the aircraft's AOA, and the engine RPM was reduced to 77 percent, presumably because the crew determined they were no longer flying in icing conditions. After holding for over half an hour, the aircraft was cleared to descend to 8,000 feet, and the crew retracted the flaps to avoid a flap overspeed warning.

c. According to the NTSB, the encounter with the icing conditions in the hold resulted in a ridge of ice accreting aft of the aircraft's wing deicing boots and in front of the aircraft's unpowered ailerons. As the aircraft descended to its cleared altitude, its AOA increased and the airflow began to separate in the area of the right aileron. This resulted in a sudden and unexpected aileron hinge reversal that exceeded the autopilot's ability to control the aircraft, and it disconnected. This left the flightcrew in a full right-wing-down position within a quarter of a second, which was followed by a series of unsuccessful attempts to correct the aircraft's attitude, resulting in a descent that at times reached 24,000 feet per minute and precipitated the structural failure of the aircraft's elevators. The aircraft then impacted a soybean field at high speed resulting in the deaths of all 68 passengers and crew.

d. The NTSB's investigation resulted in several findings, but ultimately, the most important regarding the effects of icing conditions on aircraft was the degree to which the conditions affected a properly certificated aircraft and the limited information available to the flightcrew with respect to the severity of the conditions they were experiencing.

2. Air Florida B-737 (Washington, District of Columbia).

a. Although this accident is well known because it illustrates the dangers of taking off without proper ground deicing, for the purposes of this AC, the accident offers another lesson with respect to icing and its hazards. On January 13, 1982, almost an hour after the B-737 had been deiced; it took off from Washington's National Airport in light-to-moderate snowfall with temperatures below freezing. In addition to snow and ice forming on the aircraft fuselage during the extended taxi, ice had collected in the compressor inlet pressure probes of the two engines, apparently because the flightcrew neglected to turn on the engine anti-icing system. These inlets are used in conjunction with exhaust pressure to determine engine thrust settings for display in the cockpit as an Exhaust Pressure Ratio (EPR). As one of its functions, the engine's anti-icing system is designed to maintain a flow of heated air over the compressor inlet to prevent the formation of ice on these probes.

b. As the flightcrew increased the engine throttles to takeoff thrust, the engines actually were developing less thrust than was indicated on the EPR gauges. This thrust deficit, combined with the accumulation of snow and ice on the wings, resulted in a stall immediately after rotation, with the aircraft climbing only to 200 or 300 feet before stalling and colliding with the 14th Street bridge.

c. While this accident, like almost all others, was caused by a combination of factors, it serves as an example to pilots that icing hazards affect not only aircraft aerodynamics but also aircraft instrumentation. In fact, studies conducted after the accident indicated that an immediate combined application of full power and lowered aircraft attitude theoretically could have allowed a safe recovery in a situation similar to this accident.

3. Northwest Orient B-727 (Thiells, New York).

a. Because this accident was a ferry flight and only the flightcrew of three was killed, it has not gained the notoriety of other airline crashes. However, it is significant to the subject matter of this AC, because it is an example of how a well-trained, professional flightcrew neglected to use the anti-icing equipment available on a modern aircraft and then became confused and disoriented by the inconsistent instrument indications that resulted.

b. On December 1, 1974, the aircraft in question was slated to conduct a nighttime ferry flight from New York's John F. Kennedy International Airport to Buffalo, New York, to position for a return charter flight. After a normal takeoff, the aircraft was climbing to its assigned altitude of 31,000 feet when ATC received a series of radio transmissions from the flightcrew in which they declared an emergency and stated that they were out of control and in a stall. The aircraft descended rapidly, broke up in flight, and crashed in a forest near Bear Mountain, New York.

c. NTSB investigators examining the aircraft wreckage the next morning discovered that the two pitot head heater switches were in the "off" position. An analysis of the aircraft flight data recorder and cockpit voice recorder (CVR) revealed that the before-takeoff checklist was followed incorrectly by the first officer, resulting in the pitot heat being turned off instead of on as required by the checklist.

d. Investigators determined that as the aircraft was climbing through 16,000 feet at 305 knots and at a climb rate of 2,500 feet per minute, airspeed and vertical speed indicators began to climb, without any change to the engine power settings, to a point that actually exceeded the aircraft's capability. This created confusion among the flightcrew, but the CVR revealed that they attributed the aircraft's performance to the aircraft's light load. As the aircraft reached 23,000 feet, the mach overspeed warning came on and the crew continued to pull on their yokes to trade speed for altitude. This resulted in an excessive AOA followed by a stall. The flightcrew became disoriented and confused by the series of alarms and contradictory indications, resulting in a spiral dive from which they could not recover. The encounter with icing conditions was further worsened because the B-727 has tail-mounted pitot tubes for the elevator feel system that also were blocked with ice. The feel system modulates the amount of force the pilots have to exert on the elevator controls with changes in speed. Because the pitot tubes were covered with ice, smaller movements of the controls resulted in higher control movements and eventually higher vertical acceleration forces on the aircraft.

e. While the loss of a pitot static system is something that all instrument-rated pilots are trained to cope with, the insidious nature of such system malfunctions can result in confusion because the instruments often provide erroneous readings without necessarily indicating a system failure. Pilots must remain vigilant for such unusual indications from their instruments and instead rely on attitude flying.

4. Mitsubishi MU-2B-36 (Malad City, Idaho).

a. This accident demonstrates the importance of ensuring that ice protection systems are operational when flying into an environment where the possibility of encountering icing conditions exists. It also highlights how critical airspeed awareness is, especially while flying in icing conditions.

b. On January 15, 1996, a Mitsubishi MU-2 departed Salt Lake City, Utah, and climbed to 16,000 feet on a part 91 IFR flight to Pocatello, Idaho. The airplane encountered structural icing conditions while in cruise, and according to radar data, began slowing from a cruise speed of about 190 knots while slightly deviating from heading and altitude. The airspeed decreased to about 100 knots and the flightcrew declared an unspecified emergency; then radio contact was lost. The airplane began a right turn, then entered a steep descent and crashed. All aboard the airplane were killed because of the impact. The pilot of a Beech 1900 about 12 minutes in trail of the MU-2 stated that he encountered moderate rime ice at 16,000 feet. The Beech pilot activated the pneumatic boots three times and descended to 12,000 feet to exit the icing conditions. The MU-2 AFM warned that during flight in icing conditions, stall warning devices may not be accurate and should not be relied on, and, to minimize ice accumulation, pilots should maintain a minimum cruise speed of 180 knots or exit the icing conditions. An investigation determined that the captain of the MU-2 was aware of deficiencies in the timer for the pneumatic boots, along with other maintenance deficiencies. Although icing conditions were forecast in the destination area, no icing was forecast for the en route portion of the flight.

c. The NTSB determined that the probable cause of the accident was continued flight by the flightcrew into icing conditions with known faulty pneumatic equipment, structural (airframe) ice, and failure of the flightcrew to maintain adequate airspeed, which resulted in the loss of aircraft control and collision with terrain. The en route icing condition, which was not forecast, was also cited as a factor relating to the accident.

5. Piper PA-34-200T (Des Moines, Iowa).

a. The circumstances surrounding this accident demonstrate the dangers associated with tailplane icing and why proper use of deicing equipment is critical to flying in icing conditions.

b. On January 9, 1996, a Piper PA-34 departed Sioux Center, IA, bound for Des Moines, IA (DSM). In his written statement, the pilot stated that he flew a normal ILS approach with 10 degrees of flaps extended. Upon breaking out of the clouds, he checked for ice with a flashlight, and observed the windshield and the left inboard wing, to be free of ice. He elected to fly the approach fast, and with 25 degrees of flaps.

c. Upon crossing the runway threshold at DSM, the pilot stated that he lowered the flaps to 25 degrees, and that the airplane responded by pitching down. The pilot then stated that he immediately released the flaps and added power, but said the airplane was "basically uncontrollable at this point." He then reduced power and lowered the flaps before striking the runway on its centerline and sliding 1,000 feet before coming to a stop. The accident resulted in serious injury to the pilot, who was the sole occupant.

d. Examination of the wreckage revealed heavy impact damage to the airplane's forward fuselage, engines, and wings. Approximately one-half inch of rime ice was observed adhering to the leading edges of the left and right horizontal stabilizers and along the leading edge of the vertical stabilizer.

e. The DSM airport's ATIS, at 2256 EST, reported that a pilot in a Cessna 210 experienced light to mixed icing, 8 miles northeast of the airport, between 2,500 and 3,700 feet MSL.

f. The NTSB determined the probable cause of the accident was the pilot's failure to use the airplane's deicing system, which resulted in an accumulation of empennage (tail assembly of an airplane) ice and a tailplane stall. Factors relating to this accident were the icing conditions and the pilot's intentional flight into those known conditions.

6. Embraer EMB-120 (West Palm Beach, Florida).

a. This accident is another example of a stall in icing conditions, suspected to be SLD. The NTSB was unable to determine if the stall warning system activated prior to stall. This accident also illustrates the rapid loss of airspeed that can occur in icing conditions and the need for pilots to monitor airspeed closely in icing conditions, even with autopilot engaged.

b. On March 19, 2001, Embraer EMB-120, operated by Comair Airlines, Inc., was en route from Nassau International Airport, Bahamas, to Orlando International Airport, Florida. While in cruise flight at 17,000 feet, the aircraft encountered icing conditions, and departed controlled flight, descending to an altitude of about 10,000 feet. The pilots recovered control of the airplane and diverted to West Palm Beach, Florida, where they landed without further incident. Though none of the 28 persons on board was injured, the airplane sustained substantial damage to the elevators and the horizontal stabilizer.

c. In post accident interviews, the captain stated that while in visual conditions, the airplane flew normally. Flight data recorder (FDR) data indicate that about 7 minutes before the upset occurred, the airplane was at about 17,000 feet, with the autopilot engaged and airspeed stabilized near 200 knots. The data indicates the airspeed slowed to 185 knots over a several minute period as the autopilot began trimming airplane nose-up (ANU) to maintain altitude. The airspeed then decreased to about 137 knots over the next 3 minutes. The airplane continued to maintain a constant altitude as the autopilot trimmed the airplane from about 0 to about 7 degrees ANU. The first officer stated that immediately before the upset occurred, he switched the leading-edge deicing system inflation cycles switch from "light" to "heavy" and the propeller deicing system cycles switch from “norm” to “cold” because he saw “more ice accumulation than he had ever seen” on the wing and spinner. FDR data indicate that when torque indications for both engines were about 55 percent and the airspeed was about 141 knots, the autopilot was disengaged. The airplane then pitched down and rolled about 80 degrees to the left, then rolled back to near level. During the next 20 seconds, engine torque increased to about 98 percent on both engines, the airplane rolled about 110 degrees to the left, returned to level flight, rolled about 130 degrees to the right, returned to level flight, then rolled 360 degrees to the right before returning to near wings level, with torque on both engines stabilized at about 22 percent. The airplane’s behavior during the upset is consistent with an ice-induced stall event.

d. The first officer stated in post accident interviews that the stick shaker and aural stall warning, which is part of the airplane’s stall warning/protection system, activated but did not indicate whether it was before, during, or after the upset. The Safety Board’s investigation could not precisely determine whether or when the stick shaker and aural stall warning activated.

e. Meteorological data at the time of the accident indicated that Comair flight may have encountered an area of icing conducive to the formation of super-cooled large droplets (SLD). The EMB-120 is not certified for flight in SLD conditions. FDR data indicate that airspeed had decreased to only about 137 knots before control of the airplane became difficult and altitude was no longer maintained. However, according to the Embraer EMB-120 AFM performance section, the airplane stalling speed is about 115 knots calibrated airspeed for an airplane at the accident airplane’s approximate gross weight at the time of the event (23,800 pounds).

f. The National Transportation Safety Board determined the probable cause(s) of this accident as follows:

- The failure of the flightcrew to maintain airspeed during an encounter with severe icing conditions.

- This resulted in an inadvertent stall, loss of control, and structural damage to the airplane.

7. Raytheon (Beech) BE-90 (Rawlins, Wyoming).

a. This accident is another example of a stall in icing conditions. The need for extra vigilance by pilots near a destination airport reporting precipitation (snow) near freezing is highlighted in this accident. The ice accretions on the airplane suggest the conditions may have been worse than forecast and exceeded part 25, appendix C criteria.

b. On January 11, 2005, a BE-90, operating as an air ambulance was flying from Steamboat Springs, Colorado (SBS), to Rawlins Municipal Airport/Harvey Field (RWL). Approaching RWL, the pilot initiated a right turn outbound to maneuver for the final approach course of the VOR/GPS approach to runway 22. On the inbound course to the airport, the airplane impacted mountainous terrain, approximately 2.5 nautical miles east-northeast of the airport. The airplane, configured for landing, struck the terrain wings level, in a 45-degree nose-down dive, consistent with impact following an aerodynamic stall. There were three fatalities and one serious injury.

c. Approximately 5 minutes before the accident, the ASOS at RWL reported the weather as few clouds at 500 feet above ground level (AGL), scattered clouds at 900 feet AGL, overcast ceiling at 1,500 feet AGL, visibility 2 miles with light snow and mist, temperature 32°F, dew point 32°F, winds 250 degrees at 3 knots, and altimeter 29.35 inches of mercury (Hg). Before departing SBS, the pilot received a weather briefing from Denver Flight Service. The briefer told the pilot that there was a band of light to moderate snow shower activity half way between Rock Springs and Rawlins, spreading to the northeast. The briefer told the pilot there were adverse conditions and flight precautions along his route for occasional mountain or terrain obscurations. The pilot responded that he planned to fly instrument flight rules for the entire flight.

d. The Surface Analysis showed a north-south stationary front positioned along the front range of the Rocky Mountains beginning at the Wyoming/Montana border and extending south into north-central Colorado. Station plots indicated patchy snow over western Colorado and Wyoming. The most recent AIRMET reported, “Occasional moderate rime, or mixed icing in clouds and precipitation between the freezing level and flight level 220.” The freezing level for the area encompassing the route of flight began at the surface. Witnesses in the vicinity of RWL reported surface weather conditions varying from freezing rain to heavy snow. The Current Icing Product (CIP) showed no potential for SLD, yet an examination of the airplane showed clear ice up to 1½ inches thick adhering to the vertical stabilizer, the left and right wings, the right main landing gear tire, and the right propeller.

e. The airplane’s aerodynamic performance was degraded due to the ice contamination, leading to a stall. An examination of the airplane’s systems revealed no anomalies. FAA Advisory Circular (AC) 135-15, Emergency Medical Services/Airplane (EMS/A), addresses several subject areas that were not practiced by the operator, including the recommendation of avoiding flight in icing weather whenever possible.

f. The National Transportation Safety Board determined that the probable cause of this accident was the pilot’s inadvertent flight into adverse weather (severe icing) conditions, resulting in an aerodynamic stall and impact with rising, mountainous terrain during approach. A factor contributing to the accident was the pilot’s inadequate planning for the forecasted icing conditions.

8. Cirrus SR-22 (Childersburg, Alabama).

a. This accident shows the importance of obtaining an up-to-date weather briefing that includes icing forecasts and freezing levels. It also highlights the performance degradation that can occur when an airplane not certificated for flight in icing exceeds its limits.

b. On January 13, 2006, a Cirrus SR-22 was en route from Birmingham, AL to Orlando, FL, when it encountered icing conditions and entered an inadvertent stall and spin. The pilot deployed the ballistic recovery system parachute, and the aircraft descended into the trees leaving the three occupants of the aircraft uninjured.

c. The night before the accident, the pilot obtained a full Direct User Access Terminal (DUATS) briefing, though the briefing was not valid for the time of the accident. The National

Weather Service (NWS) issued an AIRMET Zulu update 3 for icing and freezing level data valid from 1445 CST until 2100 CST. The advisory warned of occasional moderate to mixed icing-in-clouds and in precipitation between 3,000 to 8,000 feet. Within the boundaries of the advisory were the departure airport and the accident site. The pilot requested an abbreviated DUATS weather briefing at 1244 EST for his route of flight. The in-flight advisories were to expire at 1500 CST. The briefing provided several adverse weather phenomena impacting the route of flight from icing, turbulence, and thunderstorms. The pilot stated he was not aware of AIRMET ZULU UPT 3 that was issued by the NWS before he departed Birmingham, though the airplane was equipped with an XM Satellite radio and the AIRMET was transmitted by the NWS over the XM radio installed in the airplane. This was significant, considering the airplane is not certificated for flight into icing conditions.

d. The pilot stated the flight departed from runway 24 and he contacted the air traffic controller on the radio. ATC radar identified the aircraft and the pilot was instructed to climb to 7,000 feet and proceed direct to HANDE intersection. With the autopilot engaged, the airplane entered the clouds at 5,000 feet, climbing at 120 knots. Upon reaching 7,000 feet, the airplane encountered icing conditions. The pilot informed the controller that he would like to climb to 9,000 feet and that was approved.

e. As the airplane reached the cloud tops in visual flight conditions at 8,000 feet, the airplane began to buffet. The pilot looked at his airspeed indicator and it indicated 80 knots. A stall ensued, followed by a spin that descended the airplane back into instrument flight conditions. The pilot deployed the ballistic parachute system and informed the air traffic controller of his actions. The airplane descended under the parachute canopy into the trees.

f. The NTSB determined the probable cause(s) of this accident as follows:

(1) The pilot’s inadequate preflight planning, failure to obtain a current weather briefing, and his decision to operate the airplane into a known area of icing outside the airplanes certification standards.

(2) This resulted in the aircraft accumulating ice, a loss of airspeed, an inadvertent stall/spin, and subsequent collision with trees.

APPENDIX 2. REGULATORY ISSUES RELATED TO ICING

Title 14 CFR parts 91, 121, 125, and 135 specify the responsibilities of flightcrews concerning flight in icing conditions. Pilots are advised to check the current regulations for revisions. They are noted here for reference only and to illustrate the degree of similarity between parts 91, 121, 125, and 135 with respect to regulation of flight into icing conditions. An important distinction in each of these regulations is the restriction on flight into "known or forecast" conditions. Because of the limitations of icing forecasts, it is admittedly difficult for pilots to be certain whether the conditions in which they are flying actually will result in an icing encounter, and it is even more difficult to determine the severity of the possible encounter. Pilots can be caught inadvertently in icing conditions that exceed these legal limits.

General operating and flight rules for GA aircraft are found in part 91, but not all rules within part 91 are applicable to all GA aircraft. Section 91.501 states that the rules in subpart F apply only to large and turbojet-powered multiengine airplanes that are *not* covered by parts 121, 125, 129, 135, and 137. Section 91.527, Operating in icing conditions, falls within subpart F and thus is not applicable to all GA aircraft.

1. Part 91 Icing Regulations.

a. IFR. No pilot may fly an airplane under IFR into known or forecast moderate icing conditions unless one or more of the following apply:

(1) The aircraft has ice protection provisions that meet the requirements in 14 CFR part 135, appendix A, paragraph 34 of Special Federal Aviation Regulation (SFAR) No. 23.

(2) The aircraft has ice protection provisions that meet the requirements for transport category airplane type certification.

(3) The aircraft has functioning deicing or anti-icing equipment protecting each propeller, windshield, wing, stabilizing surface, control surface, airspeed instrument, altimeter, rate of climb instrument, and flight attitude instrument system.

b. VFR. No pilot may fly an airplane under VFR into known light or moderate icing conditions unless one or more of the following apply:

(1) The aircraft has ice protection provisions that meet the requirements in SFAR 23 paragraph 34 (same as part 135, appendix A, paragraph 34, and § 23.1419 at Amendment 23-14).

(2) The aircraft has ice protection provisions that meet the requirements for transport category airplane type certification.

(3) The aircraft has functioning deicing or anti-icing equipment protecting each propeller, windshield, wing, stabilizing surface vertical tail, control surface flap, aileron, elevator, airspeed instrument, altimeter, rate of climb instrument, and flight attitude instrument system.

c. Severe Icing. No pilot may fly an airplane into known or forecast severe icing conditions unless:

(1) The airplane has ice protection provisions that meet the requirements in SFAR 23 paragraph 34, or;

(2) The airplane has ice protection provisions that meet the requirements for transport category airplane type certification.

NOTE: Even airplanes approved for flight into known icing conditions should not fly into severe icing. Many Airplane Flight Manual Limitations Sections require an immediate exit when these types of conditions are encountered.

NOTE: Airplane certification for flight into known icing conditions does not include freezing drizzle and freezing rain. In fact, some airplanes are prohibited from flying into freezing drizzle or freezing rain, regardless of its intensity. These conditions are very dangerous and can cause ice to form behind the protected areas. (See § 91.527, Operating in icing conditions, for the exact language of the above regulations.)

d. Aircraft Not Certificated for Flight in Icing Conditions.

(1) Aircraft certificated since the mid-1970s that are not certificated for flight in icing conditions will have a limitation in the AFM or POH and possibly a placard on the aircraft stating that flight into "known icing conditions" is prohibited. "Known icing conditions," as defined in the AIM, are conditions in which ice is observed or detected in flight, by your aircraft or another aircraft, or an airport. Such limitations are binding under § 91.9, Civil aircraft flight manual, marking, and placard requirements, and this regulation takes precedence over §§ 91.527 and 135.227. However, if a pilot of such an airplane were to takeoff and fly in area in which icing is forecast (e.g., AIRMET Zulu), it is expected the pilot will through preflight planning and in-flight execution:

(a) First attempt to avoid areas of "potential icing conditions", which are areas of visible moisture such as clouds at temperatures below freezing;

(b) If that is not practical, attempt to avoid areas of forecast icing by all tools available (e.g., AIRMETs, SIGMETs, CIP and FIP); and

(c) If icing is encountered, declare an emergency and exit the conditions immediately.

NOTE: Failure to follow the section above may result in enforcement action under § 91.103, Preflight action, or § 91.13, Careless or reckless operation, depending on the circumstances and the actions a reasonable pilot will take. Pilot should remember, these airplanes were not tested for inadvertent encounters and since most icing conditions consist of small drops and low

LWC, should not assume their airplane can tolerate all icing conditions after one successful encounter.

(2) Aircraft certificated prior to the mid-1970s that are not certificated for flight in icing conditions may not have any prohibitions stated in the AFM or POH. If not, they are not covered by either § 91.527 or § 91.9. However, given that information on the dangers of aircraft icing has been widely disseminated for many years, certain actions, such as taking off with wings coated with ice, could be interpreted as prohibited under § 91.13.

2. Part 121 Icing Regulations (see § 121.341, Equipment for Operations in Icing Conditions).

a. Icing Conditions. No person may fly an airplane in icing conditions unless one or more of the following apply:

(1) The aircraft has functioning deicing or anti-icing equipment protecting each propeller, windshield, wing, stabilizing surface, control surface, airspeed instrument, altimeter, rate of climb instrument, and flight attitude instrument system.

(2) The aircraft is type certificated under the transport category airworthiness requirements relating to ice protection.

(3) The aircraft is a non-transport category airplane type certificated after December 31, 1964, which meets the provisions detailed below.

b. Non-Transport Category Airplanes Type Certificated After December 31, 1964.

(1) IFR. No pilot may fly a non-transport category airplane under IFR type cerftificated after December 31, 1964, into known or forecast light or moderate icing conditions unless one or more of the following apply:

(a) The aircraft has ice protection provisions that meet part 135, appendix A, paragraph 34.

(b) The aircraft has ice protection provisions that meet the requirements for transport category airplane type certification.

(c) The aircraft has functioning deicing or anti-icing equipment protecting each propeller, windshield, wing, stabilizing surface, control surface, airspeed instrument, altimeter, rate of climb instrument, and flight attitude instrument system.

(2) VFR. No pilot may fly a non-transport category airplane under VFR type certificated after December 31, 1964, into known light or moderate icing conditions unless one or more of the following apply:

(a) The aircraft has ice protection provisions that meet part 135, appendix A, paragraph 34.

(b) The aircraft has ice protection provisions that meet the requirements for transport category airplane type certification.

(c) The aircraft has functioning deicing or anti-icing equipment protecting each propeller, windshield, wing, stabilizing surface, control surface, airspeed instrument, altimeter, rate of climb instrument, and flight attitude instrument system.

(3) Severe Icing. No pilot may fly a non-transport category airplane type certificated after December 31, 1964, into known or forecast severe icing conditions unless one or more of the following apply:

(a) The aircraft has ice protection provisions that meet part 135, appendix A, paragraph 34.

(b) The aircraft has ice protection provisions that meet the requirements for transport category airplane type certification.

NOTE: Even airplanes approved for flight into known icing conditions should not fly into severe icing. Many Airplane Flight Manual Limitations Sections require an immediate exit when these types of conditions are encountered.

NOTE: Airplane certification for flight into known icing conditions does not include freezing drizzle and freezing rain. In fact, some airplanes are prohibited from flying into freezing drizzle or freezing rain, regardless of its intensity. These conditions are very dangerous and can cause ice to form behind the protected areas.

(4) Nighttime Icing Conditions. No person may operate an airplane in icing conditions at night unless:

(a) Means are provided for illuminating or otherwise determining the formation of ice on safety-critical parts of the wings.

(b) Any illumination used is of a type that will not cause glare or reflection that would handicap crewmembers in the performance of their duties.

3. Part 125 Icing Regulations (see § 125.221, Icing Conditions: Operating Limitations).

a. Frost, Ice, and Snow Accumulation. No pilot may take off an airplane that has frost, ice, or snow adhering to any propeller, windshield, wing, stabilizing surface, control surface, powerplant installation, airspeed instrument, altimeter, rate of climb instrument, or flight attitude instrument system unless:

(1) Frost adhering to the wings, stabilizing surfaces, or control surfaces has been polished to make it smooth.

(2) The Administrator has authorized takeoffs with frost under the wing in the area of the fuel tanks.

b. Anticipated Frost, Ice, or Snow Accumulation. When conditions are such that frost, ice, or snow may reasonably be expected to adhere to the airplane, no certificate holder may authorize an airplane to take off, nor may any pilot take off, unless the pilot has completed the testing required under § 125.287(a)(9) and one or more of the following apply:

(1) A pretakeoff contamination check established by the certificate holder and approved by the Administrator for the specific airplane type has been completed within five minutes prior to beginning takeoff. A pretakeoff contamination check is a check to make sure the wings and control surfaces are free of frost, ice, or snow.

(2) The certificate holder has an approved alternative procedure under which the airplane is determined to be free of frost, ice, or snow.

(3) The takeoff complies with the certificate holder's approved deicing/anti-icing program (which must comply with § 121.629(c)).

c. IFR. No pilot may fly an airplane under IFR into known or forecast light or moderate icing conditions unless one or more of the following apply:

(1) The aircraft has ice protection provisions that meet part 125, appendix C.

(2) The aircraft has ice protection provisions that meet the requirements for transport category airplane.

(3) The aircraft has functioning deicing or anti-icing equipment protecting each propeller, windshield, wing, stabilizing surface, control surface, airspeed instrument, altimeter, rate of climb instrument, and flight attitude instrument system.

d. VFR. No pilot may fly an airplane under VFR into known light or moderate icing conditions unless one or more of the following apply:

(1) The aircraft has ice protection provisions that meet part 125, appendix C.

(2) The aircraft has ice protection provisions that meet the requirements for transport category airplane type certification.

(3) The aircraft has functioning deicing or anti-icing equipment protecting each propeller, windshield, wing, stabilizing surface, control surface, airspeed instrument, altimeter, rate of climb instrument, and flight attitude instrument system.

e. Severe Icing. No pilot may operate into known or forecast severe icing conditions unless one or more of the following apply:

(1) The aircraft has ice protection provisions that meet part 125, appendix C.

(2) The aircraft has ice protection provisions that meet the requirements for transport category airplane type certification.

4. Part 135 Icing Regulations (see § 135.227, Icing Conditions: Operating Limitations.)

a. IFR. No pilot may fly an airplane under IFR into known or forecast light or moderate icing conditions unless one or more of the following apply:

(1) The aircraft has ice protection provisions that meet part 135, appendix A, paragraph 34.

(2) The aircraft has ice protection provisions that meet the requirements for transport category airplane type certification.

(3) The aircraft has functioning deicing or anti-icing equipment protecting each propeller, windshield, wing, stabilizing surface, control surface, airspeed instrument, altimeter, rate of climb instrument, and flight attitude instrument system.

b. VFR. No pilot may fly under VFR into known light or moderate icing conditions unless one or more of the

(1) The aircraft has ice protection provisions that meet part 135, appendix A, paragraph 34.

(2) The aircraft has ice protection provisions that meet the requirements for transport category airplane type certification.

(3) The aircraft has functioning deicing or anti-icing equipment protecting each propeller, windshield, wing, stabilizing surface, control surface, airspeed instrument, altimeter, rate of climb instrument, and flight attitude instrument system.

c. Severe Icing. No pilot may operate into known or forecast severe icing conditions unless one or more of the following apply:

(1) The aircraft has ice protection provisions that meet part 135, appendix A, paragraph 34.

(2) The aircraft has ice protection provisions that meet the requirements for transport category airplane type certification.

NOTE: Even airplanes approved for flight into known icing conditions should not fly into severe icing. Many Airplane Flight Manual Limitations Sections require an immediate exit when these types of conditions are encountered. Airplane certification for flight into known icing conditions does not include freezing drizzle and freezing rain. In fact, some airplanes are prohibited from flying into freezing drizzle or freezing rain, regardless of its intensity. These conditions are very dangerous and can cause ice to form behind the protected areas.

APPENDIX 3. ICING CHECKLISTS

The following checklists contain icing-specific items that should be considered before operating in possible icing conditions. The checklists are intended to supplement pilot information. These checklists should not replace or supersede AFM or POH.

1. Aircraft Not Certificated or Equipped for Flight in Icing Conditions.

a. Preflight.

(1) Always obtain a thorough preflight weather briefing. Evaluate cloud types, bases, and tops; types of precipitation; freezing levels; and pilot reports. Check for AIRMET Zulus and convective SIGMETS. Supplement your weather briefing by reviewing graphical data at: http://adds.aviationweather.gov.

(2) Pack additional items in your flight bag such as a large flashlight, spare fresh batteries, and transceiver.

(3) During preflight planning, identify alternate airports along the route of flight to be used if unscheduled weather is encountered. If possible, choose airports with long runways.

(4) Always know how to escape icing conditions (i.e., either climb or descend into warmer areas, make a 180-degree turn, etc.)

(5) During the preflight inspection, clean all ice, frost, and snow off the aircraft.

(6) Check that pitot heat is operable.

(7) Check pitot/static openings, fuel drains, and stall warning sensors to ensure they are not clogged with ice.

(8) Clear any accumulated ice or snow from brakes and wheel fairings.

(9) Check controls externally for ice/snow binding.

b. Taxi/Takeoff/In-Flight.

(1) Use brakes carefully during taxi to prevent skidding.

(2) Ensure that carburetor heat or alternate air is working.

(3) Check controls for full range of motion.

(4) Aircraft with turbine engines: Perform regular turbine engine power run-ups while taxiing to shed ice, per the AFM procedures.

(5) After takeoff, if recommended by the manufacturer, cycle landing gear to clear snow or slush from wheel wells.

(6) During flight, monitor engine RPM. A drop in RPM or manifold pressure may indicate induction icing. Apply carburetor heat or alternate air if required.

(7) If ice is encountered in-flight, exit the conditions immediately.

(8) Use visual cues to identify ice formation. If ice forms on the wing, there is a possibility the tail may be accumulating ice as well.

(9) Stay alert for any performance or handling degradation that may be an indicator of ice accumulation.

(10) Remember that recovery procedures from an ice-induced tailplane stall are opposite from those for an ice-induced wing stall.

(11) If using an autopilot, when workload permits, periodically disengage and manually fly the aircraft to identify possible handling changes or control jamming caused by ice.

c. Approach and Landing.

(1) Be prepared for unexpected attitude changes when changing the airplane's configuration. If the aircraft's performance characteristics change suddenly, return to the previous configuration.

(2) If landing with an accumulation of ice on the tailplane, perform a no-flap landing at a higher approach speed. Use a longer runway if available.

(3) After touchdown, use brakes sparingly to prevent skidding.

2. Piston Aircraft Certificated or Equipped for Flight in Icing Conditions.

a. Preflight.

(1) Always obtain a thorough preflight weather briefing. Evaluate cloud types, bases, and tops; types of precipitation; freezing levels; and pilot reports.

(2) Pack additional items in your flight bag such as a large flashlight, spare fresh batteries, and transceiver.

(3) During preflight planning, identify alternate airports along the route of flight to be used if unscheduled weather is encountered. Choose airports with longer runways.

(4) Always know how to escape icing conditions (either climb or descend to warmer areas, make a 180 degree turn, etc.).

(5) During the preflight inspection, clean all ice, frost, and snow off the aircraft.

(6) Check that pitot heat and static heat are operable.

(7) Check pitot/static openings, fuel drains, and stall warning sensors to ensure they are not clogged with ice.

(8) Cycle deicing and anti-icing systems to check for proper operation.

(9) Clear any accumulated ice or snow from brakes and wheel fairings.

(10) Check controls externally for ice/snow binding.

b. Taxi/Takeoff/In-Flight.

(1) Use brakes carefully during taxi to prevent skidding.

(2) Ensure that carburetor heat or alternate air is working.

(3) Check controls for full range of motion.

(4) After takeoff, if recommended by the manufacturer, cycle landing gear to clear snow or slush from wheel wells.

(5) During flight, monitor engine RPM. A drop in RPM or manifold pressure may indicate induction ice. Apply carburetor heat or alternate air if required.

(6) Refer to the AFM or POH for proper operation of anti-icing and deicing systems. A rule of thumb is that anti-ice systems should be activated at the first sign of visible moisture with air temperatures some margin above freezing. Deicing systems should be activated at the first sign of ice accretion.

(7) Use visual cues to identify ice formation and regularly check for ice accumulation behind protected areas on the aircraft. If ice forms on the wing, there is a possibility that the tail may be accumulating ice as well.

(8) Stay alert for any performance or handling degradation that may be an indicator of ice accumulation.

(9) Remember that recovery procedures from an ice-induced tailplane stall are opposite from those for an ice-induced wing stall.

(10) If using an autopilot, if workload permits, periodically disengage and manually fly the aircraft to identify handling changes caused by airframe icing.

c. Approach and Landing.

(1) Be prepared for unexpected attitude changes when changing the airplane’s configuration. If the aircraft begins to roll or pitch unexpectedly, return to the previous configuration.

(2) If landing with an accumulation of ice, use a higher approach speed. Use a longer runway if available.

(3) After touchdown, use brakes sparingly to prevent skidding.

3. Turbo-Propeller Aircraft.

a. Preflight.

NOTE: Professional flightcrews flying complex, high performance aircraft should always refer to the AFM or POH and company guidance materials as the authority for procedures for flight into icing conditions.

(1) For ground deicing operations, refer to company manuals, AC 120-58, and AC 135-17 for guidance.

(2) Always obtain a thorough preflight weather briefing. Look for cloud types, bases, and tops; types of precipitation; freezing levels; and pilot reports.

(3) Preflight icing inspections of the aircraft in ground icing conditions are essential. Tactile inspections are mandatory for some aircraft and are very valuable for detecting clear ice. By physically touching the surface, any fine contaminants not easily visible can be detected. Refer to AFM or POH to determine if a tactile inspection is mandatory for your aircraft.

(4) Clean all ice, frost, and snow off of the aircraft

(5) Check that pitot heat and static heat are operable.

(6) Check pitot/static openings, fuel drains, and stall warning sensors to ensure they are not clogged with ice.

(7) Cycle anti-icing and deicing systems to check for proper operation.

(8) Clear any accumulated ice or snow from brakes and wheel fairings.

(9) Inspect the engine inlets of turbine engines and remove any accumulated ice from the nacelle inlet as well as around the nacelle drain hole and around the fan blades.

b. Taxi/Takeoff/In-Flight.

(1) Use brakes carefully during taxi to prevent skidding.

(2) Check controls for full range of motion.

(3) After takeoff, if recommended by the manufacturer, cycle landing gear to clear snow or slush from wheel wells.

(4) Refer to the AFM or POH for proper operation of anti-icing and deicing systems. A rule of thumb is that anti-ice systems should be activated at the first sign of visible moisture with air temperatures some margin above freezing. Deicing systems should be activated at the first sign of ice accretion.

(5) Power settings with bleed air on should be set according to the POH or AFM reference section.

(6) For turbine engines, perform regular engine power run-ups to shed accumulated ice while taxiing, per the AFM

(7) Use visual cues to identify ice formation and regularly check for ice accumulation behind protected areas on the aircraft.

(8) Stay alert for ice formations on wings that may cause control problems.

(9) If there is a need to use wing-deicing systems, there is a possibility that the tail may be accumulating ice as well.

(10) Remember that recovery procedures from an ice-induced tailplane stall are opposite from those for an ice-induced wing stall.

(11) If using an autopilot, if workload permits, periodically disengage and manually fly the aircraft to identify handling changes caused by ice. Some pilots have been known to rest their leg against the airplane's trim wheel to monitor the amount of trim being put in by the autopilot.

(12) Use airspeed bug to monitor changes to airspeed.

c. Approach and Landing.

(1) Be prepared for unexpected attitude changes when changing the airplane's configuration. If the performance characteristics change suddenly, return to the previous configuration.

(2) Determine if freezing drizzle or freezing rain are being reported and avoid flying into these areas. A ground observation of ice pellets indicates possibly freezing drizzle or rain aloft. A ground observation of any type of precipitation when temperatures are near freezing may indicate freezing precipitation aloft, so be vigilant for severe icing conditions.

(3) If landing with an accumulation of ice, use a higher approach speed. Use a longer runway if available.

(4) Carry some power on flare and flare slightly faster than normal if carrying ice. Use a longer runway if available.

(5) Cycle boots just before final approach.

(6) After touchdown, use brakes sparingly to prevent skidding.

4. Turbojet Aircraft.

a. Preflight.

NOTE: Professional flightcrews flying complex, high performance aircraft should always refer to the AFM or POH and company guidance materials as the authority for procedures for flight into icing conditions.

(1) Because turbojet airplanes have the performance capabilities to fly around or quickly pass through areas where icing conditions are encountered in-flight, icing will pose more of a hazard during the takeoff phase. Therefore, particular attention should be paid to ground deicing.

(2) For ground deicing operations, refer to company procedures, AC 120-58, and AC 135-17 for guidance.

(3) Ensure that deicing fluids are not sprayed into engines, auxiliary power units, pitot inlets, probe openings, or static ports.

(4) Do not spray heated fluids onto cold windows.

(5) Deicing fluid fumes are toxic. If the aircraft is being sprayed with passengers on board, close all outside vents.

(6) Always obtain a thorough preflight weather briefing. Look for cloud types, bases, and tops; types of precipitation; freezing levels; and pilot reports.

(7) Preflight icing inspections of the aircraft in ground icing conditions are essential. Tactile inspections are mandatory for some aircraft and are very valuable for detecting clear ice. By physically touching the surface, any fine contaminants not easily visible can be detected. Refer to AFM or POH to determine if a tactile inspection is mandatory for your aircraft.

(8) Ensure that all ice, frost, and snow is removed from the aircraft

(9) Ensure that heated flight information warning sensors, AOA, pitot/static, etc., are operating properly.

(10) Check pitot/static openings, fuel drains, and stall warning sensors to ensure they are not clogged with ice.

(11) Cycle anti-icing and deicing systems to check for proper operation.

(12) Clear any accumulated ice or snow from brakes and wheel fairings.

(13) Inspect the engine inlets of turbine engines and remove any accumulated ice from the nacelle inlet as well as around the nacelle drain hole and around the fan blades.

b. Taxi/Takeoff/In-Flight.

(1) Ensure that controls have full range of motion.

(2) Refer to the AFM or POH for proper operation of anti-icing and deicing systems. A rule of thumb is that anti-ice systems should be activated at the first sign of visible moisture with air temperatures some margin above freezing. Deicing systems should be activated at the first sign of ice accretion.

(3) Power settings with bleed air on should be set according to the POH or AFM reference section.

(4) For turbine engines, perform regular engine power run-ups to shed accumulated ice while taxiing, per the AFM.

(5) Use visual cues to identify ice formation and regularly check for ice accumulation behind protected areas on the aircraft.

(6) Stay alert for ice formations in front of control surfaces that may cause control problems.

(7) If there is a need to use wing-deicing systems, there is a possibility that the empennage may be accumulating ice as well.

(8) Remember that recovery procedures from an ice-induced tailplane stall are opposite from those for an ice-induced wing stall.

(9) If using an autopilot, if workload permits, periodically disengage and manually fly the aircraft to identify handling changes caused by ice. This is especially important if operated in slow flight or in a holding pattern.

c. Approach and Landing.

(1) Be prepared for unexpected attitude changes when changing the airplane’s configuration. If the aircraft’s performance characteristics change suddenly, return to the previous configuration.

(2) Determine if freezing drizzle or freezing rain are being reported and avoid flying into these areas. A ground observation of ice pellets indicates possibly freezing drizzle or rain aloft. A ground observation of any type of precipitation when temperatures are near freezing may indicate freezing precipitation aloft, so be vigilant for severe icing conditions.

(3) Cycle boots before final approach, if equipped.

(4) In accordance with the POH or AFM, use a higher approach speed into the landing when carrying an accumulation of ice. Use a longer runway if available.

(5) Carry some power on flare and flare slightly faster than normal if carrying ice. Use a longer runway if available.

(6) After touchdown, use brakes sparingly in case of ice buildup in brakes.

APPENDIX 4. RECOMMENDED READING

1. This AC was developed as an easy-to-read resource on flight in icing conditions. As of the date of publication, this AC contains the most current information available. The suggested reading list that follows may not have been updated recently but may contain other useful and valid information. For more detailed information, pilots are referred to the following U.S. Government publications:

a. Aeronautical Information Manual.

b. AC 00-6A, Aviation Weather for Pilots and Flight Operations Personnel.

c. AC 00-45F, Aviation Weather Services.

d. AC 20-29B, Use of Aircraft Fuel Anti-icing Additives.

e. AC 20-73A, Aircraft Ice Protection.

f. AC 20-113, Pilot Precautions and Procedures to be Taken in Preventing Aircraft Reciprocating Engine Induction System and Fuel System Icing Problems.

g. AC 20-117, Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing.

h. AC 23.1419-2D, Certification of Part 23 Airplanes for Flight in Icing Conditions.

i. AC 91-51A, Effect of Icing on Aircraft Control and Airplane Deice and Anti-Ice Systems.

j. AC 150/5220-16C, Automated Weather Observing Systems for Non-Federal Applications.

k. NTSB Aircraft Accident Report AAR-96-01, In-flight Icing Encounter and Loss of Control Simmons Airlines, d.b.a. American Eagle Flight 4184 Avions de Transport Regional (ATR) Model 72–212, N401AM Roselawn, Indiana; October 31, 1994.

l. P-8740-24, Tips on Winter Flying — FAA Accident Prevention Program Publication.

2. For related reading materials, refer pilots to the following publications.

a. Buck, Robert N., *Weather Flying*, McGraw-Hill, Fourth Edition; 1998.

b. De Remer, Dale, *Aircraft Systems for Pilots*, Jeppesen Sanderson, Inc., 1996.

c. Flight Safety Digest, *Protection Against Icing: A Comprehensive Overview,* June-Sept. 1997, Flight Safety Foundation, 1997.

d. Hurt Jr., H. H., *Aerodynamics for Naval Aviators,* U.S. Navy, 1991.

e. Job, Macarthur, *Air Disaster (Volume I),* Aerospace Publications Pty Ltd., 1994.

f. Job, Macarthur, *Air Disaster (Volume II),* Aerospace Publications Pty Ltd., 1996.

g. MaChado, Rod, *Instrument Pilot's Survival Manual*, The Aviation Speakers Bureau, 1997.

h. Newton, Dennis, *Severe Weather Flying,* McGraw-Hill, 1983.

i. Wild, Thomas W. *Transport Category Aircraft Systems,* Jeppesen Sanderson, Inc., 1990.

j. Mason, et al, *The Ice Particle Threat to Engines in Flight.* AIAA 2006, 44th AIAA Aerospace Sciences meeting and Exhibit, 9-12 January 2006, Reno, Nevada.