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This advisory circular (AC) contains updated and additional information for the pilots of airplanes under Title 14 of the Code of Federal Regulations (14 CFR) parts 91, 121, 125, and 135. The purpose of this AC is to provide pilots with a convenient reference guide on the principal factors related to flight in icing conditions and the location of additional information in related publications. As a result of these updates and consolidating of information, AC 91-74A, Pilot Guide: Flight in Icing Conditions, dated December 31, 2007, and AC 91-51A, Effect of Icing on Aircraft Control and Airplane Deice and Anti-Ice Systems, dated July 19, 1996, are cancelled. This AC does not authorize deviations from established company procedures or regulatory requirements.

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CHAPTER 1. INTRODUCTION

1-1. PURPOSE. This advisory circular (AC) updates the previous version and contains essential information concerning safe flight in icing conditions, what conditions a pilot should avoid, and 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 pilot's operating handbook (POH). This material is not regulatory, nor does it establish minimum standards. Where the term "must" is used in this AC, it reflects actual regulatory requirements; where the term "should" is used, it reflects recommendations from the Federal Aviation Administration (FAA).

1-2. CANCELLATION. AC 91-74A, Pilot Guide: Flight in Icing Conditions, dated December 31, 2007; and AC 91-51A, Effect of Icing on Aircraft Control and Airplane Deice and Anti-Ice Systems, dated July 19, 1996, are canceled.

1-3. 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. Airmen'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. An AIRMET concerns weather of lesser severity than that covered by an advisory of significant meteorological information (SIGMET) or a convective SIGMET. AIRMETs may include advisories of moderate icing.

c. Automated Surface Observing System (ASOS). 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 an ASOS and an All Weather Operations Specialist (AWOS) (see subparagraph 1-3d). 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 current ASOS limitation is its inability to simultaneously detect and report freezing drizzle, ice pellets, or any other freezing precipitation without human augmentation when other forms of precipitation are present. A detailed description of ASOS's capabilities can be found at the NWS ASOS homepage: http://www.nws.noaa.gov/asos/index.html.

d. Automated Weather Observation System (AWOS). A suite of weather sensors that are procured by the FAA or purchased by individuals, groups, airports, etc. 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 or have precipitation reporting capability. A detailed description of AWOS's capabilities can be found in the AIM.

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 air traffic control (ATC).

f. Center Weather Advisory (CWA). An unscheduled weather advisory issued by NWS meteorologists for use by ATC in alerting pilots to existing or anticipated adverse weather conditions within the next 2 hours. A CWA may modify a SIGMET.

g. Clear Ice. A glossy, clear, or translucent ice formed by the relatively slow freezing of supercooled water drops. 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. If the freezing becomes more rapid, clear ice will turn cloudy as small bubbles of air become trapped in the ice. If the conditions persist, the ice would be classified as mixed.

h. Convection. An atmospheric motion resulting in the transport and mixing of atmospheric properties.

i. Cumulus Clouds. Clouds in the form of detached domes or towers that 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.

j. 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). This product is automatically produced with no human modification. More information can be found on the Aviation Weather Center (AWC) Aviation Digital Data Service (ADDS) Web site.

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

l. Forecast Icing Product (FIP). The FIP examines numerical weather prediction model output to calculate the probability and severity of icing conditions, plus SLD potential. This product is automatically produced with no human modification. More information can be found on the AWC ADDS Web site.

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 water that remains in a liquid form at air temperatures less than 0 °C (supercooled) and can freeze upon contact with objects on the ground or in the air.

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, remains in liquid form (supercooled), 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.

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

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

(3) 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.

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

p. Hazardous Weather Information. Summary of SIGMETs, Convective SIGMETs, urgent Pilot Weather Reports (PIREP), CWAs, AIRMETs, and any other significant weather provided to pilots that might not be routinely provided in a standard format or report.

q. Ice Crystals. Ice crystals, which are often in high concentrations near convective weather systems and lower concentrations in stratus or cirrus clouds, can accrete within turbine engines and cause power loss when in high concentrations. Ice crystals are not typically detected by either conventional ice detectors or airborne radar, and typically do not accrete on external airframe surfaces.

r. Icing Envelopes. Icing envelopes used for the certification of aircraft for flight in icing conditions specify atmospheric icing conditions in terms of altitude, temperature, Liquid Water Content (LWC), and drop size represented by the Median Volume Diameter (MVD). (The envelopes use the term mean effective diameter, but this equates to the MVD 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.

s. Impingement. The striking and adherence of a water droplet on an aircraft surface. The impingement rate is the rate at which droplets of a given size collect on a particular surface. In general, impingement rates are higher for larger drops and smaller components, such as a very high frequency (VHF) or a Global Positioning System (GPS) antenna.

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

u. Light Icing. The rate of ice accumulation may create a problem if flight is prolonged in this environment (over 1 hour). Requires occasional cycling of manual deicing systems[1] to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is ¼ inch to 1 inch (0.6 to 2.5 cm) per hour[2] on the outer wing.[3]

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

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

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

y. Moderate Icing. The rate of ice accumulation requires frequent cycling of manual deicing systems[1] to minimize ice accretions on the airframe. The rate of accumulation is such that anything more than a short encounter is potentially hazardous. A representative accretion rate for reference purposes is 1 to 3 inches (2.5 to 7.5 cm) per hour[4] on the outer wing.[5]

z. 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.

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

bb. Outside Air Temperature (OAT). The measured or indicated air temperature outside the aircraft that is uncorrected.

cc. Pilot Briefing. A service provided by a Flight Service Station (FSS) or other FAA-approved provider that can assist pilots with flight planning. Briefing items may include weather information, Notices to Airmen (NOTAM), military activities, flow control information, and other items, as requested.

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

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[1] 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.

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

[3] 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 part 91 §§ 91.13(a) and 91.527, part 121 § 121.341, part 125 § 125.221, and part 135 § 135.227).

[4] See footnote 2.

[5] See footnote 3.

ee. Rime Ice. A rough, milky, opaque ice formed by the instantaneous freezing of small, supercooled water drops. It is generally rougher in appearance than clear ice.

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

gg. Severe Icing. The rate of ice accumulation is such that ice protection systems fail to remove the accumulation of ice and accumulation occurs in areas not normally prone to icing, such as aft of protected surfaces and other areas identified by the manufacturer. A representative accretion rate for reference purposes is more than 3 inches (7.5 cm) per hour[6] on the outer wing. Immediate exit is required by many Airworthiness Directives (AD), flight manuals, and operations under part 91, §§ 91.13(a) and 91.527; part 121, § 121.341; part 125, § 125.221; and part 135, § 135.227.[7]

hh. 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.)

ii. 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.

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

kk. Sublimation. A process in which ice turns directly into water vapor without passing through a liquid state.

ll. Supercooled Large Drops (SLD). Water drops with a diameter greater than 50 micrometers (0.05 mm) that exist in a liquid form at air temperatures below 0 °C. SLD conditions include freezing drizzle drops and freezing raindrops.

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

nn. 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 ¼ inch (6 mm) per hour on the outer wing. Deicing/anti-icing equipment is not utilized unless encountered for an extended period of time (over 1 hour).

oo. 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.

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[6] See footnote number 2.

[7] 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.

1-4. DISCUSSION. Aircraft icing remains a key aviation safety issue. Accident data has shown that pilots are (intentionally or inadvertently) flying aircraft not certificated for flight in icing conditions into such conditions, often with fatal results. Additionally, several accidents have involved aircraft that are certificated for flight in icing conditions. Such accidents are often the result of pilot complacency, lack of situational awareness (e.g., lack of awareness of loss of airspeed), poor technique, poor understanding of the airplane's limitations and performance in icing conditions, misconceptions about certification of the airplane and systems for flight in icing, or a misunderstanding of icing terminology.

a. Certification. Pilots must determine if 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 ensure the aircraft is certificated to fly in icing conditions and that the appropriate deicing/anti-icing equipment is installed and operational prior to operating in icing conditions. It is also critical that the pilot understand and comply with the applicable limitations and procedures when operating in icing conditions.

b. Flight Planning. If an aircraft is not certificated for flight in icing conditions, each flight should be planned carefully so that icing conditions are avoided. During a flight, the pilots should monitor available weather information (see Chapter 5, Icing Operations, 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 ATC as necessary, and declaring an emergency. In a recent study (American Institute of Aeronautics and Astronautics (AIAA) 2006-82, "A Study of U.S. Inflight Icing Accidents and Incidents, 1978 to 2002"), conflicts with ATC were common when pilots take action to exit icing conditions after an inadvertent icing encounter. 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 offered to declare an emergency for the pilot, but the pilot declined. In another subset, the frequency was too busy for communications, often because the controller was 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 fatal.

c. Engine Upsets. This AC also includes information about 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.

d. Pilot Certification. 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, despite a substantial ice buildup in some cases. However, a pilot should not relax his or her vigilance in icing conditions because of such experiences. A thin ice accretion on critical surfaces that develops 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. ATMOSPHERIC CONDITIONS ASSOCIATED WITH ICING

2-1. AIRCRAFT ICING CONDITIONS.

a. Supercooled Clouds. Nearly all aircraft icing occurs in supercooled clouds. Liquid drops are present at outside air temperatures (OAT) below 0 °C (32 °F) in these clouds. At OAT close to 0 °C (32 °F), the cloud may consist entirely of such drops, with few or no ice particles present. At decreasing temperatures, the probability increases that ice particles will exist in significant numbers along with the liquid drops. In fact, as the ice water content increases, the Liquid Water Content (LWC) 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. Ice Accumulation. The general rule is that the more ice particles and the fewer liquid drops 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 drops freeze and adhere. As a result, ice accumulation is often greatest at temperatures not too far below 0 °C (32 °F), where LWC can be abundant. LWC is usually negligible at temperatures below about -20 °C (-4 °F).

c. Thermal Ice Protection. An exception to the general rule just stated may be made for surfaces heated by a thermal ice protection system (or from compressibility at higher speeds).

d. Runback Ice Accretion. Tests have shown that when outside air temperatures (OAT) are near freezing, the result is no ice accretion near the stagnation point, but the freezing or refreezing of 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 OAT between -5 °C (23 °F) and +2 °C (35 °F).

e. Drop Adherence. The greater the LWC of the cloud, the more rapidly ice accumulates on aircraft surfaces. The size of the drops also is important. Larger drops have greater inertia and are less influenced by the airflow around the aircraft than smaller drops. The result is that larger drops will adhere to more of the aircraft surface than smaller drops.

f. Median Volume Diameter (MVD). Every supercooled cloud contains a broad range of drops, 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 drop 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.

> **NOTE: Icing conditions can occur during operations in clouds with a significant amount of liquid water in drops with diameters larger than 100 micrometers. These conditions are referred to as freezing drizzle aloft in cloud or Supercooled Large Drop (SLD) in cloud. Paragraph 3-16 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 drops may be present in a cloud.**

g. SLD Conditions. An aircraft does not always have to be in a cloud to encounter SLD as conditions can exist in freezing precipitation below a cloud deck.

2-2. CLOUD TYPES AND AIRCRAFT ICING.

a. Formation. 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 drops form a cloud. Cloud water drops 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. Extent of Icing. If rising air is moist (i.e., water vapor is plentiful) and lifting is vigorous, the result can be clouds with substantial LWC and, sometimes, large drops. The greater the LWC, the more rapid the icing; and the larger the drops, the greater the extent of icing. Tops of clouds often contain the most liquid water and largest drops, because the drops that reach the tops have undergone the most lifting. If the temperatures are cold enough at the tops (below or around -15 °C (5 °F)), ice particles will usually start to form that tend to deplete the liquid water.

c. Hazardous Conditions. 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 LWC 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 paragraph 3-16 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 LWC. 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 LWCs. 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 drops.

(b) Wave clouds, recognized by their wavy tops, can have high LWCs. 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 drop, 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. Drop mass affects how far aft of the stagnation point (leading edge surfaces) drops will strike the aircraft. Subsequently, freezing rain will result in ice forming in areas far aft of where it would normally form in icing conditions without freezing rain.

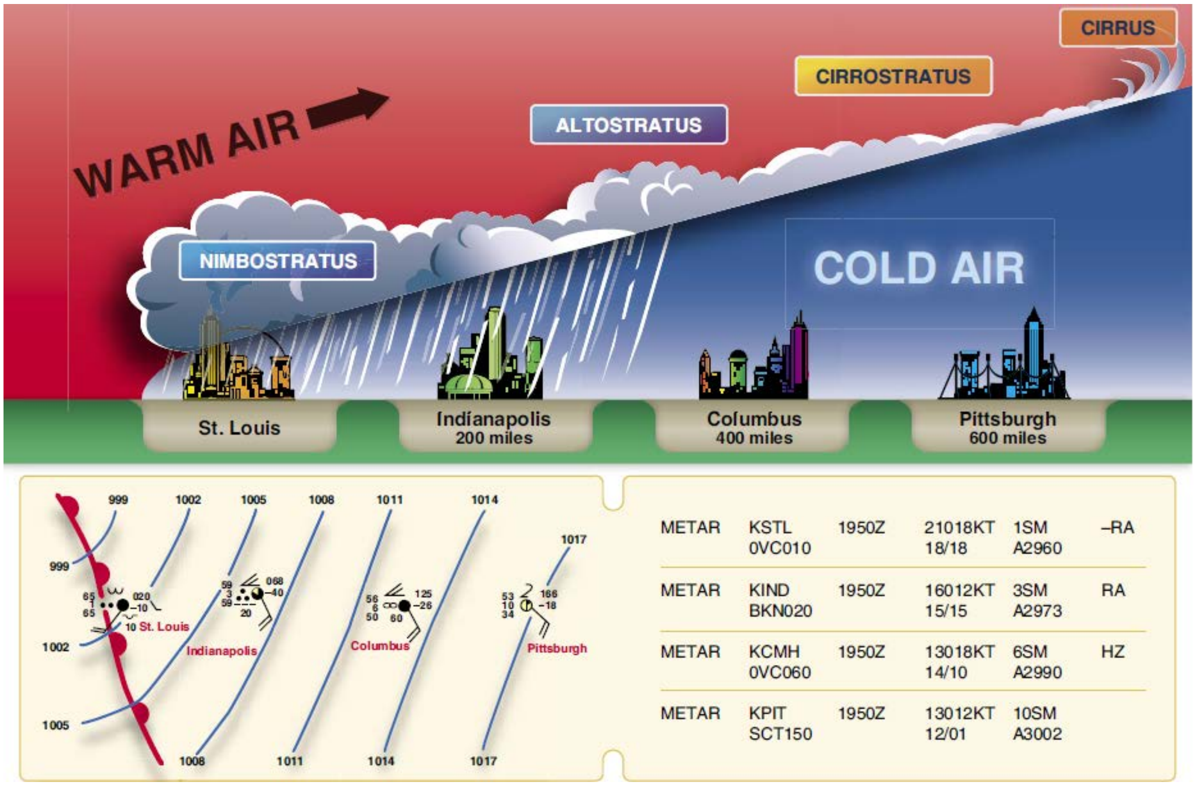
(3) Drops of freezing drizzle consist of supercooled liquid water drops that have diameters smaller than 500 micrometers (0.5 mm) and greater than 50 micrometers (0.05 mm). While smaller than freezing rain, drops of freezing drizzle are still larger than regular cloud drops, and can form through the 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). However, freezing drizzle is perhaps more commonly formed by a different process, known as the collision-coalescence process. When some drops in a cloud grow to approximately 30 micrometers in diameter through condensation, they begin to settle, falling fast enough so that they collide with some smaller drops. If the drops coalesce, the result is a larger drop, which now has an even better chance of capturing smaller drops. Under favorable conditions, this process can produce drizzle-size drops in a supercooled cloud, usually near the top, where the larger drops 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 nonconvective clouds. Thus, in freezing drizzle, the pilot cannot assume that a warm layer (above 0 °C (32 °F)) exists above the aircraft. 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.

2-3. FRONTS.

a. Formation. 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.

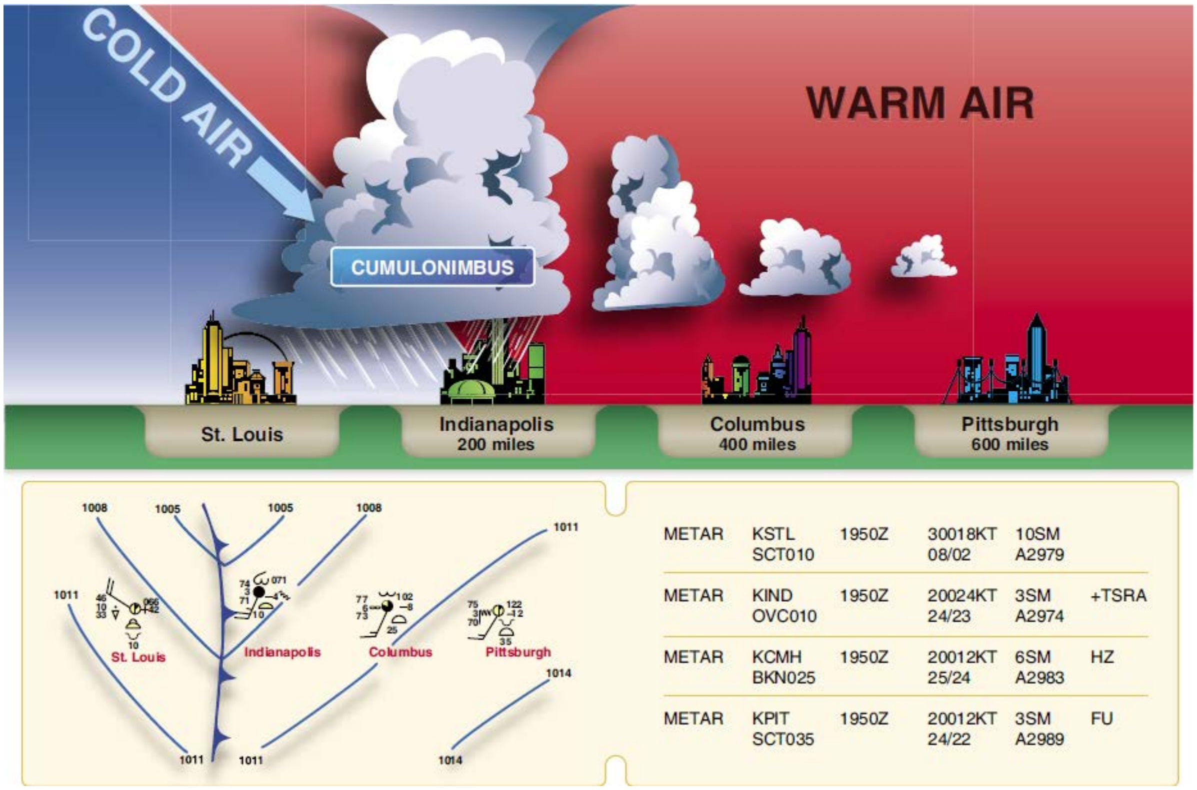
b. Warm and Cold Fronts. Along a warm front, the warmer air tends to slide gradually over the cold front, forming stratus clouds conducive to icing (see Figure 2-1). In a cold front, the cold air plows under the warm air, lifting it more rapidly and resulting in the formation of cumulus clouds with high LWC if the lifted air is moist (see Figure 2-2). SLD in the form of freezing rain and freezing drizzle are sometimes found near fronts, as explained above.

FIGURE 2-1. WARM FRONT



METAR	KSTL	1950Z	21018KT	1SM	–RA
	OVC010		18/18	A2960	
METAR	KIND	1950Z	16012KT	3SM	RA
	BKN020		15/15	A2973	
METAR	KCMH	1950Z	13018KT	6SM	HZ
	OVC060		14/10	A2990	
METAR	KPIT	1950Z	13012KT	10SM	
	SCT150		12/01	A3002	

FIGURE 2-2. COLD FRONT



METAR	KSTL	1950Z	30018KT	10SM	
	SCT010		08/02	A2979	
METAR	KIND	1950Z	20024KT	3SM	+TSRA
	OVC010		24/23	A2974	
METAR	KCMH	1950Z	20012KT	6SM	HZ
	BKN025		25/24	A2983	
METAR	KPIT	1950Z	20012KT	3SM	FU
	SCT035		24/22	A2989	

c. Navigating a Front. Because of the icing and other hazards associated with some fronts, exposure to icing conditions of varying severity is possible. When flying through a front, the pilot should take the shortest route through the front, instead of flying along the front, to reduce the time spent in potential icing conditions.

2-4. CONVECTIVE WEATHER AND ICE CRYSTALS.

a. Convective Weather Systems. 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. Clouds and temperatures less than 10 °C are better indicators of the possible presence of ice crystals when near convective weather.

b. Hazards. Above flight level (FL) 250, clouds contain little liquid water and mostly contain ice particles. These clouds with no liquid water have about 20 times less radar reflectivity than rain drops, and therefore are difficult to detect. Airborne weather radar will receive little to no returns at these altitudes unless it is tilted down to lower altitudes near or below the freezing level. Strong returns from the lower altitudes indicate the possibility of hail, severe turbulence, or large quantities of ice crystals that could be encountered above and accrete inside turbine engines when overflying these areas. Large deposits may ultimately result in engine upset, engine damage from ice shedding, power loss, or engine shutdown.

CHAPTER 3. ICING EFFECTS, PROTECTION, AND DETECTION

3-1. 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 adhere to them and freeze. Small and/or narrow objects are the best collectors of drops 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 3-1, Clear Ice). 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 3-2, Clear Ice Buildup with Horns). Temperatures close to the freezing point, large amounts of liquid water, high aircraft velocities, and large drops are conducive to the formation of clear ice.

FIGURE 3-1. CLEAR ICE

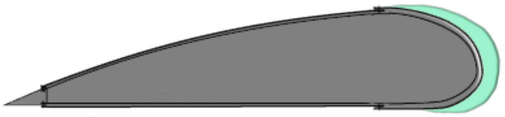
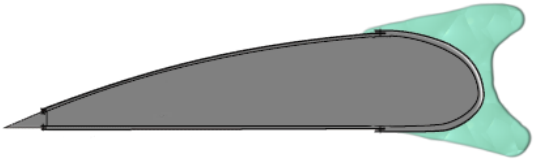
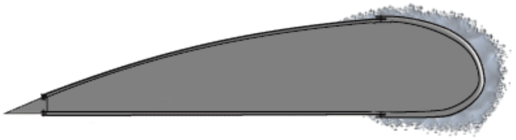


FIGURE 3-2. CLEAR ICE BUILDUP WITH HORNS



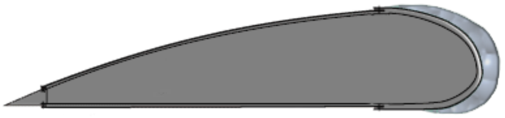
(2) Rime Ice. A rough, milky, opaque ice formed by the instantaneous or very rapid freezing of supercooled drops as they strike the aircraft (see Figure 3-3, Rime Ice). The rapid freezing results in the formation of air pockets in the ice, giving it an opaque and rough appearance, making it porous and 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 drops favor formation of rime ice.

FIGURE 3-3. RIME ICE



(3) Mixed Ice. Mixed ice is a combination of clear and rime ice formed on the same surface. Because there is a difference in rates of ice accumulation, ice that builds up quickly traps air pockets that give the ice a cloudy appearance (see Figure 3-4, Mixed Ice). Hence, mixed ice is sometimes called cloudy ice. It is the location, size, shape, and roughness of the ice that is most important from an aerodynamic point of view. This is discussed in paragraph 3-2.

FIGURE 3-4. MIXED ICE



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.

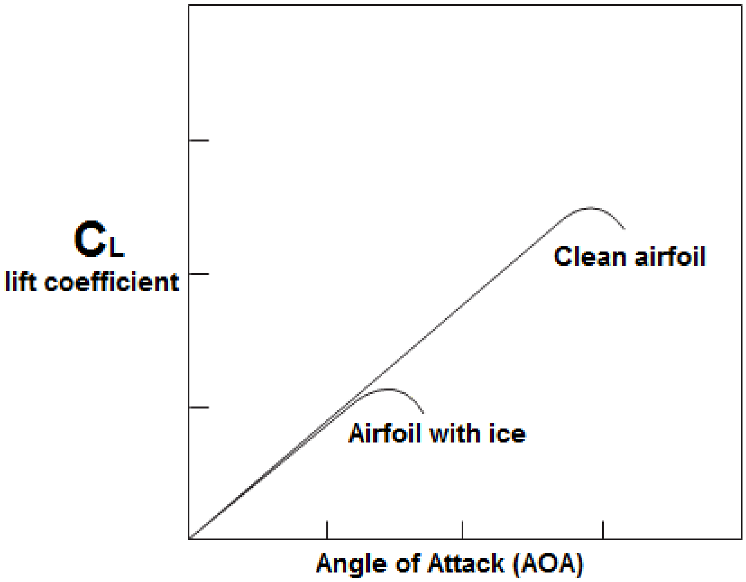
(2) In turbine-engine-powered aircraft, air that is drawn into the engines creates an area of reduced pressure at the inlet, which lowers the temperature below that of the surrounding air. In marginal icing conditions (i.e., conditions where icing is possible), this reduction in temperature may be sufficient 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 (e.g., engine inlet temperature or Engine Pressure Ratio (EPR) probes), which can lead to erroneous readings of engine instrumentation (e.g., Air Florida B-737 accident National Transportation Safety Board (NTSB) accident report NTSB/AAR-82-08).

(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 (i.e., straight-line-of-sight inlet design). However, on turboprop engines that include an inlet section with sharp turns, 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 Airplane Flight Manual (AFM) is very important. Supercooled water drops 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.

3-2. GENERAL EFFECTS OF ICING ON AIRFOILS. Figure 3-5, Lift Curve, and Figure 3-6, Drag Curve, below, depict important information about the effects of ice contamination on an airfoil. (For this AC, an airfoil is a cross-section of a wing or tailplane).

a. Stall. Figure 3-5 shows how ice affects the lift coefficient for an airfoil. Note that the Maximum Coefficient of Lift (CLmax) is significantly reduced by the ice, and the Angle of Attack (AOA) at which a stall occurs (the stall angle) is much lower with ice than without ice. When slowing down and increasing the AOA for an approach, the pilot may find that ice on the wing that had little effect on lift in cruise now induces a stall at a higher AOA associated with a lower airspeed. 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. This effect may be even larger if ice accretes behind areas normally protected.

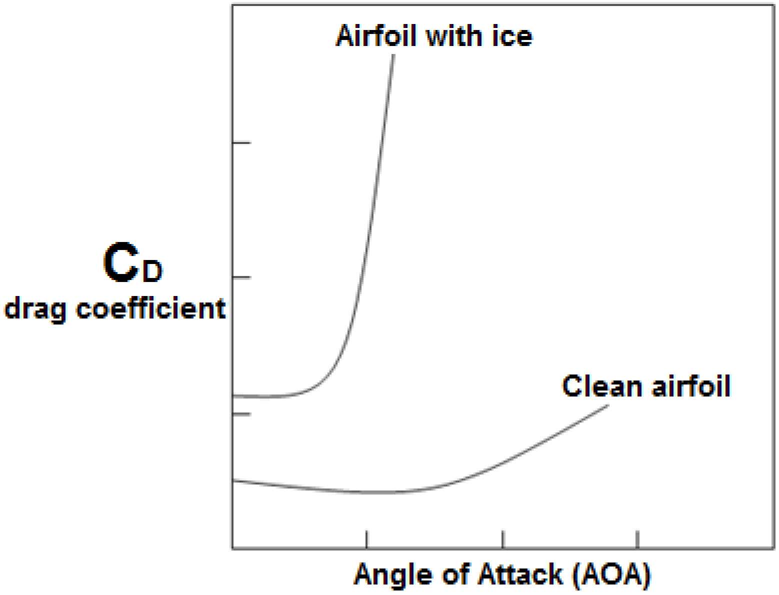
FIGURE 3-5. LIFT CURVE



b. Drag. Figure 3-6 shows how ice affects the drag coefficient of the airfoil. Note that the effect is significant even at very small AOAs.

(1) A significant reduction in CLmax and a reduction in the AOA where stall occurs can result from a relatively small ice accretion. A reduction of CLmax 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 3-6. DRAG CURVE



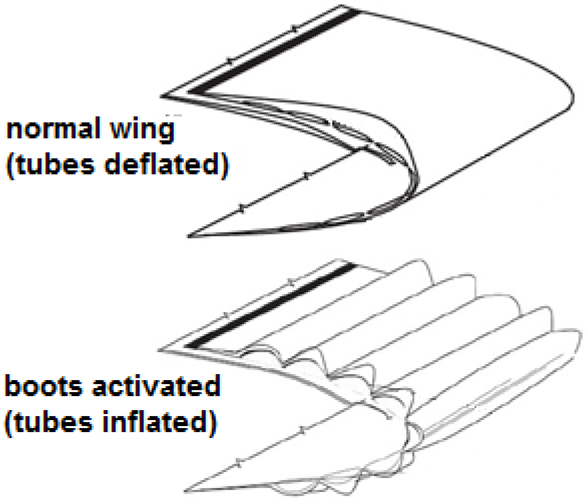
(2) Ice on an airfoil can have other effects not depicted in these curves. Even before airfoil stall, there can be changes in the pressure over the airfoil that may affect a control surface at the trailing edge.

3-3. EFFECTS OF ICING ON UNPROTECTED WINGS. An aircraft with a completely unprotected wing is unlikely to be certificated for flight in icing conditions, but 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 or an increase in the power 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. 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 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.

3-4. DEICING SYSTEMS. The operating philosophy behind deicing systems differs from that of anti-icing systems because deicing systems are activated after encountering icing conditions, permitting a certain amount of ice accumulation.

a. Pneumatic Boots. Pneumatic boots, pictured in Figure 3-7, 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.

FIGURE 3-7. WING BOOT



(1) Because ice is permitted to accrete between cycles (called intercycle or residual ice) the wing or the tailplane is never entirely clean. Residual and intercycle ice is 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. The amount of ice increases as airspeed or temperature decreases. At airspeeds typical of small airplanes, it may take many boot cycles to effectively shed layers of ice. It may appear that the boots are not having any effect at all until shedding occurs. In many icing accidents and incidents, loss of airspeed and stall can occur in a span of minutes. Any remaining ice accretion will increase in the stall speed.

(2) A layer of ice that is rough at any thickness on a wing's leading edge 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. The FAA recommends that the deicing system be activated at the first indication of icing as activating the boots early and often never results in having more ice on the wing than waiting for a late activation. It is essential that the pilot consult the AFM or pilot's operating handbook (POH) (the POH must be consistent with the operating limitations section of the AFM) for guidance on proper use of the system.

(3) At the AOA typical of cruise, this ice should have very little effect on lift. An increase in stall speed becomes more of a concern at higher AOAs characteristic of approach and landing because the aircraft is operating closer to CLmax. 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 pilot cannot exit the icing conditions 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.

(4) 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 forms to the shape of an expanding 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. Studies done in the late 1990s 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 half century or more.

b. Electroimpact System. 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 and the shattered ice is then carried away by the airflow. This system is the least commonly used.

c. Electrothermal System. 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, thus repeating the cycle. Such systems are common on propellers and helicopter main rotors, and have been recently introduced on wing and tail leading edges.

(1) 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.

(2) Intercycle and residual ice can accrete on airplanes with electrothermal deicing systems. It is typical for these systems also to produce runback ice behind a protected area. 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 CLmax, but note that this effect is significant only at higher AOA.

3-5. ANTI-ICING SYSTEMS. 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 or through an evaporative or running wet system. Anti-icing systems are designed to be turned on prior to encountering icing conditions. Operating them as deicing equipment may result in a system failure or damage.

a. Bleed Air Systems. Bleed 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.

NOTE: One drawback of a hot air system is that tapping air from the engine to anti-ice large surfaces affects engine temperature limits that require reduced power settings, which reduce the performance of the engine(s). This 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. 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.) 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.

b. Evaporative/Running Wet Systems. Evaporative or running wet systems are newer designs used on smaller jet aircraft, turbopropeller, and piston aircraft. These 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. This 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 14 CFR part 25 appendix C icing conditions.

NOTE: 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.

3-6. EFFECTS OF ICING ON ROLL CONTROL.

a. Ailerons. This paragraph 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 generally a 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. Airflow. 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.

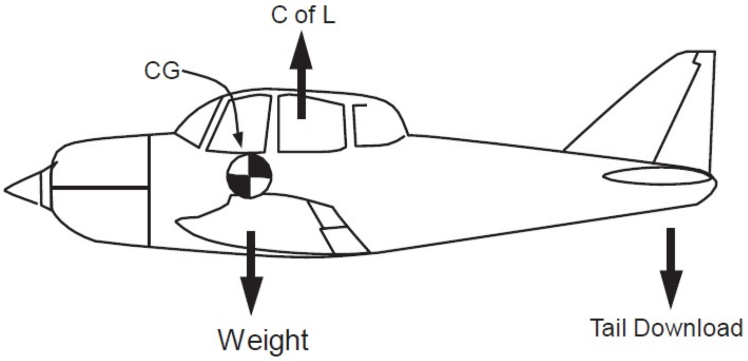
(1) This is the phenomenon that the NTSB found to be responsible for the accident of an ATR-72 turbopropeller aircraft in Roselawn, Indiana in October, 1994. Flight test investigations following the accident suggested two ways in which the ailerons might be affected by ice in front of them.

(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.

3-7. TAILPLANE ICING.

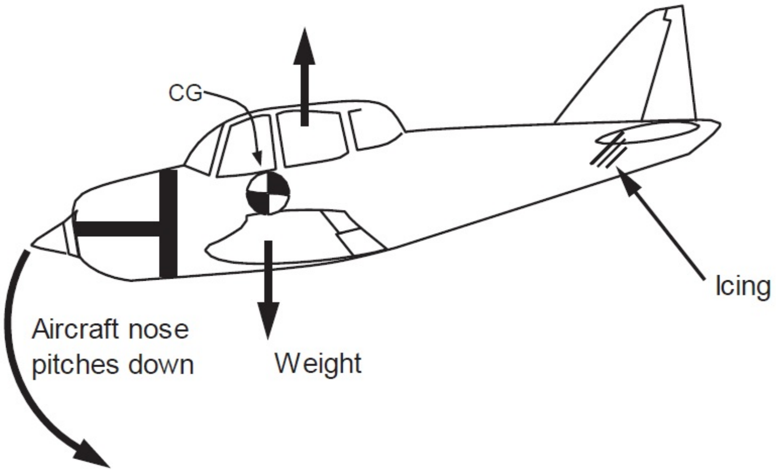
a. Downward Lift. Most aircraft have a nose-down pitching moment from the wings because the center of gravity (CG) is ahead of the center of lift. It is the role of the tailplane to counteract this moment by providing downward lift (see Figure 3-8, Tail Down Moment). The result of this configuration 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 deployment of flaps (see Figure 3-9, Pitchover Due to Tail Stall).

FIGURE 3-8. TAIL DOWN MOMENT



b. Tailplane Stall. 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 after full flap deflection, on airplanes not evaluated for susceptibility. A no-flap landing should be considered to avoid a tailplane stall, consistent with AFM procedures. Tailplane stall is discussed in detail in Chapter 5, paragraph 5-12.

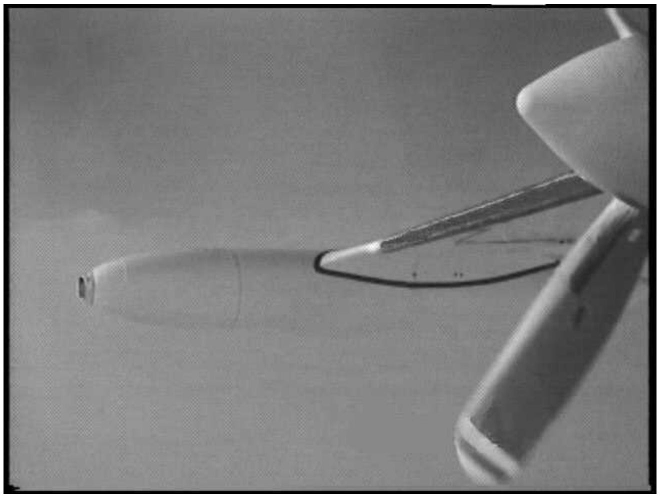
FIGURE 3-9. PITCHOVER DUE TO TAIL STALL



c. Testing and Analysis. On many 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.

3-8. PROPELLER ICING. Ice buildup on operating 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 case of suspected large drop icing during a flight test (see Figure 3-10, Propeller Ice Accretion During an SLD Encounter), ice was experienced along the entire span of the propeller blades. This resulted in a 50 knot loss of airspeed in 1 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 3-10. PROPELLER ICE ACCRETION DURING AN SLD ENCOUNTER



3-9. 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.

3-10. 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 icing protection system on older airplanes. Pilots should check their airplane's AFM to determine if the cooling inlets are protected from ice.

3-11. 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 (i.e., 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 as the altitude increased. As altitude is decreased, 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 airflow-activated stall warning switch. The stall warning vane (also called an “AOA sensor” since it is a part of the stall warning system) has a wedge-like shape, 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 connected to the stall warning switch 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 AOA due to ice on the airfoil. Heated or unheated, if the wing is contaminated in any way, an AOA will become unreliable. The stall onset would occur prior to activation of stall warning devices leading to a potential pitch or roll upset. It is imperative that pilots maintain airspeed and monitor AOA closely when in icing conditions.

d. Windshields.

(1) 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. Engine Pressure Ratio (EPR) Probe (Turbine Engines).

(1) Ice crystals can clog and freeze over turbine 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 (e.g., the Air Florida B-737 accident, NTSB accident report NTSB/AAR-82-08). Pilots of turbojet aircraft should calculate a backup N1 setting for takeoff/go-around in icing conditions as a crosscheck for EPR. The activation of engine nacelle anti-ice when flying in heavy clouds usually prevents ice blockage.

f. Outside Air Temperature (OAT)/True Air Temperature (TAT) Probe.

(1) Ice crystals can clog and freeze over the heated temperature probe on some aircraft. This tendency to freeze over appears to be sensitive to the location of the probe on the airframe. If the OAT/TAT probe freezes over, the indicated temperature will erroneously rise to 0 ºC 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.

3-12. CERTIFICATION FOR FLIGHT IN ICING CONDITIONS.

a. Current Icing Certification. Aircraft which are “certificated for flight in icing conditions” by Amendment 25-121 or higher go through an extensive procedure intended to ensure that they can safely operate throughout those icing conditions encompassed by the icing envelopes specified by the FAA. The current icing certification process 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. The objective is to verify that the aircraft has functioning ice protection and to ensure that the aircraft will have acceptable performance and handling qualities in all the environmental conditions covered by the icing envelopes for which the aircraft has been tested. 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 (LWC) outside the envelopes, which may be indicated by a very rapid rate of accumulation. This can result in runback and ice accumulation aft of protected surfaces.

b. Limits of Icing Certification. SLD may result in drops impinging aft of protected surfaces and causing ice accumulation behind the protected area of leading edges. 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. The effect on stall speed increase and drag may be large. This can be very hazardous, particularly on approach and landing. On November 4, 2014, part 25, § 25.1420 and part 25 appendix O became effective in order to address SLD certification for new, transport category airplanes, but SLD has not yet been incorporated into the certification of other aircraft types.

> **NOTE: If an aircraft has certain Supplemental Type Certificate (STC) items installed, these may affect the icing certification of the aircraft as defined by the manufacturer, some of which might not operate correctly when exposed to icing or be certified for icing conditions.**

c. How to Know Whether a Small Airplane is Certificated for Icing.

(1) The airplane was certificated to 14 CFR part 23, § 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 online Regulatory and Guidance Library (RGL) 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).

d. Icing Certification Has Changed Over the Years.

(1) Current part 23 icing regulations have only been applied to new airplane designs certificated since 2000. In these new designs, the stall warning system on an icing-certified airplane is designed and tested with critical ice accretions along the entire span of the wing. In many new designs this results in the stall warning speed biased higher in icing conditions.

(2) Prior to 2000, a clear and unambiguous buffet was accepted for stall warning in icing conditions, even if the airplane was equipped with a stall warning system and a heated stall warning sensor.

NOTE: If the certification basis is Amendment 23-43 or higher, you can be sure the stall warning systems functions in the icing conditions for which the airplane is certified. If it is lower than Amendment 23-43, do not rely on your stall warning system in icing.

(3) Airplanes certified for flight in icing after 1994 have been tested for susceptibility to Ice-Contaminated Tailplane Stall (ICTS). ICTS cannot occur if AFM limitations and procedures are followed.

(4) Prior to 1973, there were no requirements to test part 23 airplanes in icing conditions. Part 23 airplanes were approved for flight in light icing conditions, and moderate icing for limited time, if they were properly equipped. Many of these airplanes remain in the fleet today. The ice protection systems on these airplanes should be considered a means to help exit icing conditions.

e. How Certification Relates to Operating Rules. Operation of an aircraft in known icing is based upon when an aircraft was built and how that aircraft was certified during manufacture. Manufacturers specify how the installed equipment in that aircraft is to be operated in the POH and AFM within certain conditions of limitation.

3-13. AIRPLANES NOT CERTIFICATED FOR ICING.

a. Ice Protection. 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. Avoidance. Airplanes not certified for icing are not tested for inadvertent icing encounters. Pilots of these airplanes must avoid icing conditions and immediately exit icing if inadvertently encountered.

(1) In recent years these airplanes have been involved in more icing accidents than icing-certified airplanes.

(2) Do not believe the myth that thicker General Aviation (GA) airfoils are tolerant of ice accretion. Research has shown that even for small amounts of ice accretion, effects not apparent while operating in the middle of the flight envelope may be noticeable when operating at the edge of the flight envelope. The most common are an increase in stall speed (with a late or no warning) or the inability to climb at altitude.

c. Inadvertent Encounter. Some GA aircraft not certificated for flight in icing conditions have ice protection systems on their wings and tailplane, providing an additional safety margin, should an inadvertent encounter with icing occur. These are intended for emergency use only.

(1) The FAA recommends that aircraft not certificated for flight in icing conditions exit icing conditions as expeditiously as possible.

(2) 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.

3-14. 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 and is highly recommended. Testing in 2005 showed that the proper application of ice adhesion inhibitors improved ice shedding at colder temperatures and a reduced amount of residual and intercycle ice. 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. Maintenance personnel should evaluate defects in the boots when they are found.

a. Preflight Inspection. Flightcrews should always examine their airplane’s anti-icing and deicing equipment as part of the normal preflight inspection. A full check of anti-icing and deicing equipment should be performed especially when flight into known or forecast icing is expected as identified in the AFM procedures.

b. Equipment Deficiencies. Flightcrews should consult the airplane’s MEL for details on what is permitted to be inoperable and what equipment deficiencies constitute no-go items.

3-15. 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, for some aircraft, 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 or unprotected protuberances visible to the crew may also serve as ice indicators. For example, windshield wipers, pod pylons, or landing lights can serve as icing references because they tend to build up ice first, or manufacturers may provide one for this purpose. These ice detectors, referred to as “ice evidence probes,” are typically in plain view of the cockpit. 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. If possible, pilots should monitor critical surfaces at temperatures near freezing, since ice may form on critical surfaces prior to forming on visual ice indicators.

3-16. VISUAL CUES 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 content rather than SLD. Excessive runback icing, however, may have effects similar to SLD, so similar pilot action may be appropriate. The cues are:

a. Wing. Ice may become visible on the upper or lower surface of the wing, aft of the active part of the deicing/anti-icing system. If the wings are visible, pilots should monitor for ice accretion aft of the protected area. Pilots should also look for irregular or jagged lines of ice or for pieces of ice shedding off the airplane. During night operations, pilots should use adequate illumination to observe all areas.

b. Propeller. 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. Windows. 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. Engine Nacelles. Ice may form on engine nacelles behind the inlet lip.

(1) Airframe. 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.

CAUTION: Pilots should be vigilant for the ice accretions listed above when the following are observed: (1) visible rain or drizzle at temperatures below +5 °C OAT, and/or (2) drops that splash or splatter on impact at temperatures below +5 °C OAT.

CAUTION: 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 4. FLIGHT PLANNING

NOTE: 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. Aviation meteorologists at the National Weather Service (NWS) Aviation Weather Center (AWC), local NWS Field Offices, major airlines, and private companies prepare icing forecasts and continue to improve upon their accuracy. A review of the current edition of AC 00-45, Aviation Weather Services, is strongly recommended as pilots will need to understand and apply Current Icing Products (CIP), Forecast Icing Products (FIP) and other services to the flight planning and operations discussed in this AC.

4-1. PREFLIGHT PLANNING INFORMATION. Information concerning icing can be obtained through several different sources. Pilot Weather Reports (PIREP) are generally the most useful as they are factual weather reports for specific times and places. Area forecasts, Airmen's Meteorological Information (AIRMET), and significant meteorological information (SIGMET) provide general information on forecasted inflight icing. Winds aloft forecasts also provide information to determine the approximate freezing level. The graphical CIP and the FIP combined with text based forecasts, provide adequate information for flight planning when icing conditions may exist.

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. Pilots can reasonably expect inflight icing when flying in clouds with temperatures at or below 0 °C (+32 °F). Forecasts, weather reports, and PIREPs of the cloud bases and tops are essential when flight planning for aircraft that have not been certified for flight in icing conditions.

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 NWS 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 a weather advisory issued only to amend the area forecast concerning weather phenomena which are of operational interest to all aircraft and potentially hazardous to aircraft having limited capability because of lack of equipment, instrumentation, or pilot qualifications. A SIGMET is a weather advisory issued concerning weather significant to the safety of all aircraft. Pilots should not rely on these alone for reasons stated before as AIRMETs for icing will not be issued unless the affected area is large, and a severe icing PIREP will not automatically result in an icing SIGMET.

- 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 4-2).
- The ADDS Web site at http://adds.aviationweather.gov/airmets provides a graphical depiction of the areas covered by AIRMETS and SIGMETS.

e. PIREPs. Pilots should consult PIREPs, since AIRMETs and SIGMETs will not necessarily be issued as previously discussed. PIREPs are of high value since they are actual weather reports at specific places and times. However, PIREPs from high-speed aircraft may not represent the actual icing conditions as the ram air temperature rise can mask the true icing conditions. The simplicity and the susceptibility to icing of the small low-speed general aviation airplanes provide the most accurate reports of inflight icing. An example that shows the importance of studying PIREPs is National Transportation Safety Board (NTSB) accident report ERA12FA115.

f. Aviation Routine Weather Reports (METAR). Pilots should be aware that surface observations not augmented by a human observer (“AUTO” in METAR) cannot report freezing rain (FZRA) or freezing drizzle (FZDZ) concurrently with other occurring precipitation. Since supercooled water drops can occur simultaneously with other reported precipitation, pilots on icing-certified airplanes should be vigilant for severe icing when approaching such an airport, particularly if “snow” or “snow and mist” are reported at temperatures slightly below or above freezing. An example that show the limitations of automated surface observations is NTSB accident report DEN05FA051.

g. Air Temperature and Pressure. Icing tends to be found in low-pressure areas and at temperatures at or around freezing. Pilots can reference the surface analysis charts to identify areas of low pressure. Freezing levels can be determined from the winds aloft forecast.

h. 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.

i. 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.

j. Snow. In flight, dry snow is unlikely to pose a hazard with respect to icing; however, wet snow may begin to adhere to aircraft surfaces. If wet 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 and declare an emergency or contact air traffic control (ATC) as necessary. Be aware that freezing drizzle can coexist 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.

k. Freezing Rain and Drizzle. If flying into an airport with no human augmentation of automated weather, be alert for severe ice accretions due to FZRA or FZDZ that would not be automatically detected, particularly if the reported temperature is near freezing and any precipitation (snow, mist, rain, drizzle) is being reported by the automated station.

l. Ice Pellets. Ice pellets by themselves are not a hazard to the airframe with respect to icing, but a ground observation of ice pellets could indicate Supercooled Large Drops (SLD) aloft.

m. 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. It is important to note that aircraft that are approved for instrument flight rules (IFR) operations but not certified for known icing conditions were not tested 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.

4-2. ICING INTENSITY. To report the intensity of icing, such as in a PIREP, the following descriptions are used (see paragraph 1-3 for complete definitions):

a. 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 ¼ inch (6 mm) per hour on the outer wing. The pilot should consider exiting the icing conditions before they become worse.

b. 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 ¼ inch to 1 inch (0.6 to 2.5 cm) per hour on the unprotected part of the outer wing. The pilot should consider exiting the condition.

c. 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 unprotected part of the outer wing. The pilot should consider exiting the condition as soon as possible.

d. 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. A representative accretion rate for reference purposes is more than 3 inches (7.5 cm) per hour on the unprotected part of the outer wing. By regulation, immediate exit is required.

4-3. PIREP CAUTIONS. Although PIREPs are excellent sources of information about in-flight icing, there are situations when these reports can be misleading.

a. No Recent PIREP. 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. No Icing Reported. An aircraft encountered icing, but the pilot did not report it. Pilot workloads might prevent a pilot from making a report, particularly when making an approach. An aircraft might also encounter icing conditions that are more serious than those are reported in any recent PIREPs in the given area. 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 slower 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, and pilots are reminded that such reporting of meteorological hazards is a regulatory requirement under 14 CFR part 91, § 91.183; part 121, § 121.561; and part 135, § 135.67. 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. Pilots are encouraged to provide in-flight icing observations as part of the weather forecasting process as often as practical. The importance of PIREPs to provide additional input into NWS forecasting products cannot be stressed enough. A report of no icing in a particular PIREP can be just as useful as those reporting ice subsequently improving the quality of CIP/FIP.

CHAPTER 5. ICING OPERATIONS

5-1. GENERAL. This chapter focuses primarily on how to safely fly an aircraft certificated for flight in icing conditions, what is expected regarding communications of 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 Airplane Flight Manual (AFM) or pilot's operating handbook (POH) for approved checklists and operations in their particular aircraft.

5-2. REGULATIONS FOR ICING OPERATIONS. 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. 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 General Aviation (GA) aircraft are found in part 91, but not all rules within part 91 are applicable to all GA aircraft. Part 91, § 91.501 states that the rules in subpart F apply only to large and turbojet-powered multiengine airplanes and fractional ownership program aircraft 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. For aircraft not covered by subpart F, there are no specific icing regulations; however, § 91.9 prohibits you from flying without complying with the operating limitations in the POH or placards. For part 121 aircraft, refer to part 121, §§ 121.341 and 121.629; for part 125 aircraft, refer to part 125, § 125.221; and for part 135 aircraft, refer to part 135, § 135.227. The operating rules have the following language on severe icing:

a. Severe Icing. No pilot may fly a nontransport category airplane type-certificated (TC) after December 31, 1964 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.

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

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

CAUTION: 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.

b. Communications with Air Traffic Control (ATC). When encountering icing, controllers will not know if an aircraft is certificated or equipped for icing, the severity of the conditions, or what anti-icing or deicing equipment is installed on the aircraft. The pilot should communicate to ATC the severity of the icing conditions, its effect on their aircraft and continued operations, whether an alteration of the current course and altitude is required, and, if necessary, if an alternate destination is needed. If an aircraft that is not certificated for flight in icing conditions inadvertently encounters ice, exit icing conditions as expeditiously as possible and declare an emergency to ATC. Inform the controller of what actions are being taken by the pilot to cope with the emergency and coordinate with ATC for additional instructions, altitudes, or headings needed to resume safe flight operations.

(1) 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 safety is compromised. In this case, it is recommended that the pilot declare an emergency and exit the conditions as soon as practical.

(2) If an aircraft certificated for flight in icing conditions encounters freezing rain or freezing drizzle, advise ATC and do not attempt sustained flight in these conditions. Final authority and responsibility for the safety of a flight rests with the pilot in command (PIC).

(3) At any time, a 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. Pilots should not accept an airspeed assigned by ATC that is inconsistent with their manuals or the airplane manufacturer recommended airspeed, or if there is no specific icing airspeed information provided in the manuals, inconsistent with 50 percent to 60 percent margin above stall speed (V_S) as recommended.

5-3. AVAILABLE IN-FLIGHT INFORMATION. Available services and products are best described in the current edition of AC 00-45, Aviation Weather Services. Brief descriptions of some of the basic services are provided below:

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 a Flight Service Station (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 automated flight service station (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.

b. Hazardous In-Flight Weather Advisory Service (HIWAS). The HIWAS provides continuous, recorded hazardous in-flight weather forecasts over selected Very High Frequency (VHF) Omnidirectional Range (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 (TWEB). The 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 includes, among other information, 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, pilots should avoid cells painted on radar 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, ice crystals that have little to no liquid water present that can be in heavy concentrations near convective weather systems.

f. Data Link/Satellite Radio. Pilots now have the option to subscribe to and receive near-real-time weather and airspace information via satellite to their panel-mounted or handheld avionics which may include free products via Flight Information Service-Broadcast (FIS-B), a component of Automatic Dependent Surveillance-Broadcast (ADS-B), transmitted to the cockpit avionics (refer to the current edition of AC 00-63, Use of Cockpit Displays of Digital Weather and Aeronautical Information, Appendix 1). These services can provide textual or graphical METARs, Terminal Area Forecasts (TAF), SIGMETs, and AIRMETs, updated pilot reports, updated winds and temperatures aloft, information about severe thunderstorms, icing levels, and graphical displays of temporary flight restrictions. Such up-to-date information can assist pilots in avoiding hazardous weather and identifying potentially hazardous areas of unforecast weather. Pilots must understand that some of the products available to them may not include pertinent icing information. Pilots are advised to verify the products they are receiving include the necessary information consistent with their aircraft capabilities and route of flight.

5-4. PREFLIGHT. The first step in preparing for any flight is to obtain a thorough weather briefing as previously discussed in Chapter 4 and 5 using products presented in AC 00-45.

a. Considerations. Operations in or around 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 for any degradation data.

(3) Determine icing exit strategies during preflight. Determine if climbing or descending will be viable options based on the planned route of flight which includes required altitudes to maintain clearance from terrain, airspace, published routes, departure procedures, arrival procedures and approaches.

(4) When choosing alternate airports, remember that if structural icing occurs, higher approach speeds and, consequently, additional runway length may be required for landing.

(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 of additional fuel needed to operate icing systems or from excess drag or weight caused by ice formation that may require extra power to maintain altitude or airspeed, 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.

b. Frost. Frost can form on an airplane sitting outside on a clear night when there is moisture present in the air as the airplane's skin temperature falls below freezing due to radiation cooling.

(1) Certain airplanes may be more vulnerable to ice formation from cold-soaked fuel than others depending on how the fuel tanks are arranged and how much fuel they contain (more information regarding icing certification and testing can be found in the current edition of AC 20-147, Turbojet, Turboprop, Turboshaft, and Turbofan Engine Induction System Icing and Ice Ingestion). Most aircraft specify allowances for the amount of frost that may be present underneath the wing. On the Ground, clear ice can form on the upper surfaces of the wing when cold-soaked fuel (due to aircraft prolonged operation at high altitude) remains in contact with the fuel tanks' upper surfaces after landing, and during time on the ground when the airplane is exposed to conditions of atmospheric moisture (for example, fog, precipitation, and condensation of humid air) at ambient temperatures above freezing. Atmospheric moisture, when in contact with cold wing surfaces, may freeze. This can even occur if conditions remain above freezing and are not expected to be, or recognized as, icing conditions.

(2) Frost, snow, or ice also can be removed with freezing-point depressant fluids. Refer to the current edition of 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 so that most of the fluid will flow off the aircraft by the time the aircraft reaches rotation speed; consequently, they provide no icing 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.

(3) 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.

(4) 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.

> **CAUTION: If undetected and still present during takeoff, ice is most likely to shed when the wings flex at takeoff rotation. Simultaneous ice shedding from both wings of an airplane with aft mounted engines has been known to result in ice ingestion damage and power loss in both engines during takeoff.**

5-5. TAXI. Always perform a pretakeoff check of the anti-ice/deice systems in accordance with the AFM or POH prior to takeoff.

a. Speed. 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. Braking. 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 runup; 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. Wheel Fairings. 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. Defroster. 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.

5-6. 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. Preparation. 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. Ice Accumulation. Airplanes are vulnerable to ice accumulation during the initial climbout in icing conditions because lower speeds often translate into a higher Angle of Attack (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. At rotation and climbout, some aircraft occasionally are susceptible to stall warning horn activation in icing. Pilot awareness of this hazard in his or her particular aircraft is important to maintain situational awareness.

c. Vigilance. 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. Monitor Airspeed. When climbing with the autopilot engaged in the vertical speed mode, ice accretion will result in a loss of climb performance. If the vertical speed is not reduced, the autopilot will maintain the rate until stall. It is critical that the pilot monitor airspeed to assure that the aircraft maintains at least the minimum flight speed for the configuration and environmental conditions.

5-7. 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 flightpath, this is certainly advisable (see Chapter 3, paragraph 3-13). During any icing encounter, the pilot should carefully monitor the behavior of the aircraft and know when to activate the airplane's anti-ice and deicing systems. Unless otherwise stated in the flight manual, the pilot should activate pneumatic boot deicing systems at the first sign of ice accretion.

a. Flight Speed. 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. However, do not exceed any maximum airspeed limitations for your airplane. An additional margin of speed should be added to maintain at least 50 percent to 60 percent above V_s in a clean configuration as a minimum (V_s x 1.5 or 1.6). Airspeed and engine power settings should be closely monitored during in-flight icing conditions, and the pilot should make certain adequate speed margins are maintained without requiring excessive power. This requires special attention on airplanes not equipped with autothrottle systems. In many icing events airspeed decreased from cruise to stall in less than 3 minutes. The pilot should treat occurrences of buffet or shudder in icing conditions as an imminent wing stall.

b. Residual or Intercycle Ice. 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. On an aircraft equipped with in-flight deicing systems, there will at all times be residual or intercycle ice on the wings.

c. Effect of Airspeed. Airspeed in cruise can have a significant effect on the nature of an icing encounter as the rate of accumulation generally increases with airspeed. However, if the airspeed is fast enough, 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.

d. Awareness. 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.

e. Autopilot. 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. When the autopilot is disconnected, pilots should be aware that additional forces may be needed to maintain the current flightpath or pitch attitude. 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 nonboosted controls, a situation may develop in which autopilot servo-control power is exceeded. The autopilot disconnects abruptly, and the pilot may be suddenly confronted by an unexpected control deflection.

f. Limitations. 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. Unless authorized in the AFM, the preferential vertical mode of the autopilot is airspeed hold, while the least desirable is vertical speed, which should not be used. Pilots should be prepared for the possibility of unusual control forces and flight control displacements when disconnecting the autopilot, especially in severe icing conditions.

g. Airspeed Monitoring. 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.

h. Weather Systems. The pilot should exercise care 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. The pilot should activate nacelle and engine anti-ice systems if the presence of ice crystals is suspected and follow the procedures outlined in the aircraft's AFM as needed.

5-8. DESCENT.

a. Speed of Descent. 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. Configuration Changes. If the pilot makes configuration changes, he or she should take into consideration any effects of icing conditions on the aircraft and make the necessary adjustments. (See the discussion in Chapter 4.)

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

5-9. HOLDING.

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

c. Configuration Changes. 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. Flaps. Consult the AFM for use of flaps. Many AFMs prohibit use of flaps for extended periods in icing conditions.

5-10. APPROACH AND LANDING.

a. Sudden Movements. 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. The pilot should deploy flaps and slats in stages, carefully noting the aircraft's behavior at each stage.

(2) For some aircraft, 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. For other aircraft, retracting the flaps or slats at this stage could lead to a stall. Therefore, configuration changes in this situation should only be performed per manufacturer guidance.

(3) Additionally, before beginning the approach, the pilot should cycle deicing boots 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. Forward Visibility. 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 or credit card).

c. Workload. 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 pilot’s operation of the airplane at a low altitude.

d. Final Phases. 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. Ice contamination may lead to wing stall, Ice-Contaminated Tailplane Stall (ICTS), or roll upset.

e. Stall and Roll. Wing stall and roll upset may occur in all phases of flight. However, available statistics indicate that ICTS rarely occurs until flaps are fully extended on susceptible airplanes. Some AFMs have a limitation on the maximum flap approved for use in icing conditions due to ICTS susceptibility, and some airplanes have been shown not to be susceptible. Airplanes certified for icing after 1994 were tested for susceptibility.

(1) If your airplane was certified for icing after 1994, adhere to AFM limitations and procedures for flap use in icing, if any.

(2) If your airplane was certified for icing prior to 1994 and it is less than 19,000 lb., consider a partial- or no-flap landing.

f. Approach Airspeed. Unless your AFM, POH, or any placard has specified an airspeed for flight in icing, increase approach airspeed by at least 25 percent above non-icing airspeed for the applicable flap setting. Follow your AFM, POH, or any placard that has limitations or procedures for reduced flaps in icing conditions. If not and your airplane weighs less than 19,000 lb., consider a reduced-flap landing if landing field distance permits. Increase your approach speed accordingly and expect an increased landing distance. Estimate that landing distance will increase 20 percent for each 10 percent increase in airspeed. If the runway is contaminated, this distance may be even greater (refer to the current edition of AC 91-79, Mitigating the Risks of a Runway Overrun Upon Landing).

g. Decrease in Lift. During the landing flare, if ice is present on the wing's leading edges, expect a loss and an unpredictable response in lift due to the added drag and contaminated airflow. Carry higher-than-normal power if there is ice on the airplane and limit the flare. Many icing accidents have been attributed to an induced stall during flare.

5-11. WING STALL.

a. Angle and Speed. 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. Landing. An increased landing speed will mean a longer landing roll. If possible, the pilot may want to consider a longer runway for increased rollout distances.

c. Ice Contamination. It has been noted that some incidents or accidents have ice contamination as a contributing or causal factor. Stall recovery training for pilots is based on recovery at the first indication of stall. Complying with the FAA template and/or manufacturer guidance for aircraft stall recovery will restore control in both pitch and roll for all aircraft. This includes recovery from possible abrupt roll-off caused by asymmetrical wing icing.

d. Uneven Accretion. As explained in Chapter 4, 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.

5-12. ICTS.

a. General. The basic aerodynamics of ICTS were described briefly in Chapter 3. ICTS occurs when a tailplane with accumulated ice is placed at a sufficiently negative AOA. There are no known incidents of ICTS in cruise (when flaps would not ordinarily be deployed) or with partial flaps. When the flaps are fully deployed, tailplane ice, which previously had little effect other than a minor contribution to drag, may now be a contributing factor to a stall event.

b. Signs of Wing Stall. 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. Since most icing accidents have been attributed to wing stall, you should always suspect a wing stall with any vibration or buffet if you have not just deployed full flaps. On airplanes certified for icing prior to 2000, you may not get stall warning, only buffet, prior to wing stall.

c. Flap Setting. Deployment of flaps permits the aircraft to be flown with wings at a less positive AOA, decreasing the probability of wing stall, but the AOA at the tailplane is more negative making it more susceptible to icing accumulation. 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 that varies by aircraft with respect to use of the flaps and to airspeed to prevent ICTS. Airplanes certified for icing after 1994 have been tested for ICTS susceptibility. On these airplanes, following AFM limitations and procedures will preclude ICTS. Some airplanes have been shown not be susceptible to ICTS and do not need reduced-flap setting.

d. Guidance. 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. 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.

e. Landing. When landing with an increased risk of a stall, the pilot should avoid uncoordinated flight such as side or forward slips 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. Landing with a tailwind component may result in more abrupt nose-down control inputs and should be avoided if possible. For some aircraft designs, if the aircraft 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 necessary for this procedure.

5-13. ROLL UPSETS.

a. Prevention. Roll upsets caused by ice accumulations forward of the ailerons are also 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 reducing the aircraft pitch. If in a turn, the pilot should roll the wings 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.

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

b. Proper Procedure. 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 6. SUMMARY

6-1. GENERAL. 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 the current editions of two other pilot guides, AC 120-58 and AC 135-17. 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.

6-2. AVOIDANCE. 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.

6-3. VIGILANCE. 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.

6-4. GUIDANCE. 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 adherence to minimum airspeeds during or after flight in icing conditions. Monitor airspeed, pitch attitude, and do not rely on the airplane’s autopilot or 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 conditions.

APPENDIX 1. RECOMMENDED READING

1. This advisory circular (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 current editions of the following U.S. Government publications:

a. Aeronautical Information Manual (AIM).

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

c. AC 00-45, Aviation Weather Services.

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

e. AC 20-73, 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 20-149, Installation Guidance for Domestic Flight Information Service-Broadcast.

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

j. AC 91-79, Mitigating the Risks of a Runway Overrun Upon Landing.

k. AC 150/5220-16, Automated Weather Observing Systems (AWOS) for Non-Federal Applications.

l. National Transportation Safety Board (NTSB) Aircraft Accident Database.

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

APPENDIX 2. 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 Airplane Flight Manual (AFM) or pilot's operating handbook (POH).

1. Piston Aircraft.

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 in accordance with the POH or AFM.

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

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

(8) In accordance with the POH or AFM, cycle any 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 revolutions per minute (rpm). A drop in rpm or manifold pressure may indicate induction ice. Apply carburetor heat or alternate air if required.

(6) If your aircraft is not certified for flight into icing conditions and icing is encountered in flight, you should exit the conditions immediately. Anti-icing systems are to be activated prior to entering icing conditions, while deicing systems are normally activated at the first sign of ice accretion. Refer to the AFM or POH for proper operation of anti-icing and deicing systems.

(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) 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) 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.

(3) After touchdown, use brakes sparingly to prevent skidding or in case of ice buildup in brakes.

2. Turbopropeller 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 in accordance with the POH or AFM.

(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) In accordance with the POH or AFM, 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) Perform regular engine power run-ups to shed accumulated ice while taxiing, per the AFM.

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

(5) 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.

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

(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) 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.

(11) 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) 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.

(4) In accordance with the POH or AFM, 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 or in case of ice buildup in brakes.

3. 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 (APU), pitot inlets, probe openings, or static ports.

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

(5) Deicing fluid fumes are a potential irritant. 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 in accordance with the POH or AFM.

(9) Ensure that heated flight information warning sensors, Angle of Attack (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) In accordance with the POH or AFM, 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 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) 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 to prevent skidding or in case of ice buildup in brakes.

Advisory Circular Feedback Form

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by contacting the General Aviation and Commercial Division (AFS-800) or the Flight Standards Directives Management Officer.

Subject: AC 91-74B, Pilot Guide: Flight in Icing Conditions

Date: ____________________

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph ____________ on page _______.

☐ Recommend paragraph _____________ on page __________ be changed as follows:

____

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☐ In a future change to this AC, please cover the following subject:
(Briefly describe what you want added.)

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☐ Other comments:

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☐ I would like to discuss the above. Please contact me.

Submitted by: ________________________________ Date: ______________________