



Aircraft Icing

Introduction

This Safety Advisor discusses:

- Icing accident statistics
- Structural ice
- Tailplane icing
- Deicing and anti-icing equipment
- Ice flying strategies and tactics
- Induction system ice

Why Ice Is Bad

Ice in flight is bad news. It destroys the smooth flow of air, increasing drag while decreasing the ability of the airfoil to create lift. The actual weight of the ice on the airplane is insignificant when compared to the airflow disruption it causes. As power is added to compensate for the additional drag and the nose is lifted to maintain altitude, the angle of attack is increased, allowing the underside of the wings and fuselage to accumulate additional ice. Ice accumulates on every exposed frontal surface of the airplane—not just on the wings, propeller, and windshield, but also on the antennas, vents, intakes, and cowlings. It builds in flight where no heat or boots can reach it. It can cause antennas to vibrate so severely that they break. In moderate to severe conditions, a light aircraft can become so iced up that continued flight is impossible. The airplane may stall at much higher speeds and lower angles of attack than normal. It can roll or pitch uncontrollably, and recovery may be impossible.

Ice can also cause engine stoppage by either icing up the carburetor or, in the case of a fuel-injected engine, blocking the engine's air source.

“When ice is encountered, immediately start working to get out of it. Unless the condition is freezing rain, or freezing drizzle, it rarely requires fast action and certainly never panic action, but it does call for positive action.”



-Capt. Robert Buck

Kinds of Ice and Their Effects on Flight

Structural ice is the stuff that sticks to the outside of the airplane. It is described as rime, clear (sometimes called glaze), or mixed.

- Rime ice has a rough, milky white appearance, and generally follows the contours of the surface closely. Much of it can be removed by deice systems or prevented by anti-ice.
- Clear (or glaze) ice is sometimes clear and smooth, but usually contains some air pockets that result in a lumpy translucent appearance. The larger the accretion, the less glaze ice conforms to the shape of the wing; the shape is often characterized by the presence of upper and lower “horns.” Clear ice is denser, harder, and sometimes more transparent than rime ice, and is generally hard to break.
- Mixed ice is a combination of rime and clear ice.

Ice can distort the flow of air over the wing, diminishing the wing's maximum lift, reducing the angle of attack for maximum lift, adversely affecting airplane handling qualities, and significantly increasing drag. **Wind tunnel and flight tests have shown that frost, snow, and ice accumulations (on the leading edge or upper surface of the wing) no thicker or rougher than**

a piece of coarse sandpaper can reduce lift by 30 percent and increase drag up to 40 percent. Larger accretions can reduce lift even more and can increase drag by 80 percent or more. Even aircraft equipped for flight into icing conditions are significantly affected by ice accumulation on the unprotected areas. A NASA study (NASA TM83564) showed that close to 30 percent of the total drag associated with an ice encounter remained after all the protected surfaces were cleared. Nonprotected surfaces may include antennas, flap hinges, control horns, fuselage frontal area, windshield wipers, wing struts, fixed landing gear, etc.

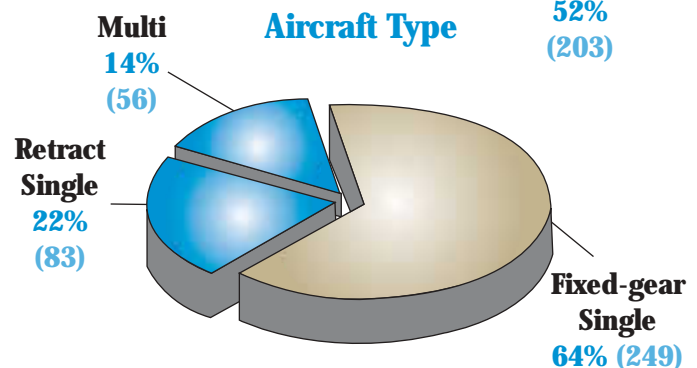
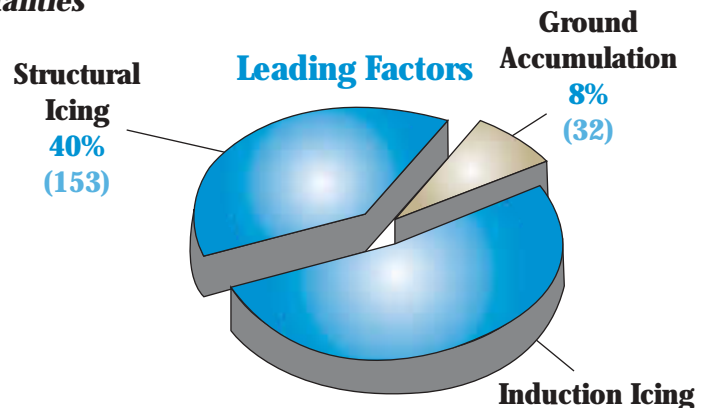
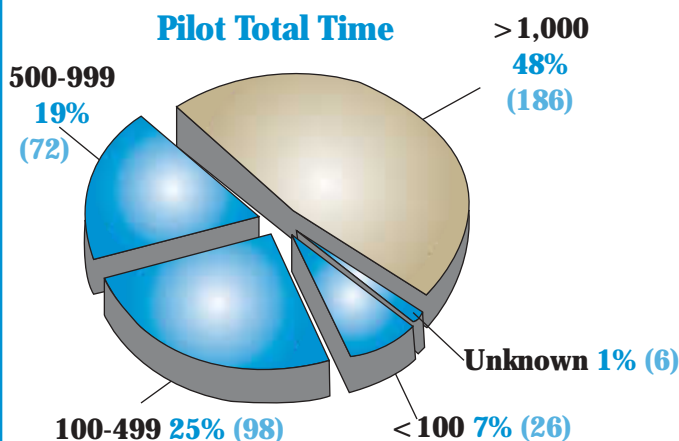
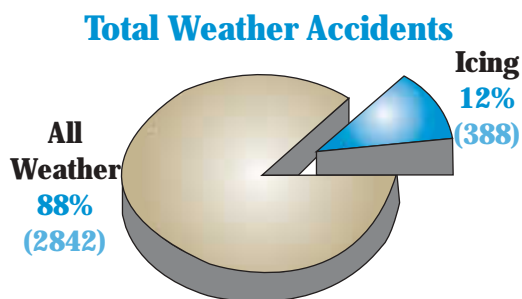
Some unwary pilots have, unfortunately, been caught by surprise with a heavy coating of ice and no plan

Icing Risk					
Cumulus Clouds		Stratiform Clouds		Rain and Drizzle	
0° to -20°C 32° to -4°F	High	0° to -15°C 32° to 5°F	High	0°C and below 32°F and below	
-20° to -40°C -4° to -40°F	Med.	-15° to -30°C 5° to -22°F	Med.		
< than -40°C < than -40°F	Low	< than -30°C < than -22°F	Low		

Icing risk

The Stats:

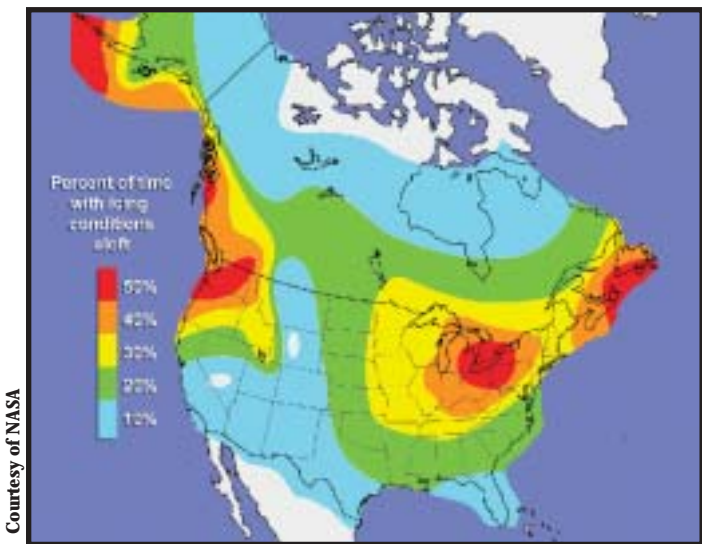
1990-2000 27% (105 accidents) involved fatalities



Source: AOPA Air Safety Foundation accident database

of action. Many pilots get a weather briefing and have little or no idea how to determine where icing may occur. However, pilots can learn enough basic meteorology to understand where ice will probably be waiting after they get their weather briefing. The pilot can then formulate an ice-avoidance flight plan before ever leaving the ground.

Ice can form on aircraft surfaces at 0 degrees Celsius (32 degrees Fahrenheit) or colder when liquid water is present. Even the best plans have some variables. Although it is fairly easy to predict where the large areas of icing potential exist, the accurate prediction of specific icing areas and altitudes poses more of a quandary. Mountains, bodies of water, wind, temperature, moisture, and atmospheric pressure all play ever-changing roles in weather-making.



Icing potential, November-March

All clouds are not alike. There are dry clouds and wet clouds. Dry clouds have relatively little moisture and, as a result, the potential for aircraft icing is low. North Dakota, because of its very cold winters, is often home to dry clouds. However, winter in the Appalachians in Pennsylvania and New York often brings a tremendous amount of moisture with the cold air and lots of wet clouds that, when temperatures are freezing or below, are loaded with ice. The Great Lakes are a great moisture source. The origin of a cold air mass is a key to how much supercooled water the clouds will carry. If the prevailing winds carry clouds over water, they will probably be wet. The chart above shows some of the areas of high icing potential. Heavy icing conditions may sometimes occur in the low-risk areas shown on the map above.

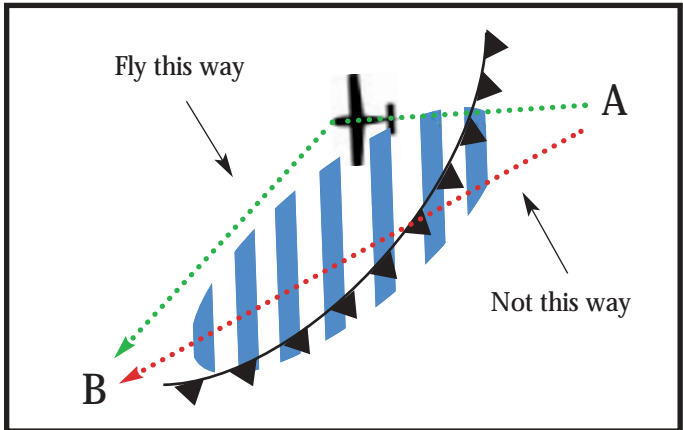
Fronts and low-pressure areas are the biggest ice producers, but isolated air mass instability with plenty of moisture can generate enough ice in clouds to make light aircraft flight inadvisable.

Freezing rain and drizzle are the ultimate enemy that can drastically roughen large surface areas or distort airfoil shapes and make flight extremely dangerous or impossible in a matter of a few minutes. Freezing rain occurs when precipitation from warmer air aloft falls through a temperature inversion into below-freezing air underneath. The larger droplets may impact and freeze behind the area protected by surface deicers.

Freezing drizzle is commonly formed when droplets collide and coalesce with other droplets. As the droplets grow in size, they begin to fall as drizzle. Both freezing rain and drizzle can fall below a cloud deck to the ground and cause ice to form on aircraft surfaces during ground operations, takeoff, and landing if the surface temperature is below freezing (Porter J. Perkins and William J. Rieke, *In-Flight Icing*. Ohio, 1999).

Along a cold front, the cold air plows under the warm air, lifting it more rapidly and resulting in the formation of moist cumulus. Along a warm front, the warmer air tends to slide over the colder air, forming stratus clouds conducive to icing. As you approach the front, the clouds build quickly and the clear air between layers rapidly disappears.

Freezing rain and freezing drizzle, including freezing drizzle aloft, are sometimes found in the vicinity of fronts. If you choose to fly through the front, be sure that it does not contain freezing rain or freezing drizzle and other hazardous weather conditions such as embedded thunderstorms. You should plan on flying



Fly the shortest route through a front

the shortest route through the front instead of flying the length of the front.

Structural Ice

How quickly a surface collects ice depends in part on its shape. Thin, modern wings will be more critical with ice on them than thick, older wing sections. The tail surfaces of an airplane will normally ice up much faster than the wing. If the tail stalls due to ice and the airflow disruption it causes, recovery is unlikely at low altitudes. Several air carrier aircraft have been lost due to tail stalls. It also happens to light aircraft but usually isn't well documented.

Since tail stall is less familiar to many pilots, it is emphasized in this advisor, but wing stall is the much more common threat, and it is very important to correctly distinguish between the two, since the required actions are roughly opposite.

Wing Stall

The wing will ordinarily stall at a lower angle of attack, and thus a higher airspeed, when contaminated with ice. Even small amounts of ice will have an effect, and if the ice is rough, it can be a large effect. Thus an increase in approach speed is advisable if ice remains on the wings. How much of an increase depends on both the aircraft type and amount of ice. Consult your AFM or POH.

Stall characteristics of an aircraft with ice-contaminated wings will be degraded, and serious roll control problems are not unusual. The ice accretion may be asymmetric between the two wings. Also, the outer part of a wing, which is ordinarily thinner and thus a better collector of ice, may stall first rather than last.

Effects of Icing on Roll Control

Ice on the wings forward of the ailerons can affect roll control. Wings on GA aircraft are designed so that stall starts near the root of the wing and progresses outward, so the stall does not interfere with roll control of the ailerons. However, the tips are usually thinner than the rest of the wing, so they are the part of the wing that most efficiently collects ice. This can lead to a partial stall of the wings at the tips, which can affect the ailerons and thus roll control.

If ice accumulates in a ridge aft of the boots but forward of the ailerons, this can affect the airflow and interfere with proper functioning of the ailerons. If aileron function is impaired due to ice, slight forward pressure on the elevator may help to reattach airflow to the aileron.

What Is a Tail Stall?

(Perkins and Reike, In-Flight Icing)

The horizontal stabilizer balances the tendency of the nose to pitch down by generating downward lift on the tail of the aircraft. When the tail stalls, this downward force is lessened or removed, and the nose of the airplane can severely pitch down. Because the tail has a smaller leading edge radius and chord length than the wings, it can collect proportionately two to three times more ice than the wings and, often, the ice accumulation is not seen by the pilot.



Normal forces — no ice



Tail stalls — loss of lift from horizontal tail

Recognizing and Recovering from a Tail Stall

You are likely experiencing a tail stall if:

- When flaps are extended to any setting, the pitch control forces become abnormal or erratic.
- There is buffet in the control column (not the airframe).

Recovery from a tail stall is exactly opposite the traditionally taught wing stall recovery. Remember, in a tail stall recovery air flow must be restored to the tail's

lower airfoil surface, and in a wing stall recovery air flow must be restored to the wing's upper airfoil surface.

Here is how to recover from a tail stall:

- Immediately raise flaps to the previous setting.
- Pull aft on the yoke. Copilot assistance may be required.
- Reduce power if altitude permits; otherwise maintain power.
- Do not increase airspeed unless it is necessary to avoid a wing stall.

Is Your Aircraft Approved?

There are two kinds of aircraft—those that are FAA approved for flight in icing conditions and those that are not. Icing approval involves a rigorous testing program, and relatively few light aircraft carry this approval. From a legal perspective, aircraft that do not have all required ice protection equipment installed and functional are prohibited from venturing into an area where icing conditions are known. There are some legal issues beyond the scope of this publication regarding what constitutes "known" ice. We will focus on the operational and safety issues. Partial equipment, such as a heated propeller or windshield, does not prepare an aircraft for flight in icing conditions; it only makes the escape a little easier.



In-flight wing leading edge ice formation

Most light aircraft have only a heated pitot tube, and without full approval for flight in icing, their cross-country capability in cooler climates during late fall, winter, and early spring is limited.

In addition to the wings, other parts of the aircraft can ice up quickly. A completely blocked pitot tube due to an inoperative heater will cause the airspeed indicator to function like an altimeter. As the aircraft climbs, so does the airspeed. As the aircraft descends, so does

the airspeed indication. A Boeing 727 crew neglected to turn on pitot anti-ice, stalled, and crashed the jet when they thought it was going into an overspeed condition because of the high indicated airspeed during climbout.

In certain icing conditions, control surfaces may bind or jam when the pilot really needs full control authority. Ice-approved aircraft have been tested with significant ice accumulations on all control surfaces to ensure no binding occurs. If you look closely at some approved aircraft, you will see space around the edges of control surfaces to allow ice to build up without interfering with their movement.

Unheated fuel vents can become blocked, which may lead to fuel starvation. Fuel tanks, especially bladder types, may collapse because air is unavailable to replace the used fuel. The engine may stop.

A number of accidents occurred when flights had successfully negotiated the en route phase and approach, but the pilot could not see ahead well enough to land through an iced-up windshield.



Mixed ice formation on wing leading edge

Invariably, the question comes up as to how much ice a particular non-approved aircraft can carry. The answer is, no one knows because it has never been tested. Without an approved icing package, you become the test pilot. We don't recommend betting your life on the local airport sage who may have been in ice a few times and is prepared to dispense all the

free advice you're willing to gamble on. You and your passengers deserve better. The best course of action is to exit the icing condition immediately.

Any guidance given on flying in icing conditions is intended for aircraft that are certified for flight in known icing conditions. Non-certified aircraft **MUST** exit icing conditions **IMMEDIATELY**.

Deicing and Anti-Icing Equipment

Many aircraft have some, but not all, the gear required for approved flight into icing conditions. In some cases, the equipment has been added as an after-market modification. Although it may give the pilot more time to escape an icing encounter, it has not been tested in the full range of conditions and, therefore, does not change the aircraft's limitation prohibiting flight into icing. Plan to avoid icing conditions, but if you experience unexpected ice buildup, use the equipment to escape—do not depend on it for prolonged periods, particularly in moderate or heavier ice.

Anti-icing is turned on before the flight enters icing conditions. Typically this includes carburetor heat, prop heat, pitot heat, fuel vent heat, windshield heat, and fluid surface deicers (in some cases).

Deicing is used after ice has built up to an appreciable amount. Typically this includes surface deice equipment.

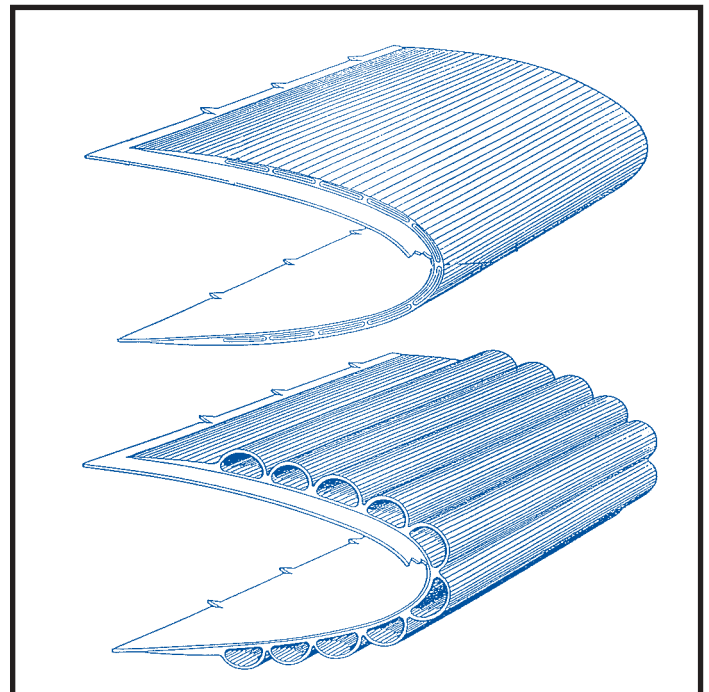
Propeller Anti-icers: Ice often forms on the propeller before it is visible on the wing. Props are treated with deicing fluid applied by slinger rings on the prop hub or with electrically heated elements on the leading edges.

Wing Deicer, and Anti-icing Systems: There is presently one type of wing deicer—boots—and two anti-icing systems—weeping wing systems (fluid deice systems) and heated wings—that are commonly used in general aviation today. For the most part, general aviation aircraft equipped to fly in icing conditions use boots and, to a lesser extent, weeping wings. Hot wings are typically found on jets and will not be discussed in this publication.



Alcohol (inset) and electrically heated prop anti-ice equipment

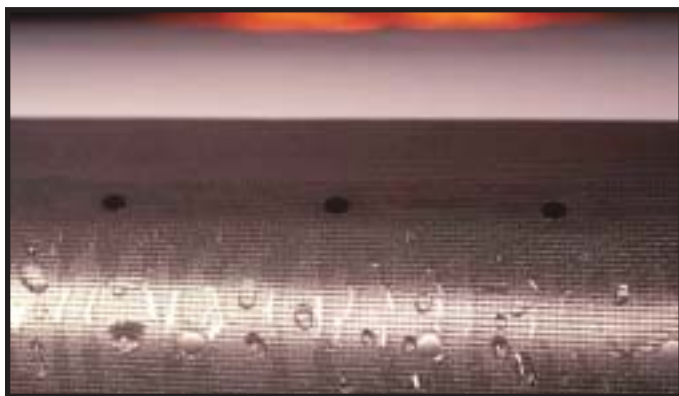
Boots are inflatable rubber strips attached to and conforming to the leading edge of the wing and tail surfaces. When activated, they are pressurized with air and they expand, breaking ice off the boot surfaces. Then suction is applied to the boots and they return to their original shape. A persistent myth holds that if the boots are cycled too soon after an icing encounter they may expand the ice layer instead of breaking it off. Then when the boots deflate, a “bridge” of ice remains that cannot be shed during the next inflation cycle. Although some residual ice may remain after a boot cycle, “bridging” does not occur with any modern boots. Pilots can cycle the boots as soon as an ice



Goodrich pneumatic boots

accumulation is observed. Consult the POH for information on the operation of boots on your aircraft.

Weeping wing deicing systems pump fluid from a reservoir through a mesh screen embedded in the leading edges of the wings and tail. Activated by a switch in the cockpit, the liquid flows all over the wing and tail surfaces, deicing as it flows. It can also be applied to the prop and windshield.



TKS patented alcohol deicer system

Windshield Anti-icers: Because being able to see for landing is critical, there are two systems used in light aircraft. An electrically heated windshield, or plate, or a fluid spray bar located just ahead of the pilot's windshield is used to prevent ice. Another method is the windshield defroster. This is never acceptable by itself



Electrically heated windshield

on approved aircraft, but for the rest of us, it's the only source of ice prevention that may keep at least a small area of the windshield clear enough to peer through during an inadvertent icing encounter.

Carburetor Heat/Alternate Air: Carburetor heat is recommended for most carbureted engines when throttling back from cruise power and may be used during

snow or rain and in clouds with near-freezing temperatures. The POH should be consulted for proper carburetor heat operation. Fuel-injected engines depend on airflow as well, and if the primary air intake ices, an alternate air door either opens automatically or is activated by the pilot to keep the engine running.

“Ice Flying”: The Strategy

Smart “ice flying” begins on the ground. For VFR flight operations, with the exceptions of freezing rain, freezing drizzle, and carburetor icing, staying clear of the clouds by a safe margin solves the icing problem. For pilots choosing to go IFR, it becomes more complicated.

Use the many resources available to you: television, the Direct User Access Terminal (DUAT) system, flight service stations, ADDS (Aviation Digital Data Service), found online at <http://adds.aviationweather.noaa.gov/>, AOPA Online, and Aviation Weather Center's current icing potential (CIP), <http://cdm.aviationweather.gov/cip/>. Continue to request pireps—and make some of your own—along your route if you suspect icing to be a potential problem.

Ask the right questions, and remember that conditions that appear to be similar to weather you've dealt with before may be much different.

Where are the fronts? Know the big picture because most ice is in fronts and low-pressure centers.

Where are the fronts moving? Where will they be when I depart and when I arrive? Check "upstream" weather reports and trends. If the destination is Cincinnati, what's the weather in Indianapolis 100 miles to the northwest? Remember that forecasts are not guarantees and plan accordingly.

Where are the cloud tops? You cannot climb through a front with tops to 30,000 feet. For most light non-turbocharged aircraft, once the tops reach 8,000 feet, climbing is no longer an option. Once on top, can you stay on top? Expect much higher clouds over mountains.

Where are the cloud bases? Below the clouds where freezing rain or freezing drizzle is not present, there will be no structural icing.

Where is the warm air? If the freezing level is high enough above the IFR minimum en route altitude (MEA), the flight may be feasible. However, air traffic control may not be able to guarantee you the MEA due to traffic or conflicts with other sectors. If it's freezing on the surface and the clouds are close to the surface and more than a few thousand feet thick, it is foolish to attempt to climb through to clear conditions on top.

Air mass clouds or frontal clouds? Know the difference between air mass clouds and frontal clouds. Frontal clouds are usually indicative of large areas of significant weather, so an aircraft flying through frontal clouds can be exposed to icing conditions for a longer period of time. Air mass clouds may have snowshowers but do not have large areas of steady snow. Unless you are flying in the mountains, steady snow or rain means significant weather is building.

With the exceptions of freezing rain and freezing drizzle, the only way to gather structural ice is in an actual cloud. Flying in snow or between cloud layers will not cause structural ice, although wet snow may adhere to the aircraft.

What alternate routes are available? Flying the flatlands with lower MEAs is likely to provide much better weather, a smoother ride, and less ice than the same trip over the mountains. Detour if necessary. Avoid flying south through a front that is 200 miles long when you could fly west and be through it in 35 miles.

What are the escape routes? At any time during a flight where structural ice is a possibility, you need an alternate plan of action. That could be a climb, descent, 180-degree turn, or immediate landing at a nearby airport. It will depend on traffic, terrain, cloud conditions, visibility, and availability of suitable airports. Quickly tell ATC you are in ice and want out. Ask for a higher or lower altitude or a 180-degree turn. If ATC won't let you climb due to traffic, let them know that you are willing to accept a climb at any heading.

What pireps are available? Pay particular attention to pireps. Because icing is forecast for extremely broad areas, pireps may be the only information you'll have as to where the ice is actually occurring. They tell you what the conditions really were at a particular time in a specific place. Think about whether those conditions are likely to be duplicated during your flight.

How will you handle it? What are your escape plans?

Pireps are individual judgment calls, so having several for the same area will usually result in a better picture. Be prepared for surprises if you rely on just one pirep. The type of aircraft making the pirep is also critical. When jets or turboprops report moderate ice or worse, that's a mandate for light aircraft to plan a different strategy immediately. Turbine-powered airplanes are equipped for flight into icing conditions and have much higher performance to punch through an icing layer quickly. A "light" ice report from turbine aircraft may mean moderate ice for you. How old is the pirep? Weather moves and changes, so a report more than 45 minutes old may be of limited use.

For more information about pireps, visit ASF's Web site to participate in the interactive SkySpotter® program, www.aopa.org/asf/skyspotter/.

The *Aeronautical Information Manual* (AIM) defines how in-flight icing should be reported when filing a pirep:

- **Trace:** Ice becomes perceptible. Rate of accumulation is slightly greater than the rate of sublimation. (Note: The FAA has proposed the elimination of this definition, since even a small accumulation may be hazardous depending on its roughness and location.)
- **Light:** The rate of accumulation may create a problem if flight is prolonged in this environment (over one hour). Occasional use of deicing/anti-icing equipment removes/prevents accumulation. It



Clear ice formation on wing leading edge

Photo credit: NASA

does not present a problem if the deicing/anti-icing equipment is used.

- Moderate: The rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or flight diversion is necessary.
- Severe: The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. An immediate flight diversion is necessary.

“Ice Flying”: The Tactics

(In-flight portions of this section are intended for aircraft that are certified for flight into known icing conditions. Non-certified aircraft must exit any icing conditions immediately.)

Preflight

Carry extra fuel. In icing conditions, extra power is needed because of increased aerodynamic drag and/or because carburetor heat is used. Fuel consumption will increase.

Other than extra fuel, keep the aircraft as light as possible. The more weight to carry, the slower the climb and the more time spent in ice.

Remove all frost, snow, or ice from the wings. There is no point in starting the day with two strikes against you. Every winter there are "frostbitten" pilots who crash as a result of guessing how much frost their aircraft will carry. A perfectly clean wing is the only safe wing. Don't count on blowing snow off when taking off. There could be some nasty sticky stuff underneath the snow. If you think it's light enough to blow off, it should be very easy to brush off before starting. Do it!



Photo Credit: FAA Aviation News

Remove all frost, snow, or ice from the wings

The propeller(s) must be dry and clean. Check the controls to be sure there is freedom of movement in all directions.

Check the landing gear (especially retractables) and clean off all accumulated slush. Wheelpants on fixed-gear aircraft should be removed in winter operations because they are slush collectors. Be sure to check wheel wells for ice accumulation. This is always a good idea after taxiing through slush.

Be sure that deice and anti-ice equipment works. When was the last time you actually checked the pitot heat for proper functioning?

Taxiing

Taxi slowly on icy taxiways. The wind may become a limiting factor because the ability to steer and counteract weathervaning tendencies is poor. Tap the brakes lightly and briefly. Hard braking pressure will lock the wheels, resulting in a skid. If the runup area is slick, it may be impossible to run the engine up without sliding. It might be better to stop on the taxiway, leave room to slide, and watch where you're going. If there is a dry patch of pavement, stop there to do the runup.

Make sure the wing tips and tail are clear of any snow piled up along the edge of the taxiways.

Departure

Know where the cloud bases and the tops are, and check for recent pireps. If you encounter icing conditions, have a plan either to return to the departure airport or climb above the ice. If you decide to return, be sure you can safely fly the approach in the existing weather conditions. In either case, advise ATC you will need clearance to proceed as soon as possible. If there is heavy traffic, there may be some delay. If you don't factor this into the plan, you are not prepared.

You may want to cycle the landing gear after take-off to help shed ice from the landing gear.

During climb, even though you are anxious to get out of icing, do not climb too steeply because ice can form on the underside of the wing behind the



Ice can cause antennas to vibrate so severely that they break

Immediate - A Word to Live By

Pilots are invariably better judges of their flight environment than controllers, but sometimes pilots have difficulty expressing their predicament to ATC. We want to exit icing conditions as soon as possible, but ATC may delay our request for any number of reasons. Now there is a way, short of declaring an emergency, for pilots to get expeditious handling. Requesting an immediate climb, descent, or turn lets the controller know that unless the request is handled quickly an emergency situation will likely develop.

boot. Remember that as the ice accumulates on the underside of the wing, drag increases, sometimes dramatically. Do not lose control of the aircraft.

En route

Make pIREPS as you go and ask for them en route. Talk to ATC and flight service about any weather developments or forecast changes. All the cautions about pIREPS mentioned earlier apply here.

Airspeed is a key to measuring ice accumulation. If normal cruise speed is 140 KIAS and you notice the airspeed has dropped to 130 KIAS, it's time to exit immediately. If you can't climb or descend, then a 180-degree turn is the only option, and that will result in a loss of at least another 10 KIAS until you're out of the ice. A 20-knot drop in airspeed is plenty. Add power to increase airspeed, since stall speed margins shrink with speed loss. Speed discipline is essential in icing conditions. The lower the performance of the aircraft, the less airspeed loss can be tolerated. Remember, an aircraft not certified for flight into icing conditions should start working to get out of those conditions at the first sign of ice.

At the first sign of ice accumulation, decide what action you need to take and advise ATC. Do you know where warmer air or a cloud-free altitude is? If you need to modify your route to avoid ice, be firm with ATC about the need to change altitude or direction as soon as possible. Don't wait until the situation deteriorates; start working with ATC early. If you need to declare an emergency to solve the problem, do it. This is a far better alternative than crashing.

If you're on top of a cloud layer and can stay on top, ask ATC for a climb well before getting into the clouds. Icing is much worse in the tops of the clouds. If you're in the clouds and the temperature is close to freezing, ask for a top report ahead. This tells you whether going up is a better option than descending. In a low-power aircraft, climbing through a 3,000-foot icing layer to get on top is chancy.

If flying around mountains, be extra cautious. The air being lifted up the mountain slopes by the wind (called orographic lifting) is known to produce moderate to severe icing conditions.



Courtesy of NASA

Be extra cautious when flying around mountains

Expect severe icing potential when flying over or when downwind of the Great Lakes and other large bodies of water. The air is extremely moist, and if the temperatures are freezing or below, the clouds can be loaded with ice.

Do not use the autopilot when in icing conditions. It masks the aerodynamic effects of the ice and may bring the aircraft into a stall or cause control problems. The situation can degrade to the point that

autopilot servo control power is exceeded, disconnecting the autopilot. The pilot is then faced with an immediate control deflection for which there was no warning or preparation.

In 1994, an ATR 72 crashed in Roselawn, Indiana, during a rapid descent after an uncommanded roll excursion while on autopilot. The airplane was in a holding pattern in freezing drizzle and was descending to a newly assigned altitude. The NTSB determined that one of the probable causes of this accident was “loss of control, attributed to a sudden and unexpected aileron hinge moment reversal that occurred after a ridge of ice accreted beyond the deice boots... Had ice accumulated on the wing leading edges so as to burden the ice protection system, or if the crew had been able to observe the ridge of ice building behind the deice boots... It is probable that the crew would have exited the conditions.” A contributing factor was the lack of information in the flight manual about autopilot operation during such conditions.

Approach and Landing

Most icing accidents occur in the approach and landing phases of flight.

If on top of ice-laden clouds, request ATC's permission to stay on top as long as possible before having to descend.

When carrying ice do not lower the flaps. The airflow change resulting from lowering the flaps may cause a tail with ice accretion to stall.

Remember the stall speed is increased when carrying a load of ice, and the stall margin is reduced when you slow to land. If the aircraft is iced up, carry extra power and speed on final approach—at least 10 to

20 knots more speed than usual. Do not use full flaps when carrying this extra speed, or a tail stall may occur. Remember, speed discipline is essential in icing conditions. Most icing accidents occur when the aircraft is maneuvering to land. Be very cautious of turns. The stall potential is high.

If you have a choice of airports, use the longest runway possible, even if it means renting a car to get home. A 3,000-foot strip is not the place to go when carrying ice, even though it might be twice the runway you normally use. Because of increased airspeed and a no-flap configuration, the landing distance will be much longer than normal. If there is ice aloft, frequently there may be ice on the runway as well, which greatly increases stopping distance.

If you are unfortunate enough to have an inadvertent icing encounter in an aircraft without windshield anti-ice, turn the defroster on high to possibly keep a portion of the windshield clear. Turn off the cabin heat if that will provide more heat to the windshield.

If the windshield is badly iced, open the side window and attempt to scrape away a small hole using an automotive windshield ice scraper, credit card, or other suitable object. You may damage the windshield, but the alternative could be much worse. Do not lose control of the aircraft when removing ice from the windshield.

Induction System Ice

Not all aircraft ice is structural; induction icing is the cause of many accidents. There are two kinds of induction system icing: carburetor icing, which affects engines with carburetors, and air intake blockage, which affects both carbureted and fuel-injected engines. Induction icing accidents top the charts as the number one cause of icing accidents, comprising a whopping 52 percent. (See chart on page 2.)

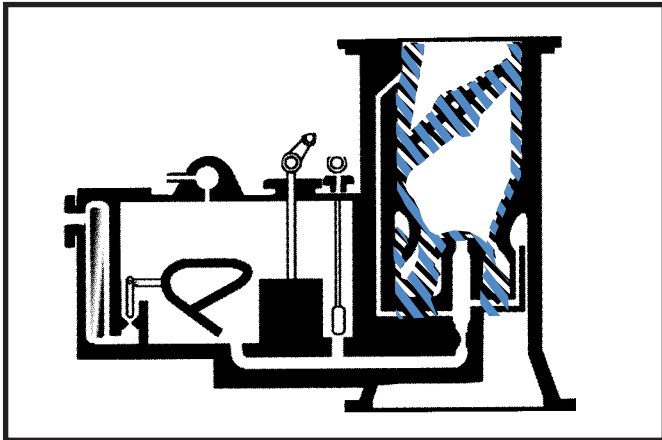
Unless preventive or corrective measures are taken, carburetor icing can cause complete power failure. In a normally aspirated engine, the carburetion process can lower the temperature of the incoming air as much as 60 degrees Fahrenheit. If the moisture content is high enough, ice will form on the



Photo credit: NASA

Glaze ice

throttle plate and venturi, gradually shutting off the supply of air to the engine. Even a small amount of carburetor ice will result in a power loss, indicated by reduced rpm with a fixed-pitch propeller and a loss of manifold pressure with a constant-speed propeller, and may make the engine run rough.



Carburetor icing

It is possible for carburetor ice to form even when the skies are clear and the outside air temperature is as high as 90 degrees Fahrenheit, if the relative humidity is 50 percent or more particularly when engine rpm is low. This is why, when flying most airplanes with carbureted engines, students are drilled to turn on the carburetor heat before making a significant power reduction. Carburetors can, however, ice up at cruise power when flying in clear air and in clouds. The envelope for the most severe buildups of carburetor ice is between 60 and 100 percent relative humidity and 20 to 70 degrees Fahrenheit.

At the first indication of carburetor ice, apply full carburetor heat and LEAVE IT ON. The engine may run rougher as the ice melts and goes through it, but it will smooth out again. When the engine runs smoothly, turn off the heat. (If you shut off the carburetor heat prematurely, the engine will build more ice—and probably quit because of air starvation.) The engine rpm should return to its original power setting. If the rpm drops again, fly with the carb heat on. Do not use partial heat.

With carburetor heat on, the hot air is less dense, so the mixture becomes richer, and as a result, the

rpm will drop a bit further. Lean the mixture, and most of the rpm loss should return. If you don't lean, fuel consumption increases. A number of fuel exhaustion accidents have resulted from miscalculations.

If carburetor heat is used for landing and you decide to go around, advance the throttle smoothly, then remove the carb heat. This will ensure all available power for takeoff.

Fuel-injected engines have no carburetor and, therefore, no carburetor ice problem. However, when conditions are favorable for structural ice, fuel-injected engines can lose power and even fail if the air filter and intake passages are blocked by ice. (This can also occur in airplanes with carburetors.) At the first sign of power loss, activate the alternate induction air door or doors. When these doors open, intake air routes through them, bypassing the ice-blocked normal induction air pathway. Many alternate induction air systems activate automatically; these designs use spring-loaded doors. Suction in an ice-blocked air intake draws these alternate air doors open. Some older fuel-injected airplanes have alternate air doors that must be manually opened. Knobs or levers have to be physically moved to the open position in order for alternate air to reach the engine. Check the POH for your airplane to find out how and when to use this system.

Note: Both carburetor heat and alternate air sources use unfiltered air. They should be closed when on the ground, unless conditions are conducive to engine icing while taxiing.

Just a Little Ice

by Jim Schlick, CFI and retired B-52 radar navigator

(The following story shows why a non-certified aircraft MUST exit icing conditions immediately if they are inadvertently encountered. The pilot delayed in exiting the icing conditions, and in just a couple of minutes disaster almost resulted.)

This story began as an attempt to get some actual IMC for an aspiring instrument pilot. He would fly; I would file IFR and instruct. We had a well-equipped C-172 with the 180-horsepower conversion avail-

able. The weather and our schedules matched on Saturday, November 8. Conditions seemed ideal. There was warm, moist air over most of Minnesota, with a southerly flow and widespread low-overcast conditions. A slow-moving cold front lay across northwestern Minnesota and was forecast to reach the St. Cloud area that evening.

We departed at 10 a.m. on a flight from St. Cloud to Duluth, planning to complete the return leg before 3 p.m. That Saturday morning, St. Cloud, Duluth, and all en route reporting stations had surface temperatures of 35 to 38 degrees Fahrenheit. Sky conditions were overcast at 600 to 1,000 feet. Visibility below the overcast was four to six miles in mist and haze. Winds aloft were out of the southwest, and forecast freezing levels were 6,000 feet. We had two pireps that indicated the cloud deck along our route was about 2,000 feet thick with no mention of icing. The only icing forecast was along the cold front in northwestern Minnesota.

We picked up an IFR clearance to 4,000 feet and departed. The instrument student climbed through the overcast at St. Cloud. Because we were IMC, we had the pitot heat on. I watched the outside temperature; it held at 35 degrees through the climb. There was moisture in the clouds; water beads were forming and rolling back off the Skyhawk's wing strut. Leveling at 4,000 put us 200 feet above the tops in brilliant sunshine. The temperature read 38 degrees.

Our clearance was St. Cloud-Mora-Duluth, and we planned to do an en route NDB approach at Mora. The NDB is on the field. The distance from St. Cloud to Mora is less than 40 nautical miles. After enjoying the sunshine for a few minutes, we requested the NDB at Mora from Center. The controller gave us 3,000 feet. As we leveled at 3,000, 15 nm southwest of Mora, we were cleared for the approach. Mora's ASOS was reporting 800 overcast, five miles in haze, and 36 degrees. Our loran was giving us distance information to the NDB.

A couple of minutes after leveling at 3,000, I noticed a trace of rime ice forming on the leading edges. I was surprised because this was not forecast, and we had climbed through the overcast 20 miles back with no problems. I was a little complacent.

Though the temperature here was 32 degrees, I knew this deck was just 2,000 feet thick, and there was warmer air above and below. I was still hoping to complete the practice approach. As we neared the NDB, still at 3,000, I realized the ice was building and that we had to leave that air mass. I told Center we were going missed approach and requested 5,000 feet direct Duluth. As soon as Center answered with the clearance, we started climbing and pulled the control for alternate static air. During this time, the rate of ice buildup increased significantly. Ice ridges formed on the windshield, and the protrusions on the leading edges grew rapidly. Then, I realized the aircraft had leveled at 3,500 feet.

The aircraft had full power, was flying at 70 knots, and was unable to climb. Incredulous, I said I would take the airplane and climb the last 300 feet to clear air. As I took the airplane, I increased the angle of attack slightly. Shortly thereafter, I began having trouble with roll control. Still IMC, the attitude indicator showed a constant left bank of 20 to 25 degrees. The rudder yawed the airplane, but would not lift the wing. Ailerons did not lift the wing. I suspected an attitude indicator failure. Then I realized the heading indicator was rotating in a constant left turn. The turn coordinator also showed a left bank. It had to be true. We were indeed flying 65 to 70 knots in a constant left bank, level at 3,500 feet, too iced up to control the bank at that airspeed. It was clear we could not climb out.

I lowered the nose and headed for the NDB. Unsure of our instruments, I asked the other pilot to continuously read out the aircraft heading from the compass while I turned to the bearings shown on the ADF and loran. I told Center we had encountered some ice and were flying the NDB 35 at Mora to a full stop. We crossed the NDB at 2,800 feet. In descending flight, we had control and the instruments worked fine. However, ice was still forming. I flew outbound for the procedure turn and let the aircraft continue to settle. When the other pilot called one minute south of the NDB, we were at 2,500 feet (300 feet below the published altitude for the procedure turn), and I noticed water streaming up the windshield. I added power, held altitude, flew a tight procedure turn, and descended to the NDB.

We broke out at 800 feet agl as expected. I gave the airplane to the other pilot, who circled the field and landed smoothly without flaps at 80 knots. While he circled, I noticed the chunks of ice being carried away by the slipstream. On the ground, we saw horn-shaped ice formations on all the leading edges. Ice covered the center of the leading edges, then ballooned into an ice ridge three times the thickness of the attached section. To me, it looked like a large, three-sided engineering ruler attached to the leading edge of the wing at one of the three points. We called Flight Service to close our flight plan and give them our icing prep.

Over a cup of coffee, we discussed the lessons learned. The time from the first trace to the decision to climb out was about five minutes. From that decision to the point where the aircraft stopped climbing was, perhaps, another four minutes. The rate of buildup was many times higher during the last minutes of the encounter. We reflected on the danger incurred when the aircraft went into an uncontrolled left bank during the attempted climbout. At that point, we both suspected instrument failure. Being IMC, it took all our combined skill to interpret the situation and realize that we had to increase airspeed, which required a descent. Without pitot heat, we would not have had the airspeed indicator. Could we have maintained control

without airspeed? How close to the stall did we get? The actual stall speed was anybody's guess. We decided the aircraft went into a bank because the ailerons lost effectiveness. With ice masking the ailerons and substantially increased drag on the wings, those control surfaces would no longer overcome the aircraft's left-turning tendencies at slow speed. The rudder was effective throughout this scenario. From practicing slow flight, we knew that at minimum controllable airspeeds, the rudder is more effective than ailerons.

It would have been a very dangerous approach if the icing conditions had continued to the surface. Throughout the scenario, it was reassuring to have the current ASOS and know we would break out in warmer air. The landing was not difficult, as we had forward visibility and a long runway to accommodate the required high-speed touchdown.

I will never again doubt that ice can form very quickly. I also know that a moderate amount of ice will prevent a small airplane from climbing and will impact slow-speed flight characteristics. I was reminded, again, that complacency is a dangerous flight mate—thinking about the warmer air above and below made me complacent enough to stay in the icing conditions until getting out required unnecessary and dangerous risks.





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