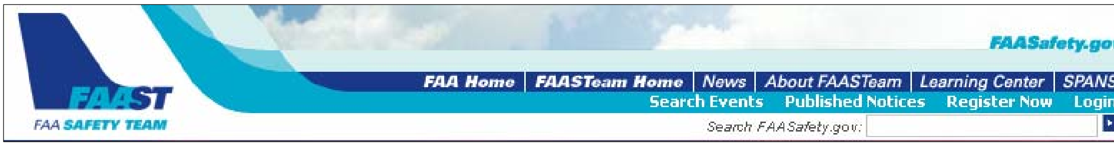


# Course Notes

# Inflight Icing

## Online Courses

## Introduction

Despite improvements in equipment and forecast technique, inflight icing is a contributing factor in accidents and incidents each year. What are the reasons for these encounters, and what can you as a pilot do to safely manage the risk associated with icing?

In this course you will learn that water does not always freeze at 32° F. or 0° C. You'll discover which temperatures are most conducive to clear, rime, and mixed icing, and how water content and droplet size relates to icing severity. You may discover that the de-ice or anti-ice equipment on your aircraft cannot always provide adequate protection. You will find tools for evaluating icing conditions before flight, and you'll have the opportunity to understand and learn how to avoid or, if necessary, recover from roll upset and tail stalls caused by structural ice.

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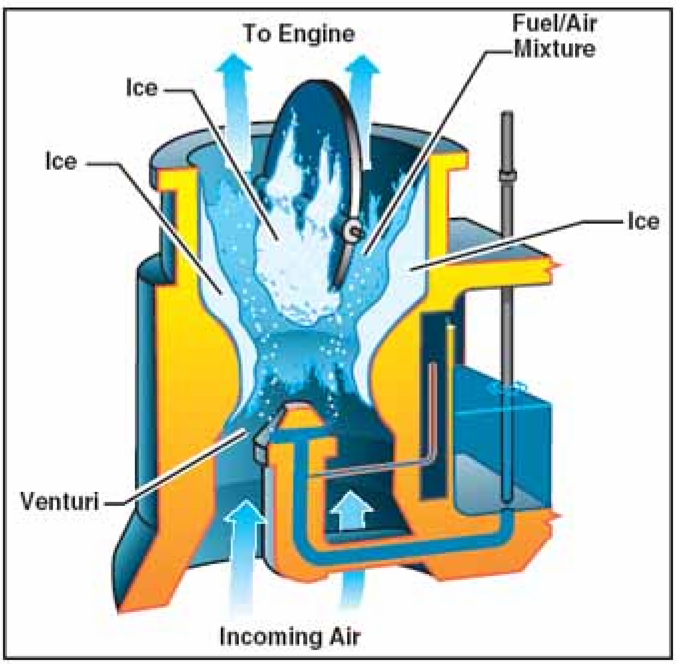
## Induction Ice

There are two major types of icing: induction and structural.

**Induction icing** consists of any ice accumulation that blocks the venturi, air filter, ducting, and/or fuel metering device. **Impact ice**, a type of induction icing, can occur anywhere that temperatures are near to, or colder than, the freezing point of 0° C. Impact ice can block the air filter and rob the engine of air needed for combustion, even on a fuel injected engine. If you suspect impact ice, activate alternate air or carburetor heat as directed by your POH/AFM.

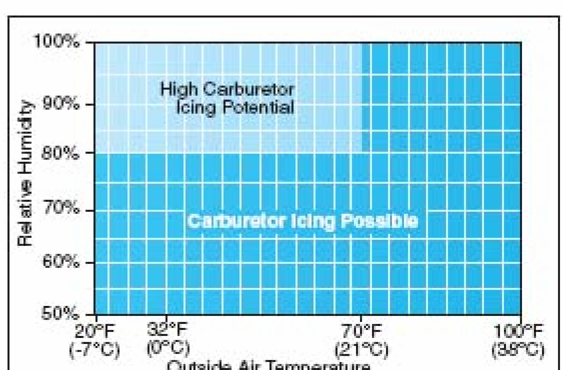



**Carburetor icing** (ice that forms in the carburetor) occurs when the drop in air pressure inside the venturi causes rapid cooling of moisture-laden air, or due to vaporization of fuel.

The resulting ice accumulation in the carburetor intake tube can greatly reduce engine performance. In severe cases, it can reduce intake flow to the point that the engine may stop.

Carb heat is both an anti-ice and a de-ice system. By pre-heating air before it enters the carburetor and preventing ice formation, it is an anti-ice system. By melting ice that has already accumulated inside the carburetor, it is a de-ice system. Remember, though, that carb heat cannot eliminate a large ice accumulation. In addition, use of carb heat results in decreased performance since the warmer air is less dense.

Carburetor icing is a deceptive hazard. Unlike impact ice, carburetor icing often occurs when outside air temperatures are well above freezing.



**Application & Risk Management**

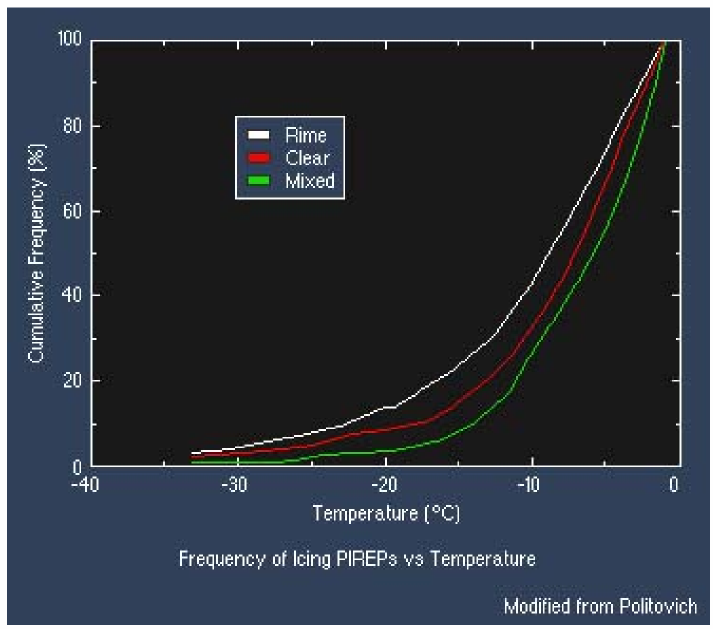
- A fuel injected engine does not prevent impact ice.
- If you suspect impact ice, activate carb heat or, for fuel injected engines, alternate air.
- Expect carb icing when relative humidity is high and temperatures are between 20°F and 70°F. Indications of carb ice include rough running engine, and loss of RPM (fixed pitch propeller) or loss of manifold pressure (constant speed propeller).
- In general, apply carb heat or alternate air immediately if you suspect carb icing. Be prepared for an initial additional decrease in engine performance as the ice melts and moves through the system.
- *Always* follow specific manufacturer's recommendations.

## Structural Ice Formation

Understanding conditions conducive to icing allows you to evaluate weather data and make a safe decision as to whether an planned flight should be made.

**Myth.** *Water always freezes at 0º C/32º F.*

**Fact.** *Moisture can exist* as a supercooled liquid until about -40° Celsius, the theoretical limit. Contaminates in the atmosphere, however, set the practical limit to approximately -20°C.




For ice to form naturally in the atmosphere, there must be either very cold temperatures or **ice nuclei** available to trigger the freezing process. Liquid cloud droplets can use natural material such as plant matter, bacteria, clay, dust or other ice structure-resembling substances as the catalyst for ice formation. Without ice nuclei, water tends to remain in the liquid state (**supercooled droplets**) -- even at temperatures below freezing.

An aircraft functions as a giant flying ice nucleus, and **structural icing** occurs when supercooled droplets come into contact with a surface (like your aircraft) at temperatures near or colder than 2 °C .

***Did you know?*** Ice nuclei are not abundantly available in the atmosphere at temperatures warmer than -20°C. However, as the temperature decreases, more ice nuclei become available to promote the freezing of cloud droplets. The limited presence of ice nuclei at temperatures warmer than -20°C. contributes to making supercooled droplets more likely at temperatures between -20° C. and 0°C.

**Application & Risk Management**

- If the aircraft surface is below freezing, ice can form even when the static air temperature is above 0°C.
  - This situation can occur on descent from subfreezing temperatures.
  - It can also occur where the local temperature is reduced to below freezing due to low pressure areas and airflow acceleration.
- Structural icing is most likely when the static air temperature is between +2° and -20°C and liquid precipitation or clouds are present.
- Temperature, moisture content, and droplet size will determine the shape and structure of the ice. The ice shape and structure in turn determine how it affects the aircraft's aerodynamic and handling (control) qualities.

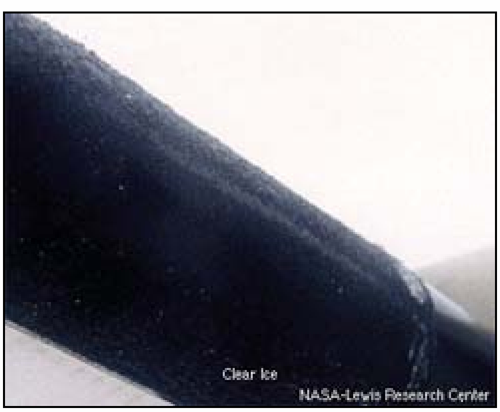
## Structural Icing Type

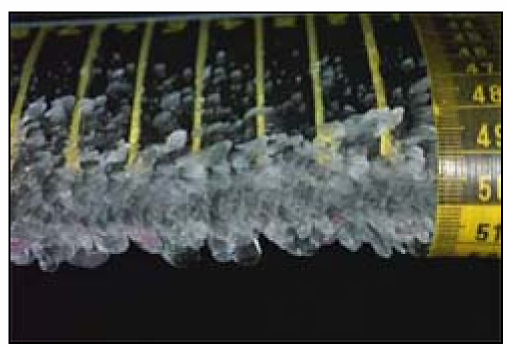
### Structural Icing Type

| Outside Air Temp. Range | Icing Type |
|---|---|
| 2 ° C to -10° C | Clear |
| -10° C to -15° C | Mixed |
| -15° C to -20 ° C | Rime |

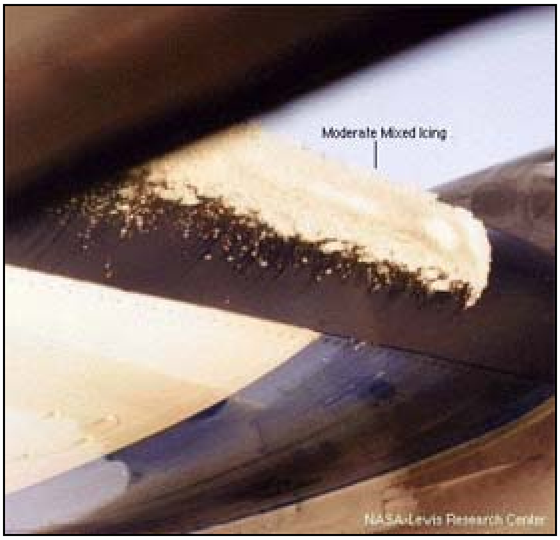
There are three types of structural icing: clear, rime, and mixed. In most cases, the type of structural ice is most dependent on the air temperature. However, the likelihood of clear ice increases with droplet size.

**Clear ice** typically forms when temperatures are around 2 ° C. to -10° C. and with the presence of large water droplets freezing drizzle, or freezing rain. Clear ice is the most dangerous type of structural ice not only because it is hard to see, but also because it can change the shape of the airfoil. In addition, clear ice often forms well beyond the ice-protected areas of the aircraft.



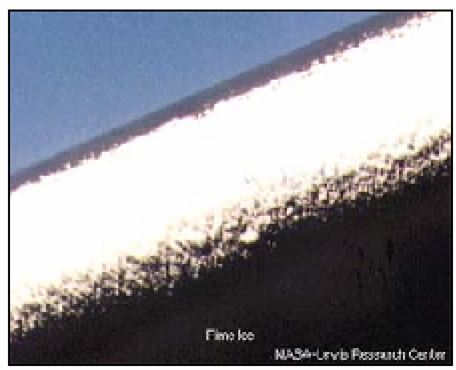




The more hazardous clear ice shapes, as in the two examples above, tend to form at temperatures closer to 0°C. In warmer temperatures, supercooled water droplets first impact a surface and then flow aft before freezing. This process often forms "horns" or other shapes that can substantially disrupt airflow over the wing.




**Mixed ice,** a combination of clear ice and rime ice that has the worst characteristics of both, can form rapidly when ice particles become embedded in clear ice and build a very rough accumulation. Mixed ice is most likely to form at temperatures between -10° C to -15° C.

**Rime ice** forms when small droplets freeze immediately on contact with the aircraft surface. It typically occurs with temperatures between -15° C. and -20 ° C. Rime ice has a milky, opaque appearance resulting from air trapped when it strikes the leading edge of an airfoil and freezes. It is less dense, and usually easier to remove than clear ice. Rime ice tends to form wedge-shaped accretions that do not disturb airflow as much as clear ice.




***Did you know?*** Any type of structural icing can block the pitot tube and static ports and cause the breakage of antennas on the aircraft. This can cause a pilot to lose or receive erroneous indications from various instruments such as the airspeed indicator and altimeter and can cause loss of communications and radio navigation capabilities.

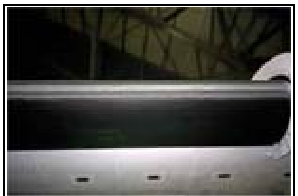
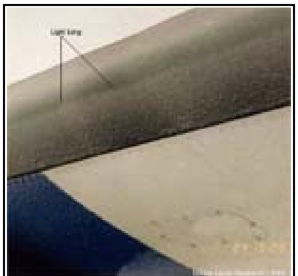
**Application & Risk Management**

- To evaluate the risk of a structural icing encounter, remember that temperature, moisture content, and droplet size determine the shape and structure of the ice.
- The ice shape and structure in turn determine how it affects the aerodynamic and handling qualities of the aircraft.

## Structural Icing Intensity

For ice to accumulate on an aircraft in flight, there must be sufficient *liquid* water in the air. Water vapor, snow, or ice will generally not stick to a flying airplane's external surfaces. The problem comes from flying through liquid, which will be visible in the form of clouds or liquid precipitation. Remember, though, that an aircraft on the ground can easily accumulate ice due to the lack of airflow over aircraft surfaces.

There are four levels of intensity for structural icing, defined primarily by the rate of accumulation.

| Intensity | Airframe Accumulation | Pilot Action |
|---|---|---|
|  Trace | Ice becomes perceptible. Rate of accumulation of ice is slightly greater than the rate of loss due to sublimation. | Unless encountered for one hour or more, deicing/anti-icing equipment and/or heading or altitude change not usually required. |
|  Light | The rate of accumulation may create a problem if flight continues in this environment for one hour or more. | Deicing/anti-icing required occasionally to prevent accumulation and/or heading or altitude change required. |
|  Moderate | The rate of accumulation is such that even short encounters become potentially hazardous. | Deicing/anti-icing required or heading or altitude change required. |
|  Severe | The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. | Immediate heading or altitude change required. |

When flying in clouds, remember that the greater the liquid water content of the cloud, the more rapidly ice accumulates on aircraft surfaces. Theoretically, the amount of water in the air is measured in mass of water per volume of air, $g/m^3$ and can also affect the ice shape. However, droplet size is a major factor in determining icing intensity: large droplets can quickly lead to severe icing.

***Did you know?*** The most hazardous aspect of structural icing is its aerodynamic effects. Ice can:

- Alter the shape of an airfoil, causing the aircraft to stall at a significantly higher airspeed.
- Reduce the amount of lift that an airfoil produces and increase drag.
- Block or limit control surfaces, making control inputs less effective.

Learning Center Courses

# Inflight Icing

Course Chapters: Intro | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Review | Preview Exam

## Icing Certification

For aircraft type certification with respect to ice protection, an aircraft manufacturer must meet either the requirements of 14 CFR 23.1419, or 14 CFR 25.1419. These rules require the manufacturer to demonstrate that the aircraft is "able to operate safely" while accumulating ice within two operational envelopes:

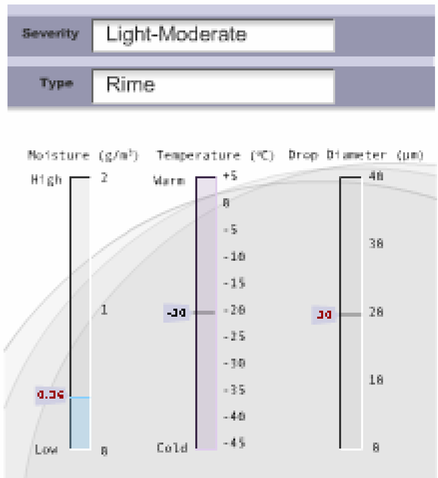

**Continuous maximum** : Intended to represent icing typical to stratus clouds with amounts of liquid water between 0.2-0.8 g/m³ and droplet sizes 15-40 microns in diameter over a 17.4 nm encounter.

**Intermittent maximum** : Intended to represent icing typical of isolated cumulus clouds with amounts of liquid water ranging between 1.1-2.9 g/m³ and droplet sizes 15-50 microns in diameter over a 2.6 nm encounter.

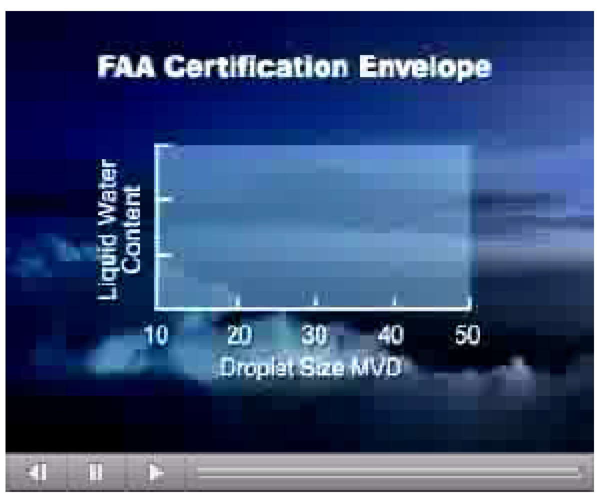
It is important to understand that an airplane equipped with some types of de-ice and/ or anti-ice systems may still not be approved for flight into known icing conditions. For example, some have partial installations of de-icing and/or anti-icing equipment that do not meet the certification or the regulatory requirements for flight into icing conditions. In such cases, the AFM or other approved material must explain the operating procedures for approved use of the partial de-icing and/or anti-icing equipment. It must also contain a clear statement that the aircraft is not approved for flight into known icing conditions.

Freezing drizzle and freezing rain are outside the FAA certification requirements,so remember that even when an aircraft is approved for flight into known icing, that **does not include**freezing rain or freezing drizzle, or conditions with a mixture of supercooled droplets and snow or ice particles.

**Flash Certification**
This animation depicts icing certification limits based on the median volumetric diameter of the liquid water droplets and liquid water content.




**Flash Experiment with Icing Type and Intensity**
Use this animation to see how liquid water content, temperature, and drop diameter influence the type and intensity of structural icing.

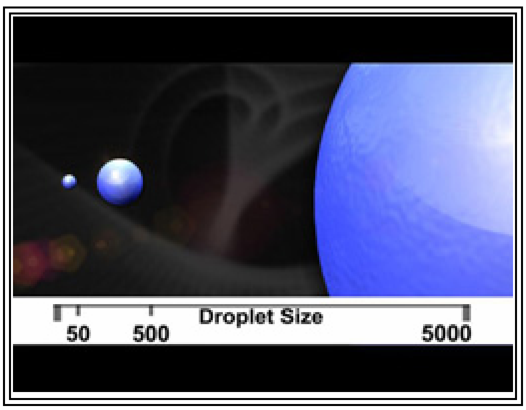



***Did you know?*** The icing envelopes developed in the 1940s by NACA (NASA's predecessor) were intended to cover most naturally-occurring conditions. We have learned, however, that it is possible to encounter clouds with that have significantly greater amounts of liquid water or larger droplet sizes, and that cover larger areas. Several accidents in recent years are thought to have occured after encounters with conditions that exceed the "standard" envelopes.

## Supercooled Large Droplets (SLD)

Most icing encounters involve droplets about the size of a thin human hair -- defined in formal terms as a "median volumetric diameter" (MVD) between 15 and 50 microns). An aircraft certificated for flight into known icing can handle flight in stratus-type clouds with droplet MVDs up to 40 micrometers, and flight in cumulus clouds with droplet MVDs up to 50 micrometers.

Supercooled Large Droplets (SLD) can be up to 100 times larger, and their mass is so great that they can strike well behind the protected areas of an aircraft. Despite icing certification limitations, accidents and incidents in SLD conditions have been documented, especially following sustained flight in freezing drizzle or freezing rain.




Larger droplets have greater inertia, and are less influenced by the airflow around the aircraft. As a result, larger droplets adhere to more of the aircraft surface, and are more likely to move behind ice protected surfaces ("flowback").

**To detect SLD, look for:**

1. Visible ice behind the active part of the de-icing boots.
2. Granular dispersed ice crystals, or total translucent or opaque coverage of the unheated portions of the front or side windows.
3. Unusually extensive coverage of ice, visible ice fingers, or ice feathers on parts of the airframe not normally covered by ice.

**Additional SLD cues when temperatures are near freezing:**

1. Visible rain with very large water droplets.
2. Droplets splashing or splattering on impact with the windshield. (*Note: Droplets covered by icing certification envelopes are so small that they are usually below the threshold of detectability.*)
3. Water droplets or rivulets streaming on heated or unheated windows. (*Note: Droplets or rivulets are an indication of high liquid water content*).
4. Weather radar returns showing precipitation.

**Actions when encountering to SLD conditions:**

1. Disengage the autopilot, which can mask important cues or abruptly disconnect and present unusual attitudes or control conditions.
2. Keep control inputs as smooth and small as possible.
3. Advise ATC and promptly exit the condition. Find an area above freezing, substantially colder than the current temperature, or clear of clouds.
4. Avoid rapid descents close to the ground.
5. When icing conditions exist, help other pilots by submitting a PIREP.

**Flash Droplet Size**
This animation shows the relative size of droplets used for icing certification, as compared with the significantly larger supercooled large droplets.

## Weather Forces that Produce Icing

How do you determine whether conditions along any part of your planned route are likely to produce icing encounters? You need to know:

Where is temperature and moisture content conducive to icing?

- If the air is unstable or there are fronts or mountains that can lift it, the risk of inflight icing can be high.

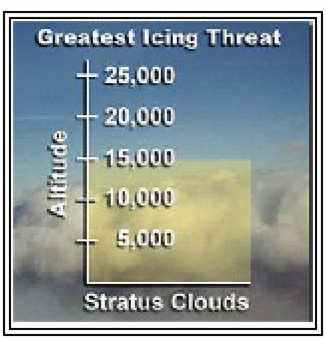
Where are the cloud tops and bases, relative to both the freezing level and underlying terrain.

- This information will help you make a plan to minimize risk of exposure to icing, and to exit unexpected icing quickly.

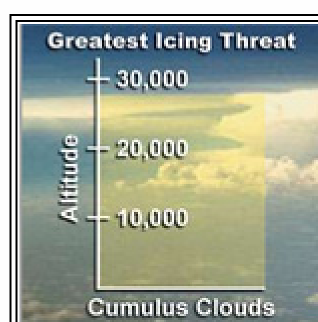
On a broader level, understanding how cloud formations, geography, seasons, and fronts affect icing encounter will help you manage these risks.

**Cloud formations**

Cloud type provides important information regarding the stability of the air mass and the type and severity of the icing threat.




**Stratus clouds** develop into fairly uniform horizontal layers. They typically contain lower amounts of liquid water than cumulus clouds, but can still contain significant amounts of liquid water. Thickness can go to several thousands of feet; however, the vertical exent of an icing layer in a stratus cloud usually does not exceed 3,000 feet. Icing in stratiform clouds is usually found in the higher temperature mid-to low-level clouds below 15,000 feet AGL.

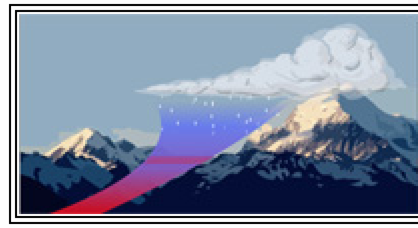



**Cumulus clouds** are formed when ample moisture exists and the airmass is unstable. Cumulus clouds not associated with convective activity usually have limited horizontal extent (2-6nm), but vertical development can cause the range of icing to cover many thousands of feet.

Cumulus clouds develop rapidly and often contain high amounts of liquid water and larger droplet sizes. Icing is most intense in the updrafts that have high liquid water content, which sometimes support SLD. Icing in cumulus clouds is usually found below 27,000 feet at temperatures between +2° and -20°C. Icing encounters in these clouds are usually short in duration, but they may be severe in intensity.

## Application & Risk Management

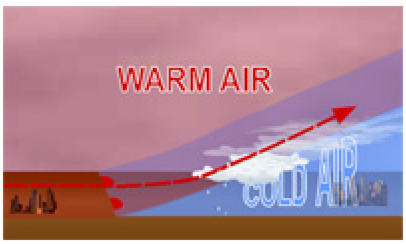
- *Icing in status clouds*: Immediately activate ice protection systems. Monitor closely, and change altitude by at least 3,000 feet to avoid prolonged icing exposure.
- *Icing in cumulus clouds*: If the temperature is conducive to icing, attempt to maintain visual separation from the clouds.
- Consider cues from geography of the intended route of flight:
  - Icing risk can increase near large bodies of water, since moisture added to overlying air masses increases water content.
  - Air flowing over a mountain range can produce serious icing hazards, especially along the windward side of a major range.
- Always consider routes or altitudes that limit your risk of an icing encounter. For example, remember that mountainous terrain also limits escape options.



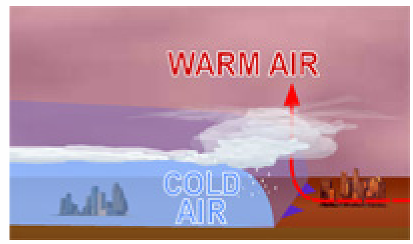
***Did you know?*** Icing is not limited to winter months. In summer, air masses tend to be warmer and can contain larger amounts of water vapor. Warmer surface temps can lead to instability and stronger convective updrafts.

## Fronts

Areas near fronts can be conducive to icing due to moisture and enhanced lifting.



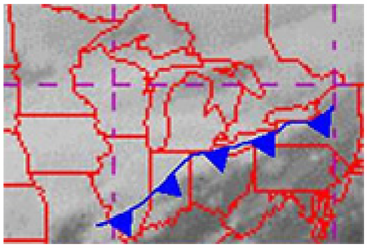

A **warm front** forms when warm air slides gradually over a cooler air mass.



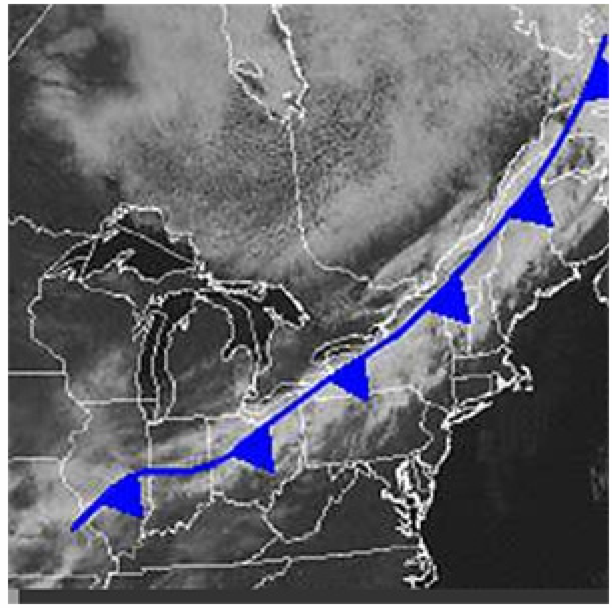

A **cold front** forms when colder air undercuts warmer air. There are two types of cold fronts.

In the vicinity of a **warm front**, stratus cloud formations hundreds of miles ahead of the front are often apparent. During colder months, warm fronts can be very dangerous: warmer air rising over a layer of subfreezing air can produce freezing rain or freezing drizzle. The icing environment in a warm front could be 10,000 feet thick or more, although a 3,000 foot change of altitude will usually take you out of these conditions. Given their wide extent, lateral deviations are not practical with warm fronts.

You should be aware of two types of **cold fronts** and their associated hazards.



**Shallow cold fronts** are typically associated with the cold season. Widespread stratus behind the front can cover several states, but they are capped by a temperature inversion and typically not very deep - usually less than 5,000 feet.



The **classic cold front** is characterized by extensive cumulus cloud development which often straddles the front and is typically associated with the warm season. Intense lifting by the front usually limits the cloud development to narrow bands of clouds tens of miles wide near the surface location of the front. These convective clouds can develop into full blown thunderstorms with heavy precipitation, turbulence, hail, and high levels of supercooled liquid water.

**Application & Risk Management**

- Fly perpendicular to the direction of frontal movement, and/or fly behind it.
- Use standard thunderstorm avoidance techniques to avoid classic cold front icing.
- Do not rely solely on weather radar - cells not yet visible on radar can produce substantial icing.
- Along a shallow cold front, change altitude by at least 3,000 feet if you encounter icing.

***Did you know?*** The risk of having a severe icing encounter in freezing rain or freezing drizzle is higher in the vicinity of a warm or occluded front, which can occur when a warm air mass is trapped between two colder air masses. Occluded fronts may combine the characteristics of both warm and cold fronts. In either case, warmer air rising over a layer of subfreezing air may result in the formation of freezing rain or freezing drizzle.

## *Preflight Planning*

### Personal Minimums

This chapter provides tips on developing a plan to avoid icing, as well as a strategy to exit an unexpected icing encounter.

First, you must be familiar with your aircraft, its systems, and understand its capabilities and limitations. You also need to know your own personal limitations. For tips on developing your individual personal minimums, download the article and worksheet below.

| ***Related Media for this Section*** |
|---|
| **Developing Personal Minimums**<br>Developing Personal Minimums.pdf (1.15 MB) |

### Weather Resources

Second, you need weather information to develop a flight plan that will minimize risk of an icing encounter. It should include:

- Alternate routes and altitudes, as well as alternate airports.
- Consideration of MEAs, MOCAs, etc.
- Escape routes (i.e., know how to exit icing at any point on your route).

Be familiar with current and forecast weather along your intended and alternate routes. In addition to getting a standard weather briefing from flight service or DUATS, check resources such as www.aviationweather.gov, and ADDS to supplement and prepare for the briefing. For example:

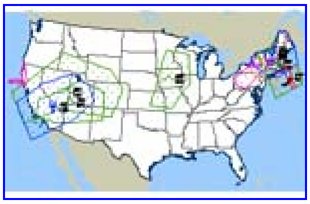
Aviation Weather Center **Area Forecast**

The Area Forecast is the primary source of cloud type (cumulus or stratus) and height information for the en route part of the flight.


From the area forecast, you can determine location of fronts and where there is likely to be visible moisture in the form of clouds or precipitation.

The synopsis includes location and movement of pressure systems, fronts, and other weather patterns over a large area.

The risk of an icing encounter is greatest near relatively cold, moist air when there is a front or other source of lifting (mountains).

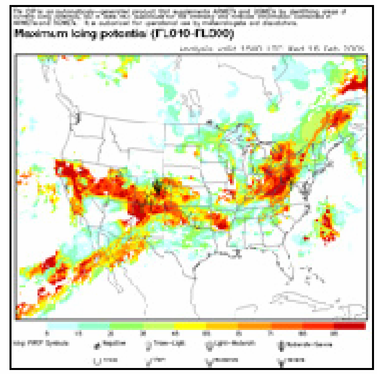


Aviation Weather Center **AIRMETS and SIGMETS**

Icing is directly forecast in AIRMET ZULU, SIGMETS, & Center Weather Advisories. Remember that icing is assumed in Convective Sigmet Areas.

Aviation Weather Center **Current Icing Potential** (CIP) and **Forecast Icing Potential** (FIP)

The CIP display shows expected potential for icing, but does not yet show severity. This tool can give you icing potential information for particular altitudes and geographic locations, but should be used as a supplement to your official weather briefing.



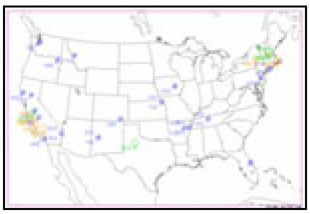

Both composite and constant altitude displays are available. Try the composite display first to see if your flight takes you through a geographic location where there is a potential for ice. Then use the constant altitude display to see if there is an acceptable altitude range with a lower icing potential.

The CIP also provides constant altitude and composite displays of the expected current potential for Supercooled Large Droplets.

***Did you know?*** You should not rely exclusively upon on AIRMETs and SIGMETs to effectively assess the risk of icing. If the forecast conditions are not expected to affect an area of at least 3,000 square miles, an AIRMET or SIGMET may not be issued. AIRMETs and SIGMETs are not always issued for local occurrences.

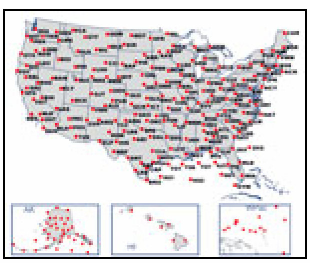
## Weather...continued

Aviation Weather Center **PIREPS**



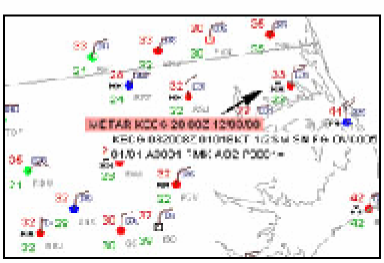
Remember that the severity of an icing encounter depends in part on the aircraft. Slower aircraft take longer to transit icing areas, and are exposed to potential hazards for longer periods of time. The pilot of a piston single might encounter moderate or greater icing, while the twin turboprop aircraft might report light icing. A regional jet might accumulate very little ice. Be sure and consider the type of aircraft in the report. Be sure to report conditions of icing and non-icing conditions.

Aviation Weather Center **Winds/Temperatures Aloft**



While checking winds aloft for fuel burn, examine temperatures aloft. Since inflight icing is most likely to occur between +2° and -20°C, you will generally want to know at which altitudes you will find air temperatures outside this range.

**Check the TAFs and METARs** available from the Aviation Weather Center



One way to exit icing conditions is to descend below the cloud bases. Consult TAFs for airports along your route to obtain cloud base and surface precipitation forecasts, so you can determine possible exit strategies. The TAF and METAR JAVA tools are a great way to get a quick, graphical depiction of conditions along the route for many airports.

Use METARs to confirm and pinpoint actual surface location conditions, as well as to identify reports of freezing precipitation, or frozen precipitation such as ice pellets at the surface (which indicate freezing precipitation aloft). ***WARNING:*** Some automated stations have limited precipitation reporting capabilities, or do not report precipitation at all. None are capable of reporting freezing drizzle without human help.

***Did you know?*** There is currently no validated technology for remotely observing icing from the ground or space. Pilots are the only ones who can make direct observations of icing. The absence of a PIREP confirming icing conditions is not proof of the lack of icing. You should not rely entirely on PIREPs to identify known icing conditions. Likewise, hearing several reports of light rime icing is not a guarantee that your aircraft will experience the same type and intensity of icing.

## Additional Resources

For additional tips on weather, download the document below, or click here for an online version of the General Aviation Pilot's Weather Decision-Making Guide.

| *Related Media for this Section* |
| --- |
| **General Aviation Pilot's Weather Decision-Making Guide**<br>GA Weather Decision-Making Aug06.pdf (934.06 KB) |

## Preflight Inspection

Flight into icing is neither safe nor legal unless the aircraft's ice protection system is functioning properly. Properly check all components prior to flight in accordance with Airplane Flight Manual or Pilot's Operating Handbook specifications.

## Roll Upset

Most pilots have experience with recovering from aerodynamic stalls with clean wings, but the aircraft may stall very differently with ice on the wings. Aggressive actions may be needed to break an ice-induced wing stall.

Another hazard of structural icing is **roll upset**, an uncommanded roll phenomenon associated with severe inflight icing. Roll upset can result from severe icing conditions, and occur without the usual symptoms of ice accumulation or aerodynamic stall.

Wing stalls typically occur following a speed reduction or premature flap retraction.

**Recovery from Uncommanded Roll or Wing Stall:**

1. Immediately reduce the angle of attack, lower the nose (Be prepared for more aggressive pitch and greater loss of altitude than during training for clean wing stalls)
2. Add power

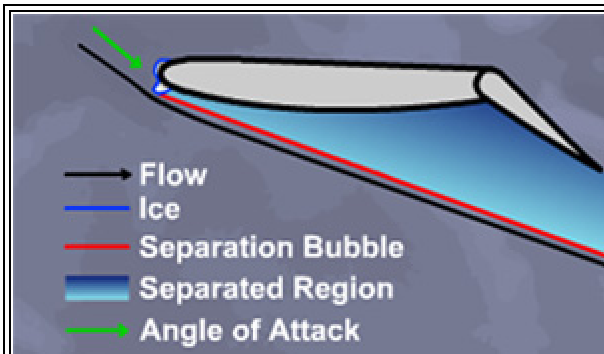
**Tail Stall**

Another hazard of structural icing is the **tailplane (empennage) stall**. Sharp-edged surfaces are more susceptible to collecting ice than large blunt surfaces. For this reason, the tailplane may accumulate ice before the wings, and may accumulate ice faster.

Because you cannot readily see the tail, you may be unaware of the situation until the stall occurs. Few pilots have any experience recovering from tail stalls.

**Tailplane Stall Symptoms**

Tail stalls usually occur during an approach when flaps are at full extension and/or the aircraft is being flown near the upper speed limit for flap extension. There may be few or no symptoms prior to flap extension. Symptoms include:




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

- Abnormal elevator authority, vibrations, and or/effectiveness.
- Sudden uncommanded nose down pitch
- Autopilot performing excessive pitch trimming.

### Recovery from Tail Stall

To recover from a tail stall, you must take actions that are almost completely opposite from those required to recover from a wing stall. If flaps are extended and you experience lightening of the controls, difficulty trimming, or buffet in the control column, immediately retract the flaps and maintain or reduce thrust -- in other words, undo what you just did.

- Pull yoke back (opposite to action for a wing stall recovery). This reduces angle of attack of the tailplane and moves it away from the critical angle.
- Retract flaps.
- Maintain or reduce thrust.

## Additional Resources

- Advisory Circular 91-51A - Effect of Icing on Aircraft Control and Airplane Deice and Anti-ice Systems Appendix 1-Roll Upset and Appendix 2 Tailplane Stall (PDF)
- NASA's Ground and Inflight Icing Courses

***Related Media for this Section***

**Course Notes - Icing**
Course Notes - Icing.pdf (2.11 MB)

## Review

### Chapter 1 - Induction Ice

Induction icing consists of any ice accumulation that blocks the venturi, air filter, ducting, and/or fuel metering device. Impact ice, a type of induction ice, can occur anywhere that temperatures are near or colder than the freezing point of 0° C. Impact ice can block the air filter and rob the engine of air needed for combustion, even on a fuel injected engine. If you suspect impact ice, activate alternate air or carburetor heat as directed by your POH/AFM.

Carburetor icing occurs when ice forms within an engine's carburetor. Rapid cooling of air caused by the drop in air pressure inside the venturi and also due to the vaporization of fuel can induce freezing and ice accumulation within the carburetor intake tube. If you suspect carburetor ice, immediately apply alternate air or carb heat and leave it on until all ice has been removed. Be prepared for an initial further decrease in engine performance after carb heat is applied. Always follow specific manufacturer recommendations.

### Chapter 2 - Structural Ice

Moisture can exist as a supercooled liquid until about -40° Celsius, the theoretical limit. Contaminates in the atmosphere, however, set the practical limit to approximately -20°C. For ice to form naturally in the atmosphere, either very cold temperatures must exist or ice nuclei must be available to trigger the freezing process. Structural icing is most likely when the static air temperature is between +2° and -20°C and liquid precipitation or clouds are present.

### Chapter 3 - Type

There are three types of structural icing:

**Clear ice** typically forms when temperatures are around 2 °C. to -10° C. and water droplets are large, or freezing drizzle or freezing rain is present. Clear ice is the most dangerous type of ice since it is hard to see, can change the shape of the airfoil, and often forms well beyond the ice-protected areas of the aircraft.

**Rime ice** forms if the droplets are small and freeze immediately when contacting the aircraft surface, typically when temperatures are between -15° C. to -20 ° C. Rime ice has a milky, opaque appearance.

**Mixed ice** is a combination of clear ice and rime ice. with the worst characteristics of both. It can form rapidly when ice particles become embedded in clear ice, building a very rough accumulation. It is most likely to form at temperatures between -10° C to -15° C.

**Chapter 4 - Intensity**

There are three levels of intensity for structural icing, based primarily on the rate of accumulation. The greater the liquid water content of the cloud, the more rapidly ice accumulates on aircraft surfaces. Theoretically, the amount of water in the air is measured in mass of water per volume of air, $g/m^3$ and can also affect the ice shape. However, droplet size is a major factor in determing the level of icing intensity. Large droplets can quickly lead to severe icing.

**Chapter 5 - Certification**

With regard to ice protection, an aircraft manufacturer must demonstrate that the aircraft is "able to operate safely" while accumulating ice within two operational envelopes. *Continuous maximum* is intended to represent icing typical to stratus clouds with amounts of liquid water between 0.2-0.8 $g/m^3$ and droplet sizes 15-40 microns in diameter over a 17.4 nm encounter. *Intermittent maximum* is intended to represent icing typical to isolated cumulus clouds with amounts of liquid water ranging between 1.1-2.9 $g/m^3$ and droplet sizes 15-50 microns in diameter over a 2.6 nm encounter.

An airplane equipped with some types of deice and/ or anti-ice systems may not be approved for flight into known icing conditions. Also, it is possible to encounter clouds that have significantly greater amounts of liquid water, larger droplet sizes, and cover larger areas than used for certification purposes. Several accidents in recent years are presumed to have occured after encounters with conditions that exceed these envelopes.

**Chapter 6 - Supercooled Large Droplets**

Most icing encounters involve droplets of a median volumetric diameter (MVD) between 15 and 50 microns (about the size of a thin human hair). An icing-certificated aircraft is certificated for flight in stratus-type clouds with MVDs up to 40 micrometers and for cumulus-type clouds with MVDs up to 50 micrometers. Supercooled Large Droplets (SLD) can be up to 100 times larger. The mass of these large droplets is so great that they can strike well aft of the protected regions of an ice protected aircraft. These droplets are, by definition, larger than those for which any aircraft is certificated, and accidents and incidents have occurred following sustained flight in freezing drizzle or freezing rain.

**Chapter 7 - Weather Forces that Produce Icing**

To determine if conditions along any portion of the planned route of flight are likely to produce serious icing encounters, know where the temperature range and the moisture content of the air is conducive to icing. If the air is unstable or there are fronts or mountains that can lift it, the risk of inflight icing can be high.

If you encounter icing in stratiform clouds, immediately activate the ice protection system. Monitor the situation. Change your altitude by at least 3,000 feet as flight at a constant altitude may result in prolonged icing exposure.

If the temperature is prime for icing conditions and you can maintain visual separation, navigate laterally around cumulus clouds.

The geography near the intended route of flight provides important cues to icing threat.

**Chapter 8 - Fronts**

The areas near fronts can be conducive to icing due to the enhanced lifting and moisture that may be present. In the vicinity of a warm front, stratus cloud formations hundreds of miles ahead of the front are often apparent. During colder months, warm fronts can be very dangerous. Warmer air rising over a layer of subfreezing air may result in the formation of freezing rain or freezing drizzle.

Shallow cold fronts are typically associated with the cold season. Widespread stratus behind the front can cover several states, but they are capped by a temperature inversion and typically not very deep - usually less than 5,000 feet. The classic cold front is characterized by extensive cumulus cloud development which often straddles the front and is typically associated with the warm season. Intense lifting by the front usually limits the cloud development to narrow bands of clouds tens of miles wide near the surface location of the front. These convective clouds can develop into full blown thunderstorms with heavy precipitation, turbulence, hail, and high levels of supercooled liquid water.

**Chapter 9 - Preflight Brief**

Be familiar with current and forecast weather along your route and along your alternate routes. Always obtain a standard weather briefing from flight service or DUATS, but utilize other resources such as www.aviationweather.gov, and ADDS to supplement and prepare for the brief. Checks should also include Area Forecasts, AIRMETS, SIGMETS, and CIP/FIP products.

**Chapter 10 - Briefing Continued**

Check PIREPS, winds aloft, as well as METARs and TAFs for your routes. Build or revise a flight plan that will minimize the risk you will have a serious icing encounter. Have alternate routes and altitudes, as well as alternate airports. Consider MEAs, MOCAs, etc in your planning and have an escape route. Know how you would exit icing.

Flight into icing is neither safe nor legal unless the aircraft's ice protection system is functioning properly. Properly check all components prior to flight in accordance with Airplane Flight Manual or Pilot's Operating Handbook specifications.

**Chapter 11 - Roll Upset & Tail Stall**

Wing stalls typically occur following a speed reduction or premature flap retraction. To recover from a roll upset or wing stall, immediately reduce the angle of attack and add power.

Tail stalls usually occur during an approach when flaps ar at full extension and/or the aircraft is being flown near the upper speed limit for flap extension. There may be few or no symptoms prior to flap extension, but they can include abnormal elevator authority, vibrations, and or/effectiveness, sudden uncommanded nose down pitch and/or autopilot performing excessive pitch trimming.

To recover from a tail stall, you must take actions that are almost completely opposite from those required to recover from a wing stall.  If flaps are extended and you experience lightening of the controls, difficulty trimming, or buffet in the control column, immediately retract the flaps and maintain or reduce thrust. Undo what you just did. Pull yoke back, retract flaps, and maintain or reduce thrust.