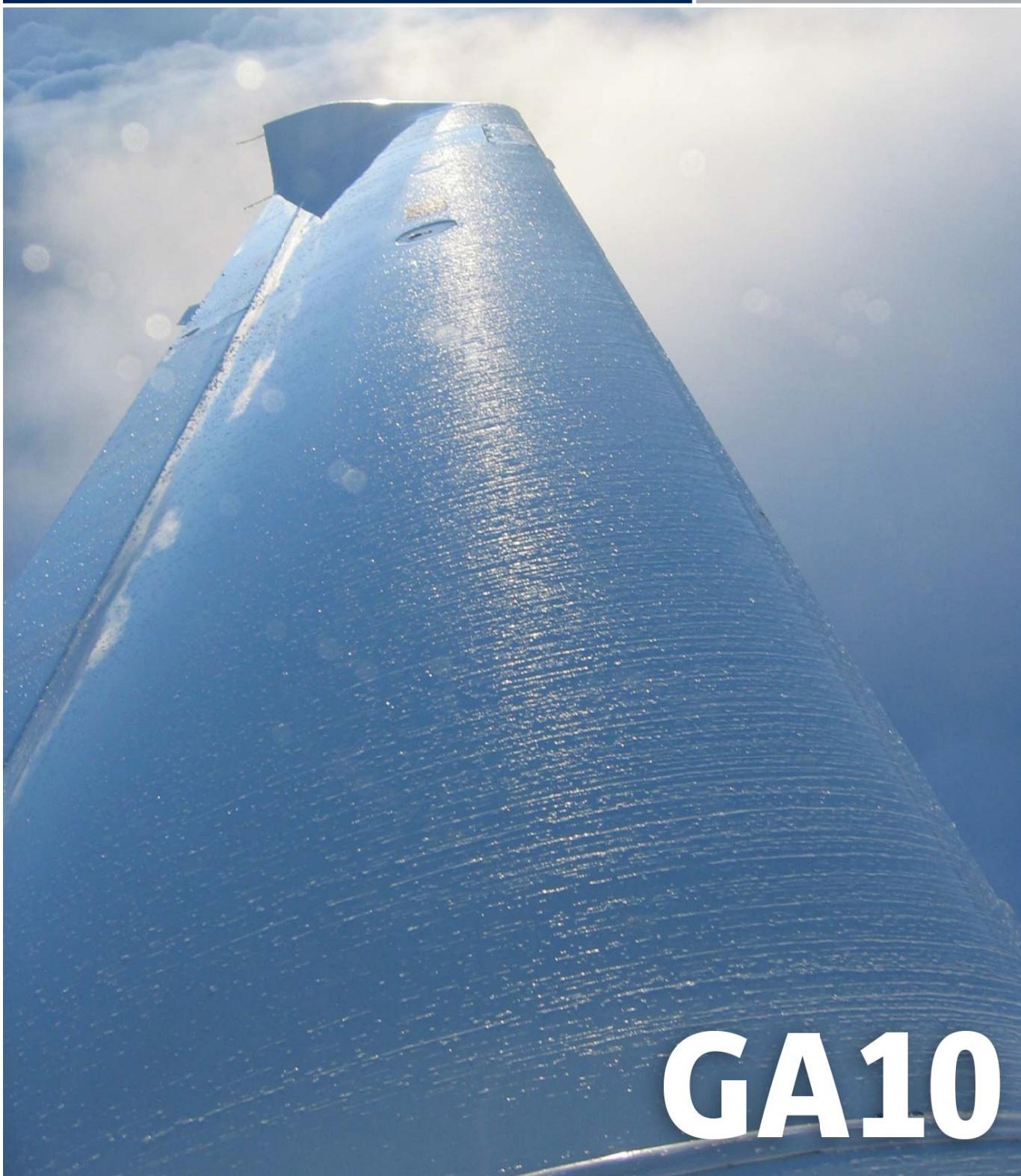


# IN FLIGHT ICING

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FOR GENERAL AVIATION PILOTS

SAFETY PROMOTION LEAFLET



**GA10**

## Introduction

This leaflet has been produced by the European General Aviation Safety Team EGAST and is intended to provide guidance to pilots of Non-Complex Aeroplanes without modern Ice Protection systems who may encounter in-flight airframe icing.



Icing conditions General

## In-flight icing after landing

Ice will form on an aircraft if liquid water impacts a part of the airframe which has a temperature below freezing. At very low temperatures, ice tends to form close to leading edges and is generally easy to see. At temperatures just below zero, the ice spreads back, is less visible, and affects more of the airframe.

Water droplets in cloud with a temperature below freezing do not necessarily turn into ice. If there are no particles on which they can glaciate, water droplets can remain supercooled in liquid form down to  $-40^{\circ}\text{C}$ . These supercooled droplets are most commonly found in convective cloud with temperatures just below freezing down to approximately  $-10^{\circ}$ . Although cumulus clouds with significant vertical motion usually contain the largest proportion of supercooled droplets, it is also common to find high concentrations of supercooled liquid water at the top of stratocumulus cloud.

The severity of icing conditions varies enormously, and depends on the concentration of supercooled liquid water and the droplet size. Where the cloud at a particular level is composed mainly of ice particles, it may be possible to fly through it without encountering supercooled liquid water. Thus the top of a shower cloud which has glaciated (turned to ice crystals, which appear wispy) is likely to provide less severe icing than the 'cauliflower' or 'bubbling' top of a growing towering cumulus.



Growing cumulus top

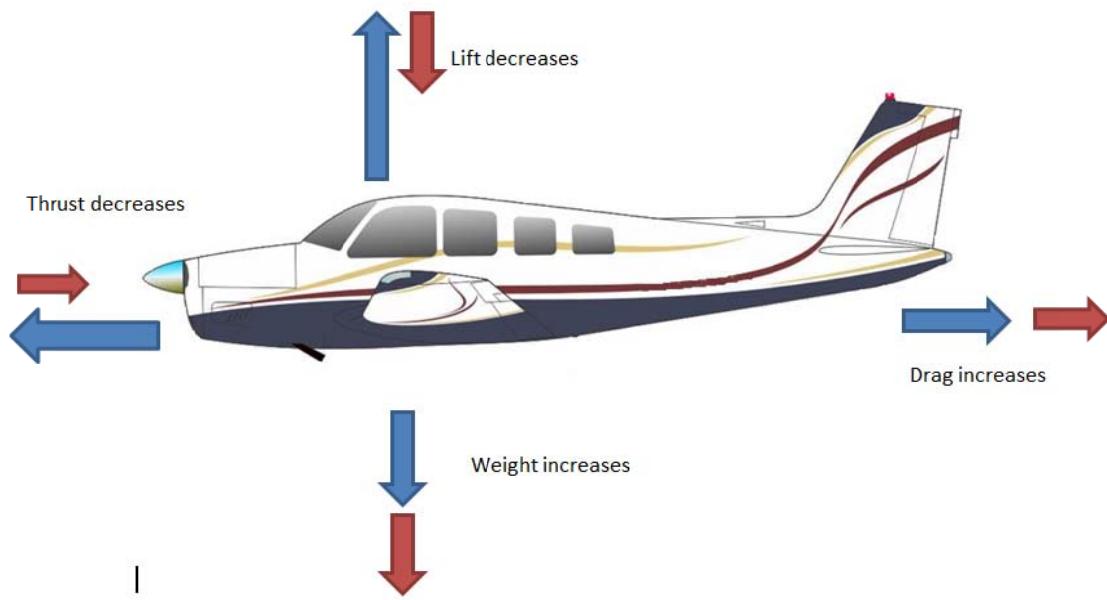
Dry snow in flight represents a less significant hazard for airframe icing as it usually does not stick. However, impact icing is likely to occur on air intakes and leading edges.

Typically, precipitation starts as ice and, as it falls, either reaches lower levels as snow or hail, or melts into rain as it passes into above-freezing temperatures at the lower levels. However, if rain falls through an inversion into sub-freezing temperatures again, it produces the most severe icing conditions if it contacts an airframe. This “rain ice”, also known as “freezing rain”, is a clear ice type and difficult to see and builds up very quickly.

## Effects of icing

Ice on an aerofoil changes its properties, reducing lift and increasing drag for a given angle of attack. Ice on a propeller blade reduces the efficiency of the propeller and reduces thrust. In addition, the weight of the accrued ice increases the aircraft weight and therefore the lift required. Because for a given airspeed the angle of attack must be increased to provide the necessary lift, the critical (stalling) angle is reached at a higher airspeed than when ice is not present. **The Stall speed increases.**

Pilots should also be aware that icing on a tailplane has been known to cause uncontrollable pitch forces as flaps have been lowered. Always be prepared to reverse any flap selection to regain control.



The effect of airframe ice on aircraft performance

## Stall Warning

Since ice buildup on the wing lowers the stall angle of attack the stall warning sensor might not provide warning in icing conditions. Pilots therefore should:

- Know the POH/AFM minimum icing airspeeds and treat them as limitations, even if they are not in the Limitations section. If your POH/AFM does not have minimum icing airspeeds, add 15-20 KIAS to your normal operating airspeed. This goes for all phases of flight, including approach and landing where most small airplane icing accidents occur, but be mindful of the effect on landing distance required.
- Treat any buffet or vibration as an impending wing stall.
- Limit manoeuvring in icing conditions.

## Temperature

The effect of adiabatic compression due to compressibility and the kinetic heating due to friction is negligible at air speeds up to Mach 0.2. Therefore the Temperature measured by a simple external temperature probe (typical in GA aircraft) is close to the Total Air Temperature (TAT), which is at low speeds slightly above the

Static Air Temperature (SAT).

The order of magnitude of difference between TAT and SAT at higher speeds is 1°C at 100 knots and 4°C at 200 knots. The airframe may therefore be a few degrees above the temperature of the air outside, which offers a small but helpful mitigation against the risk of ice accretion..

## Propeller icing

If ice accretes on an unprotected propeller, the thrust lost can be so significant that you might not be able to climb out of the icing conditions or maintain the altitude.



Ice on propeller blade

## Aircraft in icing conditions

The ice accretion rate over time is not only dependent on the atmospheric conditions. The geometry of the leading edges of the impinged areas have a great influence on the efficiency rate as well as the speed. Ice tends to build first on parts of the airframe with a low radius of curvature .



Ice on low radius of curvature aerofoils

Pilots should look out for visual cues of ice accretion. So it will for example tend to form on the tailplane before the mainplane, and small protuberances like a typical GA temperature probe or door stop may well see the first traces of icing. First signs of ice accretion may also be noticed at the propeller spinner or the windshield frame. Pilots should learn where icing starts to form on their particular airframe, because performance can be degraded with quite small accumulations of icing. A millimeter of ice is sufficient to affect some modern aerofoils.

The rates of icing accretion can be difficult to predict and can vary substantially, because of differences in liquid water concentration. Conditions that look the same can bring ice accumulation rates that vary by an order of magnitude or more. This variability means that one flight in visible moisture below freezing may not accumulate any significant amount of ice. However, on another occasion in apparently similar conditions a pilot may encounter a significant icing problem.



Flight in visible moisture

In severe icing conditions, the ice accretion can become critical within a few minutes.

## Aeroplane ice protection certification

Modern aeroplane ice protection systems can be certified in accordance with regulations such as CS 23.1419 or FAA AC 23.1419-2. The Flight Manual will contain a statement to the effect "This airplane is approved for flight in icing conditions as defined in part 25, Appendix C." Such certification was introduced by the FAA in 1973 and evidences the aircraft's capability to fly in a wide range of icing conditions for significant periods. While some accidents (such as the loss of American Eagle Flight 4184 near Chicago in 1994, an ATR that encountered freezing rain) indicate that nature is capable of generating even more extreme conditions, such certification effectively entitles a crew to rely on the anti-icing or de-icing systems to cope with any "normal" icing conditions likely to be encountered.

By contrast, aircraft without ice protection, and those certified to early standards for flight in e.g. “light icing conditions” or “moderate icing conditions” offer no such guarantee to the crew. It is vital for crews of such aircraft to create a contingency plan that guarantees they can take the aircraft out of icing conditions if icing is encountered during flight. The rest of this guidance is aimed at pilots of these aircraft.

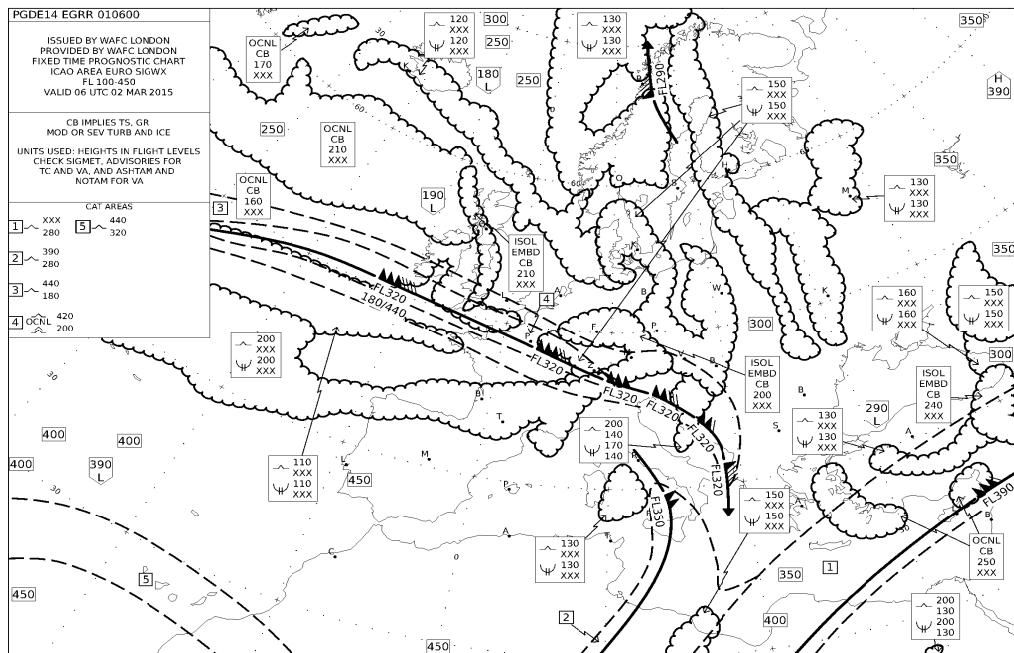
## Preflight planning

It is often impractical to plan a flight in a way that leaves no *possibility* for icing conditions to be encountered, in the same way that it is impractical to plan a flight on a convective day in a way that leaves no possibility for an encounter with cumulonimbus, because it is never possible to be certain exactly where such a cloud would form. But, just as a crew must always have a plan which allows them to avoid flying into a thunderstorm that appears on their intended route, so they must have a plan to avoid icing conditions more severe than the aircraft’s systems, if any, can cope with, and to escape from any such icing that is actually encountered.

Usually this means a plan to descend into warmer air, but in some circumstances it may be possible to climb above the icing layer. However, an aircraft which has already accumulated ice has a significantly poorer performance than a clean airframe, so it may not always be possible to climb above an icing layer. An underused but effective manoeuvre when icing is encountered is simply to reverse course back to conditions that were ice-free.

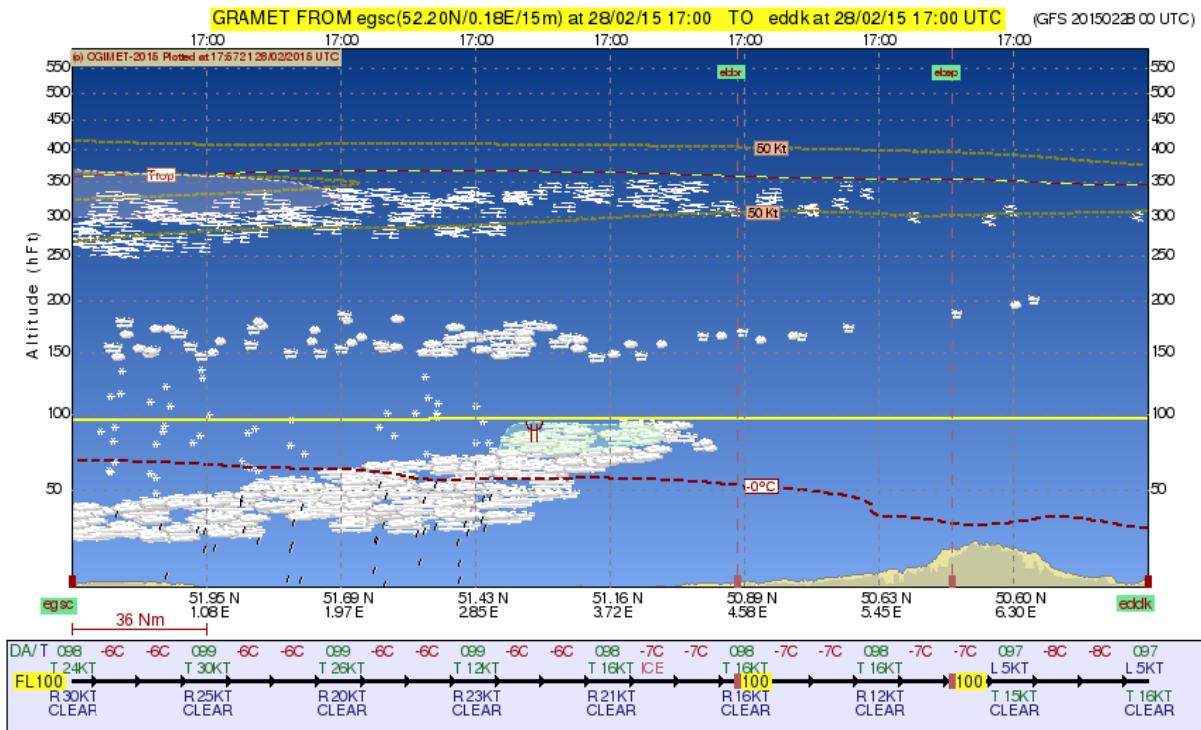
Thus a key pre-flight planning check is to compare the freezing level with minimum practicable IFR altitudes. As with other sorts of hazardous weather, some co-operation from ATC may be assumed, but terrain-safe lower levels may not always be available, for example around busy TMAs.

Compared to even a decade ago, aviation forecasts can predict temperatures and winds aloft much more accurately. Note the relative humidity at planned cruising altitudes; that can offer some guidance on the presence of cloud. However, in an unstable airmass, cumuliform clouds can and do rise into layers of the atmosphere with lower humidity.



## Met Significant weather chart

Some web sites provide unofficial but useful cross-section weather information for positions or routes, including freezing levels.



Courtesy of the Ogimet site

## Preflight aircraft checks when sub-freezing temperatures aloft are forecast

The pitot-static system should be checked for water which can freeze and block the system. If pitot and static drains are fitted, know where they are and how to use them.

Check that all the airframe, propeller and windscreens systems are operating correctly. De-icing systems suffer from neglect and may prove faulty when required. Leaks may have developed in inflatable boots especially on the tailplane (due to stones thrown up by the landing gear/propellers), so check that they all inflate properly.



De-Icing Boot with Patch Repairs

Check any other parts of the airframe where water can accumulate, paying particular attention that controls are free.

Check that the pitot heater really is warming the pitot head – but don't burn your hand (use the back of it) or flatten the battery.

## Ground De-Icing

While this guidance is not intended to address ground de-icing procedures, it is of course essential that the aircraft is and remains free of all ice before flight. Ice on an aerofoil will significantly reduce your take-off performance. Snow will not blow off, and neither will frost. Maintain the “Clean Wing” concept

Icing Contamination on aircraft surfaces must be removed before takeoff to prevent any handling and control difficulties, performance loss or mechanical damage.

De-icing is a procedure that removes snow, frost and slush from the aircraft while anti icing prevents contamination by frost/ice/snow for a limited period (Hold Over time).

Various types of fluids are available :

- Type I (de-icing only) ,
- Type II/III/IV (anti icing fluids), containing a pseudo-plastic thickening agent, which enables the fluid to form a thicker liquid wetting film on external aircraft surfaces.
- Type III fluid is intended for aircraft with slow rotation speed.

When fluids are used, increase rotation speed and anticipate increased take-off distance and/or greater stick forces.



Frosted Wing

### Aircraft icing scenarios

A typical scenario for icing encounters is convective cloud rising up through the freezing level on an unstable day. If your cruising level is above the freezing level but below the tops, you face the potential for icing. Where the convective clouds are well scattered and it is possible to see them it may be possible to avoid them and the associated icing conditions. Bear in mind however that this requires visual conditions and any ice accumulation on the windshield is likely to limit the options for further visual avoidance.



Convective clouds may be avoided visually

The tops of stratocumulus clouds, especially just below an inversion, often contain high concentrations of supercooled liquid water. Their significant horizontal extent means that icing is continuous, and only a level change can provide relief from the icing conditions.



Stratocumulus clouds ahead

Flight in cold air below precipitating cloud in warmer air above, as for example under a warm front or occlusion, is likely to expose an aircraft to the hazard of rain ice, which can build up very rapidly and be difficult to see. Monitor the temperature gauge, and if rain is experienced in sub-zero temperatures, leave the conditions immediately.



Rain in freezing conditions should be avoided

Climbing through a thin layer of icing conditions is generally more problematic than descending through one. In the climb, speed is usually lower so the airframe is cooler and the angle of attack exposes more of the wing to potential ice accumulation. Vertical speed is limited by the aircraft's performance and rate of climb progressively reduces as ice forms,

increasing the time spent in the icing layer. Information on cloudbase is usually more accurate than on the level of cloud tops, so the depth of the icing layer is more predictable when descending.

Although, in principle, accumulated icing can be removed by sublimation in clear air even in temperatures below freezing, such a process is generally slow. Even small amounts of icing encountered on a climb to clear air above can lead to a deterioration in performance and increased fuel consumption, which should be carefully considered in pre-flight planning.

## SUMMARY

### Actions on encountering icing

- Consider the available options to mitigate risk immediately. While the accumulation of small amounts of ice may not constitute an emergency, it does require immediate attention, and a contingency plan must be available if the icing conditions persist or worsen.
- Perform any actions required by the Flight Manual, which may include for example the selection of alternate air. Pitot heat should, of course, already be on. Typically, use of the autopilot is discouraged or prohibited in icing.
- Where equipped, use de-icing equipment as directed by the Flight Manual, but do not rely on such equipment to allow flight in icing conditions indefinitely. In particular, propeller anti/de-ice may help to avoid some performance deterioration.
- Monitor any accumulation carefully, remembering that ice is likely to build more rapidly on parts of the airframe that are not easily visible.
- Liaise with ATC to understand the available alternative levels or routes
- Leave the icing conditions before aircraft performance or controllability suffers any significant deterioration.
- Anticipate a higher stall speed if icing has accumulated, and anticipate higher fuel consumption.
- Consider higher approach speeds, and keep power on during the landing.
- Anticipate possible pitch forces during flap movement – be ready to reverse the selection

### Useful Links

The AOPA Air Safety Foundation has written several 'Safety Advisors' on icing that pilots will find useful. You can find these at:

<http://www.aopa.org/asf/publications/advisors.html>

There are also numerous icing training products produced by NASA, in cooperation with the FAA. These are listed at:

<http://icebox-esn.grc.nasa.gov/education/products.html>

<http://aircrafticing.grc.nasa.gov/courses.html>

## IMPRINT

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