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METEOROLOGY FOR AUSTRALIA

CHAPTER 19 – AIRFRAME AND ENGINE ICING

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AIRFRAME ICING

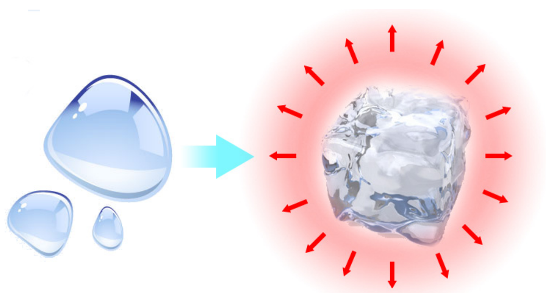
OVERVIEW

Before looking into Airframe Icing, the following points must be clearly understood:

- Freezing Level (FZL) is the height at which 0°C occurs.
- Freezing Point (or Temperature) is usually 0°C.
- For airframe icing to occur, the **air temperature and the aircraft skin temperature must be less than 0°C**.

THE FREEZING PROCESS

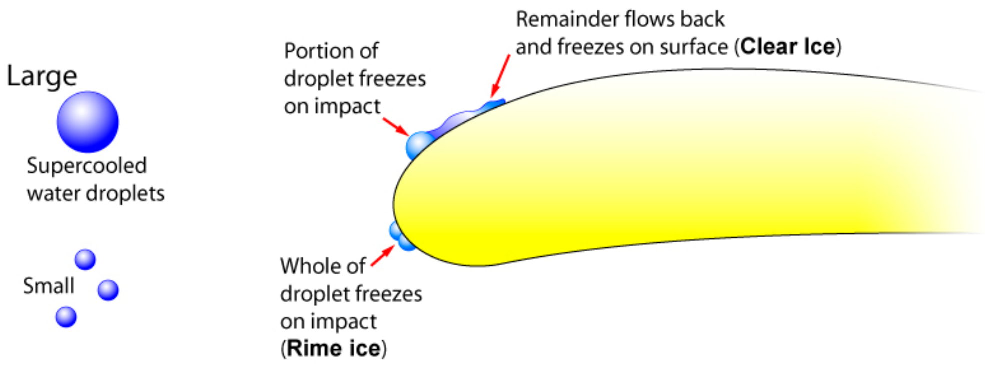
As in condensation the change of state from liquid to solid also needs a nucleus. **Freezing nuclei** are insoluble particles, and, unlike condensation nuclei, they are often in short supply in the atmosphere. Thus water in liquid droplet form can exist at temperatures well below 0°C, when it is known as a super-cooled water droplet (SCWD). If cooled far enough, SCWDs will eventually freeze spontaneously, the larger drops tending to freeze first, leaving only the smallest droplets as liquid at temperatures of minus 40°C or so. The disturbance arising when a super-cooled droplet is struck by an aircraft also enables freezing to take place.



Latent heat is released during the freezing process (80 calories per 1 gram of water). This has a heating effect on the water droplet, and while some of the supercooled water will freeze, immediately, some of the droplet will remain as a liquid due to this heat release. As a rule **1/80 of the SCWD per °C** of supercooling freezes instantly whilst the rest flows back over the surface of the wing, rapidly cools and freezes as it flows.

The temperature of the leading edge of the aircraft is raised due to **kinetic heating.** However the cooling effect of latent heat absorption by the atmosphere offsets the heat gained by kinetic heating. Therefore it is best to ignore kinetic heating as an icing factor at a TAS of less than 400 kts.

As the diagram below shows, droplet size plays a large part in the freezing process.



Ice-Type Dependent on Droplet Size

TYPES OF ICING

There are 4 main types of icing. They are described below in increasing order of severity.

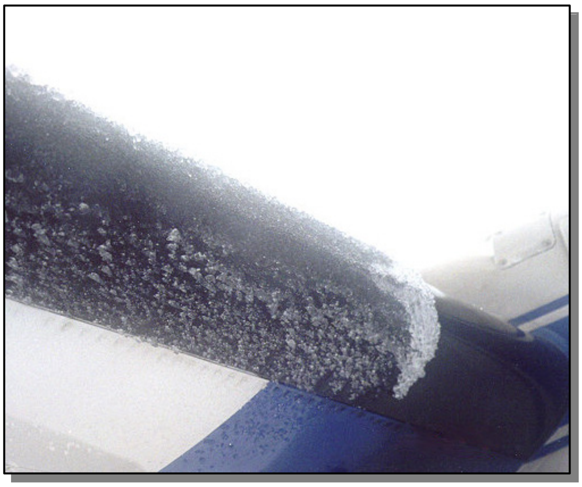
Hoar Frost (White frost)

This is a thin crystalline deposit, which results from sublimation (from vapour directly to a solid; which is sometimes also called 'deposition'). When an aircraft descends rapidly from a high altitude in very cold temperatures, into a lower region of high relative humidity, water vapour may form frost on the airframe. Windscreen frosting can seriously impede forward vision.

When a cold aircraft climbs up through an inversion, warmer air (which may contain more moisture) may be encountered. The result could be, again, Hoar Frost.

Hoar Frost isn't of course confined to the air. Should conditions be favourable (temperature below freezing, high Relative Humidity and little or no wind), then water vapour in the air can sublimate directly onto airframe surfaces when the temperature falls to Frost Point. This will coat the airframe with a layer of frost, which may not seem too serious, but can seriously affect the flying characteristics of the aircraft. **Do not ever fly with any form of icing on the wings or control surfaces**. Make sure the ice or frost is removed first.

Rime Ice



Rime Ice is usually a product of small water droplets, typically to be found in stratiform cloud. It can form in very low temperatures and at high altitudes. A large part of the droplet freezes on impact (1/80th per °C below freezing point). The frozen droplet contains air, thus it is granular, not very strong or adhesive, and can be removed easily. De-icing is covered later in this Chapter.

In appearance it is opaque (not clear) as a result of air being trapped within the ice when it freezes quickly.

Clear Ice (Translucent Ice or Glazed Ice)

Clear Ice forms when the droplets the aircraft encounters are large, typically in Cumuliform cloud where strong updraughts can suspend these larger droplets. As shown in the diagram on page 4, only a small amount of the droplet freezes on impact, allowing the rest of the water to flow back over the wing, freezing slowly and very firmly. This strong adhesiveness makes it very difficult to remove (see de-icing later in this Chapter). It will typically be found at temperatures just below Freezing Point (0 to -10°C)

Clear Ice has, as its name implies, a clear, glassy appearance. It is very heavy, severely affecting the weight of the aircraft and it will also badly distort the aerodynamic shape of the wings, seriously affecting the flying characteristics of the aircraft, in particular reducing lift and increasing stalling speeds.

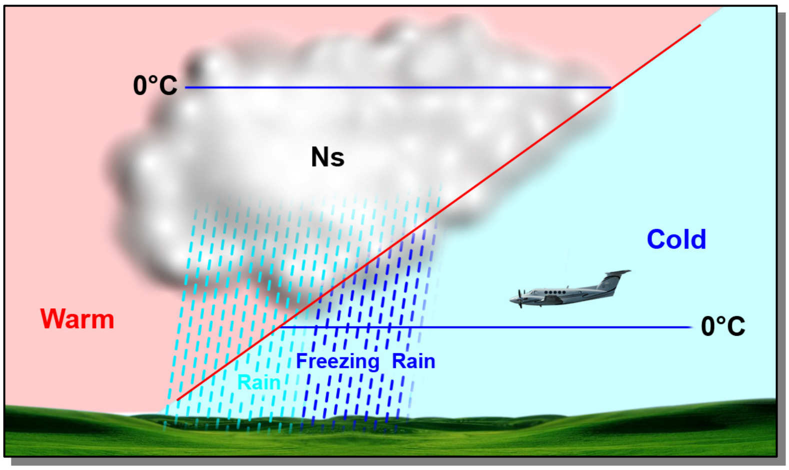
Rain Ice (or Freezing Rain)

Freezing rain produces clear ice when the large supercooled raindrop impact with the aircraft or with the ground.

The droplets are supercooled and freeze rapidly when “disturbed”. This occurs when the aircraft flies through them or the droplets strike the ground. It occurs with Ns cloud with the ground temperature less than 0°C or if the aircraft is flying in a temperature of less than 0°C.

A distinctly possible scenario for the formation of Rain Ice is if an aircraft flies underneath a warm front. In the diagram below imagine an aircraft flying in the cold air ahead of the front. Its skin temperature will be less than 0°C. If it then flies into the rain falling from the warm front, then the rain will freeze on the aircraft as it impacts with the rain.

Rain Ice is very adhesive and very difficult to remove.



AEROFOIL SHAPE AND ICING

With a low drag aerofoil shape the airflow more closely follows the outline of the airframe, whereas a high drag form will cause the air to divert from the outline of the wing. Hence there will be more water droplets actually in contact with the airframe in the low drag case. Additionally, low drag will normally infer a higher speed and therefore the number of water droplets encountered in unit time will be higher and thus icing rate may be increased.

Thin objects such as aerials, struts, leading edges of propellers, etc., are more prone to icing than are the more prominent parts of the airframe such as the nose of the fuselage.

CLOUD TYPES AND ICING

Stratiform Clouds

The types and severity of icing associated with stratiform clouds at various temperatures are:

i. **- 40°C to -07°C** No severe clear ice. Moderate rime at warmer temperatures.
ii. **- 07° to 0°C** Increasing threat of clear ice, severe in very thick cloud, e.g. Ns, and with orographic uplift.

Cumuliform Cloud

The types and severity of icing associated with cumuliform cloud at various temperatures are:

i. **- 40°C to - 23°C** No severe clear ice. Moderate rime ice at warmer temperatures.
ii. **- 23°C to 0°C** Increasing threat of clear ice, as temperature approaches 0°C. Severe in Cb clouds.

Lenticular Cloud

Due to the strong updraughts and the short life span of any SCWD as it passes through the lenticular cloud, there are more SCWD at lower temperatures. Severe clear ice can occur at temperatures as low as -27°C.

Orographic Cloud

The extra uplift due to mountains enables the cloud to support more moisture. The risk of icing is increased; the potential for more severe clear ice is greater and the freezing level will be lower.

EFFECT OF CLOUD BASE TEMPERATURE

Warm air can hold more moisture than cold air therefore icing of a given level in a convective cloud is likely to be greater in tropical than in temperate latitudes and greater in summer than in winter.

ENGINE ICING

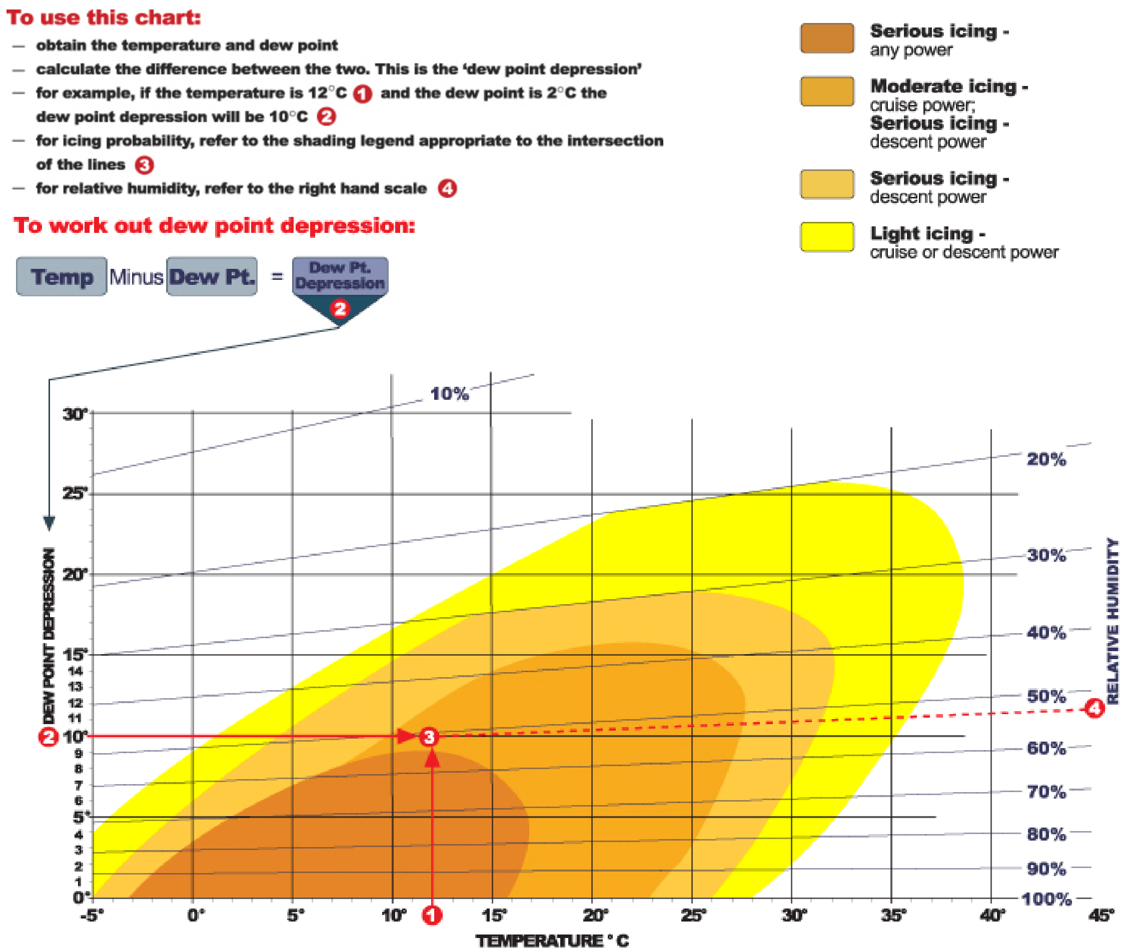
TURBINE ENGINE ICING

This may occur when an aircraft flies through supercooled rain, sleet, snow etc and may form ice on the rim of air intakes, supporting struts, and the forward blades of the compressor stages. A pressure reduction occurs in the engine air intake, adiabatic cooling occurs and icing is possible even if the OAT is higher than 0°C. The most dangerous temperature range is **+3°C to -5°C.** and is most likely in very moist air or in a St/Sc layer.

PISTON ENGINE ICING

You have already been taught the principles of piston engine icing in AGK 1 but the following revision will not come amiss.

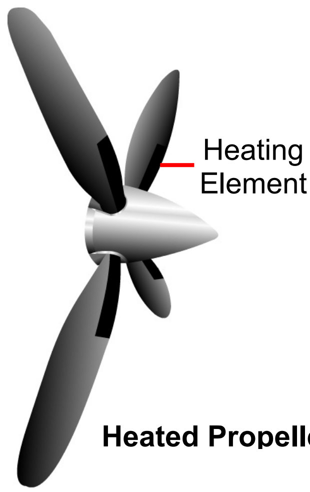
In piston-engine aircraft, engine icing is influenced by additional factors not relevant to airframe icing, such as the decreased pressure at the inlet manifold and carburettor. This decrease, and extraction of latent heat from the air in vaporising fuel, makes piston engines vulnerable to icing in surprisingly high temperatures in very moist air. The chart below shows the wide range of ambient conditions conducive to the formation of carburettor icing in a typical light aircraft piston engine. Note that there is much greater risk of serious icing under descent power.



Carburettor Icing

DE-ICING AND ANTI-ICING

The technical aspects of De-icing and Anti-icing are not in the meteorology syllabus, but are covered in depth in the Aircraft Systems syllabus. In essence though, there are two separate systems, one for preventing any ice in the first place (Anti-icing), and the other to remove ice once it has formed (De-icing).



Heated Propeller

ANTI-ICING

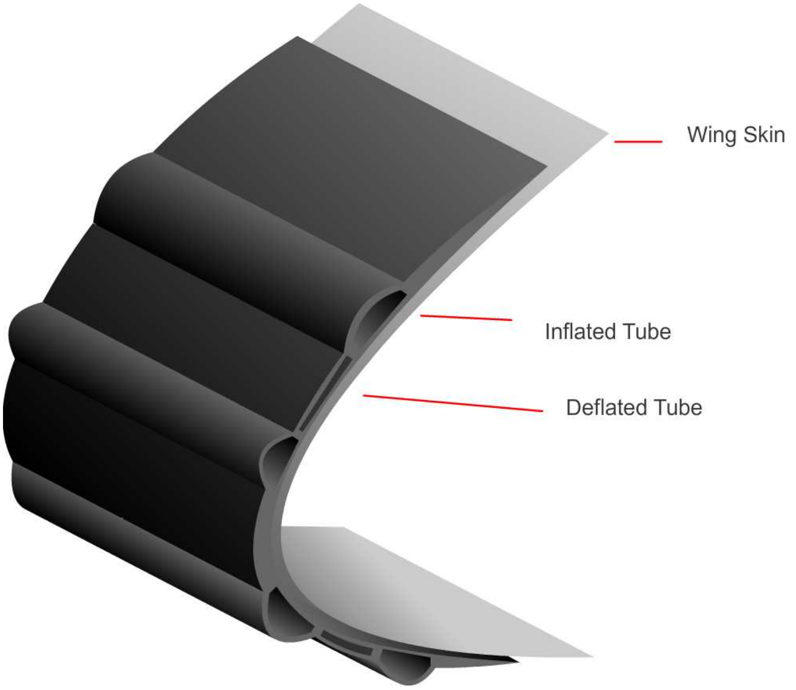
An Anti-icing system will normally use hot air, electricity or a chemical compound to prevent the formation of ice on surfaces or perhaps leading edges. In Turbine aircraft hot air would be "tapped" or "bled" from the engines and ducted to wherever it was required, usually the engine air intakes, and the wing and tail leading edges.

In slower piston engine aircraft, an ice resistant compound (such as alcohol) would be sprayed or bled over the wings, or perhaps centrifugally along the propeller blades.

In any type of aircraft it is possible to use electrical heating elements to pre-heat propeller blades, windscreens etc.

DE-ICING

De-icing is when ice which has already formed on a part of the aircraft, is removed. A typical system is "De-icing boots". When ice has formed on the leading edges of the wings or fin, de-icing boots (inflatable rubber tubes attached to the leading edges) would be inflated, breaking the ice off the surface.

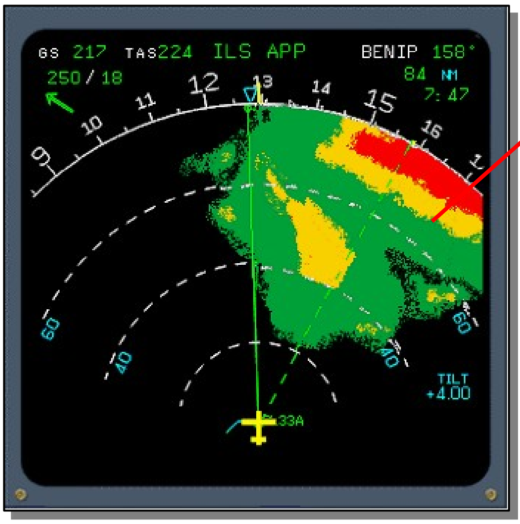


Typical pneumatic de-icing boot installation

CLASSIFICATION OF ICING

- **Light:** No change of course or altitude is necessary and no loss of speed caused
- **Moderate:** Change of heading and/or altitude is considered desirable. Ice accretion continues to increase but not at a rate sufficiently serious to affect the safety of the flight, unless it continues for an extended period of time; air speed may be lost.
- **Severe:** Change of heading and/or altitude is considered essential. Ice accretion continues to build up and begins to affect seriously the performance and manoeuvrability of the aircraft.

ICING - WEATHER RADAR DETECTION



The magenta area indicates severe turbulence \ icing hazard

A radar echo is likely to indicate a region where ice accretion is possible if the temperature is below 0°C. A clear-cut echo of high intensity frequently indicates a cloud of the convective type. Warm front clouds usually give echoes, which are less well defined and less intense. The intensity of the echo is dependent upon the concentration and drop size of the liquid or frozen water in the cloud and if these are inadequate there will be no echo although ice accretion may still occur if the temperature is suitable.