

CHAPTER SIXTEEN

ICING

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AN INTRODUCTION TO ICING AND ITS BASIC CAUSES

Airframe icing can cause a serious loss of aircraft performance and this will frequently result in a large increase in fuel consumption and some difficulty with aircraft control.

Icing is difficult to forecast and therefore there is a need for a full understanding of the processes involved.

Ice will form on an airframe if there is:

- Water in a super cooled liquid state.
- Ambient air temperature below 0°C (but see later).
- Airframe temperature below 0°C.

SUPERCOOLED WATER DROPLETS (SWD).

A supercooled water droplet is a droplet of water still in the liquid state although its temperature is below 0°C. If the SWD contains a **freezing nucleus** then the droplet will start to freeze. Mention was made in humidity chapter of **condensation nuclei**, but as the number of freezing nuclei in the atmosphere is considerably less than these, the state of supercooling is a frequent occurrence. Supercooled water droplets can exist in clouds at temperatures as low as -40°C. However, when an aircraft strikes a supercooled water droplet, it will start to freeze. Supercooled water droplet size is dependant on the size of the basic cloud droplet, (controlled by cloud type) and the temperature.

Sizes will be:

- **0°C to -20°C**; both large and small supercooled water droplets can exist. The cloud type will govern the size or droplet supported. For example Stratiform cloud will only support small droplets even though the temperature may allow for both sizes. Cumuliform cloud can hold both types, but large droplets will be predominant.
- **-20°C to -40°C**; small supercooled water droplets can exist. At these temperatures large supercooled water droplets will have become ice.
- **Below -40°C**; only very small supercooled water droplets can exist. All others will have become ice. Freezing will occur without the aid of nuclei.

THE EFFECTS OF ICING

- **Aerodynamic.** Ice tends to form on leading edges, thereby spoiling the aerodynamic shape. The result is **reduced lift, increased drag, increased weight, increased stalling speed** and **increased fuel consumption**.
 - Ice, frost or snow of a thickness and roughness similar to coarse sandpaper can reduce lift by 30% and increase drag by 40%.
 - It is also possible for pieces of ice to break off other surfaces and to jam between the control surfaces and wings and tail.

- **Weight.** In severe conditions, ice can form at a rate of 1 inch in 2 minutes.
 - There will be a loss of stability due to the weight of ice not being uniform across the airframe.
 - This can lead to a displaced C of G. Similar uneven weight of ice on propeller blades can cause severe engine vibration.
 - Ice breaking off propellers can cause skin damage.
- **Instrument effects.** Ice can block pressure heads and the readings of ASIs, VSI, altimeters and mach meters can be in error as a result.
- **General.** Windscreens and canopies can be obscured.
 - A thin film of ice/frost can cause skin friction.
 - Ice in landing gear wells can affect retraction.
 - Ice on aerials can cause static interference.

CLEAR (OR GLAZE) ICE

If a large supercooled water droplet strikes an aircraft, it will start to freeze and this will release **latent heat**. This will delay the freezing process whilst part of the supercooled water droplet will flow back over the impact surface forming **clear ice**. The amount of a supercooled water droplet that freezes on impact is 1/80th of the droplet for each degree below freezing.

Clear or glaze ice is a transparent form of ice formed by **large** supercooled water droplets, it can be very dangerous. There can be much flowback and the ice appears transparent because there is no air trapped under the flowback icing. The lamination of the ice into layers increases its strength and because it has less air in it this type of ice is much stronger and much harder to remove.

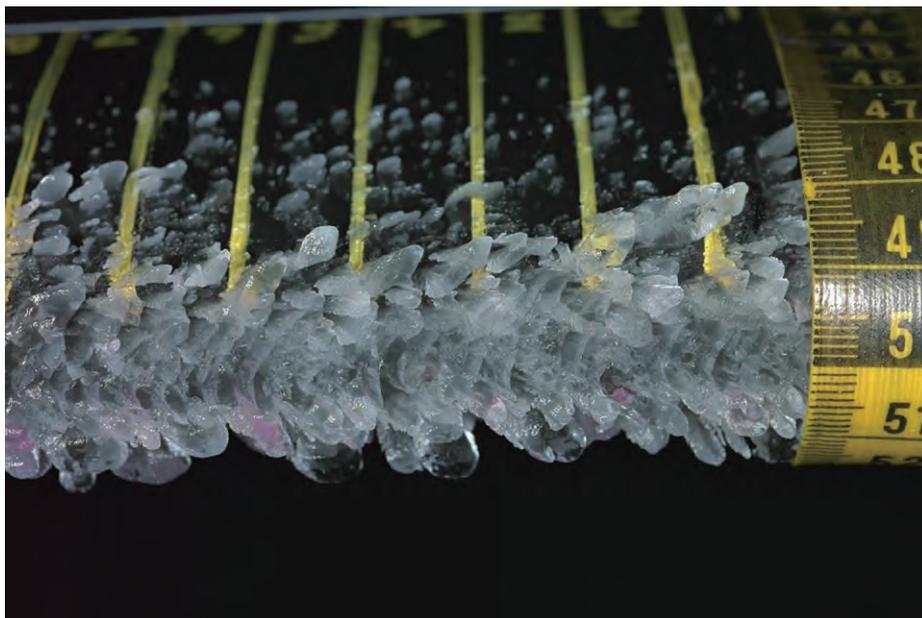


Figure 16.1: Clear ice.

The ice will destroy aerofoil shapes and its weight can cause problems of control because the build-up can be uneven.

Propeller icing can cause severe vibrations and as the ice adheres strongly, when it breaks off, the pieces can be large and cause skin damage.

Clear ice forms in Ns (especially when orographically intensified), Cu and Cb at temperatures from 0 to -20°C.

It should be noted that clear ice often forms with another type of ice called rime ice, the latter being formed from the smaller supercooled water droplets in the cloud. When the two types of ice occur together it is usually described as mixed ice. This is most common in Ns cloud and in the middle level of cumuliform clouds.



Figure 16.2: Mixed ice.

RIME ICE

When the super cooled water droplets are small (at very low temperatures) or when cloud droplets are small, the whole droplet freezes instantly on impact, each droplet sticking to the surface it strikes and becoming solid almost at once.

Air becomes trapped between each frozen droplet, which makes the ice white. Rime ice is characterised by being a **white opaque** deposit with a granular or flake like texture. It is caused by **small**, super cooled water droplets freezing instantly. This type of ice is weak and very brittle. There is little or no flowback. The ice grows out from the leading edges and is compacted by the airstream.

Some loss of aerofoil shape can occur and **air intakes** can be affected.

Rime ice can occur in any cloud where there are small super cooled water droplets; Ns, As, Ac, SC, St and the parts of heap clouds where super cooled water droplets are small which mainly near the top of the cloud.



Figure 16.3a: Removal of rime ice by the wing boot.



Figure 16.3b: Heavy rime ice.

RAIN ICE

Rain ice is the most dangerous form of icing and it occurs in **rain** which becomes **supercooled** by falling through an **inversion** into air below 0°C . The supercooled water droplets are now rain sized. The rain does not freeze in the air but once it impacts the aerofoil it freezes to form **clear ice** with significant flowback. (See Figure 16.4).

Rain ice builds up very quickly and a pilot's action should be to turn onto a reciprocal heading immediately. If the pilot perceives the rain ice very late, then the course of action would be to climb into the warmer layers above. Turning at a late stage into the icing conditions will increase the stall speed and the return journey back out of the rain ice zone will double the ice on the aircraft from when the pilot first elected to turn around.

Rain ice occurs in a narrow range of altitudes at low level, about 1,000 ft, ahead of a **warm front** or **occlusion** and is associated particularly with the moderate continuous rain which often falls from **Nimbo Stratus** cloud, this is illustrated on the next page.

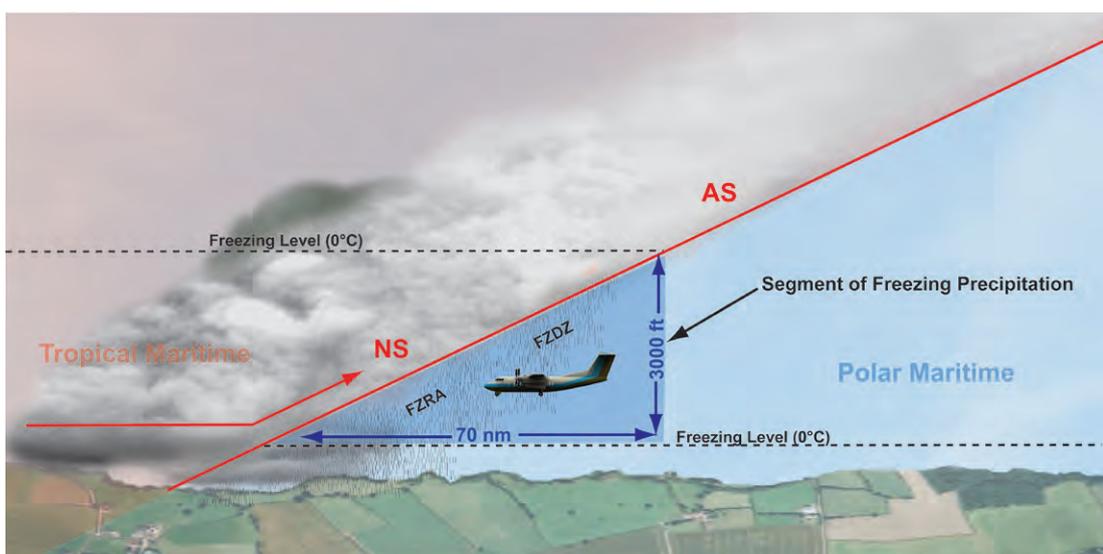


Figure 16.4: Factors affecting the formation of Rain ice.

Rain ice is rare over the UK, but is common in winter over North America and Central Europe.

PACK SNOW

Pack snow is icing which is due to a mixture of super cooled water droplets and **snow**. It can block air intakes and other aircraft openings. Normally the effects are **slight**.

HOAR FROST

Hoar frost is a **white crystal deposit** which appears similar to frost on the ground. It occurs in **clear air**. Hoar frost will form if the airframe temperature is **below 0°C** and the ambient temperature is lowered to saturation level. Water vapour in contact with the airframe is converted to ice crystals without becoming liquid, i.e. **sublimating**. This process requires the presence of another type of ice nucleus, the **sublimation nucleus**. Their composition is usually inorganic, e.g. volcanic dust, clay or soil particles.

There are two situations where hoar frost can occur:

- **On the ground**
This usually occurs at night and is similar to the frost which forms on a car. It must be cleared before take-off because:
 - Skin friction will increase the take-off run.
 - Windscreens will be obscured.
 - Radio interference will be caused by ice on aerials.
- **In flight**
Hoar frost can occur in flight in the following cases:
 - If a **rapid descent** is made from a **very cold** region to a **warm moist** layer.
 - If a climb is made from a temperature **below 0°C** through an **inversion**.

The icing is not severe. The effects can be overcome by flying in a region where the temperature is above 0°C or by flying faster to increase the kinetic heating. It should quickly disappear once the aeroplane starts to warm up.

FACTORS AFFECTING THE SEVERITY OF ICING

- **Size of the super cooled water droplets.** This is dependant on cloud type and temperature as follows:

| TYPE | DETAILS |
|---------------------------|--|
| MODERATE /HEAVY CLEAR ICE | Super cooled water droplets can only be large in Cu, Cb, Ns and then only when temperatures are in the general range 0°C to -20°C. |
| LIGHT/MODERATE RIME ICE | For layer clouds small super cooled water droplets are present from 0°C to -10°C |
| LIGHT RIME ICE | For layer clouds super cooled water droplets are smaller below -10°C. |
| RIME ICE | Super cooled water droplets are also small in Cu, Cb and Ns from -20°C to -40°C. |

At -40°C and below, super cooled water droplets are very small and icing is usually negligible.