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FORECASTING AIRCRAFT AIRFRAME ICING

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INTRODUCTION

This note draws on information from the PWC Technical Information Sheet #22. For a given air parcel, T_f (frost point) $< T_d$ (dew point). If $T = T_f$, we have an ice crystal cloud; if $T_d < T < T_f$, we have a mixed cloud with ice crystals growing at the expense of water droplets; and if $T = T_d < 0$, we have a supercooled water droplet cloud. It is therefore possible to determine the phase of clouds from tephigrams on which T , T_d and T_f are plotted. Supercooled water and icing may be present when $T < T_f < 0$. For temperatures $0 < T < -25^\circ\text{C}$., this condition is almost exactly equivalent to $T < -8D$ where $D = T - T_d$. The various types and intensities of airframe icing are well known and summarized in PWC Tech. Info Sheet #22.

METEOROLOGICAL FACTORS IN AIRFRAME ICING

These are:

- (1) Air temperature and humidity;
- (2) Supercooled water content of the air;
- (3) Ice crystal content of the air;
- (4) Size distribution of the water droplets and ice crystals.

The largest supercooled water droplets first freeze at about -15°C ., and by -40°C even the smallest droplets are frozen. If the cloud does not grow much beyond the -15°C level, then only a few ice crystals will exist in it. Clouds growing to higher and colder levels will undergo rapid formation of more ice crystals as temperature decreases, which then grow at the expense of the liquid water droplets. This process can quickly transform the entire cloud into an ice crystal cloud, although uplift will continually replenish the supercooled water supply. As the uplift weakens and then stops, the end result is "old" clouds generally composed of ice crystals.

FORECASTING AIRFRAME ICING

The following considerations should be kept in mind when forecasting airframe icing:

(1) The -8D Curve

From a radiosonde on which is plotted the -8D curve, the forecaster can easily spot layers where $T < -8D$. Icing is possible in cloud or in clear air in these layers. Of course, conditions may change from the time of the radiosonde to the time the forecast will be valid, but at least the -8D curve allows some quantitative measure of where icing may be found at the time of the radiosonde.

(2) Temperature

As a rough statistical rule, icing is most likely at temperatures from -2°C to -8°C , with an observed maximum frequency at about -6°C . Below -6°C , the icing risk decreases with temperature, and is essentially zero below -40°C . In fact, studies have shown that only about 5% of icing reports occur at temperatures below -25°C . Heavy icing seldom occurs below about -15°C . However, stronger than usual upcurrents increase the probability of occurrence as well as the severity of icing at all temperatures. The usual ice formation at temperatures below about -15°C is rime, while clear (or mixed) icing is associated with higher temperatures. The forecaster should also remember that the level of the 0°C isotherm can be lowered in heavy showers and will also be modified in air flow over mountain ridges.

As previously described, the temperature of an ascending air parcel will determine the numbers of ice crystals which form in the parcel. Few if any ice crystals will form in cloud at temperatures greater than about -15°C , but it is possible that ice crystals fall from a higher cloud layer into a cloud where $T > -15^{\circ}\text{C}$. This "seeding" of the lower cloud will deplete to some extent its supercooled water content, thereby reducing the risk of icing in that cloud. Conversely, the risk of icing is substantial in clouds which do not extend above the -15°C isotherm if there are no other higher cloud layers from which ice crystals can fall. It is also substantial in developing clouds of any depth in which the fall of ice crystals from above is hindered by updrafts.

(3) Initial water vapor content of ascending air

Generally, an airmass of maritime origin has more water vapor which may potentially form clouds through lift than does an airmass of continental origin. This greater moisture leads to increased potential for icing. One particular circumstance to watch out for in this regard is an injection of moisture from the subtropics.

(4) Rate of ascent of the air

The effect of topography in modifying the rate of ascent of the air is very important. The icing can be tremendously augmented when the airmass is forced to rise over a mountain barrier. Even in the absence of mountains, a particularly active frontal system, with much greater than average vertical motion, will have a greater probability of icing than a normal system. In such a case the icing risk should be increased accordingly and extended to lower temperatures, particularly within about 150km. of frontal and trowal positions.

An unstable airmass can lead to strong updrafts and convective clouds with heavy clear or mixed icing. In a latently unstable airmass such convection will be embedded in the main layer cloud deck. In winter, many SC layers over the ocean are in effect low level convective clouds capped by an inversion. Thus the icing in these clouds is enhanced compared to that in other SC layers formed by, for example, turbulent mixing.

(5) Vertical extent of cloud

The temperature of the cloud tops is important in determining the likelihood of ice crystals being formed, after which they could grow and spread through the rest of the cloud. In some cases, due to wind shear or to mountains which block lower level cloud, the upper level clouds containing the ice crystals are carried away from the lower clouds. In this case the lower clouds will not be seeded by ice crystals from above, so that substantial icing will often be present in this lower cloud even if the weather system supporting it appears weak. A similar situation may occur in a system that is sharply sloped in the vertical.

(6) Cloud types

Other than in the convective clouds which have been previously mentioned, the greatest rate of icing occurs in wintertime ST and SC. This is due to their high liquid water content, which is almost invariably higher than that of middle level clouds. The low level of these clouds and their frequency of occurrence make them significant for all types of aircraft operations, especially in winter. The enhancement of icing in SC over water due to convective effects has already been mentioned.

In most frontal systems, the up-currents are insufficient to maintain saturation with respect to water in the presence of ice crystals at temperatures much below 0°C. Therefore, AS and the middle and upper levels of NS are generally composed almost entirely of ice crystals and the icing risk is low. With NS, however, the uplift is such that the low levels of the cloud will usually continue to have replenishment of the supercooled liquid water content above the freezing level, especially in maritime environments. The risk of icing can therefore be quite high in the lower levels of NS, and with very strong uplift (over mountains or due to the dynamics) this could be true at middle levels as well.

AC clouds are composed of supercooled water droplets, but the amount of liquid water is low and serious icing is not expected in these clouds. I emphasize again that such general rules will have to be modified in the case of a very vigorous weather system, or if updrafts are augmented by terrain effects, or if the air-mass is particularly moist.