ICING

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I. ICING

A. General

Aircraft icing is one of the most feared and respected weather hazards, and with good reason. The formation of ice on an airfoil not only reduces efficiency, but also increases weight, increases the drag, which decreases lift. The combination of these factors may result in loss of altitude, or loss of control of the aircraft.

Ice forms on the leading edge of the airfoil, and most readily where the radius of curvature is shortest.

Icing is caused by super-cooled water droplets striking the forward edge of the airfoil and freezing on impact.

B. The Types of Icing Are:

1. Clear - Clear icing is a heavy, transparent, glossy ice formed by large, super-cooled drops as they strike the airfoil and have a chance to spread out before freezing. This type of icing usually forms in cumuliform clouds and will begin to form at temperatures just below freezing.
2. Rime - Rime icing is opaque and rough, and is similar to the buildup observed in a home freezer. It is formed as small, super-cooled droplets strike the airfoil and freeze on impact, keeping their nearly spherical shape and trapping air between the ice crystals. This type of icing is usually found in a stratiform layer.
3. Mixed - Mixed icing is simply a mixture of clear and rime icing.

C. The Formation of Icing is Dependent Upon:

1. Sustained Lift. This is often the most overlooked factor in icing formation, but is the factor that lifts the liquid water quickly, allowing it to remain in a liquid state, even though it's temperature is below freezing. Lift is usually caused by convection, convergence, fronts, or orographic features.
2. Liquid Water Content. The (LWC) of the air is measured in grams per cubic meter. This is a quantitative amount of water available per unit of air but is not usually available to the aviation forecaster. A good 'Rule of Thumb' is: "The lower and warmer the base of the cloud, then the higher the LWC of that cloud."
3. Temperature - It is easy to see that the colder the super-cooled water, the faster it will freeze to the airfoil.
4. Droplet Size
5. Airfoil Geometry - The curvature, shape, and angle of attack of the airfoil affect the formation of icing.
6. Airspeed - The faster the speed, the less icing will occur.
7. Duration of Exposure
8. Cloud Type

An old rule of thumb used while I was in the Navy: "The heavies icing conditions aloft, **not associated with freezing precipitation**, is most often reported between 4,000 and 6,000 feet above the freezing level. The temperature at that level is usually between -10 and -15 C. Other conditions needed are: (1) High moisture content, and (2) a sustained updraft.

Heavy icing occurs only when there is an abundance of super-cooled droplets present and this usually requires the freezing level to be at least several thousand feet above the surface.

D. Icing vs. Cloud Type
   1. Stratiform Clouds.
      a. In low and middle clouds:
         1) Icing is usually confined to a layer 3,000 to 4,000 feet thick.
         2) The intensity usually is a trace to light, with maximum values occurring near the upper portions of the cloud.
         3) Rime and mixed is most prevalent.
         4) The horizontal extent of the icing is the same as the cloud. Stratiform clouds have a great horizontal extent, and the extent of the icing will be the same as the cloud.
      b. High cloud layers.
         1) High clouds are usually composed of ice, so little icing would normally be expected in high clouds.
   2. Cumuliform Clouds
      a. The horizontal extent of cumuliform clouds is not as great as with stratiform clouds, so neither is the icing. However, the **VERTICAL** extent is greater.
      b. Icing may occur at all levels within the cloud above the freezing level, but is usually most intense in the upper half of the cloud.
      c. Intensities vary greatly from a trace in super-cooled cumulus, to moderate to heavy in cumulus congestus...with the most severe buildup occurring in cumulus congestus just before they become cumulonimbus.
      d. Icing is generally found in the updraft portion of mature cumulonimbus, and in a shallow layer near the freezing level in a dissipating thunderstorm.
      e. Heavy rime is most frequently reported in cumulus tops that are not developing rapidly and the freezing level is at least several thousand feet above the surface.
      f. Clear icing is most likely found in building cumulus, but will usually become rime icing after the thunderheads are fully developed.
   3. Clouds associated with frontal systems seem to have a higher probability for icing. This is due to the lifting motion that is associated with fronts. The following is a brief discussion of some of the characteristics of icing associated with fronts:

E. Warm Fronts
   1. Icing is usually widespread with a warm front and may occur either above or below the frontal inversion.
   2. Moderate to severe clear icing usually occurs where freezing precipitation occurs. This happens when temperatures above the frontal inversion are above freezing and the temperatures below the frontal inversion are below freezing.
   3. Icing above a warm front where the air is colder than freezing is usually confined to layers less than 3,000 feet thick.
   4. Warm front icing may precede the front by as much as 300 miles.

F. Cold Fronts
   1. Icing is usually more "spotty" with clod fronts with less horizontal extent than with warm front, but with greater vertical extent.
   2. Clear icing is the most common type reported. Moderate to heavy icing is usually limited to super-cooled cumuliform within 100 miles to the rear of the cold front, but is most intense above the frontal zone.
   3. Dew point spread of 3 degrees C ore less in the cold frontal zone is a sure sign that icing will occur.

G. Charts
   1. On upper air soundings, look for temperature-dew point spread of 3 degrees or less, and temperatures between freezing and -15C for the heaviest icing area.
   2. On 500 or 700 mb charts, look for temperature-dew point spread of 4 degrees or less for presence of clouds, and combine this with temperatures below freezing for icing.

II. Some Rules of Thumb for Icing

(From AWS/TR-80/001)

Rule 1. If the temperature is:

A. Between 0 and -7 degrees C, and the dew point spread is greater than 2 degrees C, forecast NO ICING. There is an 80% probability that icing will not occur under these conditions.

B. Between -8 and -15 degrees C, and the dew point spread is greater than 3 degrees C, forecast NO ICING - 80% probability that icing will not occur under these conditions.

C. Between -16 and -22 degrees C, and the dew point spread is greater than 4 degrees C, forecast NO ICING - 90% probability that icing will not occur under these conditions.

D. Colder than -22 degrees C, forecast NO ICING - 90% probability that icing will not occur under these conditions.

Rule 2. If the dew point spread:

A. Is 2 degrees C of less at temperatures between 0 and -7 degrees C, or,
B. Is 3 degrees or less at temperatures between -8 and -15 degrees C in:
   1) Zones of neutral or **Weak** cold-air advection, forecast a **Trace** of icing. - 75% probability.
   2) Zones of **Strong** cold-air advection, forecast **Light** icing - 80% probability.
   3) Areas with vigorous cumulus build-ups to insolation surface heating, forecast **Light** icing. - 90% probability.

III. Icing Intensity Forecasts From Surface Chart Data.

If upper-air data and charts are not available, the conditions shown on the surface chart must be used as a guide for icing conditions, even though they are not as reliable as direct upper-air considerations. Check the surface charts for locations of the cloud shields of fronts, low pressure centers, and precipitation areas along the route.

RULE 3. Within clouds not resulting from frontal activity or orographic lifting:

A. Over areas with steady non-freezing precipitation, forecast little or no icing.
B. Over areas without steady non-freezing precipitation, particularly in cumuliform clouds, forecast light icing.

RULE 4. Within clouds resulting from frontal activity or orographic lifting, neither the presence of absence of precipitation can be used as indicators of icing.

RULE 6. Within clouds, within 100 miles behind the cold frontal surface position, forecast moderate icing.

RULE 7. Within clouds over a deep, almost vertical, low pressure center, forecast moderate icing.

RULE 8. In freezing drizzle, below or in clouds, forecast moderate icing.

RULE 9. In freezing rain, below or in clouds, forecast severe icing.

IV. ICING TYPE FORECASTS

Rules 1 through 9 forecast only the occurrence and intensity of icing, but not the type. The following rules apply to the type of icing.

RULE 10. Forecast ***RIME*** icing when temperatures at flight altitude are colder than -15 degrees C, or when between -1 and -15 degrees C in stable, stratiform clouds.

RULE 11. Forecast ***CLEAR*** icing when temperatures are between 0 and -8 C in cumuliform clouds and freezing precipitation.

RULE 12. Forecast ***MIXED*** rime and clear icing when temperatures are between -9 and -15 C in unstable clouds.

V. ICING FORECASTING METHOD

(Taken from workshop given by Ron Olson, (NAWAU) at the Aviation Weather Workshop, in Kansas City, MO, Dec. 1991)

This method uses Mean RH, between 1000-500, the vertical motion, and thickness charts to determine the areas of icing potential.

To use,

a. Locate areas of MEAN RH of 55% or greater.
b. Locate area of thickness between 522 and 558.
c. Positive vertical motion.

The potential for icing exists in the area that the above areas intersect.

Additionally,

d. Using the boundary layer temp (850 temp works the best) find the area with temperatures between 4 and -12 C.
e. Find the area with 50-70% RH.
c. Icing is possible in the place where these two areas intersect.