AIRCRAFT ICING

Capt. M.P. "Pappy" Papadakis JD

Icing Kills! It kills engines, it kills lift, it kills braking, and it kills people. Icing is a very dangerous phenomenon which aircraft must be protected from.

1. There is airframe ice.
2. There is runway ice and slush.
3. There is carburetor and induction buildup icing.
4. There is fuel ice.
5. There is ice ingestion to engines.

Airframe Icing occurs in the temperature range of 10 c. to minus 10 c. in visible moisture. Visible moisture is defined as: rain, snow, sleet, clouds, fog and conditions where ambient temperature and dew point are within 15 degrees. It is within this temperature range that ice may begin to accumulate on an aircraft's structures. The ice usually forms on the aircraft leading edges, antennae, on wing, fuselage and tail surfaces.

Ice formation on aircraft surfaces may have three bad effects, and there is never a beneficial effect. They are:

1. Added weight of the ice.
2. Increased drag.
3. Decreased lift.

These bad effects raise the stall speed of the aircraft - sometimes fatally.

There are two kinds of ice build up that can occur. They are called **RIME ICE** and **CLEAR ICE**. Rime ice builds up slowly and looks white, almost like snow or an accumulation of ice pellets. It looks like the accumulation of white ice in a refrigerator that is not of the frost free variety.

Clear ice is exactly like the ice that forms at a hockey rink or as cubes in your freezer. It is solid frozen water with little air entrapment, it is clear. Clear icing comes about as nearly frozen water comes in contact with a super cooled airframe and freezes and adheres. Aviation parlance describes ice accumulation potential in the words, light , moderate and heavy. It is stupidity to fly a non protected airplane into known or anticipated moderate or heavy icing conditions. Generally speaking the potential for icing is predictable from weather forecast, pilot reports and good pre flight planning. However, icing conditions like the weather is fluid and changeable.

Generally speaking temperatures drop a little more than 2 degrees per one thousand feet of altitude increase. The weather service will provide the freezing level altitude. Remember of course that ice may accumulate and form about 10 C. either side of freezing. If the temperature is greater than 10 C. degrees icing is unlikely because it is too hot. The converse is true below minus 10 C. degrees. At the very cold ambient temperatures any water is in the form of ice crystals already and they will not adhere.

A pilot who encounters icing in addition to turning on the anti icing equipment, can climb or descend in hopes of finding an altitude where the temperature is outside the icing range. Why the icing range you ask, rather than it occurring only at the temperature water freezes (0 c)? The answer lies in the fact that all parts of the airframe are not exactly feeling the same temperature as portrayed on the temperature probe. This variance in temperature gradient over and around airfoils is beyond the scope of this text. However, whenever airflow is accelerated and the pressure is decreased the temperature is lowered due to a Venturi effect and Bernoulli's law. Remember that the CO_2 that comes out of a bottle is very cold because of its high velocity, rapid expansion. Thus temperatures vary and the 20 degree spread is a guideline to cover most of the contingencies.

There are some jet aircraft today that have an ice problem that makes them more susceptible to a specialized icing. These airplanes have wet wing fuel tanks where the metal skin of the airplane is the fuel tank itself. When this airplane flies several hours at altitudes where the temperature is a minus 50 degrees it and the fuel become super cooled. When the airplane descends to lower altitudes and particularly on the ground it can accumulate a sheet of ice on the wing through condensation process. This especially occurs in a warm high humidity day. Water droplets condense out of the air and adhere and freeze to the wing surface. If you are a seasoned air traveler you may have had to deice the airplane on a 65 degree day. Deicing is critical on aircraft covered with ice before all take offs.

The airplanes equipped with forced air heaters for the wings are usually satisfactory for all conditions of icing. However, it is foolish to remain in heavy or severe icing for extended periods even with sophisticated equipments.

The older and smaller aircraft often utilize inflatable bladder strips on the leading edge of the wing. With this system the pilot allows a small amount of ice to accumulate and then he turns on the system. The ice is pushed up and cracks off the wing due to the alternately inflating and then deflating rubber bladders. This is an effective way to accomplish de icing if the system is designed properly. At least one turbo prop airplane has a bladder that is unsuccessful in removing all the ice. It cleans the leading edge but leaves a ridge of ice aft of the bladder. A recent court case tried to a verdict showed a turboprop as being deficient in this respect. Whenever a general aviation or corporate aircraft slows down while flying in the icing range and then stalls and plunges to the ground an investigator must at least suspect icing as a factor.

Engine and induction icing may result in the same temperature ranges for jets, and much higher temperatures for a carburetor equipped aircraft. Carb icing may occur at a much higher ambient temperature due to the Venturi effect and suction inside the carburetor. Ice accumulation may build up and cause the engine to fail. This usually manifests itself as some loss of power and a rough running engine before progressing to engine failure. Once a carburetor has iced over and the engine has failed it is unlikely that it will ever be started again since the ice is still present and the hot air supply for carb heat is from that same now failed engine. Thus it is critical for the pilot to be especially on guard for carb ice conditions.

Jet engines simply port some heated bleed air into the jet intake and the result is continued performance with the slightest decrease in power available. Jet engines are susceptible to ingesting large amounts of ice and slush during takeoff roll and at aircraft rotation. This phenomenon is especially critical on jet engines mounted on the aft fuselage. Kicking up runway water, slush and ice is so critical that you may notice special chine tires on the nose wheel and mud flaps. This is to direct splashes away from the jet intakes. At rotation the nose wheel is lifted from the ground and the rear engines are lowered as the airplane moves to takeoff attitude. During these critical seconds the engines may ingest slush, water or ice. There have been aborted takeoffs because of loss of power at this critical time. If there has been an accident I am unfamiliar with it.

De icing wings tails and fuselages of airplanes are especially critical before takeoff. At least four major accidents with airliners have been at least partially blamed on icing on the wings. Three of the cases revolve around the wing shape being slightly distorted due to the ice. This in turn destroyed the lift and the airplane stalled and crashed during the takeoff sequence. The fourth accident is blamed on the ingestion of ice peeling off the wings and fuselage and being ingested by the engines causing all engines to lose power.

The F.A.A. as we go into the winter of 1992 has finally promulgated some deicing criteria for pilots to adhere to. Most airlines routinely deice before the airplane departs the parking ramp in winter conditions. This was done religiously. The problem was in the congested airport conditions and the interminable waits for takeoff. What was happening was the pilots would have to give up their takeoff slot and returns to the ramp to get another squirt of deice. Additionally, the regulations were so worded that the onus was on the pilot to determine what was safe. There were no time limits set and no printed guarantees as to the effectiveness of the deicing fluid. In at least three of the four crashes, the airplane had been previously deiced!

There are two varieties of anti icing fluids. One is glycol and water, and the European variety is a water glycol plus additive that adheres longer before draining off. The new guidelines prescribe that the pilots know the type and concentration of the fluid, as well as the time it was applied. Then the pilot translates this to an acceptable time based on the conditions and temperature outside (computed from a chart). There is to be some set up where the deicing truck will be parked near the takeoff area and deicing will always be accomplished closer to actual takeoff time in the future.

Fuel icing is especially critical in general aviation aircraft. Water may condense in fuel tanks and be in the fuel itself. Fuel usually doesn't actually freeze until some extremely low temperature is attained. If it did Anchorage traffic in the winter would be a night mare. The water in the fuel is a contaminant and a serious potential problem. The general aviation pilot is supposed to pre flight his airplane every time before flying. This pre flight includes draining water from sumps strategically located throughout the fuel system at the lowest point.

Additionally there are commercial additives (alcohol based) that absorb or chemically join with water molecules creating a safer situation. Every year a group of us Texas flatlanders fly to ski trips in Colorado, and every year a few pilots learn a lesson that is better taught from a book. That ice kills. This icing usually occurs at fuel filters and within the carburetor when the water freezes blocking fuel flow through the filter or forming inside the carburetor. Most small airplanes do not have fuel heat. Jet airplanes are equipped with a fuel heat transfer radiator and as fuel temperature gets down to zero the switch is turned and the fuel is heated.

Ice, slush and rain on the runway creates another problem in aircraft accelerate and stop performance. Accumulation of slush on the runway degrades takeoff performance dramatically. It changes the airplanes ability to accelerate well and this in turn increases the takeoff roll distance. If the runway is already short, the problems mount since a wet or slush covered runway takes greater distance to stop as well. Most jet airplanes have restrictions allied to take off allowable weights based on how much standing slush there is up to 1/2 inch when takeoff is prohibited. This is a little ludicrous since there is no way a pilot of a 727 can determine such depths from his vantage point. The airport may not keep up with the changing runway conditions. Take Washington National for instance. They shut the airport down immediately after the Air Florida accident.

Airlines landing on icy, slush covered or rain soaked runways face the problem of increased stop distances based on the conditions reported by the airport. Rain supposedly increases planned for stop distances by about 1/3, ice creates an entirely different scenario. Here stop distances are not predicted or predictable. Instead the tower reports either braking conditions reported by an airport authority automobile designed to test braking friction at the runway, or from pilot reports of the braking action on the previous successful landing. The unsuccessful landings are simple to understand when the airport reports “runway 13 closed, disabled aircraft of the end. " Adjectives to report braking action are reported as good, fair, poor and nil. A nil report should close that runway until snow removal or improvement is reported.

Another phenomena not associated with icing is hydroplaning and it will be covered separately. When an airplane fails to stop due to icing, the investigator should get the A.T.I.S. weather, A.T.C. and Tower radio tapes to see what warnings were given not only to the accident aircraft but the previous ones as well. A check should be made to see if the airport had completed any braking friction tests or whether they have given up their braking vehicle and no longer provide that data.

Icing accidents are extremely difficult to identify solely from the wreckage because the evidence is jarred loose by impact or melted by fire. Thus the investigator must analyze the conditions of flight at the time, place and altitude. This is done by :

1. Weather reconstruction.
2. Pilot reports in the area.
3. A.T.C. radio tapes.

There is one clue that sometimes works to identify icing on a crashed airplane. The airplane may have been dirty. When it crashes with ice the ice is forcibly removed and it cleans the area where it had formed. The remainder of the airplane wreckage is still dirty.

There are usually four types of deicing equipments provided to aircraft. They are electrical heaters designed to protect critical instrument ports. These ports are the pitot air system, the static air ports, and angle of attack probes. These systems must be kept ice free and clean so that the airplanes instrument systems receive valid base data. These probes give airspeed, altitude, angle of relative wind, and data to the air data computer (more sophisticated models). These systems are so critical that they are to be in use any time the airplane is in flight. Northwest lost a 727 on a ferry flight (empty) simply because the pitot system was not turned on and it iced.

The second is to protect system airfoils such as propellers, wings and tail surfaces. They may utilize electrical heating elements, forced blown hot air, or inflating rubberized pads.

Prop deicing is usually electric. Tail is usually electric and wings are usually forced hot air ducted internally or the inflating rubberized mats on the leading edges.

Larger jets use duct air for leading edge heating.

Again the investigator must know the system. From that he may utilize switch positions and warning light bulb filaments to see if the system was in use. For the pneumatic air variety the investigator may find air valve position as the most definite means of determining whether icing was in use. Some airplanes have alcohol spray for windshield anti ice and most are electrically heated.

The third variety of anti icing equipment is to heat inlet air to carburetors and two areas of jet intakes. This is done simply by diverting warm / hot air into the inlet ducting. In general aviation carburetor type aircraft this is very critical.

The way an investigator tells if they were in use is:

1. Bulb Analysis

The fourth variety of anti icing protection is to keep the fuel from freezing (or water in the fuel from icing). This is done in jet aircraft by adding a fuel heater. In small aircraft there are approved additives to keep the fuel from freezing and to absorb the water contaminants in the fuel. These additives have an alcohol base.

The way an investigator tells if these were in use is :

1. Switch positions.
2. Valve positions.
3. Light bulb analysis.
4. Fuel sample analysis. (chemical lab)
5. Fuel receipts.