Ice Protection Systems
Pneumatic, Chemical and Electrical

Introduction

Whether you ever intend to willingly fly in “known icing” conditions or not, common sense dictates that having an ice protection on your aircraft provides a supplemental measure of safety for unexpected encounters with inadvertent icing conditions. Since flying into known icing conditions is generally regarded as something to be avoided at all costs, few piston aircraft are equipped for flight into known icing (FIKI). However, many aircraft are certified with ice protection systems (sometimes called “non-hazard” ice protection) to guard against encounters with “inadvertent icing” conditions.

Why then, if an aircraft is not certified for FIKI, does it need an anti-icing or de-icing system installed? The answer is “for safety’s sake.” Many Technologically Advanced Aircraft (TAA) are equipped with modern aircraft ice protection systems, not because they are required, but because they enhance safety. High-G safety seats, supplemental inflatable restraints and even airframe parachutes are examples of systems that, although are not required equipment, can enhance safety during normal operations.

The same holds true for ice protection systems. Although flight into known icing is strictly prohibited unless the aircraft has the required equipment, weather conditions change rapidly in flight and forecasts are only predictions of what may occur. Thus, equipping an aircraft with a level of protection against encounters with inadvertent icing can provide an escape mechanism for the pilot who encounters such conditions unexpectedly.

Consequently, this paper will briefly compare and contrast three different technologies commonly used for ice protection systems – pneumatic (rubber boots), chemical (glycol pumpers) and electro-thermal (heated).

De-icing versus Anti-icing

Although de-icing versus anti-icing may sound like simple semantics, there are a variety of cost, weight and maintenance variables to consider between these concepts. With regard to inadvertent icing protection, both types of systems (anti-ice and de-ice) are designed to achieve the same end-result but they do so in different manners.

De-icing systems remove ice from the protected areas of the airframe. Ice is first allowed to build up on the surface and the system removes the ice.

Anti-icing systems are designed to prevent ice from accumulating in the first place. This is usually done by heating the critical surface to a temperature above freezing so ice cannot form on the surface much like the theory behind a heated pitot static system that is activated before entering visible moisture.

De-ice systems = remove ice accumulation from the airframe
Anti-ice systems = prevent ice accumulation on the airframe

Pneumatic (de-icing)
Aircraft have been equipped with rubberized pneumatic de-icing systems since the 1930s. The pneumatic ice removal system consists of rubber bladders attached to the leading edges of the flying surfaces. They function by having the rubber bladders on the leading edges pneumatically inflated to break the ice so it will be removed from the airframe by the aerodynamic forces. The idea is valid and has been used successfully for decades and is commonly used in FIKI applications.

Advantages:

- Pneumatic systems are effective since compressed air provides an inexhaustible supply of de-icing capabilities

Disadvantages:

- Rubber boots on the leading edge of the flying surfaces are susceptible to damage
- Rubber boots are susceptible to degradation from UV (sun) light and must be continually treated to prevent drying and cracking
- Boots are expensive to replace, and although patching holes can prolong the life of the system, a danger lies in one side inflating and one side failing to inflate thereby causing a lift imbalance due to the degradation of the airfoil from ice accumulation on the wing that remains iced
- The required air pumps can fail
- Pneumatic systems are complicated and heavy

Chemical (de-icing or anti-icing)
Chemical de-icing/anti-icing have also been in use for decades. One example of today's applications consists of a titanium leading edge device applied to the wing, horizontal stabilizer and in some applications the vertical stabilizer. The leading edge is actually a "C-shaped" cuff laser-drilled with microscopic holes. A glycol-based chemical solution (similar to anti-freeze) is pumped from a holding tank through the leading edge panels so the solution is forced out through the microscopic holes. Since ice accumulates on the leading edge panels, the glycol solution being forced through the holes on the leading edge chemically disbonds the ice formation so it can be removed from the airframe by the aerodynamic forces. The glycol solution can also be pumped through small tubes located on a "slinger ring" behind the propeller to help coat the leading edged of the propeller. The chemical solution pumped through the slinger then enters the prop wash and may provide an ancillary level of protection to the windshield or any other surfaces in the propeller wake.

Advantages:

- Chemical systems are an effective anti-ice system if employed prior to entering icing conditions so the leading edges can be coated with the chemical solution to prevent ice accumulation
- Ancillary protection of windshield, cooling and engine inlets, landing gear and vertical stabilizer by nature of the glycol solution in the slip stream from the propeller slinger ring

Disadvantages:

- If used as an anti-icing solution, the pilot would need to anticipate conditions and activate the system prior to entering icing condition to coat the flying surfaces.
- Since there is a finite supply of fluid carried on the aircraft (limited by the tank size) the chemical system can only provide protection until the fluid supply is depleted
- The weight of the glycol fluid, approximately of 10lbs/gal., causes a significant weight penalty above and beyond the weight of the actual de-icing system
- Fluid is expended so replacement fluid must be carried on board for refills or must be must be located along the route of flight

- The system requires minor periodic preventative maintenance to keep glycol pumps from seizing
- Use of this type of system coats the aircraft with a chemical film, requiring subsequent cleaning
- Residual fluid drips onto hangar floor or ramp surface making a slippery and messy surface.

Electro-Thermal (anti-ice or de-icing)

Electric anti-icing systems are actually thermo-electric in nature and represent the most modern solution for general aviation aircraft that are either piston powered or turbine applications that don't have sufficient bleed to heat the wing leading edge. With thermo-electric systems, electric power is converted to thermal energy to heat the leading edges of the flying surfaces. One such system uses a dedicated alternator wired independently of the ship's main electrical system and provides the electricity to a graphite foil heating element applied to the leading edges of the flying surfaces. The laminate is fed with up to 7,500 watts of power to convert the electric power to thermal energy.

Since thermo-electric systems are tremendously effective in de-icing as well as anti-icing, the system can be armed at anytime and will activate itself if the temperature in flight falls below a designated point. Once armed, the system requires no input from the pilot since there is no cycle or fluid level to monitor.

Advantages:

- Operating like a heated pitot tube, the system can be armed prior to entering visible moisture, thereby reducing pilot workload
- Electricity provides an inexhaustible supply of anti-icing power and the discrete electrical source does not interfere with the ship's system
- Minimal aerodynamic impact. The heating elements are very thin when applied.
- The system requires virtually no maintenance, the only moving part is the alternator
- Light weight: overall system weight, depending on configuration, is typically 40lbs.

Disadvantages:

- The power source and heavy gauge wiring adds to aircraft empty weight
- The large alternator can extract up to 8hp of mechanical energy from the powerplant depending on surface de-ice requirements.