The Evolution of Aircraft De-Icing Systems

Ice is one of the most significant natural threats to aircraft as it increases weight, reduces lift, decreases thrust, and increases drag. All of these combine to slow aircraft down and to reduce their ability to maneuver. Another common issue caused by icing is inaccurate readings on in-light instruments. One of the most common causes of trouble is the pilot's tube: a device used to measure airspeed. Its small opening underneath the wing can become iced over, resulting in poor airspeed data. Furthermore, the accumulation of ice negatively effects engine performance. As such, ice not only poses a danger to aircraft, it also makes them more costly to operate.

This has resulted in significant investment into de-icing and anti-icing systems for aircraft. Solutions vary between on-aircraft systems and on-ground services. Commercial aircraft must undergo regular de-icing procedures on the ground to ensure proper operations. While this approach is generally simple, typically spraying the aircraft's exterior with de-icing chemical, the procedure has been improved to improve timeliness and effectiveness[i]. Despite the increasing efficacy of this approach, it is also essential, especially for high-altitude flight, to also address the issue while in air. There are a variety of current solutions to this, many of which are in a constant state of evolution.

Pneumatic De-Icing

Pneumatic de-icing is one of the most widely used methods of removing ice from aircraft, especially small to medium sized and utility planes. This was invented in 1923 by the B.F. Goodrich Corporation. The system uses boots on the leading edges of the airfoil surfaces which are expanded through the use of a pneumatic pump in order to dislodge ice. Although reasonably effective, this approach

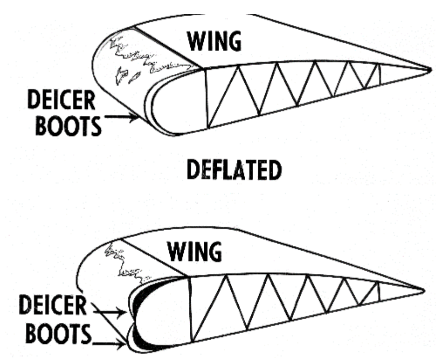

Figure 1: Pneumatic Deicing Boot

requires regular maintenance and may become overwhelmed in severe conditions[ii]. Furthermore, for larger aircraft that fly at high altitudes, pneumatic boots may not be substantial enough to address the icing caused by flying amongst clouds[iii].

Recent updates to pneumatic de-icing systems, such as B/E Aerospace's Ice Shield, have leveraged more robust materials in order to reduce the required frequency of maintenance[iv]. Furthermore, improvements to the methods in which these systems are deployed have been made in recent years, resulting in superior performance[v]. However, this relies on proper operation by aircraft crew, meaning that the effectiveness of these systems would be significantly reduced due to non-compliance with changing practices. The Federal Aviation Administration has determined that the majority of accidents related to icing resulted from not using or improperly using de-icing systems[vi].

These pneumatic solutions to aircraft icing will likely stay in use amongst many prop aircraft for the foreseeable future due to the significant amount of bleed air needed to operate passive anti-icing systems[vii]. However, the inferior efficacy and, more importantly, reliability of active solutions such as pneumatic boots means that they are growing increasingly unpopular with larger, jet aircraft, especially newer more electric aircraft.[viii] One particular difficulty of active solutions is that it is not always easy to assess the level of icing while in flight. Although some ice is clearly visible for the crew, a significant portion of buildup may be virtually impossible to see[ix]. Specially designed sensors are often used to help with the identification process; however, this shortcoming suggests that passive anti-icing is a superior approach.

Anti-Icing Solutions

A more optimal solution to icing on aircraft, especially larger jet engine planes, is to passively prevent the buildup of ice throughout operation. By doing so, the need for de-icing systems is removed. However, some anti-icing systems can be used to de-ice a plane if needed.

Typically anti-icing systems focus on heating the outside of the aircraft in order to prevent ice from forming. This can be accomplished in two principle ways: using bleed air from the engines or through electro-thermal systems. Bleed air systems use hot air bled from the engines to heat flight surfaces. One of the most widely used forms of this is the Piccolo tube which circulates bleed air throughout the flight surface from the engine's first compressor[x]. Although a relatively straightforward approach, the efficiency of bleed air anti-icing has greatly improved in recent years. The systems to be used on the upcoming A330neo, for instance, will be able to make significantly more usage of bleed air than their earlier counterparts[xi].

Another approach to anti-icing is to use electro-thermal systems which use the aircraft's electric power systems combined with resistive materials to heat the aircraft's flight surfaces[xii]. This offers a number of advantages over bleed-air systems in that this approach greatly improves the efficiency of energy usage. Furthermore, the aircraft crew has superior control over the distribution of heat. This means that electro-thermal anti-icing systems can be effectively used to both passively prevent icing and to actively remove it as necessary.

One drawback of this form of anti-icing, however, is the significant increase in demand on the aircraft's electric power systems; however, this can be offset by using the bleed air for additional power generation. As such electro-thermal anti-icing is best suited for aircraft with a more electric architecture. It is presently commonly used amongst new military and commercial aircraft built on this design architecture.

Figure 2: Chemical De-Icing on the Ground

Yet another approach to anti-icing is to use chemical solutions that hinder ice build-up. This can be accomplished both through coating and through in-flight distribution of the solution onto flight surfaces. The former is typically accomplished through the application of hydrophobic materials which inhibit fluid from sticking to the aircraft and being able to freeze there. The more active alternative uses a system of small holes from which anti-freeze chemicals can be distributed onto the body of the aircraft. A similar process is typically applied to aircraft while on the ground. Crews at airports will spray flight surfaces with an anti-icing agent in order to be remove ice and help to prevent build up in flight[xiii]. While fairly simple, this process has been improved in recent years in order to increase both the timeliness and efficiency of the process[xiv].

Icing and More Electric Aircraft

Within the more electric architecture, the possibilities for more advanced anti-icing and de-icing solutions are significant. In particular the use of electric power means that the aircraft crew can have substantially more control over the distribution of heat. This means that they can make adjustments both to optimize power consumption and to address ice buildup in specific areas of the flight surfaces.

One example of this approach in use is Boeing's 787 Dreamliner, which leverages a no-bleed system to maximize efficiency. Compared to pneumatic solutions, this approach consumes roughly half of the energy while offering greater control and efficacy[xv].

The greatest drawback to anti-icing systems that take advantage of the more electric architecture is the increased demand on the electric power systems of the aircraft. While the overall energy consumption is less, it is significantly more focused on the one form of power generation. In general this is a positive change; however, in some instances it can mean critical issues for the aircraft. Earlier in 2014, Japan Airlines experienced problems with the battery systems on a 787[xvi]. While this occurred during scheduled maintenance, this was not the first such issue. The increased demand placed on these electric power systems could represent a threat both to anti-icing procedures and to aircraft systems in general.

This threat to the electric power systems could prove particularly dangerous in icy conditions. If the aircraft is unable to effectively prevent and remove icing, the efficiency of the power systems will be significantly reduced. As such, it could become a compounding issue if not properly addressed.

Conclusion

The current state of ice protection is fairly good. As this has been an issue affecting air travel almost since the invention of aircraft, there has been a continuous push to develop improved solutions to icing. However, icing is arguably the greatest natural threat to aircraft. It is a common issue, one that occurs during regular operation for high altitude flight, and one that can potentially lead to both diminished efficiency and a harmful reduction of flight capability.

As such, it is essential to continue to develop new and better systems for addressing ice buildup. While new military and larger commercial aircraft employ electro thermal anti-icing, this is almost absent in smaller and older craft. Continued reliance on pneumatic and bleed air solutions will prove to be costly due to the excessive energy requirements. Furthermore, as pneumatic boots require proper operation, they are not an ideal solution for non-professional pilots. Fortunately, there are a number of areas of research that show promise for improved ice protection, particularly within the more electric architecture.

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