Chapter 7

SERVICE AREA: In-Flight Icing

1. Problem Description In the period 1989-early 1997, the National Transportation Safety Board indicated that in-flight icing was a contributing or causal factor in approximately 11 per cent of all weather-related accidents among general aviation aircraft. Icing was cited in roughly 6 per cent of all weather-related accidents among air taxi/commuter and agricultural aircraft. The percentage was 3 per cent for commercial air carrier accidents. The 1994 crash of an ATR-72 near Roselawn, Indiana, which claimed 68 lives, took place during icing conditions.

In-flight icing is not only dangerous, but also has a major impact on the efficiency of flight operations. Rerouting and delays of commercial carriers, especially regional carriers and commuter airlines, to avoid icing conditions lead to late arrivals and the resulting ripple effect throughout the National Airspace System. Diversions en route cause additional fuel and other costs for all classes of aircraft.

Icing poses a danger to aircraft in several ways:

- *Structural* icing on wings and control surfaces increases aircraft weight, degrades lift, generates false instrument readings, and compromises control of the aircraft.
- *Mechanical* icing in carburetors, engine air intakes, and fuel cells impairs engine performance, leading to reduction of power.

> Icing can occur in a wide variety of conditions; among the most common are:
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> - clouds or precipitation near or below freezing, and
> - clouds or precipitation containing supercooled water droplets.
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> These conditions are commonly found near active frontal boundaries during the winter months.
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> Three types of icing pose threats to aircraft in flight:
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> - *rime*,
> - *clear*,
> - *combined or mixed (rime and clear together).*

Small aircraft routinely operate at altitudes where temperatures and clouds are most favorable for ice formation, making these aircraft vulnerable to icing for long periods of time. Larger aircraft are at risk primarily during ascent from and descent into terminal areas.

2. *Objectives*

The goal is to improve in-flight icing service for the aviation community and reduce or eliminate icing-related accidents. In order to reach this goal, the *National Aviation Weather Initiatives* establishes these objectives:

- reduction in the rate of icing-related accidents and incidents for all categories of aircraft,
- reduction in the rate of icing-related delays and diversions for commercial aircraft, and
- reduction in the number of encounters with unforecast moderate-to-severe icing conditions for all classes of aircraft.

Meeting these objectives will require many changes and improvements in operational procedures and equipment, which will be described below.

3. *Operational Decision Makers*

The range of decision makers described in Chapter 2 applies in the case of in-flight icing.

4. *Current Operations Concept*

4.1 Preflight Operations. Preflight procedures relating to icing are no different from those relating to any other weather hazard. The general process is described in Chapter 2. What is different is how the pilot uses the information gathered during preflight. The decision to take off, delay, reroute, or abort rests solely with the pilot. After the pilot has collected and assimilated all available data on conditions throughout the proposed route, examining the severity of icing conditions and the availability of air space if avoidance is required, the decision to take off or not rests on

- his or her experience level in icing conditions and knowledge of avoidance and escape procedures, and
- the aircraft's capabilities in icing situations.

Since some types of aircraft are certified to fly in moderate icing conditions, while others are not, the go/no go decision is not always the same for all pilots addressing the same conditions. Pilots must combine their knowledge and experience with the best analysis and forecast products possible to ensure safe decisions. Large commercial airliners are certified to fly in icing conditions because they have adequate engine power and equipment to prevent and remove ice. Smaller aircraft often do not have these devices because of power constraints or cost considerations. It is therefore the smaller types of aircraft that are most vulnerable and of most concern.

4.2 En Route Operations. Weather-related procedures that pilots utilize from takeoff to touchdown are described in Chapter 2. Crews need to continually gather and examine all available information to maintain a clear picture of changing conditions en route. The primary icing-specific tactic requires regular checks for signs of ice formation. When icing becomes apparent, the avoidance and escape plans formulated during preflight must be implemented rapidly.

5. *Needed Service Improvements* The accident statistics provided in Section 1 indicate that the current in-flight icing service, while effective, has room for significant improvement. Ideally, decision makers should be able to direct aircraft away from icing encounters entirely. When an icing encounter inadvertently occurs, a pilot should fully understand his or her options and take appropriate avoidance or escape actions. A number of improvements will bring this operational scenario closer to reality.

A combination of clear and rime ice built up on the leading edge of the wing of a NASA research aircraft.

5.1 Production of Weather Information. Weather observation systems need to be expanded to provide higher spatial resolution for icing-related variables, with particular emphasis on humidity and cloud data. Observations, analyses, and forecasts of icing conditions need to meet specific standards of accuracy for geographical location and extent, as well as for duration and intensity. Improved precision will allow pilots and dispatchers to make avoidance plans with confidence.

5.2 Weather Product Generation and Delivery. Icing observation, analysis, and forecast products should be in clear and understandable formats, both text and graphics, that can be transmitted to Air Traffic Control and airlines operations center personnel as well as directly to pilots. This requires both product development and selection of communications paths and display systems.

5.3 Pilot Training. In general, pilots would benefit from improved understanding of icing conditions and the impact of ice accretion on airframe performance. Simulators capable of replicating in-flight icing provide the best means of gaining this knowledge and experience under controlled conditions. Interactive training aids can provide valuable, if somewhat less visceral, experience. However, such simulators are not generally available for helicopters and small airplanes because of cost and large carriers do not currently simulate flight characteristics with ice accretions on airframe parts.

5.4 Information-Provider Training. Aircraft operators and service providers throughout the system need training to help them better understand icing conditions and hazards, the impact these hazards have on individual aircraft, and the ramifications of icing conditions for sectors under their control. These personnel also need expanded training in the interpretation of icing forecast products.

5.5 Airframe Certification. Despite the considerable icing research conducted over the last 50 years, the cost of icing certification testing for helicopters and small airplanes is still high. The manufacturers of these types of aircraft cannot afford either the time or the cost of this testing, which is currently the only acceptable method for demonstrating an aircraft's ability to fly in icing conditions. Consequently, a large majority of small aircraft are not certified to fly in icing conditions, whether or not they may actually be capable of doing so. This situation could be significantly altered by the development of improved analytical and wind tunnel test techniques to predict an aircraft's icing characteristics with little flight testing.

6. In-Flight Icing Initiatives On pages 7-5 and 7-6 are the initiatives which have been identified for this service area.

Number	In-Flight Icing Initiatives	Relative Ranking*	Cooperating Organizations
1	Develop and implement icing products which are applicable for use by aircrews, ATC service providers, and airline operations centers for tactical and strategic icing avoidance.	★★★★	FAA, NOAA/NWS, Industry**
2	Develop and implement ground-to-air Flight Information Service capabilities to readily disseminate icing observations, within five minutes of availability, and forecast products, within 15 minutes of product generation, throughout the National Airspace System, i.e., to the cockpit, to airline operations centers, and to ATC providers.	★★★★	NASA, DoD, FAA, Industry
3	Develop and implement a multi-functional color cockpit display which includes icing along with terrain and traffic hazards.	★★★★	NASA, Industry
4	Develop the capability and increase the types and number of aircraft with automatic reporting of icing related variables.	★★★★	NASA, Industry, FAA,
5	Develop training packages for use by operators of all types of aircraft to increase their knowledge of icing hazards and its impact on aircraft safety.	★★★★	FAA, NASA, DoD, Industry
6	Improve the vertical and horizontal resolution and accuracy of observations of icing related variables affecting en route operations.	★★★★	NOAA/NWS, DoD, FAA
7	Improve current ground-based communications systems to readily disseminate icing products and reports within the National Airspace System, i.e., to the cockpit, to airline operations centers, and to ATC service providers.	★★	FAA, NASA
8	Develop and implement forecasting (for less than 1 hour) and modeling techniques that will improve icing guidance products for tactical avoidance.	★★	NOAA/NWS, DoD, FAA

9	Establish and institutionalize an objective, quantitative standard for characterizing icing without regard to aircraft type.	★★	FAA, NASA, NOAA/NWS
10	Develop and implement forecasting (greater than one hour) and modeling techniques that will improve icing guidance products for strategic avoidance.	★★	NOAA/NWS, DoD, FAA
11	Incorporate new remote satellite-based and ground-based radar technologies to warn of impending ice encounters.	★★	NOAA/NWS, NASA, FAA
12	Develop and implement icing-related training packages for ATC service providers and require the airlines to implement similar training packages for their pilots and operations center personnel.	★★	FAA, Industry
13	Develop and implement procedures that allow aircraft manufacturers to introduce new technologies, such as simulation-based design techniques, to streamline the aircraft certification process and improve understanding of aircraft performance in icing conditions.	★	FAA, NASA, Industry
14	Develop and incorporate new on-board ice accumulation detection and removal technologies.	★	NASA, FAA, Industry
15	Develop and incorporate new aircraft-mounted, forward-looking technologies that warn of impending icing encounters.	★	NASA, Industry

In-Flight Icing Initiatives

* The relative rankings assigned to the initiatives are based on a qualitatively calculated benefit/cost ratio. It's possible that a high-benefit initiative which is costly to implement may rank lower than a medium- or low-benefit initiative which is medium or low in cost to implement. All these initiatives are considered to have a positive benefit to aviation; however, when benefits and costs are considered, some rank relatively higher than others. Details can be provided upon request. Four stars (★★★★) is the highest ranking.

** The term "Industry" in this context refers to private organizations (e.g., airlines, manufacturers, associations) which may represent both users and providers of weather information.