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Incident Reports Highlight Problems Involving Air Carrier Ground Deicing/Anti-icing

Although icing's deadly threat to safe flight is well-known, accidents have continued to occur because of snow/ice-contaminated aircraft critical surfaces. A recent study focused on human factors associated with air carrier ground deicing/anti-icing issues.

by
Robert L. Sumwalt III

"Strange as it may seem, a very light coating of snow or ice, light enough to be hardly visible, will have a tremendous effect on reducing the performance of a modern airplane. It occurs when the ship is on the ground, and makes takeoff dangerous. To avoid this danger the airlines ... [must] make certain that all ice is off before the airplane is allowed to depart."

Jerome Lederer, April 20, 1939

During the 54 years since Flight Safety Foundation founder and president emeritus Jerome Lederer made the statement above,[1] at least 44 air carrier accidents have occurred worldwide because of inadequate ground deicing/anti-icing.[2] During the past 25 years, 35 such accidents have occurred, 21 involving jet transports. Nineteen of the 35 accidents occurred in the United States; the most recent U.S. airline accident occurred last year at New York's LaGuardia Airport. Clearly, there is a need for safety improvements to reduce the number of air carrier ground-based icing accidents.

Based on historical accident and casualty rates, the U.S. Federal Aviation Administration (FAA) has projected that unless safety improvements are made, there could be eight additional air carrier ground-based icing accidents during the next 10 years. Projections indicate that these accidents could claim 134 lives and cause 67 serious injuries. The present dollar-value benefit of preventing these accidents and casualties is approximately US$181 million.[3]

Before the beginning of winter 1992, the FAA ordered significant changes in air carrier ground deicing/anti-icing procedures.[4] After using these new procedures for one icing season, the FAA and airline industry are evaluating them for possible refinements.

The U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) shares the FAA's and the aviation industry's desire to increase aviation safety through improved airline ground deicing/anti-icing procedures. ASRS undertook this study to learn more about the human factors involving air carrier ground deicing/anti-icing, including an examination of the effects of the new FAA regulations concerning deicing/anti-icing.

Objectives and Scope Outlined

This study focused on the human factors associated with air carrier ground deicing/anti-icing. The study sought to determine psychological and physical factors that affect a person's ability to properly detect ice, remove ice and ensure that the aircraft critical surfaces are free of ice before takeoff. Psychological factors evaluated included (but were not limited to) judgment and decision making, perceptual aspects, and motivational and attention factors. Physical factors evaluated included (but were not limited to) difficulties in trying to inspect and/or remove ice from wings that are high off the ground, and procedural design issues.

For a report to be included in the study set, it must have a) involved air carrier operations and b) mentioned *ground* deicing/anti-icing activity, or made some other reference to frozen contamination not being removed from aircraft critical surfaces before takeoff.

The ultimate goal of this study was to identify specific deicing/anti-icing issues for which worthwhile safety recommendations could be made.

Fifty-two reports were reviewed that were submitted to ASRS between January 1986 and January 1993. They constituted a nonrandom sample of aviation incidents and events. All ASRS data, including those in this study, were submitted voluntarily and may reflect reporting biases. Reporters' incident descriptions were likely influenced by their individual motivations for reporting, and often gave only one perspective of an event, which was not balanced by any additional investigation or verification. Despite these biases, the general presumption underlying all research based on ASRS data was that if the incident reports were drawn from a sufficiently long time interval (several years or more), the underlying causal pattern observed in the data would be broadly representative of all the aviation safety incidents of that variety.

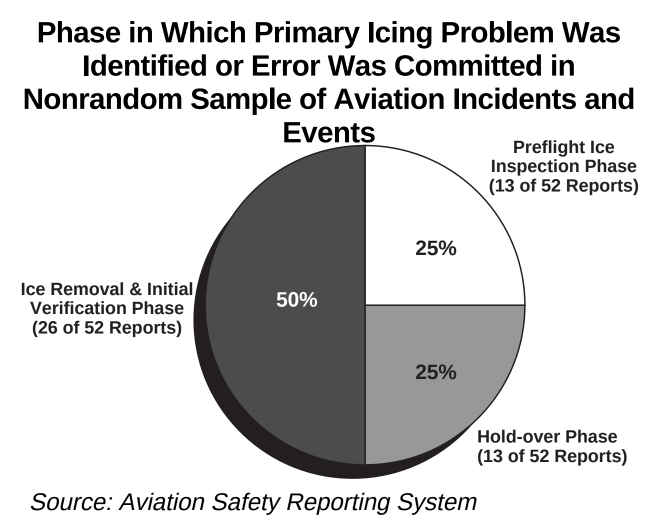

Figure 1

This research study was distinct from other work that has been done in the area of ground deicing/anti-icing. Whereas many procedural changes used today are a result of findings from accident investigations, this research project focused exclusively on ASRS incident data. Typically, ASRS reporters described what went wrong or what problems they noticed, and they often described how they dealt with these problems to keep the situation from becoming an accident. Thus, by concentrating on ASRS incident data, the study aimed to broaden the understanding of ground icing problems.

To collect data, a coding instrument was developed. This instrument was developed jointly between the principal investigator and ASRS staff members who were experienced with such research tasks. This resulted in a coding instrument that combined a strong operational background with formal research methodology.

During data collection and coding, the first major problem or error that occurred in each report was identified. This became known as the primary problem or error. According to when or where the primary problem or error occurred, each report was coded and placed into one of three mutually exclusive "phases" (Figure 1):

- The "preflight ice inspection phase" involved reports that cited difficulties inspecting for and/or detecting ice during preflight;

- The "ice removal and initial verification of ice removal phase" involved reports that cited problems or errors that occurred while removing ice; reports that mentioned crew member problems or errors with the initial verification that ice removal had been properly conducted; and, in a few instances, reports that ice had been detected during preflight but not removed; and,

- The "hold-over phase" involved reports that cited problems or errors that occurred in the final verification that aircraft critical surfaces were free of contamination, after deicing/anti-icing, but before takeoff.

Data related to the study objectives were gathered from each report. There was an interest in determining if the primary problem or error was linked to the formation of a secondary problem or error. In cases where there was such a link, there was particular interest to learn if this chain of errors was recognized before takeoff, or if a takeoff occurred with contaminated surfaces.

A takeoff with contaminated wing/tail surfaces occurred in 52 percent of the reports in this study's data set. "Close calls," whereby accidents were avoided by only a narrow margin, were described in some reports. Table 1 shows the 53 reporter citations[4] that describe the consequences of takeoff attempts with contaminated aircraft critical surfaces. Approximately two-thirds of these reported consequences could be deemed serious, because they involved aircraft controllability problems, engine failures and damage, rejected takeoffs and other potential accident causes.

Table 1

Consequences of Takeoff Attempts with Contaminated Aircraft Surfaces

❑ Engine anomalies, damage or failure due to ice ingestion	16
❑ Aircraft control difficulties/anomalies	9
❑ Return to land at departure airport	9
❑ Rejected takeoff	6
❑ FAA/Company disciplinary action threatened or feared	4
❑ Emotional trauma	3
❑ Failure or inability to adhere to air traffic control (ATC) clearances	3
❑ Emergency declared	2
❑ Significant delays	1
Total	53

Note: A citation is where an ASRS reporter stated (cited) a particular situation or occurrence. One ASRS report may contain more than one citation.

Source: U.S. National Aeronautics and Space Administration, Aviation Safety Reporting System

Although each report was placed into only one exclusive phase category, reports within each phase were divided into several non-mutually exclusive categories.

Preflight Ice Inspection Phase Examined

The preflight ice inspection phase included 25 percent of the study's primary problems or errors. Within this phase, 54 percent of the reports cited the elevated height of wing and tail surfaces as a factor in ice inspection difficulties.

Forty-six percent of the reports indicated that perceptual problems contributed to ice detection difficulties. These included factors such as crew members being unable to see ice because of poor lighting conditions, the transparent nature of clear ice or ice that was otherwise hidden from view. Not being able to reach ice during a tactile wing inspection was also cited.

Procedural problems were cited in 23 percent of the reports in this phase. These included inadequately designed or frequently revised ice inspection procedures.

Schedule pressure was a factor in only 15 percent of these reports.

Ice Removal and Initial Verification of Ice Removal Phase Examined

Exactly half of the 52 reports in the study found the primary problem or error in the ice removal and initial verification of ice removal phase. Of the 26 reports, 54 percent mentioned the airplane being inadequately deiced (i.e., ice remained on the aircraft after deicing). Twenty-three percent of the reports discussed failure to have the airplane deiced when ice was adhering to aircraft surfaces.

In the 19 cases in this phase where the aircraft was deiced, 63 percent of the flight crews relied on the deicing crew's statement or hand signals that deicing had been completed; the flight crews failed to verify successful ice removal.

Procedural problems were mentioned in 50 percent of the reports in this phase. These problems included failure of deicing crews to follow prescribed procedures, inadequate procedures for deicing and/or postdeicing checks, poor communications between deicing crews and flight crews, improperly prepared deicing fluids, lack of reliable equipment and inadequate staffing to conduct deicing.

Schedule pressure was cited in 15 percent of the reports in this phase, and perceptual problems were mentioned in 12 percent.

Nineteen percent of the reports in this phase cited factors that contributed to flight crew failure to properly verify ice removal.

Stated one report, "The value of inspecting the wing for ice from inside the cabin, especially at night, is questionable. Type II deicing fluid is the consistency of warm honey and when it covers the cabin windows, very little can be seen through them" (ASRS Record 229944). Another reporter shared a similar concern. Three reporters stated that the elevated height of wing and tail surfaces contributed to post-deicing inspection difficulties.

Hold-over Phase Examined

The hold-over phase included 25 percent of the study's primary problems or errors. Within this phase, there was some expectation that pilots had failed to mark the passage of time between deicing/anti-icing and takeoff. Nevertheless, no conclusive evidence was found to support this hypothesis.

Seventy-seven percent of hold-over phase reports provided sufficient evidence to infer that the problems encountered in these reports could have been eliminated by conducting an external inspection of the wings just before takeoff. In making this inference, it was assumed that this external inspection was conducted no more than five minutes before takeoff, and that the inspection was conducted by trained personnel using proper illumination devices and equipment to elevate them above aircraft critical surfaces.

Thirty-one percent of hold-over phase reports involved procedural problems. Reporters cited inadequate flight crew procedures for hold-over inspection and lack of flight crew planning/preparation. Reporters also cited two airport/air traffic control (ATC)-related issues. These were a lack of ATC programs to eliminate long taxi delays when ground icing conditions existed, and a lack of deicing equipment near departure runway thresholds. Thirty-one percent of hold-over phase reports cited significant ground delays because of airport snow removal or traffic volume.

Although there was an expectation to see evidence of attention factors (distractions) in the other two phases, findings showed that attention factors were unique to the hold-over phase. In this phase, attention factors were cited in 23 percent of the reports. In two narratives, the reporters mentioned that a crew member went to the passenger cabin just before takeoff to check for wing contamination. In each report, the crew member's absence from, and subsequent return to, the flight deck created or contributed to cockpit distractions. In one case, a takeoff was initiated without clearance, nearly causing a runway collision.

Twenty-three percent of the reports in this phase provided evidence that some pilots attempted to determine the amount of snow/ice accumulation on their aircraft by simply observing accumulation on other aircraft.

Twenty-three percent of the reports in this phase provided evidence that some pilots attempted to determine the amount of snow/ice accumulation on their aircraft by simply observing accumulation on other aircraft. During data analysis, these were classified as judgment/decision-making problems. Also in this classification were eight percent of hold-over phase reports that discussed pilot decisions to take off while knowing that snow/ice was adhering to wings.

Perceptual problems were noted in 15 percent of these reports.

Error Recognition Reduced Beyond the Three Phases

Of the 52 reports in the study's data set, 23 percent indicated that pilots sometimes saw snow or ice on their aircraft's surfaces but erroneously believed that the amount was inconsequential, or that it would blow off during taxi or takeoff. This report excerpt was typical: "We elected to taxi out and take off believing the snow would quickly blow off when the takeoff roll began" (ASRS Record 194669).

Ten percent of the reports in the data set mentioned that crew members or passengers expressed concern directly to the captain that the aircraft should be inspected for ice or deiced. The captain responded by taking appropriate action in only one of these cases. In another narrative, a crew member wrote that he was concerned that the captain did not deice the aircraft; however, he failed to relay this concern to the captain.

Throughout all three phases, data showed that once an error was made in preflight ice inspection, ice removal or hold-over, the error was recognized before takeoff in only 33 percent of the cases where errors were made. This statistic was subject to certain caveats. ASRS reporters seldom reported events or activities that went smoothly or without incident. Therefore, it should not be inferred that all deicing/anti-icing operations were likely to be conducted with the same proportion of errors or problems. Further, it should not be inferred that two-thirds of all air carrier aircraft that had been deiced were allowed to take off with contaminated surfaces.

The main reason these errors were recognized before takeoff was that passengers and flight attendants saw ice on the wings and relayed that information to the captain.

Following are conclusions and recommendations suggested by the study:

- Certain difficulties in detecting ice during preflight are the result of needing to inspect aircraft surfaces that are high above ground. ASRS reports indicated that operators should ensure that ladders and work stands are readily available for this purpose. Consideration should be given to using mechanical lifts to allow inspection of surfaces that cannot otherwise be accessed.

- Perceptual problems were also noted — flight crews were physically unable to see or feel ice on aircraft surfaces. A possible solution is accelerated development of electronic ice detection devices to aid in the detection of wing ice. Until these devices become fully reliable and widely used, operators may consider using high wattage illumination (such as halogen lamps) for ice inspections.

- A high percentage of the reports in this study indicated that the flight crew relied on the deicing crew's report that deicing had been successfully completed. As a quality control measure, it is recommended that flight crews (or personnel other than the deicing crew) visually inspect aircraft critical surfaces after deicing to ensure that ice removal has been satisfactorily completed.

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- Many of the problems noted in this study's data set could have been eliminated by an externally conducted inspection within five minutes before takeoff. To receive maximum safety benefit from using this procedure, the inspection should be conducted using proper illumination and mechanical lifts. Additionally, this procedure should be accomplished on the taxiway run-up pad just before takeoff. Considering the safety benefits of incorporating this procedure, it is recommended that air carriers and airport authorities work closely together to develop and implement this plan.

- Reporters wrote that problems could be reduced if time between deicing and takeoff was minimized. As a possible solution, ATC should give consideration to implementing a "queue control" procedure to minimize taxi delays because of traffic and snow removal. With this system, crews can obtain an ATC-assigned taxi time on the basis of being able to taxi and take off immediately. Aircraft will be deiced just before their assigned taxi time. At airports where "queue control" procedures are not implemented or any time substantial ground icing conditions exist, several ASRS reporters suggested, ATC and airport authorities should develop a plan to accomplish deicing on taxiways or run-up pads at or very near the departure runway's threshold.

- Twenty-one percent of this study's reports indicated that visual problems were a significant factor. Reports, for example, highlighted problems of not being able to detect ice through cabin windows that were covered with deicing fluid (or otherwise obscured). Many air carriers based their go/no-go decision on a cockpit crew member looking through cabin windows to check for ice adhering to critical surfaces. From this study, there are indications that detecting ice from inside the aircraft may be impossible, or at best, difficult. It is therefore recommended that follow-on research should be conducted to determine how visual factors affect a crew member's ability to properly detect ice.

- Crew resource management (CRM) training could address how to handle ground icing problems. In ASRS reports where ground icing problems were recognized before takeoff, the cabin crew usually notified the cockpit crew of the problem. To increase the likelihood that problems are caught before takeoff, it is recommended that cabin crew members be taught to recognize wing ice. Furthermore, all crew members should be taught — and encouraged — to clearly voice their concerns. Consider developing an easily remembered "statement of concern" that could be employed by any crew member, for example, "Captain, I am concerned that ice is on the wings." Once this statement of concern was voiced by any crew member, the captain would be required to fully reappraise the situation before takeoff.

- Pilot training in the area of deicing/anti-icing could be strengthened by emphasizing certain findings from this study.

The following recommendations were cited in ASRS reports in this study's data set:

- Pilots must not try to gauge the amount of contamination on their aircraft solely by observing the wings of other aircraft;

- Snow on aircraft wings probably will not blow off during taxi and takeoff; and,

- There really is no such thing as "just a little snow."♦

[Editor's note: This article was adapted from a study published by NASA/ASRS, *Air Carrier Ground Icing/ Anti-icing Problems*, by Robert Sumwalt III, Batelle's Aviation Safety Reporting System Program Office, Mountain View, California, U.S.]

About the Author

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References

1. From "Safety in the Operation of Air Transportation," a lecture under the James Jackson Cabot Professorship of Air Traffic Regulation and Air Transportation at Norwich University, Vermont, U.S. [Jerome Lederer was chief engineer for Barber & Baldwin (later Aero Insurance Underwriters) when he made this statement in 1939. Lederer went on to found Flight Safety Foundation in 1945.]

2. Deicing is the removal of ice from the aircraft surfaces. Typically, deicing of air carrier aircraft is accomplished by spray application of a heated glycol and water mixture. Anti-icing is a means of chemically treating aircraft surfaces to prevent ice formation while the aircraft is on the ground. Anti-icing fluids are applied in a manner similar to deicing fluids. The terms "deicing" and "anti-icing" are used interchangeably and without distinction throughout this paper.

3. *57 Federal Register*. "Aircraft Ground Deicing and Anti-icing Program; Proposed Rule." No. 142. (July 23,1992): 32852-32853.

4. Throughout this paper, the terms "reporter citation(s)" and "citation(s)" are used interchangeably. A citation is where an ASRS reporter stated (cited) a particular situation or occurrence. One ASRS report may contain more than one citation. Because of this nonexclusivity, the sums of the citation percentages will exceed 100 percent. For example, one ASRS report mentioned engine failure because of ice ingestion, followed by declaring an emergency, and then returning to land at the departure airport. Thus, there were three citations in this single report.

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