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Air Carrier Ground Deicing / Anti-Icing Problems

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ASRS PROBLEMS INVOLVING AIR CARRIER GROUND DEICING/ANTI-ICING

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"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

INTRODUCTION

It is significant that the statement above was made by the distinguished Jerome Lederer 54 years ago.[2] Since that statement was made, at least 44 air carrier accidents have occurred worldwide due to inadequate ground deicing/anti-icing.[3] Within the past 25 years, 35 such accidents have occurred, 21 involving jet transports. Nineteen of these 35 accidents have occurred in the United States. The most recent such tragedy occurred last year at New York's LaGuardia Airport.

Clearly, there is a need for safety improvements to reduce the unacceptable number of air carrier ground icing accidents. Based on historical accident and casualty rates, the Federal Aviation Administration (FAA) has projected that unless safety improvements are made, there could be 8 additional air carrier ground icing accidents within the next ten years. Projections show that these accidents would claim 134 lives and cause 67 serious injuries. The present value dollar benefit of preventing these accidents and casualties is approximately $181 million.[4]

The FAA and the U.S. airline industry are committed to making necessary safety improvements. Before the beginning of winter 1992 the FAA ordered significant changes in air carrier ground deicing/anti-icing procedures. After using these new procedures for one icing season, the FAA and airline industry are now evaluating these procedures for possible refinements.

The Aviation Safety Reporting System (ASRS) Office shares the FAA's and the Industry's desire to increase aviation safety through improved airline ground deicing/anti-icing procedures. Through this interest ASRS has undertaken this research effort 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

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

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[2] 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.

[3] "Deicing" is the act of removing 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," as used in this paper, 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 similar manner as deicing fluids. The terms "deicing" and "anti-icing" are used interchangeably and without distinction throughout this paper.

[4] 57 Federal Register. No. 142 "Aircraft Ground Deicing and Anti-icing Program; Proposed Rule." pp. 32852-32853. (July 23,1992).

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

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

APPROACH

Data

We reviewed 52 ASRS reports that were submitted to ASRS between January 1986 and January 1993. All ASRS data, including those in this study, are submitted voluntarily and may reflect reporting biases. They constitute a non-random sample of aviation incidents and events. In addition, reporters' incident descriptions are influenced by their individual motivations for reporting. They often give only one perspective of the event which is not balanced by any additional investigation or verification. Not withstanding these biases, the general presumption underlying all research based on ASRS data is that if the incident reports are drawn from a sufficiently wide time interval of several years or more, the underlying causal pattern observed in the data will be broadly representative of the total universe of aviation safety incidents of that variety.

Method

This research study is 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. This approach is as valuable as it is unique. Typically, ASRS reporters describe not only what went wrong or what problems they noticed, but they also may describe how they dealt with these problems to keep the situation from *becoming* an accident. Thus, by concentrating on ASRS incident data we hoped to broaden our 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 we identified the first major problem or error that occurred in each report. 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 "phase" categories.

- The "Preflight Ice Inspection Phase" involved reports that cited difficulties inspecting for and/or detecting ice during preflight.
- Reports placed in the "Ice Removal and Initial Verification of Ice Removal Phase" were those that cited problems or errors that occurred while removing ice; reports that mentioned crewmember problems or errors with the initial verification that ice removal had been properly conducted; and, in a few instances, reports where ice had been detected during preflight but not removed.

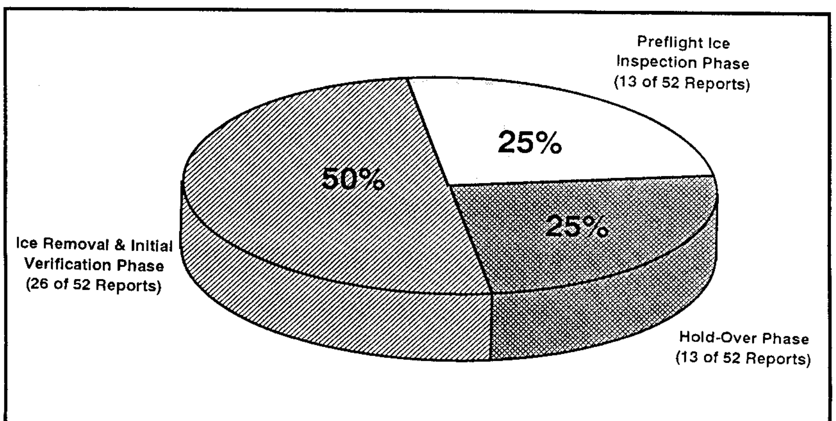

Figure 1. Phase that Primary Problem or Error was Committed

- The "Hold-Over Phase" involved reports where problems or errors occurred in the final verification that aircraft critical surfaces were free of frozen contamination, after deicing/anti-icing, but before takeoff.

Data related to the study objectives were gathered from each report. We were also interested to see if the primary problem or error was linked to the formation of a secondary problem or error. In cases where there was such a linkage we were particularly interested to see if this chain of errors was caught before takeoff, or if a takeoff occurred with contaminated (ice/snow covered) surfaces.

FINDINGS AND DISCUSSION

A takeoff with contaminated wing/tail surfaces occurred in 52 percent of the reports in this study's data set. "Close calls" were described in some reports, whereby accidents were avoided by only a narrow margin. Table 1 shows the 53 reporter citations[5] that describe the consequences of takeoff attempts with contaminated aircraft critical surfaces. It is noteworthy that approximately two-thirds of these reported consequences could be deemed as serious, as they involved aircraft controllability problems, engine failures and damage, rejected takeoffs, and other potential accident causes.

❑ 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 ATC clearances	3
❑ Emergency Declared	2
❑ Significant Delays	1
TOTAL	53

Table 1. Consequences of Takeoff Attempts with Contaminated Aircraft Surfaces

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

Preflight Ice Inspection Phase

The Preflight Ice Inspection Phase was tallied with 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 in this phase indicated that *perceptual* problems contributed to ice detection difficulties. These include factors such as flight crewmembers being unable to see ice due to 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. This included inadequately designed, or frequently revised ice inspection procedures.

We were somewhat surprised to find that *schedule pressure* was a factor in only 15 percent of these reports.

Ice Removal and Initial Verification of Ice Removal Phase

Exactly half of the 52 reports in this study were tallied as having the primary problem or error in the Ice Removal and Initial Verification of Ice Removal Phase. Of the 26 reports in this phase, 54 percent mentioned cases of the airplane being inadequately deiced (i.e., ice still remaining on the aircraft after deicing.) Twenty-three percent of this phase's reports discussed failure to have the airplane deiced when ice was adhering to aircraft surfaces.

[5] Throughout the "Findings and Discussion" section of this paper the terms "reporter citation(s)" and "citation(s)" are used interchangeably. A citation is where an ASRS reporter stated (or cited) a particular situation or occurrence. One ASRS report may contain more than one citation. Because of this non-exclusivity, the summation of the citation percentages will exceed 100 percent. As an example, one ASRS report mentioned engine failure due to ice ingestion, followed by declaring an emergency, and then returning to land at the departure airport. Thus, there were three reporter citations from this single report.

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, and therefore, failed to verify successful ice removal themselves.

Somewhat predictably, *procedural* problems were mentioned in 50 percent of the reports in this phase. These problems include failure of deicing crews to follow prescribed procedures, inadequate procedures for deicing and/or post deicing checks, poor communications between deice 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 reports in this phase and *perceptual* problems mentioned in 12 percent.

Nineteen percent of reports in this phase cited factors that contributed to flight crew failure to properly verify ice removal. Stated one report narrative, "The value of inspecting the wing for ice from inside the cabin, especially at night, is questionable. Type 2 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

The Hold-Over Phase was tallied with 25 percent of the study's primary problems or errors. Within this phase we expected to see evidence that pilots may have failed to mark the passage of time between deicing/anti-icing and takeoff. However, we could find no conclusive evidence in support of this hypothesis.

Seventy-seven percent of Hold-Over Phase reports provided sufficient evidence for the analyst to infer that the problems encountered in these reports could have been eliminated by conducting an external inspection of the wings just prior to takeoff. In making this inference the analyst assumed that this external inspection would have been conducted no more than 5 minutes before takeoff, and that it would be conducted by trained personnel using proper illumination devices and "cherry picker" equipment.

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/ATC-related issues. These were lack of ATC programs to eliminate long taxi delays when ground icing conditions exist, and lack of deicing equipment near departure runway thresholds. Thirty-one percent of Hold-Over Phase reports referenced significant ground delays due to airport snow removal or traffic volume.

Although we expected to see evidence of *attentional* factors (distraction) in the other two phases, our findings showed that it was unique to the Hold-Over Phase. In this phase, attentional factors were cited in 23 percent of the reports. In two narratives the reporters mentioned that a crewmember went to the passenger cabin just before takeoff to check for wing contamination. However, this crewmember's absence from, and subsequent return to the flight deck created or contributed to cockpit distractions. In one such case a takeoff was initiated without clearance, nearly causing a runway collision.

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

Perceptual problems were noted in 15 percent of these reports.

Universal Findings

Of the 52 reports in this study's data set, 23 percent indicated that sometimes pilots see snow/ice on their aircraft surfaces but erroneously believe that its amount is inconsequential, or that it will 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 this study's data set mentioned that crewmembers or passengers directly expressed concern to the Captain that the aircraft should be inspected for ice or deiced. In only one of these cases did the Captain respond by taking appropriate action. In another narrative, a crewmember wrote that he was concerned that the Captain did not deice; however, he failed to relay this concern to the Captain.

Universally throughout all three phases, data show that once an error was made in preflight ice inspection, ice removal, or hold-over, the error was caught before takeoff in only 33 percent of the cases where errors were made. However, this statistic is subject to certain caveats. ASRS reporters seldom report events or activities that went smoothly or without incident. Therefore, it should not be inferred that *all* deicing/anti-icing operations are 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 have been deiced are allowed to take off with contaminated surfaces.

The main reason these problems were caught before takeoff was that passengers and flight attendants saw ice still on the wings and relayed this information to the Captain.

CONCLUSIONS AND RECOMMENDATIONS

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 "cherry pickers" to inspect those surfaces that cannot otherwise be accessed.

Also noted were perceptual problems—flight crews physically being unable to see or feel for ice on aircraft surfaces. A possible solution is for industry to accelerate development of electronic ice detection devices to aid in the detection of wing ice. Until these devices can become fully implemented, operators may consider using high wattage illumination devices (such as halogen lamps) for ice inspections.

A high percentage of reports in this study indicate that after deicing was completed 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.

Many of the problems noted in this study's data set could have been eliminated by use of an externally conducted inspection within five minutes of takeoff. To receive maximum safety benefit from using this procedure, the inspection should be conducted using proper illumination devices and a cherry picker. Additionally, this procedure should be accomplished on the taxiway "run-up pad" just prior to takeoff. Considering the safety benefits associated with incorporating this procedure, it is recommended that air carriers and airport authorities work closely together to develop and implement this plan before the winter of 1993-94.

Reporters wrote in their ASRS submissions that problems could be reduced if time between deicing and takeoff is minimized. As a possible solution, ATC should give consideration to implementing a "queue control" procedure to minimize taxi delays when traffic and snow removal delays mount. With this system, aircraft can obtain an ATC-assigned taxi time on the basis of being able to taxi-out and take off immediately. Aircraft are deiced just before their assigned taxi time. At airports where "queue control" procedures are not implemented, or anytime substantial ground icing conditions exist, several ASRS reporters suggested that ATC and airport authorities 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 indicate that perceptual problems (such as physically not being able to see ice on wings) were a significant factor. Furthermore, reports highlighted problems of not being able to detect ice through cabin windows that were covered with deicing fluid (or otherwise obscured). Many air carriers base their go/no-go decision on a cockpit crewmember looking through cabin windows to check for ice adhering to critical surfaces. From this study, however, there are indications that this task may be visually impossible, or at best, quite difficult. It is therefore recommended that follow-on research be conducted to determine how these factors affect a crewmember's ability to properly detect ice.

Crew Resource Management training could specifically address how to handle ground icing problems. In ASRS reports where ground icing problems were caught before takeoff, usually it was the cabin crew who notified the cockpit crew of the problem. To increase the likelihood that problems are caught before takeoff, it is recommended that cabin crewmembers be taught to recognize wing ice formation. Furthermore, all crewmembers could be taught and encouraged to clearly voice their concerns. Consideration could be given to developing an easily remembered "statement of concern" that could be employed by any crewmember. As an example, "Captain, I am concerned that ice is on the wings." Once this "statement of concern" was voiced by any crewmember, the Captain would be *required* to fully appraise 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 aircraft in front of them.
- Snow on wings probably will not blow off during taxi and takeoff.
- There really is no such thing as "just a little snow."

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