

PRELIMINARY TEST OF HUMAN VISUAL AND TACTILE ICE DETECTION CAPABILITIES UNDER POST DEICING CONDITIONS

Edmundo A. Sierra, Jr. and Kimberlea D. Bender
Titan Corporation

Jerry Hadley
FAA Simulation and Analysis Group
William J. Hughes Technical Center, Atlantic City International Airport, New Jersey

Isabelle Marcil
Transport Canada, Transportation Development Centre

John D'Avirro and Nicoara Moc
APS Aviation

Edward Pugacz
FAA Office of Aviation Research, Flight Safety Branch
William J. Hughes Technical Center, Atlantic City International Airport, New Jersey

Frank Eyre
Transport Canada, Transportation Development Centre

Human visual and tactile ice detection capabilities while inspecting deiced aircraft surfaces have not been quantified. This report includes the findings of a preliminary human ice detection performance test conducted in March 2005 by the FAA Office of Aviation Research, Flight Safety Branch (William J. Hughes Technical Center) and Transport Canada, Transportation Development Centre. Two lead male deicers from AeroMag 2000 YUL (Montreal Pierre Elliot Trudeau International Airport), ages 31 and 27, participated in the study. We used PMG Technology's cold chamber in Blainville, Quebec, Canada to create an environment whose temperature was -5°C with 80% humidity. Ice samples were created by APS Aviation on either white painted or polished aluminum panels, as either a 315 cm^2 circular patch or fully covering the panel, with thicknesses ranging from .2 mm to 1.2 mm. All of the test samples were covered with aircraft deicing fluid. We used a two-alternative forced-choice procedure in which we showed a deicer a panel, then showed him a second panel, and finally asked him to indicate on which of the two panels ice was present. Inspection of the data showed that deicers were 1) unable to visually detect ice of any thickness on any color panel when it was fully covered by ice; 2) visual detection capabilities for ice patches on white panels decreased with decreasing levels of ice thickness; 3) visual detection of ice patches on aluminum panels was flawless; and 4) deicers could easily detect ice of any thickness or shape using a tactile check. Several implications for the experiment will be discussed.

INTRODUCTION

Currently, after preflight deicing operations, the presence of residual ice on an aircraft's wing is determined by a human checker from a deicing ground crew (for current Canadian checking procedure details, see Eyre, 2004). The presence of ice on a wing is determined visually under most circumstances. Tactile inspections may be required following deicing of certain aircraft types, or for aircraft where cold soaking of fuel contacting the wing's surface may be a problem. Tactile inspections are problematic since they are slow and limited to the checker's reach. They also expose extremities to cold surfaces, can be limited to the checker's reach, and may require close proximity to an aircraft when engines are on.

If visual and tactile inspections for the presence of ice on a wing are to be replaced with other methods, human visual and tactile capabilities must be determined to serve as a measure against which other methods can be evaluated.

A detailed procedure for the determination of human capabilities must also be provided. These ice detection capabilities have not been documented before, there is nothing decisively applicable from the literature, and no similar work is known to have been done. This paper provides the details of preliminary testing of a procedure which we will use to determine human visual and tactile ice detection capabilities. It includes two visual detection studies and two tactile detection studies. With the results of our studies, designers of new methods and devices used to detect ice can evaluate their device's detection ability as it compares to human capabilities. Regulatory agencies can also use this objective data to accept or reject new systems or procedures.

As the interest in this study was with sensory capability rather than checker criterion (or *bias*) affecting detection, we used a forced-choice procedure (Green & Swets, 1988). In this procedure we show two panels in sequence to a participant, and ask him to indicate on which of the two panels ice is present. The primary interests in these studies

are visual and tactile detection. Ice will be present on either the first or the second panel and the checker will be forced to choose in which one it is present.

STUDY 1: VISUAL DETECTION OF 315 CM² ICE PATCH CONTAMINATION

Participants

Two male professional deicers from AeroMag 2000 in Montreal, Quebec, Canada participated in this study. They were 27 and 31 years old and had six and nine years of deicer experience, respectively. Both had 20/20 vision or corrected to 20/20 vision and reported that they had never experienced a cold related injury (e.g., frost bite). Since these two deicers participated in all studies reported below, the Participants section will not be repeated. We conducted all studies with our participants' safety as our first priority.

Materials

Cold chamber. We conducted the study in a PMG Test and Research Centre cold chamber. The cold chamber dimensions were 23 x 13 feet. It was divided into an ice preparation area and a test area. The temperature in the chamber was -5° (±0.5°) Celsius, 80% (± 5%) humidity, and wind speed about 1 meter per second. No precipitation was used.

We used diffused artificial lighting in the chamber. The source of the electric light was a 150 watt, high pressure sodium bulb with 14,000 mean lumens and a color temperature of 2,100 K. The light was diffused by a Halophane diffuser (Class SB1A15AHP12A). It was located above and behind the observer.

This cold chamber was used throughout all studies. To preserve space, its description will not be repeated in the other studies.

Signal and noise panels. Circular ice samples were created by APS Aviation on flat 30 mm x 50 mm (3.175 mm thick) white or polished aluminum panels. Ice thicknesses used were 0.2 mm, 0.5 mm, and 0.8 mm. The area on the panel covered by the ice patches was 315 cm² and the edges were feathered. Twenty-two ml of Type I deicing fluid diluted with water to a Brix 11 was added to the panels (see D'Avirro, 2005 for specific procedures). The fluid was held in by black barriers (see Figure 1).

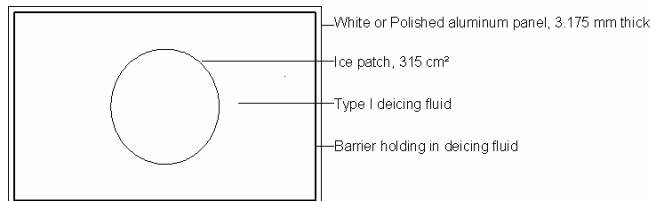


Figure 1. Diagram of the 30 mm x 50 mm panel contaminated with ice (not to scale).

A single measurement of a white panel with no ice, but having a fluid layer and a panel with 1.2 mm of ice with a fluid layer from the observer's position showed illumination of 12.3 and 10.8 footcandles respectively. The luminance for those noise and signal panels was 12.3 and 11.9 footlamberts, respectively.

Procedure

The participants viewed the panel from a distance of 2 m at a 45° angle. Figure 2 shows the visual detection study setup.



Figure 2. Visual detection study setup showing the test administrator (left) and participant (right) between observations.

A *Lazy Susan*, split in two with a screen, was used to show in sequence two panels to the participant, according to a randomized schedule. For each pair of observation, one of the panels had ice on it and the other did not. In each trial, the Test Administrator (TA) positioned the *Lazy Susan* and called out "Sample" while showing the first panel to the participant. After 4 seconds, the TA called out, "Away" and the participant looked to a point on the wall in the opposite direction to the panel. During the following 8 seconds, the TA then rotated the *Lazy Susan* to position the second panel. When the TA called out "Sample", the participant could inspect the second panel for 4 seconds. At the end of these observation periods, the TA called out, "Decide" and the participant indicated which panel had ice on it by pressing a 1 or 2 on a keyboard next to him.

We ran 50 trials (100 observations) for each thickness. Because of time constraints, each participant observed only one randomly assigned thickness. The dependent measure was the percent of correct detections.

After each block of trials, participants were interviewed in order to gather any relevant information on their decision-making processes and on the study procedures.

Results

White panels. Participants detected 0.2 mm, 0.5 mm, and 0.8 mm of ice at a rate of 14%, 92%, and 100% respectively. At a level of 76%, participants are no longer considered to be guessing (Green & Swets, 1988). Figure 3 shows a plot of the detection data. Each point represents data for one participant collected over 50 trials.

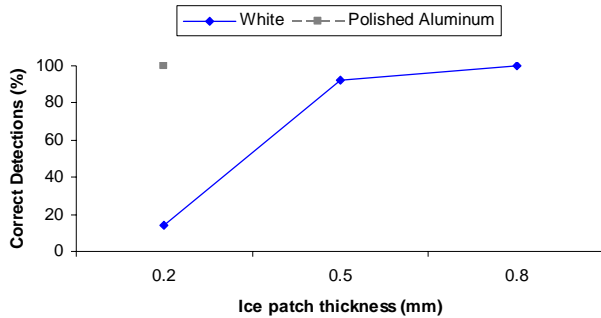


Figure 3. Correct detection (plotted as a percent) as a function of ice thickness and panel color.

Polished aluminum panels. Participants detected 0.2 mm ice patches on polished aluminum panels with 100% accuracy. Further tests with thicker ice would not yield additional useful data and we did not test other ice thicknesses on the aluminum panels.

Discussion

We were able to obtain data on a useful range of ice thicknesses for inspection of white panels. With the three thicknesses we selected to study, we found a potentially undetectable thickness, 0.2 mm, and a thickness that may always be detectable, 0.8 mm.

We were also able to gather valuable information about our procedure. Participants indicated that during the first 10 to 15 trials, they made an honest effort to determine which panel had ice on it. After they had made up their mind about which panel they thought had ice on it, they picked some other physical property to identify the panel (a scratch or a piece of lint on the Lazy Susan) and selected that panel throughout the rest of the block of trials. We plotted the data for the first 10 trials. Figure 4 shows detection at 30%, 60%, and 100% for each thickness studied.

The importance of having seemingly identical panels became evident as well.

Participants easily detected 0.2 mm ice patches on the polished aluminum panels. As 0.5 mm and 0.8 mm contaminations were easily detectable as well, we suspect that the edge of the patch made it easily detectable.

We tested our assumption that the edge made the ice easily detectable in Study 2. For this purpose, we asked APS to prepare panels that were fully contaminated with ice to eliminate the edge. We included both color panels in Study 2.

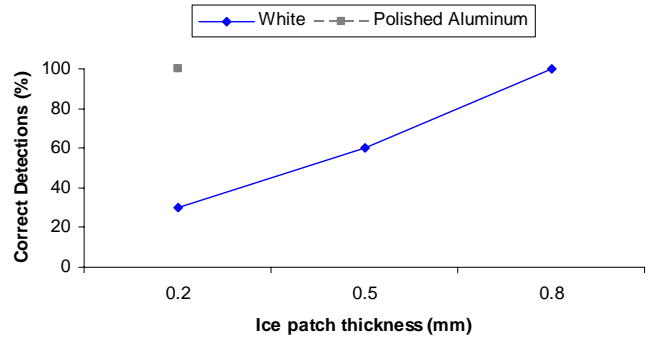


Figure 4. Correct detection (plotted as a percent) as a function of ice thickness and panel color for the first ten trials.

STUDY 2: VISUAL DETECTION OF FULL ICE CONTAMINATION

Materials

Signal and noise panels. Ice samples were created by APS Aviation. The ice samples were created on flat 30 mm x 50 mm (3.175 mm thick) white or polished aluminum panels. Ice thicknesses used on the white panels were 0.2 mm and 1.2 mm. Thicknesses of 0.2 mm and 0.8 mm were used on the polished aluminum panels. The upper limits of these thicknesses were based on the results of the first study and estimates of what the detectable thicknesses might be for each color. The panel was completely covered by the ice. Twenty-two ml of Type I deicing fluid diluted to a Brix of 11 was used to cover the panels (see D’Avirro, 2005 for specific procedures). The fluid was held in by black barriers.

Procedure

The same procedure used in Study 1 was used to collect data for this study. Please refer to the procedures described in Study 1.

Results

White panels Participants detected 0.2 mm and 1.2 mm of ice with 30% and 70% accuracy, respectively. Performance for the first ten trials was 70% for 0.2 mm and 60% for 1.2 mm.

Polished aluminum panels One participant detected 0.2 mm of ice with 90% accuracy. With regards to the 0.8 mm of ice, the other participant admitted that he could not tell which panel had ice on it. Therefore, he picked a panel by guessing and then was consistent in his choice by looking for something that was different between the two panels other than the ice (e.g., a scratch or lint on the Lazy Susan). This reaffirmed the need for identical panels. We ended the session without making all 100 observations (50 trials). The accuracy of ice detection for the first ten trials was 50% for 0.2 mm and 50% for 0.8 mm.

Discussion

In Study 2, we found through objective data collection and comments made by the participants that full contamination of ice of any thickness on the test panel was undetectable. The participant who reached 90% accuracy explained that, after a few trials, he picked a panel and then chose it consistently using other physical properties than ice contamination. Accuracy for the first ten trials supports their comments.

Through Studies 1 and 2 we found some practical boundaries for the experiment. We saw that participants were able to detect ice patches on polished aluminum panels without fail. We also saw some variability in their detection of ice patches on white panels, where some thicknesses were detectable and others were not. Finally, we found that when an edge was absent that participants were unable to detect ice of even the upper thicknesses that we tested.

Studies 1 and 2 have provided us with some useful upper and lower limits for the Visual Detection Experiment. In the following paragraphs, we will report the tactile detection studies.

STUDY 3: TACTILE DETECTION OF 315 CM² ICE PATCH CONTAMINATION

Materials

Signal and noise panels Ice samples were created by APS Aviation. The ice samples were created on flat 30 mm x 50 mm (3.175 mm thick) white panel. The ice thickness used on the white panel was 0.2 mm. The circular area on the panel covered by the ice patches was 315 cm². The edges of the patch were feathered using deicing fluid. Twenty-two ml of Type I deicing fluid diluted to a Brix of 11 was used to cover the panels (see D'Avirro, 2005 for specific procedures). The fluid was held in by black barriers.

Procedure

Bare hand The participants swiped the panel while standing using the fingers of a bare hand. Figure 5 shows the tactile detection study setup.

A *Lazy Susan*, split in two with a screen, was used to present in sequence two panels to the participant, according to a randomized schedule. For each pair of observation, one of the panels had ice on it and the other did not. The participant wore a welding mask that completely obstructed his vision. In each trial, the TA positioned the *Lazy Susan* and called out "Sample". The participant moved his hand forward until it brushed a wooden board suspended above the sample, and slid his hand down to touch the the ice patch. The participant swiped the ice a single time using a light touch. At this point, the TA called out, "Away" and the participant withdrew his hand. The TA then rotated the *Lazy Susan* to expose the other sample (7 sec turn). When

the TA called out "Sample" the participant inspected the second panel. The TA then called out, "Decide" and the checker indicated which panel had ice on it by showing either 1 or 2 fingers to the TA.



Figure 5. Tactile detection study setup showing the participant (left) and test administrator (right) before the initial observation.

We ran 25 trials (50 observations) of each thickness with each participant. Because of time constraints, each participant observed only one randomly assigned thickness. Each participant performed 5 inspections at a time in order to reduce the risk of frost bite. The dependent measure was the percent of correct detections.

Gloved Hand The procedure was the same, however, participants wore Nitrile gloves.

After each block of trials, participants were debriefed in order to gather any relevant information on their decision-making processes and on the study procedures.

Results

Participants detected the 0.2 mm ice patch with 100% accuracy with both bare hands and while wearing gloves.

Discussion

We found the ease and accuracy with which participants detected the ice with bare hands and gloves surprising. As in the visual detection study, we suspected that the presence of an edge maximized their ability to detect the ice. We examined this notion in study 4.

STUDY 4: TACTILE DETECTION OF FULL ICE CONTAMINATION

Materials

Signal and noise panels Ice samples were created by APS Aviation on flat 30 mm x 50 mm (3.175 mm thick) white panels. The ice thicknesses used on the white panels

were 0.2 mm and 1.2 mm. The entire panel was covered by the ice. Twenty-two ml of Type I deicing fluid diluted to a Brix of 11 was used to cover the panels (see D'Avirro, 2005 for specific procedures). The fluid was held in by black barriers.

Procedure

The same procedures described in Study 3 were used. We studied the 0.2 mm ice contamination using bare hand tactile inspections and 1.2 mm using both bare hand and gloved inspections.

Results

Participants detected the 0.2 mm of ice on the fully contaminated panel with 100% accuracy using bare hands. They also detected the 1.2 mm of ice on a fully contaminated panel with 100% accuracy with both bare hands and while wearing gloves.

Discussion

We found the ease and accuracy with which participants detected the ice with bare hands and especially with gloves astonishing. The research team unsystematically checked the 0.2 mm of ice with different types of gloves (e.g., silk liners, fleece, skiing) and found that ice was easily detectable.

GENERAL DISCUSSION

We gathered data from the studies to help us narrow the types of samples for the visual and tactile ice detection experiments to be conducted in April 2005. In Study 1, we found that ice patches on a polished aluminum panel could easily be visually detected, even at a thickness of 0.2 mm. We also found some variability in the detection of ice patches on white panels that we could use in our experiment. In Study 2, we found through objective data and comments made by participants that the presence of ice of any thickness was undetectable when it fully covered the panel. In studies 3 and 4, we found that participants could easily detect the presence of ice through tactile inspection.

We did not continue to investigate thicker layers of ice on fully contaminated panels for practical reasons. The detection rates might be confounded by other cues. For example, it may be possible that thicker samples would be detected visually because of the increased thickness of the panel itself or the added height of the ice and fluid combination against the barrier that holds the fluid in. A detection capability of thicker ice would also not necessarily yield useful data to regulators. Instead, we continue our studies with the awareness that the thickness and size of the patch might be less important than the

detection of an edge. But also, that the ability to detect an edge might be best tested under more realistic conditions.

With this awareness we move forward leaving some questions of potential interest to the research community only partially answered. For polished aluminum surfaces, we raised the question of the conditions where ice patches are visually undetectable. We conjectured that they were visually undetectable when an edge was not seen. We eliminated the edge in Study 2 and found that even the thickest ice we used was undetectable for both white and polished aluminum surfaces. Then, the question arose, for white and polished aluminum surfaces, under what conditions these types of contamination of ice were visually detectable. We can only refer back to Study 1 to explain that they were visually detectable when an edge was visible.

However, these are only partial answers. What other conditions influence the detectability of ice? Of course, lighting, visual noise (such as snow), and other variables can be manipulated to make any ice patch undetectable. We leave these variables for the research community to evaluate. Our approach will be to collect data for very thin ice patches on less than ideally colored surfaces under relatively good environmentally conditions in order to document human ice detection limitations and capabilities in a way that we can, with practicality, generalize to a realistic environment. We will then have some useful information about the most easily detectable ice contamination and the most difficult, in addition to the thicknesses that comprise the gray area. Finally, we will further knowledge by generating specific data for this gray area in our next experiment.

In our subsequent experiment, we will investigate visual ice detection capabilities of a 315 cm² circular ice patch on a white panel while varying the thicknesses of the ice (namely, 0.2, 0.35, 0.5, 0.65, 0.8 mm). We will also include fully contaminated polished aluminum panels with thicknesses .5 mm and 1.0 mm to replicate the findings of the preliminary studies that have been reported here. Finally, we will replicate the tactile study findings by conducting gloved tactile inspections of panels fully contaminated with 0.5 and 1.0 mm of ice. With this experimental data, designers and regulators will have the information they need to improve ice detection systems.

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