TP 15452E
Final Version 1.0
November 2020

AIRCRAFT GROUND ICING GENERAL RESEARCH ACTIVITIES DURING THE 2019-20 WINTER

Prepared for:

Transport Canada Innovation Centre

In cooperation with:

Federal Aviation Administration William J. Hughes Technical Center

Transport Canada Civil Aviation

Federal Aviation Administration Flight Standards – Air Carrier Operations

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Prepared by:

APS Aviation Inc.

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Vice President – Aviation Services

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PREFACE

Under contract to the Transport Canada Innovation Centre, APS Aviation Inc. has undertaken a research program to advance aircraft ground de/anti-icing technology. The primary objectives of the research program are the following:

- To develop holdover time data for all new de/anti-icing fluids;
- To conduct testing to determine holdover times for Type II and Type IV fluids in snow at temperatures below -14°C;
- To conduct additional testing and analysis to evaluate and/or determine appropriate holdover times for Type I fluids in snow at temperatures below -14°C;
- To evaluate and develop the use of artificial snow for holdover time development;
- To conduct wind tunnel testing with a thin high performance wing model to support the development of guidance material for operating in ice pellet conditions;
- To conduct wind tunnel testing with a vertical stabilizer model to characterize clean and contaminated fluid flow-off before and after a simulated takeoff;
- To conduct further research for the development of temperature-specific snow holdover time data;
- To conduct general and exploratory de/anti-icing research;
- To finalize the publication and delivery of current and historical reports;
- To update the regression information report to reflect changes made to the holdover time guidelines; and
- To update the holdover time guidance materials for annual publication by Transport Canada and the Federal Aviation Administration.

Some project timelines were impacted due to the COVID-19 pandemic. The details of these impacts are described in the individual reports, if applicable. The research activities of the program conducted on behalf of Transport Canada during the winter of 2019-20 are documented in six reports. The titles of the reports are as follows:

- TP 15450E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2019-20 Winter;
- TP 15451E Regression Coefficients and Equations Used to Develop the Winter 2020-21 Aircraft Ground Deicing Holdover Time Tables;
- TP 15452E Aircraft Ground Icing General Research Activities During the 2019-20 Winter;
- TP 15453E Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2019-20;
- TP 15454E Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a Vertical Stabilizer; and

- TP 15455E Artificial Snow Research Activities for the 2018-19 and 2019-20 Winters.

This report, TP 15452E, has the following objective:

- To document the exploratory research and general activities carried out during the winter of 2019-20.

PROGRAM ACKNOWLEDGEMENTS

This multi-year research program has been funded by the Transport Canada Innovation Centre, with support from the Federal Aviation Administration William J. Hughes Technical Center, Transport Canada Civil Aviation, and Federal Aviation Administration Flight Standards – Air Carrier Operations. This program could not have been accomplished without the participation of many organizations. APS Aviation Inc. would therefore like to thank Transport Canada, the Federal Aviation Administration, National Research Council Canada, and supporting members of the SAE International G-12 Aircraft Ground Deicing Committees.

APS Aviation Inc. would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data, completion of data analysis, and preparation of reports. This includes the following people: Brandon Auclair, David Beals, Steven Baker, Stephanie Bendickson, Benjamin Bernier, Chloë Bernier, Chris D'Avirro, John D'Avirro, Peter Dawson, Jaycee Ewald, Noemie Gokhool, Benjamin Guthrie, Shaney Herrmann, Peter Kitchener, Shahdad Movaffagh, Dany Posteraro, Annaelle Reuveni, Marco Ruggi, Javad Safari, James Smyth, Saba Tariq, Jodi Wilson, Ian Wittmeyer, and David Youssef.

Special thanks are extended to Antoine Lacroix, Yvan Chabot, Deborah deGrasse, Warren Underwood, and Charles J. Enders, who on behalf of Transport Canada and the Federal Aviation Administration, have participated, contributed, and provided guidance in the preparation of these documents.

REPORT ACKNOWLEDGEMENTS

APS Aviation Inc. would like to acknowledge the following people for their significant contribution to this report: Marco Ruggi for *Evaluation of Type I Frost Endurance Times with Standard Mix Fluid and of the 5-Minute Rule*, for *Type I Overspray Quantities – Historical Review*, and for *Interpretation of METAR Reported Weather for Determining Applicable Holdover Times*; Benjamin Bernier for *Temperature-Specific Snow Holdover Times*; Saba Tariq for *Technical Review, Approval, and Publication of Historical Reports* and for *Presentations, Fluid Manufacturer Reports, and Test Procedures for 2019-20*; and Chloë Bernier for *Publication of Holdover Time Guidance Materials*.

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15. Supplementary Notes (Funding programs, titles of related publications, etc.)

Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada (TC). These reports are available from the TC Innovation Centre. Several reports were produced as part of this winter's research program. Their subject matter is outlined in the preface. This project was co-sponsored by the Federal Aviation Administration.

16. Abstract

This report documents the general activities completed by APS Aviation Inc. related to aircraft ground deicing research in the winter of 2019-20. The activities documented in this report were carried out in addition to the main research projects completed in the winter of 2019-20, which are documented in separate reports. The seven activities described in this report are listed below:

1) Evaluation of Type I Frost Endurance Times with Standard Mix Fluid and of the 5-Minute Rule;
2) Type I Overspray Quantities – Historical Review;
3) Interpretation of METAR Reported Weather for Determining Applicable Holdover Times;
4) Temperature-Specific Snow Holdover Times;
5) Technical Review, Approval, and Publication of Historical Reports;
6) Publication of Holdover Time Guidance Materials; and
7) Presentations, Fluid Manufacturer Reports, and Test Procedures for 2019-20.

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15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

Plusieurs rapports de recherche sur des essais de technologies de dégivrage et d'antigivrage ont été produits au cours des hivers précédents pour le compte de Transports Canada (TC). Ils sont disponibles au Centre d'innovation de TC. De nombreux rapports ont été rédigés dans le cadre du programme de recherche de cet hiver. Leur objet apparaît à l'avant-propos. Ce projet était coparrainé par la Federal Aviation Administration.

16. Résumé

Le présent rapport documente les activités d'ordre général réalisées par APS Aviation Inc. en matière de recherche sur le dégivrage d'aéronefs au sol au cours de l'hiver 2019-2020. Les activités dont fait état ce rapport ont été effectuées en plus des projets de la recherche principale menés pendant l'hiver 2019-2020, qui sont documentés dans des rapports distincts. Les sept activités qui font l'objet du présent rapport sont énumérées ci-dessous :

1) Évaluation des durées d'endurance des liquides de type I, sous forme de mélange standard, dans des conditions de givre et de la règle des 5 minutes ;
2) Quantités de surpulvérisation des liquides de type I – Revue historique ;
3) Interprétation des conditions météorologiques signalées par METAR en vue de déterminer les durées d'efficacité applicables ;
4) Évaluation du nouvel appareil de fabrication de neige ;
5) Examen technique, approbation et publication de rapports historiques ;
6) Publication de documents d'orientation sur les durées d'efficacité ; et
7) Présentations, rapports aux fabricants de liquides et procédures d'essais pour 2019-2020.

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EXECUTIVE SUMMARY

This report documents the exploratory research and general activities completed in the winter of 2019-20 by APS Aviation Inc. (APS) on behalf of Transport Canada (TC) and the Federal Aviation Administration (FAA). This work is part of the TC/FAA aircraft ground deicing research project. The major activities of the research project are documented in separate reports; this report documents seven activities that were carried out in addition to the main research projects in the winter of 2019-20.

Evaluation of Type I Frost Endurance Times with Standard Mix Fluid and of the 5-Minute Rule (Section 2)

Industry requested an investigation to determine if the Type I standard mix fluid will generate longer frost endurance times as compared to Type I fluid mixed to a 10ºC buffer, and if the slow progression of fluid failure in frost conditions may support an extension to the 5-minute pre-takeoff contamination check rule for frost holdover times (HOTs). The preliminary results indicate that using a conservative approach, the operational time for Type I fluids in frost conditions could be roughly doubled, however does not reach the 2-hour target. Further discussion with industry is required to determine if a 1.5-hour operational window, as indicated by the preliminary results using standard mix fluid, is still of significance (in the context of the 2-hour target) and this will determine if further research is required.

Type I Overspray Quantities – Historical Review (Section 3)

TC requested that APS perform a historical review of testing studies and data that may support the requirement that at least 1 L/m^2 of fluid must be applied to deiced surfaces in order to use the published Type I fluid HOT tables. The historical research seems to indicate that quantities of 2 L/m^2 would likely have been considered for recommendation, however the 1 L/m^2 may have been adopted as an adequate compromise between the minimum safety requirements and industry acceptance of an efficient quantity.

Interpretation of METAR Reported Weather for Determining Applicable Holdover Times (Section 4)

An understanding of the statistical significance of METAR reported winter weather conditions is required to allow for proper planning towards more exhaustive holdover time guidance material. The study examined a large sample of METAR data collected primarily at the major airports in the Unites States and Canada that experience wintertime precipitation. The analysis identified differences in reporting structures

for both United States and Canada, as well as regional differences. It is recommended that work continue towards prioritization of the conditions to be addressed and developing the respective new guidance material.

Temperature-Specific Snow Holdover Times (Section 5)

In the winter of 2019-20, APS carried out work to support the development of temperature-specific snow HOTs. This was the continuation of a project started in the winter of 2018-19. The primary elements of the work completed in 2019-20 were analysis, creation of the temperature-specific HOTs database, and initial development of guidance documents related to the implementation of temperature-specific HOTs. The work is expected to be completed in the winter of 2020-21.

Technical Review, Approval, and Publication of Historical Reports (Section 6)

APS has conducted research related to ground icing, which involved writing and publishing over 207 reports on behalf of TC and the FAA since 1992. At the request of TC and the FAA, APS undertook the task to process and publish the draft reports backlogged in the system. At the beginning of this project, in 2016-17, 124 reports were identified as non-published. As of October 31, 2020, 40 reports remain to be published, excluding the current year reports for 2019-20.

Publication of Holdover Time Guidance Materials (Section 7)

The development and use of HOT guidelines represents an important contribution to the enhancement of flight safety in winter aircraft operations. In the years since their introduction, the HOT Guidelines and related guidance materials have become a standard and essential part of winter operations. APS has assisted both TC and the FAA with the development of their guidance documents as well as with updating their websites annually to reflect changes made to the guidelines.

Presentations, Fluid Manufacturer Reports, and Test Procedures for 2019-20 (Section 8)

APS produced a number of presentations, fluid manufacturer reports, and test procedures for the winter 2019-20 test program.

SOMMAIRE

Le présent rapport documente la recherche exploratoire et les activités d'ordre général effectuées au cours de l'hiver 2019-2020 par APS Aviation Inc. (APS), pour le compte de Transports Canada (TC) et de la Federal Aviation Administration (FAA). Ce travail a été effectué dans le cadre du projet de recherche de TC et de la FAA sur le dégivrage d'aéronefs au sol. Les principales activités du projet de recherche sont documentées dans des rapports distincts ; le présent rapport documente les sept activités effectuées en plus des principaux projets de recherche de l'hiver 2019-2020.

Évaluation des durées d'endurance des liquides de type I, sous forme de mélange standard, dans des conditions de givre et de la règle des 5-minutes (Section 2)

Les parties prenantes de l'industrie ont demandé la tenue d'essais dans des conditions de givre pour déterminer si l'utilisation d'un liquide de type I, sous forme de mélange standard, générait des durées d'endurance accrues comparativement à un liquide de type I, sous forme de mélange incluant une plage tampon de 10°C. Les essais visaient également à déterminer si le ralentissement de la défaillance d'un liquide dans ce contexte pouvait absorber une extension à la règle des 5 minutes pour l'inspection de contamination avant le décollage relativement aux durées d'efficacité dans de telles conditions. Les résultats préliminaires indiquent que l'utilisation d'une approche prudente, où le temps d'opération pour les liquides de type I dans des conditions de givre peut être plus ou moins doublé, ne permet pas d'atteindre la cible de 2 heures. De plus amples discussions au sein de l'industrie doivent avoir lieu pour déterminer si, comme l'indiquent les résultats préliminaires obtenus en utilisant un liquide sous forme de mélange standard, une période d'opération de 1,5 heure reste digne de considération (à la lumière de la cible de 2 heures) et si des recherches additionnelles s'avèrent nécessaires.

Quantités de surpulvérisation des liquides de type I – Revue historique (Section 3)

TC a mandaté APS d'effectuer une revue historique des essais et des données d'évaluation pouvant soutenir la nécessité d'appliquer au moins 1 l/m^2 de liquide aux surfaces dégivrées pour utiliser les valeurs publiées figurant aux tableaux des durées d'efficacité des liquides de type I. La recherche semble indiquer qu'un ratio de 2 l/m^2 aurait été envisagé comme recommandation, mais que celui de 1 l/m^2 aurait été retenu comme compromis adéquat entre le minimum pour satisfaire aux exigences en matière de sécurité et la quantité jugée efficace et acceptable par l'industrie.

Interprétation des conditions météorologiques signalées par METAR en vue de déterminer les durées d'efficacité applicables (Section 4)

Il est nécessaire de bien comprendre la signification statistique des conditions météorologiques hivernales signalées par METAR pour planifier adéquatement l'élaboration de documents d'orientation sur les durées d'efficacité plus exhaustifs. L'étude a examiné un large échantillon de données METAR recueillies principalement auprès des grands aéroports américains et canadiens devant composer avec des précipitations hivernales. L'analyse a relevé des différences dans les structures de signalement aux États-Unis et au Canada, de même que des différences régionales. Il est recommandé que le travail se poursuive quant à la priorisation des conditions à traiter et au développement de nouveaux documents d'orientation connexes.

Durées d'efficacité spécifiques à la température dans des conditions de neige (Section 5)

Au cours de l'hiver 2019-2020, APS a mené des travaux visant à appuyer l'établissement de durées d'efficacité spécifiques à la température dans des conditions de neige. Ces démarches s'inscrivaient dans la poursuite d'un projet amorcé au cours de l'hiver 2018-2019. Les principaux éléments des travaux achevés en 2019-2020 ont été des activités d'analyse, la mise au point d'une base de données des durées d'efficacité spécifiques à la température, et l'ébauche de documents d'orientation pour la mise en œuvre de ces dernières. Ces travaux devraient être achevés durant l'hiver 2020-2021.

Examen technique, approbation et publication de rapports historiques (Section 6)

Depuis 1992, APS a effectué des études sur le givrage au sol qui ont supposé la rédaction et la publication de plus de 207 rapports pour le compte de TC et de la FAA. À la demande de TC et de la FAA, APS a entrepris le traitement et la publication des rapports préliminaires accumulés dans le système. Au début de ce projet, en 2016-2017, 124 rapports ont été identifiés comme non publiés. En date du 31 octobre 2020, à l'exception des rapports annuels actuels de 2019-2020, 40 rapports doivent encore être publiés.

Publication de documents d'orientation sur les durées d'efficacité (Section 7)

L'établissement et l'utilisation de lignes directrices relatives aux durées d'efficacité contribuent grandement à l'amélioration de la sécurité des vols lors d'opérations aériennes hivernales. Depuis leur adoption, les lignes directrices relatives aux durées d'efficacité et les documents d'orientation connexes sont devenus la norme, et un élément essentiel des opérations hivernales. Pour refléter les changements apportés à ces lignes directrices, APS a assisté TC et la FAA dans l'élaboration de leurs documents d'orientation, de même que dans la mise à jour annuelle de leurs sites Web.

Présentations, rapports aux fabricants de liquides et procédures d'essais pour 2019-20 (Section 8)

APS a produit un certain nombre de présentations, de rapports aux fabricants de liquides et de procédures d'essais pour le programme d'essais de l'hiver 2019-2020.

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CONTENTS

Page

LIST OF APPENDICES

LIST OF TABLES Page

LIST OF FIGURES Page

LIST OF PHOTOS Page

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GLOSSARY

A4A	Airlines for America
APS	APS Aviation Inc.
ASOS	Automated Surface Observing Systems
AWOS	Automated Weather Observing Systems
DFIR	Double Fence Intercomparison Reference
EG	Ethylene Glycol
ET	Endurance Time
FAA	Federal Aviation Administration
HOT	Holdover Time
LOUT	Lowest Operational Use Temperatures
LWE	Liquid Water Equivalent
NRC	National Research Council Canada
OAT	Outside Air Temperature
PG	Propylene Glycol
SAE	SAE International
SCOUIC	Standing Committee on Operations Under Icing Conditions
TC	Transport Canada

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1. INTRODUCTION

Under winter precipitation conditions, aircraft are cleaned prior to takeoff. This is typically done with aircraft ground deicing fluids, which are freezing point depressant fluids developed specifically for aircraft use. If required, aircraft are then protected against further accumulation of precipitation by the application of aircraft ground anti-icing fluids, which are also freezing point depressant fluids. Most anti-icing fluids contain thickeners to extend protection time.

Prior to the 1990s, aircraft ground de/anti-icing had not been extensively researched. However, following several ground icing related incidents in the late 1980s, an aircraft ground icing research program was initiated by Transport Canada (TC). The objective of the program is to improve knowledge, improve safety, and enhance operational capabilities of aircraft operating in winter precipitation conditions.

Since its inception in the early 1990s, the aircraft ground icing research program has been managed by TC, with the co-operation of the United States Federal Aviation Administration (FAA), the National Research Council Canada (NRC), several major airlines, and de/anti-icing fluid manufacturers.

There is still an incomplete understanding of some of the hazards related to aircraft ground icing. As a result, the aircraft ground icing research program continues, with the objective of further reducing the risks posed by the operation of aircraft in winter precipitation conditions.

Under contract to the TC Innovation Centre, with support from the FAA William J. Hughes Technical Center, TC Civil Aviation, and FAA Flight Standards – Air Carrier Operations, APS Aviation Inc. (APS) carried out research in the winter of 2019-20 in support of the aircraft ground icing research program. Each major project completed as part of the 2019-20 research is documented in a separate individual report. This report documents the remaining general activities and smaller research projects.

1.1 Activities Completed in 2019-20

The general activities and smaller research projects completed in 2019-20 are documented in this report. Each activity is detailed in a separate section as follows:

a) Evaluation of Type I Frost Endurance Times with Standard Mix Fluid and of the 5-Minute Rule (Section 2);

b) Type I Overspray Quantities – Historical Review (Section 3);

c) Interpretation of METAR Reported Weather for Determining Applicable Holdover Times (Section 4);

d) Temperature-Specific Snow Holdover Times (Section 5);
e) Technical Review, Approval, and Publication of Historical Reports (Section 6);
f) Publication of Holdover Time Guidance Materials (Section 7); and
g) Presentations, Fluid Manufacturer Reports, and Test Procedures for 2019-20 (Section 8).

The sections of the TC statement of work relevant to these projects can be found in Appendix A.

1.2 Activities Completed with Limited Scope

In addition to the activities described in Subsection 1.1, two activities with limited scope were completed during the winter of 2019-20. These activities are described in the subsections below.

The sections of the TC statement of work relevant to these activities can also be found in Appendix A.

1.2.1 Development of SAE Aircraft Ground Deicing Standards

APS provides support to the SAE International (SAE) G-12 Aircraft Ground Deicing industry group in its development of aerospace standards. In 2019-20, this support consisted of reviewing most SAE standards that were balloted to the SAE G-12 committees, providing comments to document sponsors to improve the documents and/or to harmonize them with other documents, and providing feedback to TC and the FAA on possible implications of changes to SAE standards on TC/FAA regulatory guidance documents.

For 2019-20, in particular, APS provided technical comments for the revision of SAE AS9968, *Laboratory Viscosity Measurement of Thickened Aircraft Deicing/Anti-icing Fluids with the Brookfield LV Viscometer*.

1.2.2 Support to the SAE G-12 Aerodynamics Working Group

APS provides support to the SAE G-12 Aerodynamics Working Group. This includes participation in all meetings and, when required, collecting data, completing data analysis, and providing expert opinion on specific topics. In the winter of 2019-20, APS attended one in-person meeting, as well as several Webex teleconference meetings.

2. EVALUATION OF TYPE I FROST ENDURANCE TIMES WITH STANDARD MIX FLUID AND OF THE 5-MINUTE RULE

This section describes the work APS Aviation Inc. (APS) completed in the winter of 2019-20 to evaluate the Type I frost endurance times (ETs) with standard mix fluid and to evaluate the 5-minute rule for pre-takeoff contamination checks.

2.1 Background

Frost is an important consideration in aircraft ground deicing and represents a significant portion of de/anti-icing operations, especially in areas with warmer climates. Transport Canada (TC) and the Federal Aviation Administration (FAA) publish Holdover Time (HOT) Guidelines for operating with de/anti-icing fluids, and the guidance issued for Type I fluids is generic (not fluid specific) and based on fluids mixed to a 10º buffer (not standard mix). The latter two parameters may have only marginal differences for snow and freezing precipitation conditions because HOTs are shorter and the majority of the protection comes from the heat in the fluid rather than the freeze point depressant effect of the glycol. In the case of frost conditions, however, the longer HOTs may emphasize those marginal differences; the effects of the glycol and the concentration may outweigh the benefit from the heat and may provide longer fluid protection times.

Some operators currently pre-treat aircraft with Type IV fluids in active or anticipated frost conditions to allow for a quick dispatch of aircraft at the operating hubs. Alternatives to using Type IV fluids for these purposes are being explored because the very long protection times are not always required, and, in some cases, there is no active frost or frost never develops. In addition, some issues with fluid residues from Type IV pre-treatment have been reported. Currently, Type I fluids mixed to a 10° buffer are limited to 45-minute HOTs in frost conditions (for aluminum wings), and pre-takeoff contamination checks which may provide a 5-minute window to beginning of takeoff when HOT has been exceeded, (allowed by the FAA only) are not feasible for cargo aircraft. It should be noted that TC does not allow pre-takeoff contamination inspections for Type I fluids. As such, industry requested an investigation to determine if the Type I standard mix fluid concentration will generate longer frost ETs compared to Type I fluid mixed to a 10º buffer and if the slow progression of fluid failure in frost conditions may support an extension to the FAA's 5-minute pre-takeoff contamination check rule for frost HOTs. The preliminary target provided by industry was 2 hours of protection time for Type I fluids in frost.

2.2 Objectives

The preliminary evaluation had two objectives: to determine if the Type I standard mix fluid concentration will generate longer frost ETs compared to Type I fluid mixed to a 10º buffer and if the slow progression of fluid failure in frost conditions may support an extension to the 5-minute rule for frost HOTs.

2.3 Test Methodology

Testing was performed at the APS test site located at the Montréal–Pierre Elliott Trudeau International Airport. Testing was run in conjunction with regular frost HOT testing in natural frost conditions. The test stands were located in the centre of a double fence intercomparison reference (DFIR) shield to allow for the best chance of frost formation by minimizing wind effects (see Photo 2.1). More details regarding the procedure are included in Appendix B.

2.3.1 Type I 10º Buffer vs. Standard Mix Fluid – Testing Methodology

Comparative testing was performed using two frosticator plates. Both propylene glycol (PG) and ethylene glycol (EG) Type I fluids were tested. For each comparative test, the same fluid was applied to both plates in different dilutions: 10º buffer fluid on one plate and standard mix fluid on the other. The ETs were compared to evaluate the effect of the higher concentration of glycol on ET performance. Figure 2.1 provides a schematic of the comparative test setup for the 10º buffer versus the standard mix fluid.

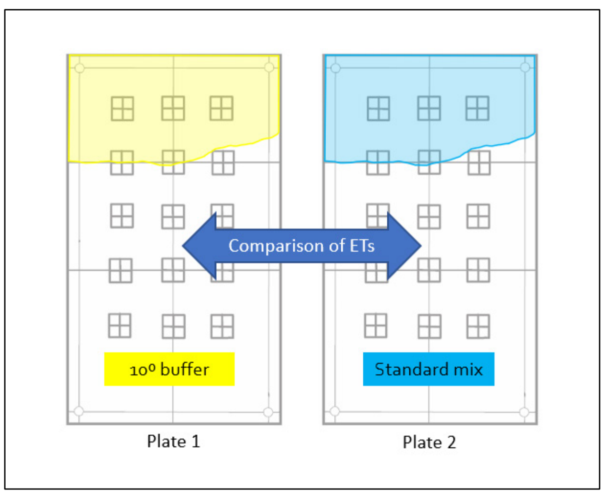

Figure 2.1: Comparative Test Setup for 10º Buffer vs. Standard Mix Fluid

2.3.2 Evaluation of 5-Minute Rule for Type I – Testing Methodology

Testing was done using individual frosticator plates (utilised for both the 10º buffer and standard mix fluid tests), and the same tests from the comparative tests were used (see Subsection 2.3.1). For each test, the failure progression was monitored on the plate over time, specifically noting when the times of first failure and 1/3 plate failure occurred. First failure was considered when ice contaminated the 2.5 cm (1 inch) line of the plate, and 1/3 failure was considered the standard failure call for when a third of the plate was contaminated with ice. Figure 2.2 provides a schematic of the failure progression testing done to evaluate the FAA's 5-minute rule for Type I fluids.

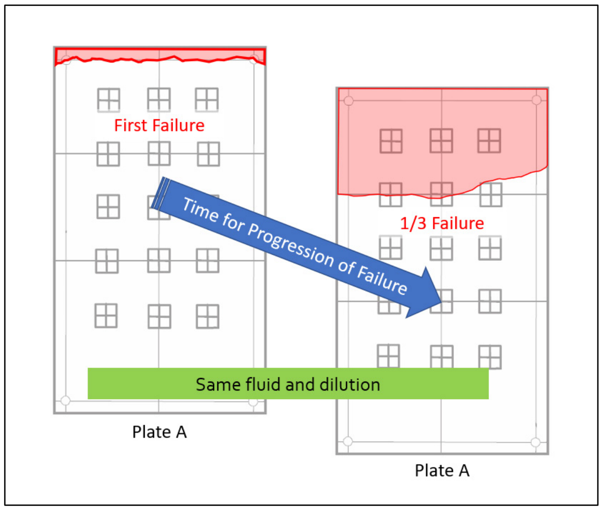

Figure 2.2: Test Setup to Evaluate the 5-Minute Rule for Type I Fluids

2.4 Data Collected

Testing was conducted during seven evening or nighttime events, mostly from 2019-20. One event from 2018-19 was also included in the data set. Table 2.1 provides a summary of the tests conducted. A more detailed data log is included in Appendix C.

It should be noted that of the 46 standard-mix vs. 10° buffer tests, 6 tests were unintentionally run with composite plates. To salvage the data, researchers increased the ETs by a 45/35 ratio based on historical performance results (from past research evaluating HOTs on composite surfaces) and as reported in HOT tables for frost. The analysis was run with and without those adjusted data points, and results did not change significantly; therefore, the data was retained.

Table 2.1: Summary of Tests Conducted

Objective	# of Tests
Standard Mix vs. 10° Buffer	46
5-Minute Rule	38

2.5 Data Analysis

The data collected was analysed and is described in the following subsections.

2.5.1 Freezing Point Comparison

A comparison of the PG and EG based Type I fluid freezing points was performed to help interpret the comparative ET results. Table 2.2 and Table 2.3 provide information on the glycol concentration and freezing points for the respective fluids at different outside air temperatures (OATs). The analysis indicates that a lower concentration of glycol is needed for EG fluids to reach the respective freezing points as compared to PG fluids. Consequently, there is a larger gap in glycol concentration between a standard mix and 10º buffer EG fluid at warmer temperatures compared to a PG fluid.

Table 2.2: PG Type I Freezing Point Comparison

PG Type I Fluid				
OAT (°C)	***Standard Mix (55/45)***		***10º Buffer***	
	Freezing Point	**% Glycol**	**Freezing Point**	**% Glycol**
-3	-36°C	55%	-13°C	33%
-10	-36°C	55%	-20°C	42%
-25	-36°C	55%	-35°C	54%

Table 2.3: EG Type I Freezing Point Comparison

EG Type I Fluid				
OAT (°C)	***Standard Mix (55/45)***		***10º Buffer***	
	Freezing Point	**% Glycol**	**Freezing Point**	**% Glycol**
-3	-41°C	55%	-13°C	27%
-10	-41°C	55%	-20°C	36%
-25	-41°C	55%	-35°C	50%

2.5.2 Type I 10º Buffer vs. Standard Mix Fluid – Testing Methodology

A total of 23 comparative tests (46 individual tests) were analysed comparing the ET performance of the standard mix fluid to that of the 10° buffer fluid. The ratio of the ETs was calculated as the standard mix fluid ET divided by the 10° buffer fluid ET for each comparative test. In addition, the time difference for each comparative set was also calculated.

The results (see Table 2.4) indicated that, on average, the standard mix Type I fluid had an ET that was 41 minutes longer than that of the respective 10° buffer fluid. Calculated as a ratio of the standard mix fluid ET to the 10° buffer fluid ET, the average ratio is 1.5. It should, however, be noted that the average 10° buffer test ET was 103 minutes, much longer than the published 45-minute HOT, indicating that the data set does not represent the worstcase scenario (which should have provided an average HOT closer to 45 minutes). However, it is expected that the calculated ratio should still be representative as, in theory, it should be proportional and also apply to the 45-minute HOT.

Table 2.4: Endurance Time Comparison of Standard Mix vs. 10° Buffer Type I Fluid

Average ΔTime (min): Standard Mix - 10° Buffer	Average Test Ratio: Standard Mix/10° Buffer
41	1.5

2.5.3 Evaluation of 5-Minute Rule for Type I – Testing Methodology

A total of 38 individual tests were analysed for the progression from first failure to 1/3 plate failure. First failure was considered when ice contaminated the 2.5 cm (1 inch) line of the plate, and 1/3 failure was considered the standard failure call for when a third of the plate was contaminated with ice.

The results (see Table 2.5) indicated that the progression from first failure to full failure is more rapid for 10° buffer fluids compared to standard mix fluids. The average delta time between first failure and full failure was 32 minutes for 10° buffer fluids compared to 53 minutes for standard mix fluids, much longer than the 5-minute rule in both cases. The results also indicated that the ice contamination (first failure) became visible at 66 percent of the ET for the 10° buffer fluids compared to 60 percent of the ET for standard mix fluids.

Table 2.5: Evaluation of Fluid Failure Progression for Type I Fluids

Fluid Dilution	Average ΔTime (min): Failure - First Failure	% of ET: First Failure/Failure
10° Buffer	32	66%
Standard Mix	53	60%

2.5.4 Operational Impact of Test Results

The test results were analysed in the context of the 2-hour Type I fluid protection time target requested by industry. The results were used to understand how the generic frost 45-minute HOT Guideline and the FAA's 5-minute pre-takeoff contamination check extension could be modified based on the preliminary data collected.

The calculated ET ratio of the standard mix fluid to the 10° buffer fluid was on average 1.5. Applying this ratio to the 45-minute HOT, which is based on the worst-case 10° buffer fluid performance, would estimate the HOT for a standard mix fluid to be 68 minutes (45 minutes x 1.5 ratio = 68 minutes). Therefore, using standard mix fluid could potentially provide a 50 percent longer HOT for Type I fluids in frost and result in a longer HOT of 68 minutes.

The ice contamination (first failure) became visible at approximately 60 percent of the ET with the standard mix fluid. The slow failure progression in frost could support an extension of the FAA's 5-minute rule for the pre-takeoff contamination check. Historically, the 5-minute window of time was meant to be a conservative estimate representing the quickest period following and inspection in which the fluid could progress from clean to failed in ground icing conditions like snow, freezing rain, et cetera. Considering a worst-case standard mix fluid HOT of 68 minutes in frost (as calculated above), we would expect that the failure would become visible during the last 40 percent, or 27 minutes, of the HOT. Therefore, if a pilot were to inspect the wing sometime following exceeding HOT, but just prior to first failure and thus observe a clean wing, we would expect that, at minimum, it would be 27 minutes (and likely longer) until full failure. The slow progression of fluid failure indicates a potential to increase the FAA's 5-minute rule for the pre-takeoff contamination check in frost conditions, and based on the data collected to date, that time could be up to 27 minutes.

2.6 Conclusions

In the context of industry's 2-hour target, the data indicates that the HOT could be increased to 68 minutes for standard mix fluid and that the time to safely depart following a pre-takeoff contamination check could be extended to 27 minutes. In total, this is an increase to 95 minutes or approximately 1.5 hours. The results indicate that a conservative approach could roughly double the operational time for Type I fluids in frost conditions; however, this does not reach the 2-hour target.

2.7 Recommendations

As this research was preliminary, additional data would be required to further validate the results obtained. Further discussion with industry is also required to determine if a 1.5-hour operational window, as indicated by the preliminary results using standard mix fluid, is of significance in the context of the 2-hour target, and this will determine if further research is required.

Photo 2.1: Test Stand Installed Inside the DFIR Shield

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3. TYPE I OVERSPRAY QUANTITIES – HISTORICAL REVIEW

This section describes the work APS Aviation Inc. (APS) completed in the winter of 2019-20 performing a historical review of the minimum quantities required for a Type I overspray.

3.1 Background

During the Standing Committee on Operations Under Icing Conditions (SCOUIC) meeting in October 2019, attended by regulators, operators, and researchers, there was significant discussion regarding minimum quantities required for a Type I anti-icing overspray. The discussion aimed at clarifying pilot requests for Type I treatment and the communication of a deicing or anti-icing completion time (and the respective holdover time (HOT) if applicable) by the deicing operator.

As a result of this discussion, Transport Canada (TC) requested that APS perform a historical review of testing studies and data that may support the requirement that at least 1 L/m^2 of fluid must be applied to deiced surfaces in order to use the published Type I fluid HOT tables. It should be noted that this study was requested by TC as part of the joint research program with the Federal Aviation Administration (FAA), and, as such, the focus was on the TC version of the guidance material.

3.2 Objective

The objective was to perform a historical review of testing studies and data that may support the requirement that at least 1 L/m^2 of fluid must be applied to deiced surfaces in order to use the published Type I fluid HOT tables.

3.3 Analysis of Historical Studies and Data

APS has supported the development of the HOT guidance material since its inception in the 1990s and, as such, has access to historical records and files related to the guidance development; in fact, many of the original researchers are still actively working for APS. From the perspective of the regulators, many of the regulatory officials involved in the early decision making related to the Type I guidance are no longer involved in the deicing program, making the search for historical material more challenging, especially when seeking information not documented in reports or other official documents. Nonetheless, APS was able to conduct and collate a historical review related to the Type I anti-icing overspray requirements.

Appendix D includes a detailed account of the historical review.

3.4 Conclusions

Studies prior to and after the publication of the 2000-01 HOT table, along with typical fluid spray quantities provided by several airlines, provide data that could reasonably have influenced the provisional recommendation that at least 2 L/m^2 of Type I fluid is needed in a one-step de/anti-icing operation, leading to the conclusion that at least 1 L/m^2 must be applied to deiced surfaces.

It is unclear what exact logic was used by the TC official at the time to determine the 1 L/m^2 requirement, and no clear documentation exists as such. The historical research seems to indicate that quantities of 2 L/m^2 would likely have been considered for recommendation; however, 1 L/m^2 may have been adopted as an adequate compromise between the minimum safety requirements and industry acceptance of an efficient quantity.

3.5 Recommendations

To further validate the current 1 L/m^2 requirement, full-scale testing could be performed. This testing should consider newer aircraft construction, which uses composite materials, and newer deicing sprayer systems, which have optimized spray patterns, pressures, and heating systems.

Perhaps the application process for Type I fluid should be limited to a two-step operation to underscore the need for an adequate overspray beyond the fluid applied for deicing and to take advantage of the later start to the HOT countdown. It may be useful to explore the optimum spray pattern to transfer heat to the wing.

Fluid quantities for frost conditions are typically lighter than for other conditions, and the loss of fluid heat from spray nozzle to wing surface greater. Type I fluid applications for frost could merit an examination of potentially different guidelines.

Perhaps for frost, it would be advantageous to replace the current 10° buffer with a buffer of 15° to 20°. This would provide protection against quick refreezing due to frost-melt dilution and may be a more reliable and perhaps less expensive approach than requiring a specified overspray amount.

4. INTERPRETATION OF METAR REPORTED WEATHER FOR DETERMINING APPLICABLE HOLDOVER TIMES

This section describes the ongoing work APS Aviation Inc. (APS) has been performing in the winter of 2019-20 aimed at interpreting METAR reported weather for determining the applicable holdover time (HOT) table guidance conditions.

4.1 Background

METARs are issued for most airports on an hourly basis with special reports (referred to as SPECI) issued whenever a significant change in weather occurs. The METAR will contain data on current conditions, including present weather conditions. When aircraft are operated in adverse winter conditions, the reported METAR weather conditions may not always have a corresponding condition in the HOT guidelines to allow for safe departure, and this is especially true for mixed conditions. An understanding of the statistical significance of the frequency of occurrence of METAR reported winter weather conditions is required to support the development of more exhaustive holdover time guidance material.

4.2 Objective

The objective was to conduct a multi-airport analysis of weather conditions, identify the METAR conditions most relevant to aircraft ground icing, and prepare a project plan to prioritize the development of appropriate guidance for the top identified conditions based on Transport Canada (TC) and Federal Aviation Administration (FAA) requirements.

4.3 Multi-Airport METAR Analysis

Freely available multi-decade METAR archives now exist on the internet, and this allows for a thorough analysis of weather conditions reported therein. This study performed an extensive analysis of wintertime weather conditions using cold season METAR data from Automated Surface Observing Systems (ASOS) sites in the United States and Canada.

Appendix E includes a detailed account of the multi-airport analysis and the statistical significance of the most frequently reported conditions.

4.4 Prioritizing the Development of Appropriate HOT Guidance Material

It is expected that the multi-airport METAR analysis will provide insight for directing and prioritizing the development of appropriate HOT guidance material for conditions where guidance may be limited or missing. The prioritization of the conditions will be determined based on a review of the analysis (see Subsection 4.3) with TC/FAA and following some more extensive discussions expected to occur in late 2020.

4.5 Development of HOT Guidelines for Conditions with Missing or Limited Guidance

It is expected that once those weather conditions with missing or lacking guidance are prioritized (see Subsection 4.4), a project plan will be prepared to develop proper guidance for those conditions. The development of guidance will likely be through a combination of analysis and testing and will likely commence in late 2020.

4.6 Conclusions

This study examined a large sample of METAR data collected primarily at the major airports in the United States and Canada that experience wintertime precipitation. The analysis identified differences in reporting structures between the United States and Canada, as well as regional differences.

4.7 Recommendations

Further investigation is needed into the differences in algorithms that produce large differences in the frequency of some weather types reported in METARs from the United States versus Canada. Additional insight may be gained by expanding the analysis of METARs to other countries from Europe or Asia and using data from sites with lower levels of observation capability in the United States [i.e., Automated Weather Observing Systems (AWOS)].

Further analysis is suggested for mixed precipitation types not currently included in HOT guidance material. Likewise, a number of conditions involving mist and fog should be investigated.

It is recommended that work continue towards prioritizing the conditions to be addressed and developing the respective guidance material.

5. TEMPERATURE-SPECIFIC SNOW HOLDOVER TIMES

This section documents the work carried out by APS Aviation Inc. (APS) in support of the development of temperature-specific snow holdover times (HOTs). This project was initiated in the winter of 2018-19 and is expected to be completed in the winter of 2020-21.

5.1 Background

Snow HOTs are derived from data collected at various temperatures. Multi-variable regression analysis is applied to this data to derive HOTs for specific temperatures; in particular, HOTs are calculated for the coldest temperature in each temperature band in the HOT tables. These HOTs are then used for all temperatures in the temperature band.

Although the data supports them, snow HOTs are not published for every temperature because it is neither practical nor user friendly to include this amount of data in the HOT tables published by Transport Canada (TC) and the Federal Aviation Administration (FAA). However, as HOTs almost always increase as temperature increases, there is an operational advantage to be gained by providing this data to operators (see example in Figure 5.1).

The adoption of electronic flight bags and the advent of apps that provide HOTs digitally have made it possible to provide HOTs for every temperature in a user-friendly format. However, there is no database of temperature-specific HOT values currently published by TC and the FAA.

HOT Table Approach

Temp.	Moderate Snow HOT
-3°C and above	1:05 - 1:55
below -3 to -8°C	0:50 - 1:25

Temperature-Specific HOTs Approach

Temp.	Moderate Snow HOT
-3°C	1:05 - 1:55
-4°C	1:00 - 1:45
-5°C	0:57 - 1:37
-6°C	0:52 - 1:32
-7°C	0:51 - 1:27
-8°C	0:50 - 1:25

Figure 5.1: Example of HOT Table vs. Temperature-Specific HOTs Approaches

At the request of industry, TC and the FAA undertook a project in the winter of 2018-19 to develop and publish temperature-specific HOTs for snow. It should be noted that the project was limited to snow – other precipitation types were not included because HOT test data does not exist for all temperatures for other precipitation types.

5.2 Previous Work

The project outline and several analytical tasks related to the development of the temperature-specific snow HOTs database were completed in 2018-19. Additional details concerning the previous work can be found in the TC report, TP 15427E, *Aircraft Ground Icing General Research Activities During the 2018-19 Winter* (1).

5.3 Objective

The objective of the project is to enable operators to use temperature-specific snow HOTs.

Table 5.1 provides the list of tasks associated with the development and publication of the temperature-specific HOTs database and all related guidance material.

Table 5.1: Project Tasks for Temperature-Specific HOTs

Task	Sub-Project
1. Prepare project plan.	Both
2. Analytical work: mine existing data to determine how much temperatures change within one hour.	Research
3. Analytical work: review endurance time data of existing fluids to determine how HOTs change with a 1, 2, and 3°C change in temperature.	Research
4. Identify decisions regarding data production; create summary document.	Research
5. Hold meetings with TC/FAA to inform them of issues and make decisions (three meetings expected).	Research
6. Hold discussions to determine the exact format of data output.	Research
7. Hold discussions to determine the appropriate regulatory process to enable data use (guidance in TP 14052E/N 8900 or an Advisory Circular, Principal Inspector approval, or TC/FAA approval of data generators).	Operational
8. Create data output.	Operational
9. Conduct detailed verification of data output.	Operational
10. Create verification tables to support data implementation.	Operational
11. Create temperature-specific HOTs implementation guidance for operators.	Operational
12. Create temperature-specific HOTs verification guidance for inspectors.	Operational
13. Support publication of data.	Operational
14. Prepare presentation for SAE G-12.	Both
15. Publish report.	Both

5.4 Analysis: Data Questions

A significant part of this project was to identify, research, discuss, and resolve questions related to the publication of temperature-specific HOT data. Preliminary analysis was carried out by APS, and the results were brought forward to TC and the FAA. Decisions by TC and the FAA were facilitated by APS through a series of meetings.

Table 5.2 provides a list of the data questions and the corresponding decisions made for each question. The majority of the questions were resolved during the 2018-19 project year; the remaining questions were resolved during the 2019-20 project year.

Table 5.2: Data Questions and Decisions

Question	Decision
1. Do users do their own calculations for temperature-specific HOTs or do TC/FAA do the calculations and publish a database?	• Decision (Feb 11, 2019): TC/FAA to do calculations.
2. Are HOT table capping rules retained (2 hours TC, 3 hours FAA)?	• Decision (Feb 11, 2019): Yes.
3. Can data be provided in a complex table format or does it need to be in a proper database format with one entry per HOT value?	• Decision (Feb 11, 2019): Needs to be a universal database; therefore, needs to be one entry per value.
4. Should HOTs be provided for the actual reported temperature or should a conservative factor be added?	• Decision (Mar 7, 2019): Add conservative factor. • Decision (Mar 15, 2019): Conservative factor will be 1°C. • Decision (Apr 11, 2019): It's okay to calculate at 1°C colder than the LOUT because HOT regression curves are not dependent on LOUT. Therefore, this will be done. • Decision (Apr 11, 2019): Populate database at boundary conditions with boundary temperature values (no 1°C buffer) to avoid lack of harmonization between HOT tables and database. • Decision (Mar 4, 2020): Use 1°C buffer, even at boundaries. Lack of harmonization not as critical as safety.
5. Should the user have to apply the temperature conservatism, or should it be embedded in the database?	• Decision (Mar 7, 2019): Embed conservatism in database.
6. Will temperature-specific HOTs be provided for diluted fluids?	• Decision (Mar 15, 2019): Do not include dilutions. Consider doing so in future if requested by industry.
7. Are HOT table rounding rules retained?	• Decision (Mar 15, 2019): No. Values will be rounded to the nearest minute. HOTs below 10 minutes will be rounded down to the nearest whole minute.
8. In what format will the data be published?	• Decision (Mar 15, 2019): Data will be published in Excel. This decision was driven by the need for average users (airlines) to be able to use the data. XML requires a program to be created to decode/process data.

Table 5.2: Data Questions and Decisions (cont'd)

Question	Decision
9. Should data be published only to the LOUT or to a very cold temperature with a caution to respect the LOUT?	• Decision (Feb 11, 2019): Publish data only to LOUT.
10. Will temperature-specific HOTs be provided for very cold snow (temperatures below -14°C)?	• Decision (Apr 11, 2019): Fluids with fluid-specific HOTs for very cold snow will be populated with temperature-specific values. Fluids with generic very cold snow HOTs will be populated with boundary temperature values (no regression for generics).
11. Will temperature-specific HOTs be provided below -25°C?	• Decision (Apr 11, 2019): Yes, HOTs will be provided to LOUT.
12. Should there be a limitation for short HOTs? (TC restricts pre-takeoff contamination inspections with Type I fluids and with Type II/III/IV fluids with HOTs below 20 minutes.)	• Decision (Apr 11, 2019): No.
13. Will temperature-specific HOTs be provided for all fluids?	• Decision (Jun 13, 2019): Will be provided for Type II, Type III, and Type IV fluids but not for Type I fluids.
14. Do notes/cautions need to be provided with temperature-specific HOTs? If yes, are these provided in the database or by the data provider (i.e., with the app)?	• Decision (Feb 4, 2020): Operators who wish to use temperature-specific HOTs must ensure that notes and cautions are available alongside the data (whether within an eHOT app or within the guidance that they incorporate).
15. What is the impact of temperature-specific HOTs on liquid water equivalent (LWE) systems? Some harmonization/thought required to ensure equivalency between HOT tables, temp-specific HOTs, and LWE HOTs. Notably, restrictions regarding changing temperatures and inclusion of notes/cautions. Need to have similar restrictions.	• Decision (Feb 4, 2020): No work required; there are no additional restrictions applicable to LWE systems that would impact the temperature-specific HOTs database.

Table 5.2: Data Questions and Decisions (cont'd)

Question	Decision
16. Should a set of generic temperature-specific HOTs be included in the data publication?	• Decision (Mar 4, 2020): Include generic values for Type II/IV. Use same methodology as standard HOT generic tables (lowest HOT value of all applicable fluids is used for each temperature).
17. Does temperature need to be provided in both Celsius and Fahrenheit formats within the database?	• Decision (Mar 4, 2020): Include only Celsius values within the database.

5.5 Draft Database

Following the resolution of the outstanding data questions, a draft version of the temperature-specific HOTs database was created to allow regulators the opportunity to review the format and suggest adjustments as needed.

The fluid-specific temperature-specific HOT values within the draft database were calculated using the regression coefficients found within the TC Winter 2019-2020 Regression Information publication.

The generic Type II and Type IV temperature-specific HOT values were determined by the shortest applicable HOT value of all fluids of the appropriate fluid type at each specific temperature.

An excerpt of the draft database (TC format) is shown below in Table 5.3. The final database is expected to be published in 2020-21 following completion of a detailed verification and the incorporation of any changes required as a result of the 2020-21 HOT testing program.

Supporting guidance material containing the requirements for proper implementation of temperature-specific HOTs into an operator's approved ground icing program is currently in development. It is expected that this guidance material will be published within an Advisory Circular (AC) for TC and within the N8900 series guidance document for the FAA.

A related guidance document is also being developed for TC/FAA inspectors. This document will provide guidelines for verifying proper use and implementation of temperature-specific HOTs by operators.

It is expected that these guidance documents will be completed during the 2020-21 project year. This guidance is considered essential for publication of the temperature-specific HOTs database; no data will be published without completion of the supporting guidance documents.

Table 5.3: Excerpt of Draft Temperature-Specific HOTs Database (TC Format)

Fluid Name	Ambient Temperature (°C)	Very Light Snow HOT Rate = 3 g/dm²/h	Very Light Snow HOT Rate = 4 g/dm²/h	Light Snow HOT Rate = 10 g/dm²/h	Moderate Snow HOT Rate = 25 g/dm²/h
Generic Type IV	3	120	120	77	33
Generic Type IV	2	120	120	77	33
Generic Type IV	1	120	120	77	33
Generic Type IV	0	120	120	77	33
Generic Type IV	-1	120	120	76	33
Generic Type IV	-2	120	120	71	33
Generic Type IV	-3	120	120	67	33
Generic Type IV	-4	120	120	63	32
Generic Type IV	-5	120	120	61	31
Generic Type IV	-6	120	116	58	29
Generic Type IV	-7	120	112	56	28
Generic Type IV	-8	120	108	54	27
Generic Type IV	-9	120	103	53	27
Generic Type IV	-10	118	97	51	26
Generic Type IV	-11	111	91	48	25
Generic Type IV	-12	105	86	45	24
Generic Type IV	-13	100	82	43	23
Generic Type IV	-14	95	78	41	22
Generic Type IV	-15	45	30	9	2
Generic Type IV	-16	45	30	9	2
Generic Type IV	-17	45	30	9	2
Generic Type IV	-18	45	30	9	2
Generic Type IV	-19	20	10	3	1
Generic Type IV	-20	20	10	3	1
Generic Type IV	-21	20	10	3	1
Generic Type IV	-22	20	10	3	1
Generic Type IV	-23	20	10	3	1
Generic Type IV	-24	20	10	3	1
Generic Type IV	-25	20	10	3	1
Generic Type IV	-26	10	7	2	0
Generic Type IV	-27	10	7	2	0
Generic Type IV	-28	10	7	2	0
Generic Type IV	-29	10	7	2	0
Generic Type IV	-30	10	7	2	0

5.6 Conclusions

Significant progress was made on the development of temperature-specific snow HOTs in the winter of 2019-20. The outstanding questions relating to the data were resolved, the draft database was created, and work was begun on creating the guidance documents to support database publication.

5.7 Recommendations

It is recommended that this project be continued in the winter of 2020-21 and that these outstanding tasks be completed. The guidance documents relating to the implementation of temperature-specific HOTs must be finalized.

Additionally, the draft database must be updated prior to publication to reflect any changes made to the 2021-22 HOT Guidelines.

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6. TECHNICAL REVIEW, APPROVAL, AND PUBLICATION OF HISTORICAL REPORTS

This section describes the process used by APS Aviation Inc. (APS) to publish reports for the de/anti-icing research program on behalf of Transport Canada (TC) and the Federal Aviation Administration (FAA). It also details the status of the technical review of historical reports in the publication process and provides guidance for handling such reports subsequently.

6.1 Background

As of October 31, 2016, APS had prepared over 187 reports on aircraft ground icing research and development on behalf of TC and the FAA. Out of these 187 reports, 124 reports were not published. This backlog is attributed to limited resources and shifting priorities within TC and the FAA. To remedy the backlog, APS was tasked to develop a prioritized list of unpublished reports, accelerate these reports through the publication process, and deliver them as Final Version 1.0.

6.2 Objective

The objective of this project for the 2019-20 year was to handle a total of 20 reports, with the aim to accelerate 6 unpublished reports to the Final Draft 2.0 stage and to publish the remaining 14 reports as Final Version 1.0 (targets for subsequent years will be determined at the completion of each year).

This objective was achieved through the measures indicated below.

- Allocating the 20 reports to be handled to two categories: Project 1 and Project 2 (all reports part of Project 1 were targeted to be published as Final Version 1.0, and all reports part of Project 2 were targeted to be brought to the Final Draft 2.0 stage).
- Coordinating and outsourcing technical and editorial reviews of reports with technical and editorial experts (done for Project 1 and Project 2 reports).
- Performing technical and editorial reviews that are to be done by technical and editorial experts (done for Project 1 and Project 2 reports) and making necessary updates to prepare reports for final editing and publishing (done for Project 1 reports).
- Providing a status of progress within the monthly progress reports.

6.3 Publication Process and Delivery of Technical Reports

APS produces reports annually for the de/anti-icing research program on behalf of TC and the FAA through a detailed reports management process that it has developed and continually updates. Figure 6.1 displays the updated Reports Management Process, offering a global view of the progression of reports from "Draft" to "Final" stages of publication. It includes all the phases with their respective milestones and detailed tasks from initiation to publication.

The Reports Management Process comprises eight phases. The first four phases are internal to APS and labelled Phase 1, 2, 3, and 4, respectively. The following four phases are related to the publication of a report and are labelled Phase 5, 6, 7, and 8, respectively. Reports typically undergo these phases prior to delivery of Final Version 1.0.

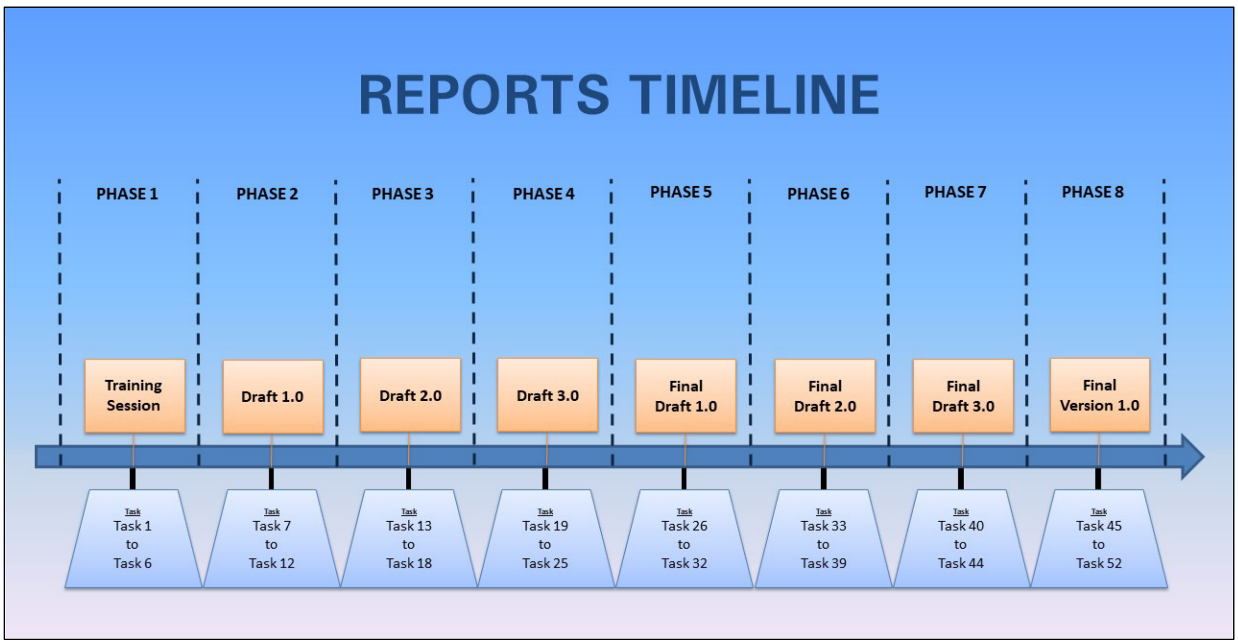

Figure 6.1: Reports Management Process

For the year 2016-17, APS surpassed the goal of 12 reports and published 16 reports in total. These reports were published and delivered to TC and the FAA as Final Version 1.0 via "WeTransfer." The details of the reports published in 2016-17 are provided in TC report, TP 15374E, *Aircraft Ground Icing General Research Activities During the 2016-17 Winter* (2).

For the year 2017-18, APS surpassed the goal of 20 reports and published 22 reports in total. The details of the reports published in 2017-18 are provided in TC report, TP 15398E, *Aircraft Ground Icing General Research Activities During the 2017-18 Winter* (3). These reports were published and delivered to TC and the FAA as Final Version 1.0 via "WeTransfer" and USB drives.

For the year 2018-19, APS achieved the goal of 20 reports and published 20 reports in total. The details of these reports published in 2018-19 are provided in TC report, TP 15427E, *Aircraft Ground Icing General Research Activities During the 2018-19 Winter* (1). These reports were published and delivered to TC and the FAA as Final Version 1.0 via "WeTransfer" and USB drives.

For the year 2019-20, APS accelerated a total of 6 unpublished reports to Final Draft 2.0 stage and published a total of 14 reports; the published reports are displayed in Table 6.1. The 14 published reports were delivered to TC and the FAA as Final Version 1.0 via "WeTransfer" and USB drives.

Table 6.1: List of Published Technical Reports (2019-20)

No.	TP Number	Year	Report Title	Category	Latest Version	Publication Date
1	TP 15425E	2018-19	Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2018-19 Winter (HOT)	HOT	Final Version 1.0	June 12, 2020
2	TP 15426E	2018-19	Regression Coefficients and Equations Used to Develop the Winter 2019-20 Aircraft Ground Deicing Holdover Time Tables (REGRESSION)	Regression	Final Version 1.0	May 22, 2020
3	TP 15427E	2018-19	Aircraft Ground Icing General Research Activities During the 2018-19 Winter (GENERAL AND EXPLORATORY)	G&E	Final Version 1.0	May 26, 2020
4	TP 15428E	2018-19	Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winters 2017-18 and 2018-19 (ICE PELLET)	Ice Pellet	Final Version 1.0	Oct 23, 2020
5	TP 14382E	2003-04	A Sensor for Detecting Anti-Icing Fluid Failure: Phase I (SENSORS)	Sensors	Final Version 1.0	May 8, 2020
6	TP 14380E	2003-04	A Protocol for Testing Fluids Applied with Forced Air Systems (FORCED AIR)	Forced Air	Final Version 1.0	May 8, 2020
7	TP 14446E	2004-05	A Sensor for Detecting Anti-Icing Fluid Failure: Phase II (SENSORS)	Sensors	Final Version 1.0	May 8, 2020
8	TP 14445E	2004-05	Evaluation of Type IV Fluids Applied Using Forced Air Assist Equipment (FORCED AIR)	Forced Air	Final Version 1.0	May 8, 2020
9	TP 14716E	2005-06	Falcon 20 Trials to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets (FALCON 20)	Falcon 20	Final Version 1.0	Oct 23, 2020
10	TP 14779E	2006-07	Development of Allowance Times for Aircraft Deicing Operations During Conditions with Ice Pellets (ICE PELLET)	Ice Pellet	Final Version 1.0	Oct 23, 2020
11	TP 14871E	2007-08	Research for Further Development of Ice Pellet Allowance Times: Aircraft Trials to Examine Anti-Icing Fluid Flow-Off Characteristics Winter 2007-08 (ICE PELLET)	Ice Pellet	Final Version 1.0	Oct 23, 2020
12	TP 15232E	2012-13	Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics and to Support the Development of Ice Pellet Allowance Times, Winters 2009-10 to 2012-13 (ICE PELLET)	Ice Pellet	Final Version 1.0	Oct 23, 2020
13	TP 15273E	2013-14	Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2013-14 (ICE PELLET)	Ice Pellet	Final Version 1.0	Oct 23, 2020
14	TP 15341E	2015-16	Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2015-16 (ICE PELLET)	Ice Pellet	Final Version 1.0	Oct 23, 2020

6.3.1 Overall Publication Status of Technical Reports

The overall status of the reports as of October 31, 2019, was as follows:

- Published reports: 123;
- Non-published reports: 79; and
- Total reports: 202.

Detailed in Table 6.1, the following 14 reports from past years were delivered to TC and the FAA as Final Version 1.0 during the 2019-20 year:

- Two reports from 2003-04;
- Two reports from 2004-05;
- One report from 2005-06;
- One report from 2006-07;
- One report from 2007-08;
- One report from 2012-13;
- One report from 2013-14;
- One report from 2015-16; and
- Four reports from 2018-19.

In 2017-18, a detailed analysis of all past APS reports was conducted, and they were consequently re-categorized in 2017-18. The overall status and progression of report publication with the new categorization from October 31, 2019, to October 31, 2020, is presented in Table 6.2.

In addition, APS is currently working on six reports for the Winter 2019-20 research activities; these are not included in the totals as of October 31, 2020.

As of October 31, 2020, estimating that APS will accelerate 6 unpublished reports to Final Draft 2.0 stage and publish 14 reports per year, it will take approximately four-and-a-half years to clear the backlog.

As of October 31, 2020, the number of published reports, including the reports that are expected to be published, totals 175.

Table 6.2: Overall Status of Reports from 2017-18 to 2019-20

Category	Description	2017-18 (# of reports as of Oct. 31, 2018)	2018-19 (# of reports as of Oct. 31, 2019)	2019-20 (# of reports as of Oct. 31, 2020)
Published Reports	TP reports that are published as Final Version 1.0.	103	123	137
Interim Reports Incorporated into a TP Report	Reports initially produced as interim reports and subsequently incorporated into TP reports.	21	22	25
Interim Reports Not to Be Published	Reports that have not been assigned TP numbers and will not be published; however, some information contained in these reports has been included in subsequent TP reports.	2	2	2
Protected Reports	Reports that are not for distribution (two reports for the Department of National Defence and one Ops Survey report for TC).	3	3	3
Non-Published Reports	TP reports that are still in Draft stages.	64	48	38
Interim Reports to Be Published	Reports that have not been assigned TP numbers and may be published.	5	4	2
Total Reports Produced	Total number of reports produced by APS.	**198**	**202**	**207**

6.4 Conclusions

APS has been involved in writing and publishing technical reports on behalf of TC and the FAA since 1992 and has prepared over 207 reports. Due to TC's and the FAA's limited resources, 124 reports were still outstanding in 2016-17, and APS was tasked with developing a prioritized list of unpublished reports that needed to be reviewed and published.

By October 2017, APS published 16 reports that were delivered to TC and the FAA as Final Version 1.0. By October 2018, APS published 22 reports that were delivered to TC and the FAA as Final Version 1.0. By October 2019, APS published 20 reports that were delivered to TC and the FAA as Final Version 1.0. By October 2020, APS accelerated 6 reports to Final Draft 2.0 stage and published 14 reports that were delivered to TC and the FAA as Final Version 1.0.

6.5 Recommendations

Since APS has taken a more active role in completing this project, it is recommended that proper resources be dedicated to continue publishing these reports on a yearly basis.

7. PUBLICATION OF HOLDOVER TIME GUIDANCE MATERIALS

This section describes the work APS Aviation Inc. (APS) completed in the winter of 2019-20 in support of Transport Canada (TC) and the Federal Aviation Administration (FAA) holdover time (HOT) guidance materials.

7.1 Background

The development and use of HOT Guidelines represent an important contribution to the enhancement of flight safety in winter aircraft operations. In the years since their introduction, the HOT Guidelines and related guidance materials have become standard and essential parts of winter operations. APS plays a significant role in the preparation and management of these documents.

7.2 APS Contribution to Holdover Time Guidance Materials

Over the years, APS has supported TC and the FAA in the development and management of the HOT Guidelines documents. APS completes the following tasks in support of the HOT guidance materials on an annual basis:

a) Develops fluid-specific HOT and regression tables for new Type II, III, and IV anti-icing fluids that undergo endurance time testing;

b) Requests, collects, and reviews information provided by fluid manufacturers related to fluid qualification dates and lowest operational use temperatures (LOUTs), resulting in updates to the list of fluids in the HOT Guidelines;

c) Recommends changes to the HOT guidance materials as a result of new research findings;

d) Maintains an ongoing list of potential future changes to the HOT guidance materials, schedules and runs meetings to review and discuss these changes with TC/FAA, and implements changes as required;

e) Drafts HOT Guidelines and HOT regression information documents on an annual basis, including TC English, TC French, and FAA versions;

f) Provides support for the update of the FAA N 8900 series document;

g) Restructures guidance material to make it accessible for people with disabilities; and

h) Provides the latest HOT Guidelines and regression information to the TC publications department for them to update their website on an annual basis (or more frequently if updates to the HOT Guidelines are necessary).

7.3 Winter 2020-21 Holdover Time Guidance Materials

In August 2020, the 2020-21 HOT Guidelines and Regression Information documents were finalized. The changes made to the documents are summarized in the documents themselves and are described in detail in two TC reports:

1. **Holdover Time Guidelines:** TP 15450E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2019-20 Winter* (4); and
2. **Holdover Time Regression Information:** TP 15451E, *Regression Coefficients and Equations Used to Develop the Winter 2020-21 Aircraft Ground Deicing Holdover Time Tables* (5).

The titles of the 2020-21 documents are listed in Table 7.1. Final drafts of TC and FAA documents were provided to the TC and the FAA publications departments, respectively, for publication on August 7, 2020.

As intended, the FAA finalized and published its N 8900 series notice, along with the other HOT guidance materials, on August 7, 2020.

Table 7.1: 2019-20 HOT Guidance Documents

HOT Guidelines	1. Transport Canada Holdover Time (HOT) Guidelines Winter 2020-2021, Original Issue, August 7, 2020
	2. Guide de Transports Canada sur les durées d'efficacité Hiver 2020-2021, version originale, 7 août 2020
	3. FAA Holdover Time Guidelines Winter 2020-2021, Original Issue, August 7, 2020
Regression Information	4. Transport Canada HOT Guidelines Regression Information Winter 2020-2021, Original Issue, August 7, 2020
	5. Transports Canada Guide des durées d'efficacité Information de régression Hiver 2020-2021, version originale, 7 août 2020
	6. FAA Holdover Time Regression Information Winter 2020-2021, Original Issue, August 7, 2020

7.4 Future Responsibilities

APS will continue contributing to the development of the TC and the FAA HOT guidance materials in the winter of 2020-21. Specifically, APS will continue carrying out the tasks listed in Subsection 7.2.

8. PRESENTATIONS, FLUID MANUFACTURER REPORTS, AND TEST PROCEDURES FOR 2019-20

This section contains an account of the presentations, fluid manufacturer reports, and test procedures prepared by APS Aviation Inc. (APS) in the winter of 2019-20.

8.1 Presentations

SAE International (SAE) G-12 Committees hold several meetings on an annual basis. During these and other meetings, APS presents the findings of work completed during the year. Most of the research presented at these meetings is also eventually documented in various reports.

In 2019-20, APS gave presentations at the following meetings:

1) Standing Committee for Operations Under Icing Conditions (SCOUIC) Meeting, Ottawa, Canada, October 2019;
2) SAE G-12 Holdover Time (HOT) Committee Meeting, Montreal, Canada, November 2019;
3) SAE G-12 HOT Committee Meeting, Online (via Webex), May 2020; and
4) Airlines for America (A4A) Ground Deicing Forum, Online (via Zoom), June 2020.

The presentations given by APS at each of these meetings are listed in the following subsections. A copy of each presentation listed is contained in Appendix F.

8.1.1 Standing Committee for Operations Under Icing Conditions Meeting, Ottawa, Canada, October 2019

The following two presentations were prepared for the SCOUIC meeting held in Ottawa, Canada, in October 2019:

1) Ground Icing Research Program Projects and Initiatives; and
2) Artificial Snow Research for Holdover Time Development.

8.1.2 SAE G-12 Holdover Time Committee Meeting, Montreal, Canada, November 2019

The following two presentations were prepared and presented at the SAE G-12 HOT Committee meeting held in Montreal, Canada, in November 2019:

1) Endurance Time Testing Program Winter 2019-20; and
2) Icing Wind Tunnel Research Simulating Ice Pellet Conditions.

8.1.3 SAE G-12 Holdover Time Committee, Online (via Webex), May 2020

The following five presentations were prepared for the SAE G-12 HOT Committee meeting held virtually, via Webex, in May 2020:

1) Winter 2019-20 Endurance Time Testing Update;
2) SAE G-12 HOT Committee: Documents Status;
3) Natural Snow Characterization to Support Artificial Snow Research 2019-20 APS Activities;
4) Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a Vertical Stabilizer; and
5) Icing Wind Tunnel Research Simulating Ice Pellet Conditions.

8.1.4 Airlines for America Ground Deicing Forum, Online (via Zoom), June 2020

The following two presentations were prepared for the A4A Ground Deicing Forum held virtually, via Zoom, in June 2020:

1) Winter 2019-20 Endurance Time Testing Update; and
2) Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a Vertical Stabilizer.

8.2 Fluid Manufacturer Reports

As part of the HOT research program, several fluids are tested for holdover performance each year. The data from commercialized fluids is published in the related Transport Canada (TC) report, TP 15450E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2019-20 Winter* (4), while the non-commercialized fluid reports are maintained by the respective fluid manufacturers for internal research purposes.

As a result of the COVID-19 pandemic, testing activities were halted in March 2020, and HOT data collection was significantly impacted. Once health and safety restrictions ease and testing activities resume, all outstanding fluid manufacturer reports are expected to be completed and provided to fluid manufacturers and to TC and the FAA.

8.3 Test Procedures

Several procedures were developed to guide and support the research team in conducting tests in the winter of 2019-20. Table 8.1 provides the list of the procedures. The procedures have been included as appendices to the Winter 2019-20 reports; the specific reports are listed in the last column of Table 8.1.

Table 8.1: List of Procedures 2019-20

Program Element #	ID #	Contract Program Element	Name of Procedure	Latest Version Details	Report
2	2.1	Endurance Time Testing for Maintenance and Publication of HOT Guidance Material	Procedure: Endurance Time Testing in Simulated Freezing Precipitation with SAE Type I, II, III, and IV De/Anti-Icing Fluids	Final Version 1.0 November 2018	HOT
2	2.2	Endurance Time Testing for Maintenance and Publication of HOT Guidance Material	Procedure: Endurance Time Testing in Natural Snow with SAE Type I, II, III, and IV De/Anti-Icing Fluids	Final Version 1.0 November 2018	HOT
2	2.3	Endurance Time Testing for Maintenance and Publication of HOT Guidance Material	Procedure: Endurance Time Testing in Simulated Snow with SAE Type I, II, III, and IV Fluids	Final Version 1.0 November 2018	HOT
2	2.4	Endurance Time Testing for Maintenance and Publication of HOT Guidance Material	Procedure: Endurance Time Testing in Active Frost with SAE Type I, II, III, and IV De/Anti-Icing Fluids	Final Version 1.0 November 2018	HOT
2	2.5	Endurance Time Testing for Maintenance and Publication of HOT Guidance Material	Overall Program of Tests at NRC, August/September 2020	Final Version 2.0, August 26, 2020	HOT
2	2.6	Endurance Time Testing for Maintenance and Publication of HOT Guidance Material	Overall Program of Tests at PMG, August 2020	Final Version 1.1, August 21, 2020	HOT
3	3.1	Snow Machine R&D Project: Natural Snow Characterization Testing and Support for NCAR Snow Machine Hardware Improvements	Procedure: Natural Snow Characterization Endurance Time Testing	Final Version 1.0, January 17, 2019	SMC
5	5.1	Exploratory Research and Standards (SAE Standards, AWG, FRWG, HOT Committee, Type I STD Mix for Longer Frost HOTs, and Other R&D)	Procedure: Evaluation of Type I Frost Endurance Times with Standard Mix Fluid	Final Version 1.0, December 11, 2019	G&E
6	6.1	Type I HOTs for Very Cold Snow (Temperatures Below -14°C)	Procedure: Endurance Time Testing in Natural Snow Below -10°C with SAE Type I De/Anti-Icing Fluids	Final Version 1.0, December 19, 2019	HOT
8	8.1	Wind Tunnel Testing – Seneca V-Stab Testing in the Wind Tunnel to Characterize Contaminated Fluid Flow-Off	Procedure: Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a Vertical Stabilizer	Final Version 1.0, January 16, 2020	WT
9	9.1	Wind Tunnel Testing – Combined R&D Testing Including Type III Low Speed and EG Specific Allowance Times	Procedure: Wind Tunnel Tests to Examine Fluid Removed from Aircraft During Takeoff with Mixed Ice Pellet Precipitation Conditions	Final Version 1.0, January 16, 2020	WT

REFERENCES

1. APS Aviation Inc., *Aircraft Ground Icing General Research Activities During the 2018-19 Winter*, APS Aviation Inc., Transport Canada, Montreal, December 2019, TP 15427E, 48.

2. APS Aviation Inc., *Aircraft Ground Icing General Research Activities During the 2016-17 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2017, TP 15374E, 52.

3. APS Aviation Inc., *Aircraft Ground Icing General Research Activities During the 2017-18 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2018, TP 15398E, 42.

4. Bernier, B., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2019-20 Winter*, APS Aviation Inc., Transport Canada, Montreal, October 2020, TP 15450E, XX (to be published).

5. Bernier, B., *Regression Coefficients and Equations Used to Develop the Winter 2020-21 Aircraft Ground Deicing Holdover Time Tables*, APS Aviation Inc., Transport Canada, Montreal, October 2020, TP 15451E, XX (to be published).

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APPENDIX A

TRANSPORT CANADA
STATEMENT OF WORK EXCERPT –
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2019-20

TRANSPORT CANADA
STATEMENT OF WORK EXCERPT –
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2019-20

1. Interpretation of METAR Reported Weather for Determining Applicable HOT Table Guidance Condition

a) Review historical work done by APS and NCAR looking at frequency of occurrence of METAR reported aviation winter weather.

b) Determine data requirements and conduct a multi-airport analysis of weather conditions to identify most relevant METAR conditions with respect to aircraft ground icing.

c) Prepare a project plan to prioritize the development of appropriate guidance. Examination of obscuration in fog and mist should be emphasized in this study.

d) Hold meetings with TC/FAA and other agencies, as required.

e) Develop guidance material for the top identified conditions based on TC/FAA discussions taking into account frequency of occurrence, and complexity of developing the condition.

   Note: should focus on conditions for which guidance can be developed analytically or with minimal research.

f) Prepare presentation for SAE G-12.

g) Prepare a report.

5. Exploratory Research and Standards (SAE Standards, AWG, FRWG, HOT Committee, Type I STD Mix for Longer Frost HOTs, and Other R&D)

Note: This program element includes research activities that will be pursued on an exploratory and ad-hoc basis. These activities were selected by representatives from TC and the FAA from a larger set of potential activities. Due to funding constraints, only those activities listed below are planned to be performed (activities may be added at the discretion of TC/FAA).

a) Support activities of SAE G-12 Aerodynamics Working Group.

b) Support activities of the SAE G-12 Fluid Requalification Working Group.

c) Provide support for further development of SAE aircraft ground deicing standards as needed.

d) Provide support to the SAE G-12 Holdover Time Committee, including providing a qualified individual to serve as the committee's secretary.

e) Support activities related to determining if frost endurance times are significantly longer with Type I fluid applied at the standard mix vs. Type I fluid applied at a 10°C buffer.

f) Provide technical support services and exploratory testing to provide regulators with timely data and documentation to address unexpected operationally driven industry incidents / concerns / questions.

Note that the following activities were also considered for inclusion, however, were not selected due to funding constraints. If additional funds become available over the course of the program, these activities may be performed at TC/FAA's discretion.

i. Support the rewrite of TP 14052E through attendance of all meeting and consultations, and providing additional technical support, as needed.

ii. Conduct additional analysis relating to rate tolerance in endurance time testing with the goal of further developing ARP5485.

iii. Conduct additional analysis relating to the use of half-plates in endurance time testing with the goal of further developing ARP5485.

iv. Investigate A319 engine icing issues experienced by a commercial operator.

v. Determine scope of work necessary to develop ethylene glycol-specific ice pellet allowance times.

vi. Support the development of an equivalency look up table (to support HOTDS systems) to cross-reference METAR reported weather vs. hot table conditions.

vii. Determine rates in mist and freezing mist to support HOT development for snow mixed with mist or fog.

viii. Evaluate the addition of heavy snow holdover times to HOT tables for 25-50 g/dm²/h.

ix. Documentation of test methods and protocols for HOT, ice pellet, snow machine, et cetera.

x. Evaluate hangar operations with and without fluids.

xi. Investigation of new technologies to support the modernization of the ground icing research program.

10. Development of Temperature-Specific Snow HOT Data: Support for Operational Implementation

a) Prepare project plan.

b) Hold meetings with TC/FAA to discuss outstanding issues identified during research and development phase.

c) Create the data output.

d) Conduct detailed verification of the data output.

e) Hold discussions to determine the regulatory process which will be employed to enable operators to use data (e.g. TP 14052E/N 8900, advisory circular, et cetera).

f) Provide assistance to TC/FAA to make regulatory changes as required.

g) Support the publication of data.

h) Prepare presentation for SAE G-12.

i) Prepare a report.

11. Technical Review, Approval, and Publishing of Technical Reports

a) Coordinate and manage the master list of reports, the list of references, et cetera.

b) Review, revise, and train staff on the Reports Training Manual.

c) Develop prioritized list of approximately 12 to 14 reports to be published as Final Version 1.0, and create and maintain schedule.

d) Coordinate technical review of approximately 10 additional reports.

e) Coordinate and schedule editorial reviews, technical reviews, and French translation of applicable reports.

f) Perform editorial review for applicable reports and make changes with author(s) to reports.

g) Perform technical review for applicable reports and make changes with author(s) to reports.

h) Perform French translation for applicable reports and make changes to reports.

i) Format applicable reports for final TC approval (including references, signatures, front matter, et cetera).

j) Support the TC approval and publishing of applicable reports.

k) Upload published reports to the APS website on behalf of TC/FAA.

12. Provision for Project Support Services (Including Progress Reporting and Preparation of Current Year Technical Reports to Final Draft 1.0 Level)

a) Provide support services for program coordination (progress reporting, setup of meetings, coordinate travel, et cetera).

b) Create task list and provide support services for management of task list.

c) Manage, schedule, and plan current year reports to Final Draft 1.0 level.

d) Develop current year reports from Draft 1.0 to Final Draft 1.0 including report components and appendices.

e) Format and finalize reports for ISO review.

f) Deliver Final Draft 1.0 to TC/FAA.

g) Coordinate, create, and manage the "Exploratory Research and Standards" report.

h) Coordinate and manage the list of reports (costed as part of a separate program element).

13. Update Source Documents for Maintenance and Publication of HOT Guidance Material

The following tasks will be completed (in general) for both phases of this work (Phase 1: New and outstanding changes to be integrated prior to March 31st; and Phase 2: Annual updates to be integrated prior to the publication expected in early August):

a) Prepare project plan and have kickoff meeting with TC/FAA;

b) Maintain a log of proposed changes to the HOT guidelines. Provide project coordination, follow-ups, and training;

c) Coordinate, plan, and lead discussions between TC, FAA, and EASA to address and approve new changes to the HOT guidance material;

d) Coordinate, plan, and lead discussions between TC, FAA, and EASA to approve annual updates to the HOT guidance material;

e) Update regression coefficients document (detailed activity costed as part of a separate program element including discussions and implementation); and

f) Provide support for publication of documents.

15. Infrastructure for TC/FAA Guideline Development

This program element does not include the actual endurance time testing of newly submitted fluids. The description of the fluid endurance time testing has been included in a previous section of this document and will be funded by the fluid manufacturers.

Fluid Management:

a) Receive and catalogue fluids;

b) Verify viscosity of newly received fluids at time of receipt and prior to simulated precipitation testing;

c) At the request of TC/FAA, verify viscosity of fluids in inventory intended for testing use; and

d) Maintain log of fluid inventory and viscosity information.

Preparation and Setup for Natural, Artificial Snow, and Frost Testing:

a) Prepare the P.E.T. test site at Trudeau International Airport (YUL) for conducting tests;

b) Upgrade test site infrastructure (i.e. trailer, shed, snow machine) to ensure personnel safety, adhere to environmental guidelines, maintain equipment inventory, and ensure equipment is calibrated;

c) Prepare an updated procedure for testing fluids in natural snow, as required;

d) Prepare an updated procedure for testing fluids in frost, as required;

e) Prepare an updated procedure for testing fluids with the snow machine, as required;

f) Evaluate current methods for measuring snowfall intensity or holdover times;

g) Develop improved, more efficient methods to measure snowfall intensity or holdover times, as required; and

h) Update and maintain iPad based HOT testing data form, as required.

Preparation and Setup for Simulated Precipitation Testing at NRC:

a) Prepare a general top-level plan to coordinate all simulated precipitation required by the research program. Testing will be conducted at the NRC Climatic Environment Facility (CEF) in U89 at Uplands, Ottawa;

Note: The NRC facility costs associated with testing at U89 are not included in this task and are dealt with directly with TC through a M.O.U. agreement with NRC;

b) Coordinate scheduling and test plans with NRC CEF personnel;

c) Prepare an updated test procedure for the conduct of endurance time tests in simulated precipitation at the NRC CEF, as required;

d) Conduct calibration to attain appropriate test conditions for each weather condition represented in the holdover time tables;

e) As the cost for this activity is highly weighted on calibration of precipitation rates, evaluate and, if possible, develop an improved, more efficient method to measure intensity of precipitation; and

f) Update and maintain the NRC Rate Calculation software.

General Activities:

a) Management and operational coordination;

b) Purchase equipment and modify test facility equipment, as required;

c) Monitor weather, provide support to projects, and provide training to staff on operations;

d) Present material and data at SAE G-12 meeting; and

e) Prepare reports.

16. Infrastructure for TC/FAA Research and Development

This program element does not include the actual research and development testing. The description of these program elements has been included in other sections of this document and has been budgeted separately.

Fluid Management:

a) Receive and catalogue fluids;

b) Verify viscosity of newly received fluids at time of receipt and prior to simulated precipitation testing;

c) At the request of TC/FAA, verify viscosity of fluids in inventory intended for testing use; and

d) Maintain log of fluid inventory and viscosity information.

Preparation and Setup for Natural, Artificial Snow, and Frost Testing:

a) Prepare the P.E.T. test site at Trudeau International Airport (YUL) for conducting tests;

b) Upgrade test site infrastructure (i.e. trailer, shed, snow machine) to ensure personnel safety, adhere to environmental guidelines, maintain equipment inventory, and ensure equipment is calibrated;

c) Prepare an updated procedure for testing fluids in natural snow, as required;

d) Prepare an updated procedure for testing fluids in frost, as required;

e) Prepare an updated procedure for testing fluids with the snow machine, as required;

f) Evaluate current methods for measuring snowfall intensity or holdover times;

g) Develop improved, more efficient methods to measure snowfall intensity or holdover times, as required; and

h) Update and maintain iPad based HOT testing data form.

Preparation and Setup for Simulated Precipitation Testing at NRC:

a) Prepare a general top-level plan to coordinate all simulated precipitation required by the research program. Testing will be conducted at the NRC Climatic Environment Facility (CEF) in U89 at Uplands, Ottawa;

   Note: The NRC facility costs associated with testing at U89 are not included in this task and are dealt with directly with TC through a M.O.U. agreement with NRC;

b) Coordinate scheduling and test plans with NRC CEF personnel;

c) Prepare an updated test procedure for the conduct of endurance time tests in simulated precipitation at the NRC CEF, as required;

d) Conduct calibration to attain appropriate test conditions for each weather condition represented in the holdover timetables;

e) As the cost for this activity is highly weighted on calibration of precipitation rates, evaluate and, if possible, develop an improved, more efficient method to measure intensity of precipitation; and

f) Update and maintain the NRC Rate Calculation software.

General Activities:

a) Management and operational coordination;

b) Purchase equipment and modify test facility equipment, as required;

c) Monitor weather, provide support to projects, and provide training to staff on operations;

d) Present material and data at SAE G-12 meeting; and

e) Prepare reports.

APPENDIX B

PROCEDURE:
EVALUATION OF TYPE I FROST ENDURANCE TIMES WITH STANDARD MIX FLUID

300293

PROCEDURE:

EVALUATION OF TYPE I FROST ENDURANCE TIMES WITH STANDARD MIX FLUID

Winter 2019-20

Prepared for

Transport Canada
Innovation Centre

Prepared by: Marco Ruggi

Reviewed by: John D'Avirro

December 11, 2019
Final Version 1.0

PROCEDURE: EVALUATION OF TYPE I FROST ENDURANCE TIMES WITH STANDARD MIX FLUID

1. BACKGROUND

Frost is an important consideration in aircraft ground deicing, and represents a significant portion of de/anti-icing operations, especially in areas with warmer climates. Transport Canada (TC) and the Federal Aviation Administration (FAA) publish holdover time guidelines for operating with de/anti-icing fluids, and the guidance issued for Type I fluids is generic (not fluid specific) and is with fluids mixed to a 10º buffer (not standard mix). The latter two parameters may have only marginal differences for snow and freezing precipitation conditions because holdover times are shorter and the majority of the protection comes from the heat in the fluid more so than the glycol. In the case of frost conditions, however, the longer holdover times may emphasize those marginal differences; the glycol and the concentration may outweigh the benefit from the heat and may provide longer fluid protection times.

Some operators currently pre-treat aircraft with Type IV fluids in active or anticipated frost conditions to allow for a quick dispatch of aircraft at the operating hubs. Alternatives to using Type IV fluids for these purposes are being explored because the longer protection times are not always required, and in some cases there is no active frost, or the frost never happens. In addition, some issues with fluid residues with Type IV pre-treatment has been reported. Currently Type I fluids are limited to 45-minute holdover times in frost conditions (for aluminum wings), and pre-takeoff contamination checks (to allow the extension of this holdover time) are not feasible for cargo aircraft. As such, industry requested an investigation to determine if the Type I standard mix fluid concentration will generate longer frost endurance times as compared to Type I fluid mixed to a 10ºC buffer. The benefit, if any will likely be more apparent at warmer temperatures.

2. OBJECTIVE

Preliminary evaluation to determine if the Type I standard mix fluid will generate longer frost endurance times as compared to Type I fluid mixed to a 10º buffer.

3. PROCEDURE

The following provides and overview of the activities:

1. Testing will be completed at the TC Dorval test site;
2. Endurance time testing in natural frost conditions is typically performed using “frosticator” plates: standard holdover time test plates which are painted white

with aircraft grade paint and have an insulated backing to allow for appropriate radiative cooling properties. The same frost testing procedures and methodologies as described in the procedure *"Endurance Time Testing in Active Frost with SAE Type I, II, III and IV De/Anti-Icing Fluids – November 2018"* will be utilized for this testing and will be modified for comparative performance testing;

3. As this is preliminary testing, only one brand of Type I EG and Type I PG will be used. Approximately 10 litres of concentrate Type I fluid (5L EG and 5L PG) will be required;
4. Testing will target 3 natural frost events. It is expected that between 1 and 3 test runs will be performed during each event; depending on frost conditions. A total of 3-9 comparative test runs (6 to 18 total tests) will be performed;
5. The performance of the Type I fluid diluted to standard mix (typically 50/50 concentration or greater) will be compared to the performance of the Type I fluid diluted to 10°C Buffer (the baseline) to determine differences in performance; and
6. The results will be analysed.

3.1 Key Notables for Testing

The following are key notables in regards to the testing procedure:

a) Testing will use full size frosticator plates;
b) Testing will only be with aluminum frosticator plates (no composite frosticator plates);
c) For each test surface, apply 0.5L of Type I fluid heated to 20°C;
d) Type I fluid must be applied using a warm fluid spreader;
e) For each test, the endurance time (1/3 failure of the plate) will be recorded and have a photo taken; and
f) Whenever possible, the time of "first failure" should also be recorded, and have a photo taken.

4. TEST PLAN

The test plan for frost testing is included in Table 4.1. The test plan is separated into PG fluid (Run #1-8) and EG fluid (Run #9-16). The order of the tests will be determined based on available temperatures at the time of testing.

For each test, the endurance time (1/3 failure of the plate) will be recorded. If possible, the time of first failure and should also be recorded.

Table 4.1: Test Plan – Frost Testing

Run #	Test #	Fluid	Dilution	Target Temp
1	1	Type I PG	10° Buff	>-5°C
	2	Type I PG	Standard Mix	>-5°C
2	3	Type I PG	10° Buff	>-5°C
	4	Type I PG	Standard Mix	>-5°C
3	5	Type I PG	10° Buff	>-5°C
	6	Type I PG	Standard Mix	>-5°C
4	7	Type I PG	10° Buff	>-5°C
	8	Type I PG	Standard Mix	>-5°C
5	9	Type I PG	10° Buff	-5°C to -10°C
	10	Type I PG	Standard Mix	-5°C to -10°C
6	11	Type I PG	10° Buff	-5°C to -10°C
	12	Type I PG	Standard Mix	-5°C to -10°C
7	13	Type I PG	10° Buff	<-10°C
	14	Type I PG	Standard Mix	<-10°C
8	15	Type I PG	10° Buff	<-10°C
	16	Type I PG	Standard Mix	<-10°C
9	17	Type I EG	10° Buff	>-5°C
	18	Type I EG	Standard Mix	>-5°C
10	19	Type I EG	10° Buff	>-5°C
	20	Type I EG	Standard Mix	>-5°C
11	21	Type I EG	10° Buff	>-5°C
	22	Type I EG	Standard Mix	>-5°C
12	23	Type I EG	10° Buff	>-5°C
	24	Type I EG	Standard Mix	>-5°C
13	25	Type I EG	10° Buff	-5°C to -10°C
	26	Type I EG	Standard Mix	-5°C to -10°C
14	27	Type I EG	10° Buff	-5°C to -10°C
	28	Type I EG	Standard Mix	-5°C to -10°C
15	29	Type I EG	10° Buff	<-10°C
	30	Type I EG	Standard Mix	<-10°C
16	31	Type I EG	10° Buff	<-10°C
	32	Type I EG	Standard Mix	<-10°C

5. EQUIPMENT

See details specified in the frost procedure *"Endurance Time Testing in Active Frost with SAE Type I, II, III and IV De/Anti-Icing Fluids – November 2018".*

6. PHOTOS

Photos of the individual tests should be taken at regular intervals during the tests, i.e. every 15-minutes, plus at the time of first failure and at the time of failure.

7. PERSONNEL

These tests can be piggybacked on regularly scheduled frost endurance time testing and require an additional person for the conduct of the tests.

8. SAFETY

See details specified in the frost procedure *"Endurance Time Testing in Active Frost with SAE Type I, II, III and IV De/Anti-Icing Fluids – November 2018".*

9. DATA FORMS AND SOFTWARE

See details specified in the frost procedure *"Endurance Time Testing in Active Frost with SAE Type I, II, III and IV De/Anti-Icing Fluids – November 2018".*

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APPENDIX C

LOG OF TYPE I FROST ENDURANCE TIME TESTS

Log of Type I Frost Endurance Time Tests

Test No.	Test Year	Start Date	Start Time	End Time	End Time (First Failure)	Fluid Dil.	Fluid Name	Test Surface	Fluid Brix Initial	Fluid Brix Final	Initial Fluid Temp (°C)	Endurance Time (min)	Endurance Time to First Failure (min)	ΔTime (min): Std Mix - 10° Buffer	Test Ratio - Std Mix/10° Buffer	ΔTime (min): Failure - First Failure	Plate Ratio - Failure/First Failure	% of ET - First Failure/ Failure
3	2018-19	18-Mar-2019	21:52:30	0:45:00	–	Std Mix	Octaflo EF	Aluminum	37	23.5	20	172.5	–	38.8	1.3	–	–	–
4	2018-19	18-Mar-2019	21:51:20	0:05:00	–	10° Buffer	Octaflo EF	Aluminum	25	21.5	20	133.7	–	–	–	–	–	–
5	2018-19	19-Mar-2019	1:13:30	4:30:00	–	Std Mix	Octaflo EF	Aluminum	37	24.75	20	196.5	–	108.3	2.2	–	–	–
6	2018-19	19-Mar-2019	1:12:30	2:40:40	–	10° Buffer	Octaflo EF	Aluminum	25	20.5	20	88.2	–	–	–	–	–	–
7	2019-20	17-Jan-2020	23:12:00	1:54:00	1:08:00	Std Mix	Dow PG	Composite	33.75	26.75	20	162.0	116.0	-1.5	1.0	46.0	1.4	0.7
8	2019-20	17-Jan-2020	23:12:30	1:56:00	1:18:00	10° Buffer	Dow PG	Aluminum	31	27.75	20	163.5	125.5	–	–	38.0	1.3	0.8
9	2019-20	17-Jan-2020	23:13:00	2:44:00	1:30:00	Std Mix	Dow EG	Aluminum	32.5	23.5	20	211.0	137.0	59.5	1.4	74.0	1.5	0.6
10	2019-20	17-Jan-2020	23:13:30	1:45:00	1:05:00	10° Buffer	Dow EG	Aluminum	27.25	23.5	20	151.5	111.5	–	–	40.0	1.4	0.7
11	2019-20	18-Jan-2020	3:25:00	6:45:00	5:48:00	Std Mix	Dow PG	Composite	33.75	26	20	200.0	143.0	-32.0	0.9	57.0	1.4	0.7
12	2019-20	18-Jan-2020	3:26:00	7:18:00	6:25:00	10° Buffer	Dow PG	Aluminum	31.25	26	20	232.0	179.0	–	–	53.0	1.3	0.8
13	2019-20	29-Jan-2020	22:57:00	1:08:10	0:36:07	Std Mix	Dow PG	Aluminum	33.75	24.75	20.5	131.2	99.1	28.2	1.3	32.1	1.3	0.8
14	2019-20	29-Jan-2020	22:59:00	0:42:00	0:17:00	10° Buffer	Dow PG	Aluminum	28	23	20.3	103.0	78.0	–	–	25.0	1.3	0.8
15	2019-20	29-Jan-2020	22:53:00	0:35:54	0:09:50	Std Mix	Dow EG	Composite	33	19.75	20.1	102.9	76.8	19.4	1.2	26.1	1.3	0.7
16	2019-20	29-Jan-2020	22:55:00	0:18:30	23:58:00	10° Buffer	Dow EG	Aluminum	24	19.25	20	83.5	63.0	–	–	20.5	1.3	0.8
17	2019-20	30-Jan-2020	2:41:00	5:06:24	3:59:30	Std Mix	Dow EG	Aluminum	33	19.25	20	145.4	78.5	48.1	1.5	66.9	1.9	0.5
18	2019-20	30-Jan-2020	2:43:00	4:20:18	3:57:31	10° Buffer	Dow EG	Aluminum	24.75	20.75	20	97.3	74.5	–	–	22.8	1.3	0.8
19	2019-20	30-Jan-2020	2:37:00	4:58:36	4:06:29	Std Mix	Dow PG	Aluminum	34	24.5	20.1	141.6	89.5	61.9	1.8	52.1	1.6	0.6

Log of Type I Frost Endurance Time Tests (cont'd)

Test No.	Adjusted Endurance Time (min)	Adjusted Endurance Time to First Failure (min)	Adjusted ΔTime (min): Std Mix - 10° Buffer	Adjusted Test Ratio - Std Mix/10° Buffer	Adjusted ΔTime (min): Failure - First Failure	Adjusted Plate Ratio - Failure/First Failure	Adjusted % of ET - First Failure/ Failure	Average Rate (g/dm²/h)	Average OAT (°C)	Approx. RH (%)	Average Wind Speed (km/h)	Approx. Plate Temperature (°C)	Approx. ΔT (°C)	Comments
3	172.5	–	38.8	1.29	–	–	–	0.08	-7.1	65	4.8	-10.8	3.69	Fluid Freeze point: -40°C
4	133.7	–	–	–	–	–	–	0.06	-6.9	65	4.5	-10.5	3.64	
5	196.5	–	108.3	2.23	–	–	–	0.09	-8.6	72	3.7	-13.1	4.46	Test was very close (25-28%) to failure at 4:30 AM, but frost slowed down considerably. From 4:30-6:30 AM, LHS of plate unfailed but RHS of plate eventually brought plate to failure. Brix at 5 AM and 6:36 AM was the same: 24.75. Used estimated fail time of 4:30AM. FFP: -40°C
6	88.2	–	–	–	–	–	–	0.13	-7.9	70	3.9	-14.5	6.62	
7	208.3	149.1	23.6	1.27	59.1	1.4	0.7	0.03	-17.6	70	8.2	-20.0	2.37	*Composite plate used for this test. See adjusted results
8	163.5	125.5	–	–	38.0	1.3	0.8	0.03	-17.6	70	8.1	-20.0	2.37	
9	211.0	137.0	59.5	1.39	74.0	1.5	0.6	0.03	-17.6	71	6.6	-19.9	2.32	
10	151.5	111.5	–	–	40.0	1.4	0.7	0.03	-17.6	70	8.5	-19.9	2.35	
11	257.1	183.9	4.9	1.11	73.3	1.4	0.7	0.04	-17.7	76	5.5	-19.0	1.35	*Composite plate used for this test. See adjusted results
12	232.0	179.0	–	–	53.0	1.3	0.8	0.04	-17.7	76	5.8	-19.0	1.35	
13	131.2	99.1	28.2	1.27	32.1	1.3	0.8	0.10	-12.4	77	5.6	-15.6	3.27	Dow PG Std Mix failed at a higher brix. Could be due to temp. drop at approx. 1 AM; EC Temp at 12 AM is -12C while at 1AM its -13.9C
14	103.0	78.0	–	–	25.0	1.3	0.8	0.10	-12.0	76	5.3	-15.6	3.64	
15	132.3	98.8	35.8	1.58	33.5	1.3	0.7	0.10	-11.8	76	5.3	-15.4	3.56	*Composite plate used for this test. See adjusted results
16	83.5	63.0	–	–	20.5	1.3	0.8	0.10	-11.7	76	5.3	-15.4	3.72	
17	145.4	78.5	48.1	1.49	66.9	1.9	0.5	0.10	-13.0	77	7.6	-16.1	3.17	
18	97.3	74.5	–	–	22.8	1.3	0.8	0.10	-12.7	77	8.4	-16.2	3.48	
19	141.6	89.5	61.9	1.78	52.1	1.6	0.6	0.10	-12.9	77	7.8	-16.1	3.22	

Log of Type I Frost Endurance Time Tests (cont'd)

Test No.	Test Year	Start Date	Start Time	End Time	End Time (First Failure)	Fluid Dil.	Fluid Name	Test Surface	Fluid Brix Initial	Fluid Brix Final	Initial Fluid Temp (°C)	Endurance Time (min)	Endurance Time to First Failure (min)	ΔTime (min): Std Mix - 10° Buffer	Test Ratio - Std Mix/10° Buffer	ΔTime (min): Failure - First Failure	Plate Ratio - Failure/First Failure	% of ET - First Failure/ Failure
20	2019-20	30-Jan-2020	2:38:40	3:58:21	3:47:45	10° Buffer	Dow PG	Composite	28.75	24.75	20	79.7	69.1	–	–	10.6	1.2	0.9
21	2019-20	20-Feb-2020	22:49:40	1:28:00	0:54:00	Std Mix	Dow EG	Aluminum	32.75	23	20	158.3	124.3	30.0	1.2	34.0	1.3	0.8
22	2019-20	20-Feb-2020	22:48:40	0:57:00	0:40:00	10° Buffer	Dow EG	Aluminum	26.25	23	20	128.3	111.3	–	–	17.0	1.2	0.9
23	2019-20	20-Feb-2020	22:52:30	1:24:00	0:37:00	Std Mix	Dow PG	Aluminum	33.6	27	20	151.5	104.5	49.3	1.5	47.0	1.4	0.7
24	2019-20	20-Feb-2020	22:51:30	0:33:40	0:08:00	10° Buffer	Dow PG	Composite	30.25	27	20	102.2	76.5	–	–	25.7	1.3	0.7
25	2019-20	21-Feb-2020	2:15:40	4:17:30	3:45:00	Std Mix	Dow EG	Aluminum	32.5	24.5	20	121.8	89.3	31.8	1.4	32.5	1.4	0.7
26	2019-20	21-Feb-2020	2:15:00	3:45:00	3:33:00	10° Buffer	Dow EG	Aluminum	26.75	23.25	20	90.0	78.0	–	–	12.0	1.2	0.9
27	2019-20	21-Feb-2020	2:16:45	4:25:30	3:45:00	Std Mix	Dow PG	Aluminum	33.5	28.75	20	128.8	88.3	48.9	1.6	40.5	1.5	0.7
28	2019-20	21-Feb-2020	2:16:10	3:36:00	3:10:00	10° Buffer	Dow PG	Composite	30.5	27.5	20	79.8	53.8	–	–	26.0	1.5	0.7
29	2019-20	24-Mar-2020	23:46:07	1:27:49	–	Std Mix	Dow PG	Aluminum	33.75	8	18.1	101.7	–	18.8	1.2	101.7	–	0.0
30	2019-20	24-Mar-2020	23:46:45	1:09:37	–	10° Buffer	Dow PG	Aluminum	18.75	9	18.1	82.9	–	–	–	82.9	–	0.0
31	2019-20	24-Mar-2020	23:43:05	1:19:27	–	Std Mix	Dow EG	Aluminum	32.5	8.25	18.1	96.4	–	23.5	1.3	96.4	–	0.0
32	2019-20	24-Mar-2020	23:43:39	0:56:30	–	10° Buffer	Dow EG	Aluminum	14.75	8	18.1	72.9	–	–	–	72.9	–	0.0
33	2019-20	25-Mar-2020	2:03:36	3:41:31	3:08:37	Std Mix	Dow PG	Aluminum	33.75	10.75	18.1	97.9	65.0	37.4	1.6	32.9	1.5	0.7
34	2019-20	25-Mar-2020	2:04:16	3:04:47	2:35:55	10° Buffer	Dow PG	Aluminum	18.75	10	18.1	60.5	31.7	–	–	28.9	1.9	0.5
35	2019-20	25-Mar-2020	2:07:08	3:43:53	3:16:38	Std Mix	Dow EG	Aluminum	32.5	9.75	18.1	96.8	69.5	34.4	1.6	27.3	1.4	0.7
36	2019-20	25-Mar-2020	2:07:35	3:09:54	2:46:01	10° Buffer	Dow EG	Aluminum	14.75	7.25	18.1	62.3	38.4	–	–	23.9	1.6	0.6
37	2019-20	28-Mar-2020	2:07:21	4:31:42	3:48:20	Std Mix	Dow PG	Aluminum	34	12	21.4	144.4	101.0	14.5	1.1	43.4	1.4	0.7

Log of Type I Frost Endurance Time Tests (cont'd)

Test No.	Adjusted Endurance Time (min)	Adjusted Endurance Time to First Failure (min)	Adjusted ΔTime (min): Std Mix - 10° Buffer	Adjusted Test Ratio - Std Mix/10° Buffer	Adjusted ΔTime (min): Failure - First Failure	Adjusted Plate Ratio - Failure/First Failure	Adjusted % of ET - First Failure/ Failure	Average Rate (g/dm²/h)	Average OAT (°C)	Approx. RH (%)	Average Wind Speed (km/h)	Approx. Plate Temperature (°C)	Approx. ΔT (°C)	Comments
20	102.5	88.8	–	–	13.6	1.2	0.9	0.11	-12.7	77	9.5	-16.3	3.63	*Composite plate used for this test. See adjusted results
21	158.3	124.3	30.0	1.23	34.0	1.3	0.8	0.06	-16.6	63	9.4	-20.7	4.04	
22	128.3	111.3	–	–	17.0	1.2	0.9	0.06	-16.6	63	9.5	-20.3	3.71	
23	151.5	104.5	49.3	1.48	47.0	1.4	0.7	0.06	-16.6	63	9.4	-20.7	4.05	
24	131.4	98.4	–	–	33.0	1.3	0.7	0.05	-16.6	62	9.6	-20.3	3.71	*Composite plate used for this test. See adjusted results
25	121.8	89.3	31.8	1.35	32.5	1.4	0.7	0.09	-16.9	72	7.5	-22.3	5.43	
26	90.0	78.0	–	–	12.0	1.2	0.9	0.09	-16.8	71	7.7	-21.7	4.91	
27	128.8	88.3	48.9	1.61	40.5	1.5	0.7	0.08	-16.9	72	7.5	-22.3	5.44	
28	102.6	69.2	–	–	33.4	1.5	0.7	0.09	-16.8	71	7.8	-21.7	4.90	*Composite plate used for this test. See adjusted results
29	101.7	–	18.8	1.23	101.7	–	0.0	0.23	0.6	83	7.6	-3.0	3.58	first failure not properly documented.
30	82.9	–	–	–	82.9	–	0.0	0.22	0.7	82	7.5	-2.8	3.53	first failure not properly documented.
31	96.4	–	23.5	1.32	96.4	–	0.0	0.23	0.7	83	7.5	-2.8	3.52	first failure not properly documented.
32	72.9	–	–	–	72.9	–	0.0	0.21	0.9	82	7.4	-2.7	3.51	first failure not properly documented.
33	97.9	65.0	37.4	1.62	32.9	1.5	0.7	0.26	-1.1	87	6.0	-4.8	3.77	
34	60.5	31.7	–	–	28.9	1.9	0.5	0.27	-0.8	87	6.3	-4.6	3.80	
35	96.8	69.5	34.4	1.55	27.3	1.4	0.7	0.26	-1.1	87	6.0	-4.8	3.71	
36	62.3	38.4	–	–	23.9	1.6	0.6	0.27	-0.9	87	6.1	-4.7	3.77	
37	144.4	101.0	14.5	1.11	43.4	1.4	0.7	0.10	-1.4	70	3.9	-7.2	5.80	

Log of Type I Frost Endurance Time Tests (cont'd)

Test No.	Test Year	Start Date	Start Time	End Time	End Time (First Failure)	Fluid Dil.	Fluid Name	Test Surface	Fluid Brix Initial	Fluid Brix Final	Initial Fluid Temp (°C)	Endurance Time (min)	Endurance Time to First Failure (min)	ΔTime (min): Std Mix - 10° Buffer	Test Ratio - Std Mix/10° Buffer	ΔTime (min): Failure - First Failure	Plate Ratio - Failure/First Failure	% of ET - First Failure/ Failure
38	2019-20	28-Mar-2020	2:08:23	4:18:12	3:28:15	10° Buffer	Dow PG	Aluminum	21.25	11	26	129.8	79.9	–	–	50.0	1.6	0.6
39	2019-20	28-Mar-2020	2:10:44	4:31:18	3:38:12	Std Mix	Dow EG	Aluminum	33	9.5	21.4	140.6	87.5	49.1	1.5	53.1	1.6	0.6
40	2019-20	28-Mar-2020	2:11:12	3:42:40	3:11:26	10° Buffer	Dow EG	Aluminum	16.75	10.75	21.8	91.5	60.2	–	–	31.2	1.5	0.7
41	2019-20	18-Apr-2020	0:36:30	2:29:29	1:32:30	Std Mix	Dow PG	Aluminum	34	12.75	17	113.0	56.0	50.8	1.8	57.0	2.0	0.5
42	2019-20	18-Apr-2020	0:37:08	1:39:20	1:24:50	10° Buffer	Dow PG	Aluminum	20	14.75	19.2	62.2	47.7	–	–	14.5	1.3	0.8
43	2019-20	18-Apr-2020	0:39:18	2:35:00	1:44:54	Std Mix	Dow EG	Aluminum	33	9.75	17.1	115.7	65.6	51.3	1.8	50.1	1.8	0.6
44	2019-20	18-Apr-2020	0:39:40	1:44:06	1:24:30	10° Buffer	Dow EG	Aluminum	15.75	10.5	19.5	64.4	44.8	–	–	19.6	1.4	0.7
45	2019-20	18-Apr-2020	3:07:25	5:05:00	4:10:49	Std Mix	Dow PG	Aluminum	34	13	18.7	117.6	63.4	43.5	1.6	54.2	1.9	0.5
46	2019-20	18-Apr-2020	3:07:56	4:22:00	4:02:42	10° Buffer	Dow PG	Aluminum	20	13.5	19.3	74.1	54.8	–	–	19.3	1.4	0.7
47	2019-20	18-Apr-2020	3:10:10	4:58:15	4:11:48	Std Mix	Dow EG	Aluminum	33	10	18.8	108.1	61.6	43.2	1.7	46.5	1.8	0.6
48	2019-20	18-Apr-2020	3:10:38	4:15:30	3:53:30	10° Buffer	Dow EG	Aluminum	15.75	10	19.8	64.9	42.9	–	–	22.0	1.5	0.7

Log of Type I Frost Endurance Time Tests (cont'd)

Test No.	Adjusted Endurance Time (min)	Adjusted Endurance Time to First Failure (min)	Adjusted ΔTime (min): Std Mix - 10° Buffer	Adjusted Test Ratio - Std Mix/10° Buffer	Adjusted ΔTime (min): Failure - First Failure	Adjusted Plate Ratio - Failure/First Failure	Adjusted % of ET - First Failure/ Failure	Average Rate (g/dm²/h)	Average OAT (°C)	Approx. RH (%)	Average Wind Speed (km/h)	Approx. Plate Temperature (°C)	Approx. ΔT (°C)	Comments
38	129.8	79.9	–	–	50.0	1.6	0.6	0.09	-1.3	69	4.0	-7.2	5.88	Although the FFPs are the same for EG & PG 10 Buffer, the lower glycol concentration for the EG resuled in a worse performance (ET)
39	140.6	87.5	49.1	1.54	53.1	1.6	0.6	0.10	-1.4	70	3.9	-7.2	5.80	
40	91.5	60.2	–	–	31.2	1.5	0.7	0.08	-1.0	66	4.3	-7.4	6.44	Although the FFPs are the same for EG & PG 10 Buffer, the lower glycol concentration for the EG resuled in a worse performance (ET)
41	113.0	56.0	50.8	1.82	57.0	2.0	0.5	0.19	-0.4	78	7.5	-6.2	5.86	
42	62.2	47.7	–	–	14.5	1.3	0.8	0.20	-0.7	79	7.2	-6.4	5.69	
43	115.7	65.6	51.3	1.80	50.1	1.8	0.6	0.20	-0.4	78	7.5	-6.2	5.86	
44	64.4	44.8	–	–	19.6	1.4	0.7	0.20	-0.6	79	7.2	-6.2	5.56	
45	117.6	63.4	43.5	1.59	54.2	1.9	0.5	0.18	-1.3	77	4.6	-6.5	5.22	
46	74.1	54.8	–	–	19.3	1.4	0.7	0.18	-0.9	77	4.9	-6.3	5.39	
47	108.1	61.6	43.2	1.67	46.5	1.8	0.6	0.18	-1.3	77	4.6	-6.5	5.26	
48	64.9	42.9	–	–	22.0	1.5	0.7	0.18	-0.9	77	4.9	-6.3	5.39	

APPENDIX D

SUMMARY REPORT:
HISTORICAL REVIEW OF TYPE I FLUID OVERSPRAY QUANTITIES

300293

Summary Report:

Historical Review of Type I Fluid Overspray Quantities

Winter 2019-20

Prepared for:

Transport Canada
Innovation Centre

In cooperation with:

Federal Aviation Administration
William J. Hughes Technical Center

Transport Canada
Civil Aviation

Federal Aviation Administration
Flight Standards – Air Carrier Operations

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Reviewed by: John D'Avirro

April 13, 2020
Final Version 1.0

Summary Report: Historical Review of Type I Fluid Overspray Quantities

This paper examines relevant deicing studies and correspondence for data that may support the requirement that at least 1 litre/m^2 of fluid must be applied to deiced surfaces in order to use the published Type I fluid HOT tables.

Note: this report was requested by Transport Canada as part of the joint research program with the Federal Aviation Administration. As such, the focus is on the Transport Canada version of the guidance material.

1. BACKGROUND

Prior to 2000, the Type I fluid HOT range for snow conditions was 6 to 15 minutes. These values were initially based on operational experience and were substantiated in tests conducted in the early 1990s. In the winter of 1999-2000, a series of endurance time tests was conducted on Type I fluids using test parameters developed to test Type II and IV fluids. These tests produced HOT values substantially shorter than those in service. When these test results were presented at the SAE G-12 Holdover Time (HOT) Subcommittee held in Toulouse, France, in May 2000, it was recommended that holdover times for snow be reduced accordingly.

The effect of this recommendation is shown in Figure 1.1. At a precipitation rate of 10 g/dm²/h (lower limit for moderate snowfall), the fluid time was reduced from 15 minutes to 6 minutes; at a rate of 25 g/dm²/h (upper limit for moderate snowfall), the time was reduced from 6 minutes to 3 minutes.

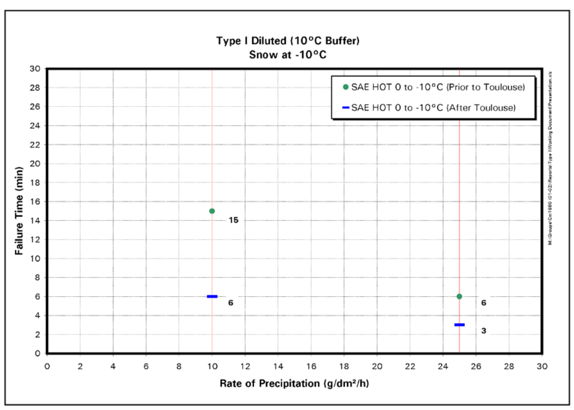


Figure 1.1: Type I Failure Times Before and After Toulouse

Because the previous HOT values for Type I fluid had been in effect for many years without issue, this reduction led to concerned discussion at industry meetings and to the general realization that the test protocol may be faulty when applied to Type I fluids. It was generally believed that the reduction resulted from the test protocol failure to recognize the contribution of the heat transfer from the heated fluid to treated aircraft surface. The test protocol was based on pouring 1 L of fluid at room temperature (20 °C) onto a standard test plate.

This concern led to two outcomes:

1. At the November 14-15, 2000 meeting of the SAE G-12 HOT Subcommittee, it was resolved that the *HOT committee will develop Type I testing protocols which consider the heat factor on simulated wing surfaces of various dilutions of Type I fluids for the purpose of developing Type I Holdover Tables that match operational use of the fluid*.

   This led to a project undertaken by APS in the 2000/2001 winter season to develop a test protocol for measuring holdover times for SAE Type I fluids that reflected real field operations. The ideal protocol would simulate the full nature of actual deicing/anti-icing operations on real wings in the natural environment.

   The protocol was to take into account the effect on endurance times of heat transferred to the wing from the heated fluid. To that end, the research was designed to provide a basis for a test surface that is thermodynamically similar to real wings in natural outdoor weather conditions.

2. Because the previous HOT values for Type I Fluid had been applied for many years without issue, Transport Canada determined that it would be acceptable to continue with their use for the winter season 2000-01. As a result, two tables were published; a Transport Canada Type I Fluid Holdover Table for use in Canada reflecting previous years HOT values, and a second SAE Type I Table for use outside of Canada reflecting the new reduced HOT values.

   However, as a precaution to ensure that aircraft critical surfaces were adequately heated, the 2000-01 Transport Canada HOT table included a caution that the table is for use only in Canada and to use these times, the fluid must be heated to a minimum temperature of 60°C and at least 1 L/m^2 (2 Gals/100 ft^2) must be applied to surfaces. The narrative concerning Type I Fluid HOT values, which was included in the introduction of the HOT Guidelines for that year, stated that fluid must be applied at a rate of at least 2 litres per square metre. This apparent discrepancy may have simply been a shortcoming in the text where the 1 L/m^2 was meant as an overspray on deiced surfaces and the 2 L/m^2 was meant as a minimum amount for a one-step deicing/anti-icing operation. This is discussed further in Section 5.

The initial caution was not limited to snow-conditions-only and thus applied to all types of contamination.

For the following year 2001-02, the Transport Canada Type I HOT Table contained two sets of values, both the SAE and the TC previous year's values. Advice changed slightly, indicating that "at least 1 litre/m^2 must be applied to deiced surfaces OTHERWISE THE ITALICISED TIMES MUST BE USED." The italicized times were the reduced SAE HOT values reported in 2000. Here the reference to deiced surfaces was included. The caution applied to snow and freezing fog.

A HOT table caution now limited to snow conditions continued in the winter season 2002-03 when new HOT values based on the new test protocol were published. The HOT table caution continued to be limited to snow conditions until the 2010-11 winter. In that and subsequent years, the Transport Canada Type I HOT Table no longer stated the caution.

The Fluid Application Procedure first stated the caution for snow conditions in winter season 2004-05. In Winter 2010-11, the caution was extended to all conditions. The current SAE Type I Fluid Holdover Time Guideline for Application of states that the caution applies to all conditions including frost.

A number of deicing studies prior to 2000 had touched on Type I (or hot water) fluid quantities. As well, subsequent studies addressing the development of the new Type I test protocol and its application, and testing for fluid endurance times in frost conditions have some references to fluid quantities. The purpose of this report is to assess the support for and potential influence on the caution that at least 1 litre/m^2 must be applied to deiced surfaces. The report also examines any correspondence that may be relevant to the issue.

2. DEICING STUDIES PRIOR TO THE HOT CAUTION FOR WINTER 2000-01

2.1 Hot Water Deicing Trials for the 1994-1995 Winter TP 12653E

Hot water deicing field trials on operational aircraft were conducted in Winter 1994-95 with the objective of determining the environmental limits for use of hot water as the first step of a two-step deicing/anti-icing process. The standard process involved removal of snow or ice with hot water at a nozzle temperature of at least 60ºC, followed by an overspray of anti-icing fluid applied before the water freezes.

The critical factor measured in the tests was the duration of the first-step (hot water) application until freezing. The applicable SAE Aerospace Recommended Practice ARP4737 suggested that a typical time to refreeze is 3 minutes and limited the use of hot water to conditions when outside air temperature (OAT) is not lower than - 3°C.

Prior to these tests, when hot water was used more widely, the second-step anti-icing spray generally consisted of a heated Type I fluid. A heated second-step fluid could be viewed as serving a natural corrective function for any early freezing of the water application not noted by the spray operator. The introduction of anti-icing fluids which were applied cold made the time-until-freezing even more critical.

The trials involved two types of tests;

- a first-step hot water spray application on the aircraft starboard wing by operators experienced in hot water deicing. Tests were conducted in dry conditions on cold wings. Any ice remaining on the wing from previous tests was removed as part of the hot water application.
- a simultaneous first-step hot water spray application followed by an anti-icing overspray of Type I fluid on the port wing.

Wing surface temperature decay was recorded with thermistor sensors. Results illustrated the high degree of influence of spray technique on results. Tests where the de-icing operator sprayed hot water starting from the wing tip and progressed to the wing root, and then worked his way out again to the wing tip, showed up in the results. Points that were sprayed twice clearly showed a double peak in temperature rise, and tended to extend the temperature decay time. Probe points that were not sprayed directly, but were reached by fluid flowing from nearby, showed the effect of heat loss already experienced by the fluid.

These temperature profiles for six of these tests were included in the development of the Type I Fluid test protocol in 2000. The relevant report TP 13827E listed fluid quantities sprayed. Two cases were reported for full two-step de/anti-icing. Fluid quantities for the two first-step applications averaged 3.1 L/m^2. The two second-step applications were 2 and 2.3 L/m^2. Fluid quantities for four one-step applications ranged from 106 to 412 L and averaged 4.2 L/m^2.

In attempting to derive overspray quantities from these results, it must be considered that the spray operator was experienced in hot water deicing and understood the importance of getting heat into the wing surface. In the context of one-step deicing/anti-icing with a Type I fluid, the spray quantities could perhaps be viewed as the total needed to clean a wing having a slight amount of contamination,

including an overspray on the deiced areas. Thus, the overspray would be some portion of the average 2.9 L/m^2amount sprayed.
Field operators experienced with the hot water deicing process stated that a cautious approach is necessary during high winds, even at moderate temperatures. In other words, the treated surface cools rapidly in windy conditions. That concern is reflected in the test data. The eventual Type I fluid test protocol for outdoor tests was based on wing and test surface cooling gradients recorded in wind conditions ranging from 2 to 25 km/h.

The report recommended that the optimum spray pattern to transfer heat to the wing should be investigated. It suggested that the nozzle setting used to clean the wing may not be optimum for the overspray where the objective is to transfer heat into the wing skin.

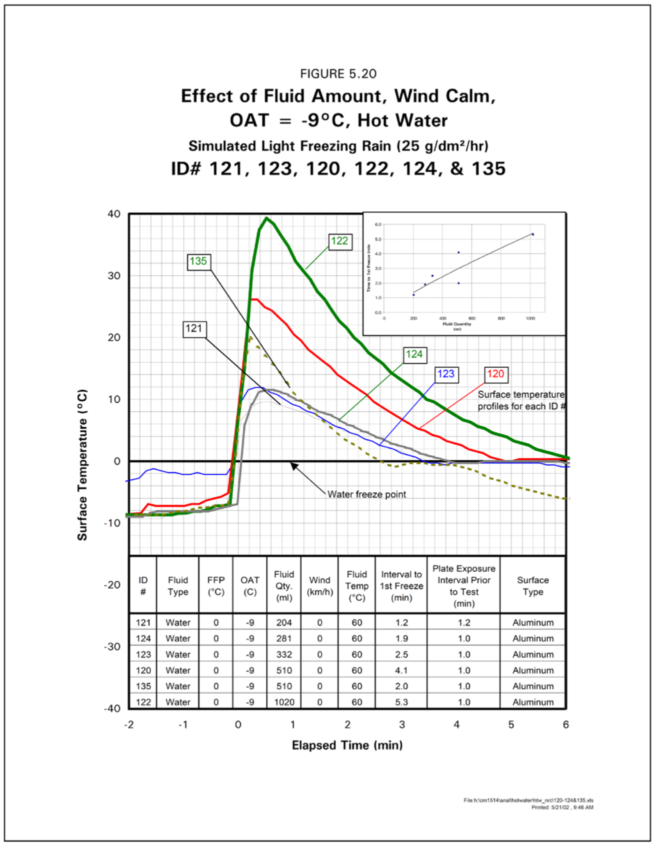
2.2 Hot Water Deicing of Aircraft 1998-99 TP 13483E

The objective of this project was to further evaluate environmental limits (OAT, wind) for the use of hot water as the first-step fluid in a two-step deicing operation. The study was conducted at the National Research Council Canada Climatic Engineering Facility in Ottawa. Test parameters included temperature, wind, active precipitation, and substrate materials. In addition to hot water, heated deicing fluids (both diluted and at standard strength) were tested to provide a reference case. Standard test plates were fabricated from typical aircraft composite materials as well as from aircraft aluminum. Because heat transfer to the test surface was a key element of the study, the loss of heat related to removal of a surface contaminant was also examined. A controlled amount of contamination was allowed to collect on the plates prior to each test run, by exposing the plate to precipitation for a predetermined time interval. The resulting layer of ice contamination was then removed by spraying as much fluid as was required to produce a clean plate. The fluid spray was stopped as soon as all contamination was removed from the plate surface.

The most critical data measured in these tests were the time intervals between initial fluid application (spray) and first appearance of ice on test surfaces. An interval of at least three minutes was the key indicator of acceptable temperature and wind limits.

In general, these tests did not include an overspray. Fluid quantities were solely based on amount needed to clean the plate surface. It is risky to extrapolate acceptable overspray fluid rates from that test data.

However, one test series was directed at determining the fluid quantity needed to provide an adequate lag time until first freezing was noted. Figure 2.1 (which is Figure 5.20 of TP 13483E) reports the effect of applying additional fluid following removal of the frozen precipitation. Conditions were calm winds, ambient temperature of -9°C, water heated to 90°C, simulated light freezing rain at 25 g/dm^2/hr.



ID #	Fluid Type	FFP (°C)	OAT (C)	Fluid Qty. (ml)	Wind (km/h)	Fluid Temp (°C)	Interval to 1st Freeze (min)	Plate Exposure Interval Prior to Test (min)	Surface Type
121	Water	0	-9	204	0	60	1.2	1.2	Aluminum
124	Water	0	-9	281	0	60	1.9	1.0	Aluminum
123	Water	0	-9	332	0	60	2.5	1.0	Aluminum
120	Water	0	-9	510	0	60	4.1	1.0	Aluminum
135	Water	0	-9	510	0	60	2.0	1.0	Aluminum
122	Water	0	-9	1020	0	60	5.3	1.0	Aluminum

Figure 2.1: Effect of Fluid Amount (Figure 5.20 of TP 13483E)

A rate of fluid application of 150 ml on the test plate is equivalent to 1 litre/m^2 on a wing surface. In test ID 121, fluid quantity needed to clear the ice was 204 ml. With no overspray, time to first freeze was 1.2 minutes. In test ID 123, an additional application of 128 ml of fluid following clearing the ice (equivalent to 0.85 litre/m^2) extended the time to freeze to 2.5 minutes. In test ID 120, a further addition of 178 ml (equivalent to 1.2 litre/m^2) extended the time to freeze to 4.1 minutes.

Test results showed that fluid strength actually improved even under precipitation (demonstrated as a drop in FFP) just following application. This characteristic was studied and observed in the deicing only series of tests that were conducted in dry conditions. This temporary fluid enhancement extended the period of protection offered by the freeze point depressant, and is an additional way that heat from the applied fluid contributes to the interval until onset of freezing.

The eventual Type I fluid test protocol for laboratory tests, designed to reflect the effect of heat transfer experienced in real operations, settled on a different approach to test fluid application and quantity. Accordingly, the above wing equivalent fluid quantities for the additional fluid application cannot be taken as absolute truths but can be seen as a valid indication of the impact of adequate quantities of overspray, or of second-step fluid application in a two-step deicing/anti-icing operation.

2.3 Hot Water Deicing of Aircraft - Phase 2 1999-2000 TP 13663E

The objectives of the 1999-2000 project were to extend hot water deicing tests to aircraft in natural outdoor precipitation conditions.

As the winter season progressed and the likelihood of occurrence of suitable conditions decreased, it was decided to conduct a session of tests using a ski hill snow gun. The test session was conducted overnight on March 10-11, 2000. OAT was -4 to -5°C, winds varied from 2 to 8 km/h, and there was no natural precipitation. The test surface was the JetStar Test Wing.

The snow was in the form of a snow pellet with a diameter of about 1.5 mm. The density of the snow was about 0.3 g/cc. The snow was slightly wet, resulting in immediate and strong adherence to the wing skin. The snow gun equipment supplier, who was present at the tests, commented that a colder OAT is necessary in order to achieve a drier form of snow.

The tests began when snow began to accumulate on the wing surface. To examine the beneficial effect of applying greater quantities of fluid, the water was to be applied either in a procedure where the contamination is removed in a single pass over the wing, or where a second pass is applied as an overspray on the cleaned wing.

Two runs (Runs 2 and 3) were conducted with the overspray procedure. The operator was instructed to attempt to apply about 170 L (equivalent to 1 L on a test plate) uniformly over the wing, including the overspray. The snowfall rate ranged from 19 to 20 g/dm^2/h. The only difference between the two tests was the quantity of hot water applied.

In Run 2, only 60 L of hot water (a rate of 2.4 L/m^2 or 0.4 L per plate) was applied, producing a protection time of about 1.8 minutes. This produced surface temperatures ranging from 5 to 25°C with both range limits on the leading-edge slat. It is possible that the operator, accustomed to spraying Type I fluid as opposed to hot water, sprayed what was felt to be sufficient.

In Run 3, 189 L of hot water (a rate of 7.6 L/m^2) produced a protection time of about 3.1 minutes. The second pass produced surface temperatures ranging from 17 to 37°C. This is in line with the wing temperature profiles used in the Type I test protocol development. Although the overspray quantity was not measured separately, because the conditions were identical to Run 2 it can be reasoned that the overspray involved at least 5 L/m^2.

Other observations from these single tests are perhaps more interesting than the fluid quantities. The lowest peak temperature (17°C) again occurred on the outer wing leading edge slat. This location cooled very rapidly and was where the first indication of snow appeared.

The pattern of freezing showed that shorter times to refreeze were distributed around the perimeter of the wing. The shortest times were at the very outer limit of the wing, conforming to observations on earlier field tests on a variety of aircraft.

The report recommended that the optimum spray pattern to transfer heat to the wing should be investigated. It suggested that the nozzle setting used to clean the wing may not be optimum for the overspray where the objective is to transfer heat into the wing skin.

2.4 Aircraft Deicing Fluid Freeze Point Buffer Requirements: Deicing Only and First Step of Two-Step Deicing 1997-98 TP 13315E

This study examined fluid freeze point buffer requirements for two specific operational conditions.

The first of these conditions concerns situations in which active precipitation has ceased, and the sole requirement is to remove contamination from the aircraft. Protection against ongoing precipitation is not required. The objective of this first study was to generate experimental data to support development of a deicing only table intended to serve as an industry guideline.

The Deicing Only study doesn't offer any insights to the requirement for a minimum overspray quantity.

The second condition concerns aspects of the standard two-step deicing procedure, wherein an initial fluid is applied to clean the surface, and a second fluid is oversprayed to provide a period of ongoing anti-icing protection (commonly known as holdover time). The objective of this study was to evaluate freeze point temperature limits for the first-step fluids.

In the First-Step study, the study was based on tests conducted in the NRC cold chamber. Preliminary tests were conducted on DC-9 aircraft to select a test surface from a set of candidates to represent aircraft wings in the laboratory trials. Aircraft wings were sprayed with a hot water or Type I fluid having freeze points equal to or above OAT in an amount equivalent to applying 0.5 litres on a standard flat plate (3.5 L/m^2). The tests were conducted in dry conditions on clean wings. The test surface selected for the laboratory tests was based on first-to-freeze and resulted in the selection of the standard test plate.

As these tests all involved that same fluid quantity, no fluid quantity comparisons can be made. The only comparisons are those based on fluid strength. The pattern of location of first freezing is of interest.

Run 5 January 22, 1998 examined the application of 160 litres (3.4 L/m^2) Type I fluid diluted to a freeze point of -12°C (negative buffer of 4°C). Freezing began at about 20 minutes following fluid application. First freezing occurred at the same location as other tests, on the outer wing just beyond the aileron. At test end, freezing was limited to spots along the trailing edge control panels, and the rear inner wing beside the fuselage.

2.5 Aircraft Deicing Fluid Freeze Point Buffer Requirements for Deicing Only Conditions 1998-99 TP 13478

In the 1997/98 Deicing Only study, a standard quantity of 0.5 L had been applied to test surfaces. At an industry meeting reviewing the results of this study, questions arose about the application of findings to field operations. A number of topics requiring supplementary testing were identified, including fluid quantities tested and fluid heat lost by melting snow contamination.

To establish whether the quantity of fluid applied to test plates was a good representation of quantities applied to aircraft wings in all conditions, several airlines were asked for data reflecting quantity of fluid applied in one-step deicing. The data made available were generally on a range of aircraft sizes and typical categories of precipitation. Using surfaces for a characteristic aircraft within each category of aircraft, the reported quantities were converted to L/m^2 on an aircraft wing in the Table 2.1. In reality, these values are probably somewhat overstated as the fluid quantity reported would comprise total fluid sprayed on the aircraft, not just on the wings.

Table 2.1: One-step Deicing Fluid Quantities Reported – Equivalent L/m²

Aircraft Type	Frost	Light Snow	Medium Snow	Heavy Snow	Overnight Snow Accumulation
Commuter	1.3 - 2.7	2.7 - 4.9	3.3 - 8.7	4.7 - 15.3	4.7 - 10.0
Small Narrow-body	0.7 - 2.7	2.7 - 6.7	4.0 - 6.7	6.7 - 11.3	6.7 - 16.0
Large Narrow-body	0.7 - 2.0	1.3 - 2.7	3.3	4.7 - 6.0	4.0 - 4.7
Small Wide-body	0.7 - 1.3	1.3 - 2.0	2.7	3.3 - 4.7	3.3
Large Wide-body	0.7	0.7	2.0	3.3	2.0

Overnight tests were conducted on a B 737 aircraft. One of these tests produced a wing leading edge cooling profile that was used in the Type I test protocol study. That test involved a spray application of 3.4 L/m².

The quantities use for one-step deicing frost may have been a reference when determining the minimum quantities for Type I applications when requiring HOT's. In Table 2.1, the one-step deicing fluid quantity to remove frost is minimal, therefore the majority of the fluid can be considered as anti-icing. Table 2.2 shows a calculation of the values reported specific to frost.

Table 2.2: Frost One-step Deicing Fluid Quantities Reported – Equivalent L/m²

Aircraft Type	Frost (Range of Values)	
Commuter	1.3	2.7
Small Narrow-body	0.7	2.7
Large Narrow-body	0.7	2
Small Wide-body	0.7	1.3
Large Wide-body	0.7	0.7
Average	0.8	1.9
Total Average	1.4	

3. RELEVANT CORRESPONDENCE AND MINUTES OF MEETINGS

3.1 Minutes of SAE G-12 Holdover Subcommittee meetings

A review of minutes for five holdover time meetings in the relevant period did not reveal any discussion on the matter. This was the case even after the caution was published in the HOT guidelines. It would seem that the caution was not an issue among the attendees.

3.2 Email APS to TDC Aug 2,2000

The following email (Figure 3.1) provided TDC with information on fluid rates. This is the same data as provided by several airlines reported in TP 13478E.

From: John D'Avirro <j.davirro@adga.ca>
Sent: Wednesday, August 2, 2000 1:40 PM
To: Barry Myers <myersbb@tc.gc.ca>
Cc: Peter Dawson (E-mail) <p.dawson@adga.ca>
Subject: Litres used per metre to deice

Barry

You asked about the quantities used to deice wings and mentioned 2 litres/ metre minimum. The data below derived from the latest deicing only report shows that the quantity varies, but in general is higher than your figure.

I hope this helps

John

fluid volume; liter per sq m

	Condition	Total Wing Area (m²)	Frost	Light Snow	Medium Snow	Heavy Snow	Freezing Rain	Overnight accumulation
BKJ	Commuter	68.0	1.0	4.0	8.8	15.0	16.5	9.9
USA	Commuter		2.8	2.8	3.6	5.0	5.0	5.0
UA								
BKJ	Small N/B	119.0	0.8	2.9	6.5	11.0	12.1	7.3
USA	Small N/B		2.6	3.2	3.9	6.5		6.5
UA	Small N/B		0.5	6.5				16.2
BKJ	Large N/B	235.0	0.4	1.7	3.7	6.2	6.8	4.1
USA			1.6	2.6	3.3	4.6		4.6
UA								
BKJ	Small W/B	361.0	0.3	1.3	2.9	4.9	5.4	3.2
USA			1.3	2.1	2.6	3.4		3.4
UA								
BKJ	Large W/B	648.0	0.2	0.8	1.9	3.2	3.5	2.1
USA								
UA								

Figure 3.1: Email re. Litres Used to Deice

The quantities use for one-step deicing frost may have been a reference when determining the minimum quantities for Type I applications when requiring HOT's. In Table 2.1, the one-step deicing fluid quantity to remove frost is minimal, therefore the majority of the fluid can be considered as anti-icing. Table 3.1 shows a calculation of the values reported specific to frost.

Table 3.1: Frost One-step Deicing Fluid Quantities Reported – Equivalent L/m²

Aircraft Type	Frost (Range of Values)	
Commuter	1.0	2.8
Small Narrow-body	0.5	2.6
Large Narrow-body	0.4	1.6
Small Wide-body	0.3	1.3
Large Wide-body	0.2	0.2
Average	0.5	1.7
Total Average	1.1	

4. DEICING STUDIES FOLLOWING 2000

4.1 SAE Type I Fluid Endurance Time Test Protocol 2000-01 TP 13827E

This report addressed the SAE G-12 HOT Subcommittee resolution that the *HOT committee will develop Type I testing protocols which consider the heat factor on simulated wing surfaces of various dilutions of Type I fluids for the purpose of developing Type I Holdover Tables that match operational use of the fluid*.

This led to a project undertaken by APS in the 2000-01 winter season to develop a test protocol for measuring holdover times for SAE Type I fluids that reflected real field operations. The ideal protocol would simulate the full nature of actual deicing/anti-icing operations on real wings in the natural environment.

The protocol was to take into account the effect on endurance times of heat transferred to the wing from the heated fluid. To that end, the research was designed to provide a basis for a test surface that is thermodynamically similar to real wings in natural outdoor weather conditions.

The study Aircraft Full-Scale Test Program for the 1996-97 Winter TP 13130E provided some insight as to which areas of the wing should be simulated in the proposed test protocol. In this study, fluid failure patterns on B 737 and DC-9 aircraft showed that both aircraft have high occurrences of first fluid failure on both the leading and trailing edges. This was typical of other cases studied.

Because contamination on the leading edge can severely degrade take-off performance, and because it experiences fluid failure earlier than most wing areas, it was identified as the critical wing surface for selection of a test unit.

Temperature decay rates for wing leading edges from the 1995 Hot Water trials and the Aircraft Full-Scale Test Program for the 1996-97 Winter yielded an initial family of curves. The relevant data were discussed earlier.

Additional data on other aircraft types was needed and efforts to gather that data are described next.

4.1.1 Tests at Lester B. Pearson International Airport, Toronto

To gather wing temperature profiles on as many aircraft as possible, it was decided that the most efficient approach would be to conduct tests on parked aircraft, thereby avoiding the need to tow them to deicing areas. As a limited level of deicing activity was permitted at the passenger terminal gate positions at Toronto airport, arrangements were made with Air Canada to conduct tests on aircraft parked overnight at Terminal 2 gate positions.

Tests on each aircraft consisted of first installing thermistor probes on the wing leading edge. Only the front portion of the wing, including the leading edge, was sprayed, thus complying with local regulations limiting the amount of deicing fluid that can be sprayed at the terminal ramp. The spray operator applied fluid to simulate the removal of light snow. The application progressed from the wingtip to the root, thus simulating cleaning of the wing, and finished with an overspray application from the wing root to the tip. Leading-edge skin temperatures were logged while the wing gradually cooled.

These tests were performed on a clear night with OAT of -7°C and low wind. By the end of the test session, frost was observed to have formed on the fuselage of aircraft parked at the passenger terminal.

The temperature and quantity of applied fluid were recorded. The temperature of the fluid, measured at the nozzle, ranged from 58°C to 76°C. Because the complete wing wasn't sprayed, it was not possible to calculate the rate of application in L/m^2. Leading edge temperature cooling profiles were recorded for A320, B 737, DC-9 and B 767 aircraft.

4.1.2 Tests at the Central Deicing Facility, Montreal International Airport, Dorval

Some measurements of wing temperature profiles were conducted during field test sessions planned for examining fluid endurance times. Temperature decay rates on wings of operational aircraft already instrumented with thermistor probes were conducted while waiting for forecasted snow to begin. Candidate test surfaces were treated at the same time and their temperature profiles measured. This session provided a valuable comparison between temperature profiles on wings and on final candidate test surfaces exposed to common weather conditions.

Temperature cooling profiles were recorded for two aircraft, Saab 340 and B 737. Fluid application rates were 3.4 and 2.0 L/m^2 respectively.

4.1.3 Outdoor Temperature Trials on the JetStar Test Wing, 7 March 2001

During January and February 2001, the condition of the JetStar test wing was upgraded, and the wing was subsequently mounted on an improved carriage. The wing was intended as a surface for laboratory trials when comparing fluid endurance times for the wing with those for test surfaces. Hence, it was important to document wing temperature profiles. These trials served two purposes:

- comparing the test wing temperature profiles to profiles from other aircraft; and
- examining the effect of varied fuel loads on wing temperature profiles.

The JetStar test wing trials were conducted at Ottawa International Airport, at its central deicing facility.

Three trials were conducted:

- The wing temperature profile was measured with empty fuel tanks;
- Fuel tanks were then partially filled by boarding 750 L (25% filled) of deicing fluid to simulate fuel; the wing was then re-sprayed and the temperature profile measured; and
- Fuel tanks were then filled to 50% capacity by boarding an additional 750 L; the wing was re-sprayed and the temperature profile measured.

The leading-edge temperature decay rate from the test with the wing 50% filled was included in the development of the test protocol.

Fluid application rate was 2.3 L/m^2.

4.2 Generation of Holdover Times Using the New Type I Fluid Test Protocol 2001-02 TP 13994E

This study had a number of objectives including:

- Finalizing the new Type I test protocol;
- Conducting Type I fluid endurance tests in natural snow conditions; and
- Examining endurance time results and comparing these to results documented from full-scale aircraft tests.

One of the activities leading to final acceptance was a test in natural snow conditions to compare fluid endurance times from the proposed test procedure to endurance times experienced on operational aircraft wings.

Although the test planning was completed early in the season, there was only one occasion when a potentially suitable overnight snowstorm occurred (night of Jan. 31/Feb. 1, 2002).

Just prior to testing, the use of an American Eagle Saab 340 as a test aircraft was cancelled. The test plan had included simultaneous tests on the JetStar test wing and these continued despite the Saab 340 cancellation.

During the test session, it did not actually snow and the only valid data gathered was for surface temperature cooling rates.

Three tests were conducted on the JetStar test wing. The first two were conducted during light freezing drizzle, with some ice on the wing.

For the third test, a thick layer of snow was built up on the wing using snow taken from the ramp. The deicing operator then cleaned the wing. Considerably more fluid was used in this test.

The following Table 4.1 shows the total amount of fluid applied in each of the three tests.

Table 4.1: Fluid Amounts for JetStar Test Wing Deicing

Run	Fluid Amount (L)	L/m^2
1	85	3.4
2	59	2.4
3	176	7.0

The amount of fluid applied in the third test was in line with the fluid amounts applied during one-step treatment of overnight accumulation as reported by several airlines in TP 13478E. Overspray amount was not measured separately.

4.3 Laboratory Test Parameters for Frost Endurance Time Tests 2001/02 and 2002-03 TP 14145

During the 2000-01 winter, APS conducted tests to corroborate published HOT values for fluid endurance in active frost conditions, and, simultaneously, to evaluate the proposed AS 5485 procedure for measuring fluid endurance times in frost conditions.

During the tests, the environmental conditions specified in AS 5485 did not produce the desired frost rates. It was concluded that the specified test conditions were not appropriate and that further research was necessary. The objective of the research was to establish test parameters that reflect natural environment conditions for active frost and to document rates of natural frost accretion to enable the specification of frost intensity rates for testing.

Although it was initially intended to complete the research in one test season (2001-02), it was necessary to extend the research over two winter seasons.

The aim of the 2001-02 winter test program was to document rates of frost accretion representative of aircraft surfaces, and the corresponding environmental conditions. These tests led to an initial recommendation for test parameters, as well as the recognition of the need to account for fluid enrichment caused by application of heated fluid.

Frost tests on a lightly frosted B 737 aircraft showed that UCAR ADF fluid enriched markedly during the 5 minutes following spray, from an initial fluid freeze point of - 19°C to an enriched value of -26°C. More than 30 minutes passed before the fluid strength diluted back to its initial value.

Test conditions were;

- OAT at -9ºC;
- Wind 5 to 10 km/h dropping to calm by test end;
- Dew point at -11ºC; Clear skies;
- Measured frost rate of 0.07 g/dm2/h; and
- 30L sprayed over the entire wing (0.6 L/m^2).

The applied rate is in line with the frost spray quantities reported by airlines as shown in the Deicing Only discussion. This spray quantity raised the wing temp from -10°C to about -4°C. This compares to the Type I protocol tests in which the wing temperatures were raised from -9°C to +20°C.

The following chart (Figure 4.1) shows the profiles for wing temperature and fluid freeze point from that study. Together, these two factors (delay of onset of frost and fluid freeze point enhancement) contributed to the observed Type I fluid endurance time.

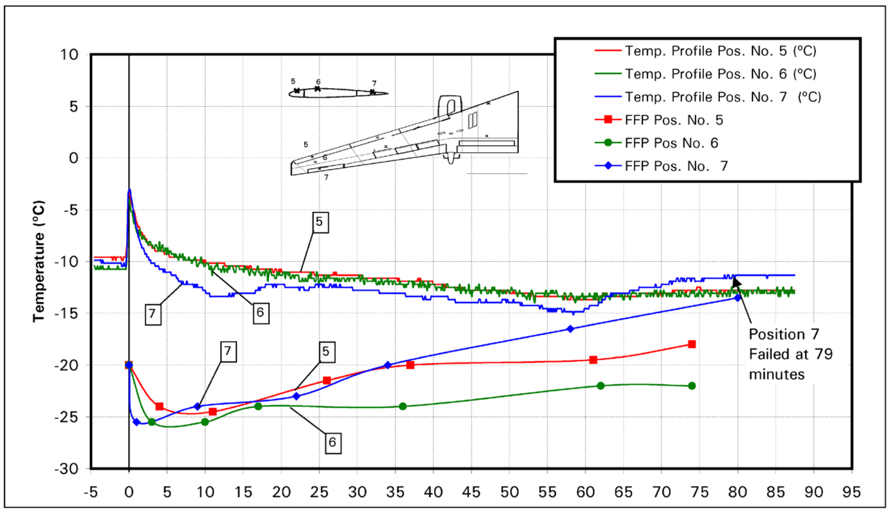


Figure 4.1: Wing Temperature and Freeze Point Profiles (TP 14145)

Further field tests to examine the extent of fluid enrichment were conducted during actual frost deicing operations in Winter 2002-03. These operations applied full strength Type I fluid on heavily frosted wings. The fluid was at a colder than normal fluid temperature. Fluid dilution occurred immediately at some wing locations. Some locations eventually showed enrichment. The two RJ aircraft involved were sprayed with 120 and 140L of fluid.

It was suspected that the observed fluid dilution was probably a result of the typical fan–pattern spray used for frost removal together with a lower than normal fluid temperature. On–wing frost may have been melted and absorbed into the fluid layer remaining on the wing. In these instances, the full-strength fluid continued to provide adequate ongoing protection.

In addition to the recommendations related to testing endurance times, the report recommended that the standard industry procedure for frost deicing be reviewed. Such a review was intended to examine the potential for immediate dilution of the fluid layer on the wing when removing frost with small quantities of fluid using the typical fan–shaped spray pattern, particularly if the fluid had not been heated to 60ºC (140ºF) at the nozzle. In combination with the use of fluid mixed to a 10ºC buffer (an increasing trend), this could contribute to early fluid failure.

The on–wing temperature of a fluid applied with the typical fan–pattern spray has been measured as being significantly lower than for fluid applied in a solid stream as used for snow removal. A previous study documented the drop in fluid temperature from nozzle to wing for frost sprays and for snow sprays. These tests were based on fluid sprayed by an experienced deicing operator, following standard procedures.

The measured fluid temperature drop from nozzle to wing is shown in the following Table 4.2. The results show that typical frost spray patterns will not input heat into the wing to the same extent as when spraying for other types of contamination.

Table 4.2: Fluid Temperature Loss From Nozzle To Wing, TP 13315E, December 1998

	Distance		Fluid Temp at Nozzle	Fluid Temp at Wing	
	m	ft.	(°C)	OAT -5°C	OAT -25°C
Frost Spray	1.7	5.5	60	48	18
	3	10	60	35	25
	4.5	15	60	40	22
Snow Spray	1.7	5.5	60	57	41
	4.5	15	60	56	35
	7.5	25	60	42	43

Perhaps for frost, it would be useful to examine the fluid FP buffer as protection against low fluid-overspray quantities or low fluid temperature, and operator variability. Based on tests, a wing-to-air temperature differential of 6°C was identified as a test parameter for frost endurance times. In effect, the FFP buffer based on OAT is only -4°C when the wing temperature is 6°C below OAT. If the fluid is quickly diluted with melted frost, little FFP protection remains. If the frost melt is flushed off the wing, the FFP buffer still remains at 4°C.

Replacing the current -10°C buffer with a buffer of -15 to -20°C would provide additional protection against quick refreezing, and may be a more reliable and perhaps less expensive approach than requiring a specified over-spray amount. The additional buffer would accommodate the wing-to-OAT temperature differential and is reasonably equivalent to the observed fluid enrichment.

In field operations, an FFP buffer of -16°C may be easier to control than requiring a greater fluid amount when the wing already appears to have been cleaned. Fluid temperature should still be at least 60°C.

SAE AS6285 was reviewed for relevant advice. A CAUTION appears in several places (8.7.1, 8.7.2, Table 1 Fluid Application Table for Type I).

CAUTION: Wing skin temperature may differ and in some cases may be lower than OAT. A mix with higher glycol concentration can be used under the latter condition to ensure a sufficient buffer.

In frost conditions, the wing temperature is always lower than OAT.

4.4 NASA – A Pilots Guide to Ground Icing

As an aside, in the early 2000s, NASA issued an instructional document or training purposes related to ground icing titles "A Pilots Guide to Ground Icing. The material described a requirement for Type I overspray indicating that only a two-step application process is acceptable for snow conditions. The following describes the protocol stated by NASA for Type I:

> *"If using Type I in snow conditions, you should use a two-step process. (In fact, this is a requirement for US and Canadian operators with an approved de-icing/anti-icing program.) The fluid must be heated to 60 – 80C (140 – 180F) at the nozzle and applied in sufficient quantities to provide for adequate heat transfer to aircraft surfaces during the second, anti-icing step."*

https://aircrafticing.grc.nasa.gov/2_5_5_1.html

5. DETERMINING THE REQUIREMENT FOR APPLYING AT LEAST 1 L/M^2 ON DEICED SURFACES

The previous sections of this report examined relevant deicing studies and corresponding data related to the requirement that operators must apply at least 1 litre/m^2 of fluid to deiced surfaces.

As mentioned in Section 1 of this report, the requirement to apply at least 1 litre/sq.^{2} to deiced surfaces was first adopted by Transport Canada in 2000-01. Studies prior to and after publication of the 2000/01 HOT table, along with typical fluid spray quantities provided by several airlines, provide data that could reasonably have influenced the narrative that at least 2 L/m^2 of Type I fluid is needed in a one-step deicing/anti-icing operation, leading to the conclusion that at least 1 L/m^2 must be applied to deiced surfaces. This is further supported by the inclusion of both the 2 L/m^2 requirement in the 2000/01 HOT Guideline introduction narrative compared to the 1 L/m^2 requirement included in the actual Type I holdover time table.

The historical research indicates that the Transport Canada official, at that time, had to provide guidance that would not only achieve the minimum overspray requirements in a two-step Type I application, but also satisfied the industry pressure to use efficient quantities of Type I. It is unclear as to the exact logic used by the Transport Canada official to determine the 1 L/m^2 requirement, and no clear documentation exists as such. However, what we do know is the following:

- Research has shown that heat is important to Type I HOTs, and that more fluid equals more heat which translates to longer HOTs;
- The data from the full-scale tests indicates that 2 L/m^2 is appropriate; and
- The quantities reported for one-step deicing frost may have been an influence when determining the minimum quantities for Type I applications when requiring HOT's, and those values are closer to 1 L/m^2.

The research seems to indicated that quantities of 2 L/m^2 would likely have been considered for recommendation, however the 1 L/m^2 may have been adopted as an adequate compromise between the minimum safety requirements and industry acceptance of an efficient quantity.

5.1 Minimum Quantities for Snow vs. All Conditions

The requirement for 1L/m^2 was originally intended for snow conditions only. It was only in the 2010-11 HOT guidelines when the guidance was moved from the HOT tables to the Fluid Application Tables that the guidance was changed to remove "in snow conditions" and hence applied to all conditions. This was related to the issuance of a separate frost table in 2009-10, and the extensive research and discussions related to radiative cooling in frost and how it affected HOTs, especially for heated fluids. Two years later, the 2012-13 guidance was further modified to state "all conditions including active frost" to remove any ambiguity and to ensure that operators were applying sufficient quantities of fluid when HOTs were required in frost to heat the underlying surface, not just melt the frost.

5.2 History of Type I Fluid Application Tables and Holdover Time Tables

Since the early 90's the HOT guidelines have undergone several format changes. To facilitate the referencing of the changes specific to the Type I Fluid Application Tables and Holdover Time Tables, two appendices were prepared which include a copy of each document in sequential order. Appendix A includes all the Type I Fluid Application Tables, and Appendix B includes all the Type I Fluid Time Tables.

6. SUMMARY

Hot Water Tests in 1995 listed fluid quantities sprayed on a DC-9. These tests provided wing temperature cooling profiles for the Type I test protocol.

- Fluid quantities for the two first-step applications averaged 3.1 L/m^2.
- The two second step applications were 2 and 2.3 L/m^2.
- Fluid quantities for four one-step applications ranged from 106 to 412 L and averaged 4.2 L/m^2.

The report recommended that the optimum spray pattern to transfer heat to the wing should be investigated. It suggested that the nozzle setting used to clean the wing may not be optimum for the overspray where the objective is to transfer heat into the wing skin.

In the 1998-99 Deicing Only study, overnight tests were conducted on a B 737 aircraft. One of these tests produced a wing leading edge cooling profile that was used in the Type I test protocol study. That test involved a spray application of 3.4 L/m^2.

Hot water tests in 1999 on the JetStar test wing under snow gun artificial snow precipitation produced two application rates.

- 60 L of hot water (2.4 L/m^2) produced a protection time of about 1.8 minutes.
- 189 L of hot water (7.6 L/m^2) produced a protection time of about 3.1 minutes

For the 1998-99 Deicing Only study, several airlines were asked for data reflecting quantity of fluid applied in one-step deicing shown in Table 6.1.

Table 6.1: One-step Deicing Fluid Quantities Reported – Equivalent L/m²

Aircraft Type	Frost	Light Snow	Medium Snow	Heavy Snow	Overnight Snow Accumulation
Commuter	1.3 - 2.7	2.7 - 4.9	3.3 - 8.7	4.7 - 15.3	4.7 - 10.0
Small Narrow-body	0.7 - 2.7	2.7 - 6.7	4.0 - 6.7	6.7 - 11.3	6.7 - 16.0
Large Narrow-body	0.7 - 2.0	1.3 - 2.7	3.3	4.7 - 6.0	4.0 - 4.7
Small Wide-body	0.7 - 1.3	1.3 - 2.0	2.7	3.3 - 4.7	3.3
Large Wide-body	0.7	0.7	2.0	3.3	2.0

Similar data was provided to TDC by email in Aug 2000.

Studies over the years have showed the critical influence of heat on Type I HOT values. As well, fluid failure patterns on wings have consistently identified leading and trailing edges as the first to fail.

The foregoing data leading up to the time that the minimum fluid overspray caution was published in the 2000-01 HOT table could well be interpreted as demonstrating that at least 2 L/m² of Type I fluid is needed in a one-step deicing/anti-icing operation, part of which could be an overspray application of 1 L/m².

Further tests were conducted during the 2000-01 Type I fluid test protocol study to expand the variety of aircraft contributing to a generic wing leading edge cooling curve. The bare-wing fluid application rates were:

Saab 340	3.4 L/m²
B 737	2.0 L/m²
JetStar test wing	2.3 L/m².

Additional aircraft wing leading edge cooling rates were measured; however, application rates could not be calculated as the wing was only partially treated.

The 2001-02 study applying the new Type I test protocol included tests comparing fluid failure times on the JetStar test wing to the new test surface and protocol.

Three tests were conducted, two during light freezing drizzle with some ice on the wing. For the third test, a thick layer of snow was built up on the wing using snow taken from the ramp. Application rates were;

Run 1	3.4 L/m²
Run 2	2.4 L/m²
Run 3	7.0 L/m²

These rates support previous test results.

Measuring or, for the spray operator, judging the quantity of overspray fluid in a one-step deicing/anti-icing operation is difficult, unless the overspray is applied in a continuous fashion such as when the operator deices the wing from tip to root, then goes back over the wing from root to tip. In effect, the latter operation mimics the two-step process. As long as the initial application has not yet failed, it is in fact a two-step. In theory then, the HOT for the second (root to tip) application should commence when the operator starts back over the wing at the root. This later start to the HOT countdown offers a distinct advantage to the operation.

To underscore the need to transfer heat to treated surfaces by application of sufficient heated fluid following deicing, perhaps the application process for Type I fluid should be limited to a two-step operation with the overspray being the second-step. This would take advantage of the later start to the HOT countdown and incidentally apply the last phase of protection to the outer wing that typically is one of the earliest locations to experience fluid failure. As noted earlier, this is how NASA already interprets the requirement. Other operators may be applying the same interpretation.

Guidelines for Frost deicing could merit a review. The airline data for frost sprays showed that considerably less fluid was typically sprayed than for other contamination. This was corroborated in frost tests on the B 737 aircraft. As well, past tests recorded that typical frost spray patterns lose much more heat from nozzle to wing than do sprays for other contamination types. Regardless of the amount of initial heat transferred to the wing surface, the resulting elevated temperature wouldn't be expected to last for the entire duration of the current Type I HOT value (45 minutes), but would have dropped to active frost levels (somewhere below OAT) early in the period of protection. Although the elevated wing temperature can't last for 45 minutes, it can delay the onset of frost as well as produce some fluid enrichment. Ongoing protection would then be provided only by the enriched thin film of Type I fluid. This is different from other contamination conditions where endurance times are much shorter and the elevated surface temperature may still continue to play a part in protection until final fluid failure.

Perhaps for frost, it would be advantageous to replace the current -10°C buffer with a buffer of -15 to -20°C. This would provide additional protection against quick refreezing, and may be a more reliable and perhaps less expensive approach than requiring a specified over-spray amount. The additional buffer would accommodate the wing-to-OAT temperature differential and is reasonably equivalent to the observed fluid enrichment in field tests. Additionally, it would address the shorter endurance times noted for composite surfaces resulting from a shorter duration of elevated temperatures and less fluid enrichment.

7. CONCLUSIONS AND RECOMMENDATIONS

Studies prior to and after publication of the 2000/01 HOT table, along with typical fluid spray quantities provided by several airlines provide data that could reasonably have influenced the narrative that at least 2 L/m^2 of Type I fluid is needed in a one-step deicing/anti-icing operation, leading to the conclusion that at least 1 L/m^2 must be applied to deiced surfaces.

It is unclear as to the exact logic used by the Transport Canada official to determine the 1 L/m^2 requirement, and no clear documentation exists as such. The research seems to indicated that quantities of 2 L/m^2 would likely have been considered for recommendation, however the 1 L/m^2 may have been adopted as an adequate compromise between the minimum safety requirements and industry acceptance of an efficient quantity.

To further validate the current 1 L/m^2 requirement, full-scale testing could be performed. This should consider newer aircraft construction which uses composite materials, and newer deicing sprayer systems which have optimized spray patterns, pressures, and heating systems.

Perhaps the application process for Type I should be limited to a two-step operation to underscore the need for an adequate overspray beyond the fluid applied for deicing and to take advantage of the later start to the HOT countdown. It may be useful to explore the optimum spray pattern to transfer heat to the wing.

Fluid quantities for frost conditions are typically lighter, and the loss of fluid heat from spray nozzle to wing surface greater, than for other conditions. Type I fluid applications for frost could merit an examination of potentially different guidelines.

Perhaps for frost, it would be advantageous to replace the current -10°C buffer with a buffer of -15 to -20°C. This would provide protection against quick refreezing due to frost-melt dilution, and may be a more reliable and perhaps less expensive approach than requiring a specified over-spray amount.

Appendix A:

History of Type I Fluid Application Tables

History of Notable Changes to Type I Heat and Quantity Guidance

Year	Notable Guidance Change
1993	Requirement for 60˚ heated fluid for all applications exists (don't have earlier documentation)
1997	Removal of "heated" fluid requirement for second step anti-icing. Remains for one-step and first step deicing.
2001	Removal of note that "clean aircraft may be anti-iced with un-heated fluid"
2002	Added back "heated" requirement for second step anti-icing
2004	First inclusion of the 1 l/m^2. Applies only to Snow conditions
2010	Removal of "snow conditions" from 1 l/m^2requirement (now indicates all conditions)
2012	Change 1L/m^2 requirement to specifically state "all conditions including active frost"
2016	Elaboration of 1L/m^2 note to indicate importance of applying the appropriate amounts of fluid

TABLE 2 - Guidelines for Application of SAE and ISO Type I Fluids as a Function of OAT.

OAT		Minimum Concentrations, Heated - Fluid/Water Ratio (% by Volume)		
°C	°F	One-Step De/Anti-Icing Procedure with Type I Fluid	Two-Step Procedure: First Step Deicing	Two-Step Procedure: Second Step Anti-Icing *
above -3	above 27	Freeze point of heated Type I fluid mixture should be at least 10°C(18°F) below OAT **	Water heated to 60°C(140°F) minimum at the nozzle, or a heated mix of Type I fluid and water	Freeze point of heated Type I fluid mixture should be at least 10°C(18°F) below OAT
below -3	below 27		Freeze point of heated Type I fluid mixture should not be more than 3°C(5°F) above OAT	

Heated fluid - Fluid temperature not less than 60°C(140°F) at the nozzle.

Note: FOR OVERNIGHT PROTECTION USE TWO-STEP PROCEDURE, SECOND STEP ANTI-ICING.

*** To be applied before first step fluid freezes, typically within 3 minutes.**

**** Clean aircraft may be anti-iced with cold fluid.**

CAUTION: Aircraft skin temperature and OAT may differ.

16

1993

TABLE 2 - Guidelines for Application of SAE and ISO Type I Fluids as a Function of OAT.

OAT		Minimum Concentrations, Heated - Fluid/Water Ratio (% by Volume)		
°C	°F	One-Step De/Anti-Icing Procedure with Type I Fluid	Two-Step Procedure	
			First Step Deicing	Second Step Anti-Icing *
above -3	above 27	Freeze point of heated Type I fluid mixture should be at least 10°C(18°F) below OAT **	Water heated to 60°C(140°F) minimum at the nozzle, or a heated mix of Type I fluid and water	Freeze point of heated Type I fluid mixture should be at least 10°C(18°F) below OAT
below -3	below 27		Freeze point of heated Type I fluid mixture should not be more than 3°C(5°F) above OAT	

Heated fluid - Fluid temperature not less than 60°C(140°F) at the nozzle.

Note: FOR OVERNIGHT PROTECTION USE TWO-STEP PROCEDURE, SECOND STEP ANTI-ICING.

*** To be applied before first step fluid freezes, typically within 3 minutes.**

**** Clean aircraft may be anti-iced with cold fluid.**

CAUTION: Aircraft skin temperature and OAT may differ.

1994

TABLE 2

Guidelines for Application of SAE and ISO Type I Fluids as a Function of OAT.

OAT		Minimum Concentrations, Heated - Fluid/Water Ratio (% by Volume)		
		One-Step De/Anti-Icing Procedure with Type I Fluid	Two-Step Procedure	
°C	°F		First Step Deicing	Second Step Anti-Icing *
above -3	above 27	Freeze point of heated Type I fluid mixture should be at least 10°C(18°F) below OAT **	Water heated to 60°C(140°F) minimum at the nozzle, or a heated mix of Type I fluid and water	Freeze point of heated Type I fluid mixture should be at least 10°C(18°F) below OAT
below -3	below 27		Freeze point of heated Type I fluid mixture should not be more than 3°C(5°F) above OAT	

Heated fluid - Fluid temperature not less than 60°C(140°F) at the nozzle.

Note: FOR OVERNIGHT PROTECTION USE TWO-STEP PROCEDURE, SECOND STEP ANTI-ICING.

*** To be applied before first step fluid freezes, typically within 3 minutes.**

**** Clean aircraft may be anti-iced with cold fluid.**

CAUTION: Aircraft skin temperature and OAT may differ.

1995

1996 missing

TABLE 6

SAE TYPE I DE-ICING FLUID APPLICATION GUIDELINES

Outside air temperature (OAT)	One-step procedure Deicing/anti-icing	Two-step Procedure First step: Deicing	 Second step: Anti-icing1
-3^0 C (27 F) and above	FP of heater fluid2 mixture shall be at least 10 C (18^0 F) below OAT	Water heated to 60^0 C (140^0 F) minimum at the nozzle or a heated mix of fluid and water	FP of fluid mixture shall be at least 10 C (18^0 F) below actual OAT
Below -3^0 C (27 F)		FP of heated fluid mixture shall not be more than 3^0 C (5^0 F) above OAT	

NOTE: For heated fluids, a fluid temperature not less then 60 C (140 F) at the nozzle is desirable. Upper temperature limit shall not exceed fluid and aircraft manufacturers recommendations.

CAUTION: Wing skin temperatures may differ and in some cases may be lower then OAT. A stronger mix can be used under the latter conditions.

1. To be applied before first step fluid freezes, typically within 3 minutes.
2. Clean aircraft may be anti-iced with cold fluid.

FIGURE 1- Guidelines for the application of SAE Type 1 fluid mixtures (Minimum Concentrations) as a Function of Outside Air Temperature (OAT)

Requirement for "heated" removed from second step anti-icing

TRANSPORT CANADA, JULY, 1997

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature OAT	One-step Procedure	Two-step Procedure	
	Deicing/anti-icing	First step: Deicing	Second step: Anti-icing [1]
-3°C (27°F) and above	FP of heated fluid[2] mixture shall be at least	Water heated to 60°C (140°F) minimum at the nozzle or a heated mix of fluid and water	FP of fluid mixture shall be at least
Below -3°C (27°F)	10°C (18°F) below OAT	FP of heated fluid mixture shall not be more than 3°C (5°F) above OAT	10°C (18°F) below OAT

NOTE: For heated fluids, a fluid temperature not less than 60°C (140°F) at the nozzle is desirable. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.

CAUTION: Wing skin temperatures may differ and in some cases may be lower than OAT. A stronger mix (more Glycol) can be used under the latter conditions.

1 To be applied before first step fluid freezes, typically within 3 minutes.
2 Clean aircraft may be anti-iced with unheated fluid.

TRANSPORT CANADA, AUGUST 1998

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TABLE 6

SAE TYPE I DE-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)	One-step Procedure De-icing/anti-icing	Two-step Procedure First step: De-icing	Two-step Procedure Second step Anti-icing [1]
-3°C (27°F) and above	FP of heated fluid[2] mixture shall be at least 10° C (18°F) below OAT	Water heated to 60°C (140°F) minimum at the nozzle or a heated mix of fluid and water	FP of fluid mixture shall be at least 10°C (18°F) below OAT
Below -3°C (27°F)		FP of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

Note: For heated fluids, a fluid temperature not less than 60°C (140°F) at the nozzle is desirable. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.

Caution: Wing skin temperatures may differ and in some cases may be lower than OAT. A stronger mix (more Glycol) can be used under the latter conditions.

FP = Freezing Point

[1]To be applied before first step fluid freezes, typically within 3 minutes.
[2]Clean aircraft may be anti-iced with unheated fluid.

TRANSPORT CANADA, AUGUST 1999

TABLE 6

SAE TYPE I DE-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature OAT	One-step Procedure	Two-step Procedure	
	De-icing/anti-icing	First step: De-icing	Second step Anti-icing [1]
-3°C (27°F) and above	FP of heated fluid[2] mixture shall be at least 10° C (18°F) below OAT	Water heated to 60°C (140°F) minimum at the nozzle or a heated mix of fluid and water	FP of fluid mixture shall be at least 10°C (18°F) below OAT
Below -3°C (27°F)		FP of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

Note: For heated fluids, a fluid temperature not less than 60°C (140°F) at the nozzle is desirable. Upper temperature limit shall not exceed fluid and aircraft manufacturers recommendations.

Caution: Wing skin temperatures may differ and in some cases may be lower than OAT. A stronger mix (more Glycol) can be used under the latter conditions.

1) To be applied before first step fluid freezes, typically within 3 minutes.
2) Clean aircraft may be anti-iced with unheated fluid.

TRANSPORT CANADA, JULY 2000

TRANSPORT CANADA HOLDOVER TIME GUIDELINES

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature OAT	One-step Procedure Deicing/anti-icing	Two-step Procedure First step: Deicing	 Second step Anti-icing [1]
-3°C (27°F) and above	FP of heated fluid mixture shall be at least 10° C (18°F) below OAT	Water heated to 60°C (140°F) minimum at the nozzle or a heated mix of fluid and water	FP of fluid mixture shall be at least 10°C (18°F) below OAT
Below -3°C (27°F)		FP of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

Note: For heated fluids, a fluid temperature not less than 60°C (140°F) at the nozzle is desirable. Upper temperature limit shall not exceed fluid and aircraft manufacturers recommendations.

Caution: Wing skin temperatures may differ and in some cases may be lower than OAT; a stronger mix may be needed under these conditions.

1) To be applied before first step fluid freezes, typically within 3 minutes.

Removal of note that "clean aircraft may be anti-iced with un-heated fluid" .

TRANSPORT CANADA , AUGUST 2001

TRANSPORT CANADA HOLDOVER TIME GUIDELINES

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature OAT	One-step Procedure Deicing/anti-icing	Two-step Procedure First step: Deicing	 Second step Anti-icing [1]
-3°C (27°F) and above	Mix of fluid and water heated to 60°C (140°F) minimum at the nozzle,	Water or a mix of fluid and water heated to 60°C (140°F) minimum at the nozzle.	Mix of fluid and water heated to 60°C (140°F) minimum at the nozzle,
Below -3°C (27°F)	with a freeze point of at least 10° C (18°F) below OAT	Freeze point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	with a freeze point of at least 10° C (18°F) below OAT

Note: Upper temperature limit shall not exceed fluid and aircraft manufacturers recommendations.

Caution: Wing skin temperatures may differ and in some cases may be lower than OAT; a stronger mix may be needed under these conditions.

1) To be applied before first step fluid freezes, typically within 3 minutes..

"Heated" added back to the anti-icing column

-12°C - OAT
-9°C - OAT

TRANSPORT CANADA, MAY 2002

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature OAT	One-Step Procedure Deicing/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[1]
-3°C (27°F) and above	Mix of fluid and water heated to 60°C (140°F) minimum at the nozzle, with a freeze point of at least 10°C (18°F) below OAT	Water or a mix of fluid and water heated to 60°C (140°F) minimum at the nozzle	Mix of fluid and water heated to 60°C (140°F) minimum at the nozzle, with a freeze point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freeze point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 To be applied before first step fluid freezes, typically within 3 minutes.

NOTE
Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.

NOTE
This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.

CAUTION
- **Wing skin temperatures may differ and in some cases may be lower than OAT; a stronger mix may be needed under these conditions.**

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature OAT	One-Step Procedure Deicing/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[1]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 To be applied before first step fluid freezes, typically within 3 minutes.

NOTE
Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.

NOTE
To use Type I holdover time guidelines in snow conditions, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.

NOTE
This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.

CAUTION
- **Wing skin temperatures may differ and in some cases may be lower than OAT; a stronger mix (more glycol) may be needed under these conditions.**

First inclusion of the 1 l/m²

Applies only to Snow

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)	One-Step Procedure Deicing/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[1]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 To be applied before first step fluid freezes, typically within 3 minutes.

NOTES
- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in snow conditions, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.

CAUTION
- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure Deicing/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 Fluids must only be used at temperatures above their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes.

NOTES

- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in snow conditions, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.

CAUTION

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure Deicing/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes.

NOTES

- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in snow conditions, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- ~~This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.~~

CAUTION

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure Deicing/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes.

NOTES

- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in snow conditions, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- The lowest operational use temperature (LOUT) for a given fluid is the higher of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).

CAUTION

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure	Two-Step Procedure	
	Deicing/Anti-icing	First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes.

NOTES

- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in snow conditions, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- The lowest operational use temperature (LOUT) for a given fluid is the higher of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).

CAUTION

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure Deicing/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes.

NOTES
- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- The lowest operational use temperature (LOUT) for a given fluid is the higher of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).

CAUTION
- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

Removal of "snow conditions" to 1L/m2 requirement to indicate all condition.

TABLE 6

SAE TYPE I DE/ANTI-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure De/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes.

NOTES
- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- The lowest operational use temperature (LOUT) for a given fluid is the higher of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).

CAUTION
- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

TABLE 6

SAE TYPE I DE/ANTI-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure De/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes. (This time may be higher than 3 minutes in some conditions, but potentially lower in heavy precipitation, colder temperatures, or for critical surfaces constructed of composite materials. If necessary, the second step shall be applied area by area.)

NOTES

- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in all conditions including active frost, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I holdover time guidelines in all conditions including active frost. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- The lowest operational use temperature (LOUT) for a given fluid is the higher of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).

CAUTION

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

Change 1L/m2 requirement to specifically state "all conditions including active frost"

Transport Canada Holdover Time Guidelines — Winter 2013-2014

TABLE 6

SAE TYPE I DE/ANTI-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure De/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes. (This time may be higher than 3 minutes in some conditions, but potentially lower in heavy precipitation, colder temperatures, or for critical surfaces constructed of composite materials. If necessary, the second step shall be applied area by area.)

NOTES

- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in all conditions including active frost, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I holdover time guidelines in all conditions including active frost. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- The lowest operational use temperature (LOUT) for a given fluid is the higher of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).

CAUTION

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

TABLE 6

SAE TYPE I DE/ANTI-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure De/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).

2 To be applied before first step fluid freezes, typically within 3 minutes. (This time may be higher than 3 minutes in some conditions, but potentially lower in heavy precipitation, colder temperatures, or for critical surfaces constructed of composite materials. If necessary, the second step shall be applied area by area.)

NOTES

- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in all conditions including active frost, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I holdover time guidelines in all conditions including active frost. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- The lowest operational use temperature (LOUT) for a given fluid is the higher of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).

CAUTION

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

Transport Canada Holdover Time Guidelines Winter 2015-2016

TABLE 9

SAE TYPE I DE/ANTI-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure De/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated mix of fluid and water	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below -3°C (27°F)		Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT	

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes. (This time may be higher than 3 minutes in some conditions, but potentially lower in heavy precipitation, colder temperatures, or for critical surfaces constructed of composite materials. If necessary, the second step shall be applied area by area.)

NOTES

- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in all conditions including active frost, at least 1 litre/m² (~ 2 gal./100 sq. ft.) shall be applied to the deiced surfaces.
- ~~This table is applicable for the use of Type I holdover time guidelines in all conditions including active frost. If holdover~~ times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- The lowest operational use temperature (LOUT) for a given Type I fluid is the higher of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).

CAUTION

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

Page 63 of 64 July 2015

Transport Canada Holdover Time Guidelines — Winter 2016-2017

TABLE 9

GUIDELINES FOR THE APPLICATION OF SAE TYPE I FLUID

Outside Air Temperature (OAT)[1]	One-Step Procedure De/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
0°C (32°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated fluid/water mixture	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below 0°C (32°F) to LOUT		Heated fluid/water mixture with a freezing point at OAT or below	

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).

2 To be applied before first step fluid freezes, typically within 3 minutes. (This time may be higher than 3 minutes in some conditions, but potentially lower in heavy precipitation, colder temperatures, or for critical surfaces constructed of composite materials. If necessary, the second step shall be applied area by area.)

NOTES

- This table is applicable for the use of Type I holdover time guidelines in all conditions including active frost. ~~If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.~~
- If holdover times are required, the temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I Holdover Times Guidelines in all conditions including active frost, an additional minimum of 1 litre/m^2 (~2 gal./100 sq. ft.) of heated Type I fluid mixture must be applied to the surfaces after all frozen contamination is removed. This application is necessary to heat the surfaces, as heat contributes significantly to the Type I fluid holdover times. The required protection can be provided using a 1-step method by applying more fluid than is strictly needed to just remove all of the frozen contamination (the same additional amount stated above is required).
- The lowest operational use temperature (LOUT) for a given Type I fluid is the higher (warmer) of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).

CAUTION

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

Elaboration of 1L/m2 note

TABLE 45: GUIDELINES FOR THE APPLICATION OF SAE TYPE I FLUID

Outside Air Temperature (OAT)[1]	One-Step Procedure De/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
0°C (32°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated fluid/water mixture	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below 0°C (32°F) to LOUT		Heated fluid/water mixture with a freezing point at OAT or below	

NOTES

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).

2 To be applied before first step fluid freezes, typically within 3 minutes. (This time may be higher than 3 minutes in some conditions, but potentially lower in heavy precipitation, colder temperatures, or for critical surfaces constructed of composite materials. If necessary, the second step shall be applied area by area.)

CAUTIONS

- This table is applicable for the use of Type I holdover time guidelines in all conditions, including active frost. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- If holdover times are required, the temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I Holdover Times Guidelines in all conditions including active frost, an additional minimum of 1 litre/m^2 (~2 gal./100 sq. ft.) of heated Type I fluid mixture must be applied to the surfaces after all frozen contamination is removed. This application is necessary to heat the surfaces, as heat contributes significantly to the Type I fluid holdover times. The required protection can be provided using a 1-step method by applying more fluid than is strictly needed to just remove all of the frozen contamination (the same additional amount stated above is required).
- The lowest operational use temperature (LOUT) for a given Type I fluid is the higher (warmer) of:
  - a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  - b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).
- Wing skin temperatures may differ and in some cases may be lower than the OAT. A stronger mix (more glycol) may be needed under these conditions.

TABLE 45: GUIDELINES FOR THE APPLICATION OF SAE TYPE I FLUID

Outside Air Temperature (OAT)[1]	One-Step Procedure De/Anti-icing	Two-Step Procedure	
		First Step: Deicing	**Second Step: Anti-icing[2]**
0°C (32°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated fluid/water mixture	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below 0°C (32°F) to LOUT		Heated fluid/water mixture with a freezing point at OAT or below	

NOTES

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes. (This time may be higher than 3 minutes in some conditions, but potentially lower in heavy precipitation, colder temperatures, or for critical surfaces constructed of composite materials. If necessary, the second step shall be applied area by area.)

CAUTIONS

- This table is applicable for the use of Type I holdover time guidelines in all conditions, including active frost. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- If holdover times are required, the temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I Holdover Times Guidelines in all conditions including active frost, an additional minimum of 1 litre/m^2 (~2 gal./100 sq. ft.) of heated Type I fluid mixture must be applied to the surfaces after all frozen contamination is removed. This application is necessary to heat the surfaces, as heat contributes significantly to the Type I fluid holdover times. The required protection can be provided using a 1-step method by applying more fluid than is strictly needed to just remove all of the frozen contamination (the same additional amount stated above is required).
- The lowest operational use temperature (LOUT) for a given Type I fluid is the higher (warmer) of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).
- Wing skin temperatures may differ and in some cases may be lower than the OAT. A stronger mix (more glycol) may be needed under these conditions.

TABLE 48: GUIDELINES FOR THE APPLICATION OF SAE TYPE I FLUID

Outside Air Temperature (OAT)[1]	One-Step Procedure De/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
0°C (32°F) and above	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT	Heated water or a heated fluid/water mixture	Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT
Below 0°C (32°F) to LOUT		Heated fluid/water mixture with a freezing point at OAT or below	

NOTES

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes. (This time may be higher than 3 minutes in some conditions, but potentially lower in heavy precipitation, colder temperatures, or for critical surfaces constructed of composite materials. If necessary, the second step shall be applied area by area.)

CAUTIONS

- This table is applicable for the use of Type I holdover time guidelines in all conditions, including active frost. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.
- If holdover times are required, the temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I Holdover Times Guidelines in all conditions including active frost, an additional minimum of 1 litre/m² (~2 gal./100 sq. ft.) of heated Type I fluid mixture must be applied to the surfaces after all frozen contamination is removed. This application is necessary to heat the surfaces, as heat contributes significantly to the Type I fluid holdover times. The required protection can be provided using a 1-step method by applying more fluid than is strictly needed to just remove all of the frozen contamination (the same additional amount stated above is required).
- The lowest operational use temperature (LOUT) for a given Type I fluid is the higher (warmer) of:
    a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
    b) The actual freezing point of the fluid plus its freezing point buffer of 10°C (18°F).
- Wing skin temperatures may differ and in some cases may be lower than the OAT. A stronger mix (more glycol) may be needed under these conditions.

Appendix B:

History of Type I Holdover Time Table

History of Notable Changes to Type I HOT Tables 1991 to 2019

- No Mention of Heat Applied and Application Quantity from 1991 to 1999
- Mention of Heat Applied and Application Quantity from 2000 to 2009
- No Mention of Heat Applied and Application Quantity from 2010 to 2019

No Mention of Heat, or Application quantity

TEST IMPLICATIONS FOR DE/ANTI-ICING FLUIDS

Type 1 fluids essentially have zero holdover time under any appreciable precipitation. They should not be used in freezing precipitation and should be used solely as a deicing fluid.

	TYPE 1 (50% WATER AND 50% GLYCOL)	TYPE 2 UNDILUTED
FROST	45	240
FREEZING DRIZZLE	5	25
STEADY SNOW		
LIGHT	5	20
MEDIUM	3	12
HEAVY	0	10

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_1991-1992_Original_OBSOLETE.pdf

1991

No Mention of Heat, or Application quantity

TABLE 2 - Guidelines for Holdover Times Anticipated by SAE Type I and ISO Type I Fluid Mixtures as a Function of Weather Conditions and OAT.

CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY AND IT SHOULD BE USED IN CONJUNCTION WITH PRETAKEOFF CHECK PROCEDURES.

Freezing Point of Type I fluid mixture used must be at least 10°C (18°F) below OAT.

OAT		Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)				
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING RAIN	RAIN ON COLD SOAKED WINGS
0 and above	32 and above	0:18-0:45	0:12-0:30	0:06-0:15	0:02-0:05	0:06-0:15
below 0 to -7	below 32 to 19	0:18-0:45	0:06-0:15	0:06-0:15	0:01-0:03	**CAUTION:** Clear ice may require touch for confirmation
below -7	below 19	0:12-0:30	0:06-0:15	0:06-0:15		

THIS TABLE DOES NOT APPLY TO OTHER THAN SAE OR ISO TYPE I FPD FLUIDS.

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER.

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_1992-1993_Original_OBSOLETE.pdf

1992

No Mention of Heat, or Application quantity

Freezing Point of Type I fluid mixture used must be at least 10°C (18°F) below OAT.

OAT		Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)				
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING RAIN	RAIN ON COLD SOAKED WINGS
0 and above	32 and above	0:18-0:45	0:12-0:30	0:06-0:15	0:02-0:05	0:06-0:15
below 0 to -7	below 32 to 19	0:18-0:45	0:06-0:15	0:06-0:15	0:01-0:03	**CAUTION:** Clear ice may require touch for confirmation
below -7	below 19	0:12-0:30	0:06-0:15	0:06-0:15		

THIS TABLE DOES NOT APPLY TO OTHER THAN SAE OR ISO TYPE I FPD FLUIDS.

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER.

Caution: The only acceptable Decision Criteria Times are the shortest (shaded) times on the hold-over time table.

1993

No Mention of Heat, or Application quantity

TABLE 1 - Guidelines for Holdover Times Anticipated by SAE Type I and ISO Type I Fluid Mixtures as a Function of Weather Conditions and OAT.

Freezing Point of Type I fluid mixture used must be at least 10°C (18°F) below OAT.

OAT		Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)				
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING RAIN	RAIN ON COLD SOAKED WINGS
0 and above	32 and above	0:18-0:45	0:12-0:30	0:06-0:15	0:02-0:05	0:06-0:15
below 0 to -7	below 32 to 19	0:18-0:45	0:06-0:15	0:06-0:15	0:01-0:03	**CAUTION:** Clear ice may require touch for confirmation
below -7	below 19	0:12-0:30	0:06-0:15	0:06-0:15		

THIS TABLE DOES NOT APPLY TO OTHER THAN SAE OR ISO TYPE I FPD FLUIDS.

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER.

Caution: The only acceptable Decision Criteria Times are the shortest (shaded) times on the hold-over time table. High precipitation rates or moisture content, high wind velocity or jet blast will reduce holdover time below the lowest time stated in the range. Holdover time will also be reduced when the fuel or skin temperature is lower than OAT.

https://www.tc.gc.ca/en/services/aviation/documents/HOT_1994-1995.pdf

1994

No Mention of Heat, or Application quantity

TABLE 1

TYPE I FLUIDS: Guidelines for Holdover Times Anticipated for SAE Type I and ISO Type I Fluid Mixtures as a Function of Weather Conditions and OAT.

OAT		Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
°C	°F	*FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FREEZING RAIN	RAIN ON COLD-SOAKED WING
above 0	above 32	0:45	0:12-0:30	0:06-0:15	0:05-0:08	0:02-0:05	0:06-0:15
0 to -7	32 to 19	0:45	0:06-0:15	0:06-0:15	0:05-0:08	0:02-0:05	Caution: Clear ice may require touch for confirmation
below -7	below 19	0:45	0:06-0:15	0:06-0:15	A	B	

* During conditions that apply to aircraft protection for OVERNIGHT FROST.
A: Approximate Holdover Time for Freezing Drizzle is 5 to 8 min below -7°C to -10°C.
B: Approximate Holdover Time for Light Freezing Rain is 2 to 5 min below -7°C to -10°C.

- THIS TABLE DOES NOT APPLY TO OTHER THAN SAE OR ISO TYPE I FREEZING POINT DEPRESSANT FLUIDS.
- FREEZING POINT OF THE TYPE I FLUID MIXTURE USED MUST BE AT LEAST 10°C (18°F) BELOW OAT.
- THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER.

CAUTION: The only acceptable decision criteria times are the shortest (shaded) times on the holdover timetable. High precipitation rates or moisture content, high wind velocity or jet blast will reduce holdover time below the lowest time stated in the range. Holdover time will also be reduced when the fuel or skin temperature is lower than OAT.

https://www.tc.gc.ca/en/services/aviation/documents/HOT_1995.pdf

1995

No Mention of Heat, or Application quantity

TABLE 1

SAE TYPE I FLUID HOLDOVER TIME TABLE

Guideline for Holdover Times Anticipated for SAE Type I Fluid Mixture as a Function of Weather Conditions and OAT

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Approximate Holdover Times Under Various Weather Conditions (hours : minutes)					
°C	°F	*FROST	FREEZING FOG	SNOW	**FREEZING DRIZZLE	LIGHT FREEZING RAIN	RAIN ON COLD SOAKED WING
above 0°	above 32°	0:45	0:12 - 0:30	0:06 - 0:15	0:05 - 0:08	0:02 - 0:05	0:02 - 0:05
0 to -10	32 to 14	0:45	0:06 - 0:15	0:06 - 0:15	0:05 - 0:08	0:02 - 0:05	
below -10	below 14	0:45	0:06 - 0:15	0:06 - 0:15			

°C = Degrees Celsius
°F = Degrees Fahrenheit
OAT = Outside Air Temperature
FP = Freezing Point

* During conditions that apply to aircraft protection for ACTIVE FROST
**Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

SAE Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10° C(18° F) below OAT

CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIMETABLE CELL.

TRANSPORT CANADA AUGUST 1996

1996

https://www.tc.gc.ca/en/services/aviation/documents/HOT_1996.pdf

No Mention of Heat, or Application quantity

TABLE 1

SAE TYPE I FLUID HOLDOVER TABLE

Guideline for Holdover Times Anticipated for SAE Type I Fluid Mixture as a Function of Weather Conditions and OAT

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Approximate Holdover Times Under Various Weather Conditions (hours : minutes)					
°C	°F	*FROST	FREEZING FOG	SNOW	**FREEZING DRIZZLE	LIGHT FREEZING RAIN	RAIN ON COLD SOAKED WING
above 0°	above 32°	0:45	0:12 - 0:30	0:06 - 0:15	0:05 - 0:08	0:02 - 0:05	0:02 - 0:05
0 to -10	32 to 14	0:45	0:06 - 0:15	0:06 - 0:15	0:05 - 0:08	0:02 - 0:05	
below -10	below 14	0:45	0:06 - 0:15	0:06 - 0:15			

°C = Degrees Celsius
°F = Degrees Fahrenheit
OAT = Outside Air Temperature
FP = Freezing Point

* During conditions that apply to aircraft protection for ACTIVE FROST
**Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

SAE Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10° C(18° F) below OAT

CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIMETABLE CELL.

FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT.

TRANSPORT CANADA, JULY 1997

t1hot97.doc
9/3/97bm

https://www.tc.gc.ca/en/services/aviation/documents/HOT_1997.pdf

1997

No Mention of Heat, or Application quantity

TABLE 1

SAE TYPE I FLUID HOLDOVER TABLE

Guideline for Holdover Times Anticipated for SAE Type I Fluid Mixture as a Function of Weather Conditions and OAT

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Approximate Holdover Times Under Various Weather Conditions (hours : minutes)					
°C	°F	*FROST	FREEZING FOG	SNOW	**FREEZING DRIZZLE	LIGHT FREEZING RAIN	RAIN ON COLD SOAKED WING
above 0	above 32	0:45	0:12 - 0:30	0:06 - 0:15	0:05 - 0:08	0:02 - 0:05	0:02 - 0:05
0 to -10	32 to 14	0:45	0:06 - 0:15	0:06 - 0:15	0:05 - 0:08	0:02 - 0:05	
below -10	below 14	0:45	0:06 - 0:15	0:06 - 0:15			

°C = Degrees Celsius
°F = Degrees Farenheit
OAT = Outside Air Temperature
FP = Freezing Point

* During conditions that apply to aircraft protection for ACTIVE FROST
**Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

SAE Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10°C (18°F) below OAT

CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.

FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT

TRANSPORT CANADA, AUGUST 1998

1998

https://www.tc.gc.ca/en/services/aviation/documents/HOT_1998.pdf

No Mention of Heat, or Application quantity

TABLE 1

SAE TYPE I FLUID HOLDOVER TABLE

Guideline for Holdover Times Anticipated for SAE Type I Fluid Mixture as a Function of Weather Conditions and OAT

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
°C	°F	FROST[1]	FREEZING FOG	MODERATE SNOW	FREEZING DRIZZLE[2]	LIGHT FREEZING RAIN	RAIN ON COLD SOAKED WING	OTHER [3]
above 0	above 32	0:45	0:12 - 0:30	0:06 - 0:15	0:05 - 0:08	0:02 - 0:05	0:02 - 0:05	CAUTION : No holdover time guidelines exist
0 to -10	32 to 14	0:45	0:06 - 0:15	0:06 - 0:15	0:05 - 0:08	0:02 - 0:05		
below -10	below 14	0:45	0:06 - 0:15	0:06 - 0:15				

°C = Degrees Celsius
°F = Degrees Fahrenheit
OAT = Outside Air Temperature
FP = Freezing Point

NOTES

1 During conditions that apply to aircraft protection for ACTIVE FROST.
2 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
3 Heavy snow, snow pellets, snow grains, ice pellets, moderate and heavy freezing rain, and hail.

SAE Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10°C (18°F) below OAT.

CAUTIONS:
THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.
THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.

FLUIDS USED DURING GROUND DE-ICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT.

TRANSPORT CANADA , AUGUST 1999

https://www.tc.gc.ca/en/services/aviation/documents/HOT_1999.pdf

1999

Mention of Heat and Application quantity

TABLE 1-TC

TRANSPORT CANADA[4] TYPE I FLUID HOLDOVER TABLE

Guideline for Holdover Times Anticipated for Type I Fluid Mixture as a Function of Weather Conditions and OAT

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
°C	°F	FROST[1]	FREEZING FOG	MODERATE SNOW	FREEZING DRIZZLE[2]	LIGHT FREEZING RAIN	RAIN ON COLD SOAKED WING	OTHER[3]
above 0°	above 32°	0:45	0:12 - 0:30	0:06 - 0:15	0:05 - 0:08	0:02 - 0:05	0:02 - 0:05	
0 to -10	32 to 14	0:45	0:06 - 0:15	0:06 - 0:15	0:05 - 0:08	0:02 - 0:05	CAUTION: No holdover time guidelines exist	
below -10	below 14	0:45	0:06 - 0:15	0:06 - 0:15				

°C = Degrees Celsius OAT = Outside Air Temperature
°F = Degrees Fahrenheit FP = Freezing Point

NOTES

1 During conditions that apply to aircraft protection for ACTIVE FROST.
2 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
3 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain and hail.
4 This is a table for Type I Fluids as used in Canada and does not apply outside Canada.

Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10°C (18°F) below OAT.

CAUTIONS:

THIS TABLE IS FOR USE ONLY IN CANADA AND TO USE THESE TIMES, THE FLUID MUST BE HEATED TO A MINIMUM TEMPERATURE OF 60°C (140°F) AT THE NOZZLE AND AT LEAST 1LITRE/M² (2GALS/100FT²) MUST BE APPLIED TO SURFACES
THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.
THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.

FLUIDS USED DURING GROUND DE-ICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT.

TRANSPORT CANADA, JULY 2000

https://www.tc.gc.ca/en/services/aviation/documents/HOT_2000.pdf

2000

Mention of Heat and Application quantity

TRANSPORT CANADA HOLDOVER TIME GUIDELINES

TABLE 1-S1C

SAE TYPE I[5] FLUID HOLDOVER GUIDELINES FOR WINTER 2001-2002

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
°C	°F	Frost [2]	Freezing Fog	Snow	Freezing Drizzle [3]	Light Freezing Rain	Rain On Cold Soaked Wing	Other [4]
above 0	above 32	0:45	0:12 - 0:30	0:06 - 0:15 [1] *0:07 - 0:12*	0:05 - 0:08	0:02 - 0:05	0:02 - 0:05	CAUTION : No holdover time guidelines exist
0 to -10	32 to 14	0:45	0:06 - 0:15 [1] *0:06 - 0:11*	0:06 - 0:15 [1] *0:03 - 0:06*	0:05 - 0:08	0:02 - 0:05		
below -10	below 14	0:45	0:06 - 0:15 [1] *0:06 - 0:09*	0:06 - 0:15 [1] *0:02 - 0:04*				

°C = Degrees Celsius
°F = Degrees Fahrenheit
OAT = Outside Air Temperature
FP = Freezing Point

OBSOLETE
DÉSUET

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C(140°F) at the nozzle and an average rate of at least 1 litre/m² (2 gals/100ft²) must be applied to deiced surfaces, OTHERWISE THE ITALICISED TIMES MUST BE USED.
2 During conditions that apply to aircraft protection for ACTIVE FROST.
3 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
4 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
5 Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10°C(18°F) below OAT.

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.**
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **Fluids used during ground deicing do not provide ice protection during flight.**

Therefore, Transport Canada has determined that for this (2000/2001) winter icing season only, the previous year's (1999/2000) will be acceptable for use in Canada. However, the fluid must be applied at a minimum temperature of 60°C, and at a rate of at least 2 litres per square metre.

Extract from introductory guidance

TRANSPORT CANADA , AUGUST 2001

https://www.tc.gc.ca/en/services/aviation/documents/HOT_2001.pdf

2001

Mention of Heat and Application quantity

TRANSPORT CANADA HOLDOVER TIME GUIDELINES

TABLE 1S-3gm

SAE TYPE I[5] FLUID HOLDOVER GUIDELINES FOR WINTER 2002-2003

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Approximate Holdover Times Under Various Weather Conditions (minutes)							
°C	°F	Frost [2]	Freezing Fog	Light Snow [1]	Moderate Snow [1]	Freezing Drizzle [3]	Light Freezing Rain	Rain On Cold Soaked Wing	Other [4]
above -3	above 27	45	11 - 17	11 - 22[6]	6 - 11	9 - 13	2 - 5	2 - 5	
-3 to -10	27 to 14	45	6 - 10	6 - 13[6]	4 - 6	5 - 8	2 - 5	CAUTION : No holdover time guidelines exist	
below -10	below 14	45	5 - 9	4 - 8[6]	2 - 4				

°C = Degrees Celsius
°F = Degrees Fahrenheit
OAT = Outside Air Temperature
FP = Freezing Point

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C(140°F) at the nozzle and an average rate of at least 1 litre/m² (2 gals/100ft²) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER
2 During conditions that apply to aircraft protection for ACTIVE FROST.
3 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
4 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
5 Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10°C(18°F) below OAT.
6 The light snow range is based on precipitation rates from 1.0mm/hr to 0.3mm/hr liquid water equivalent

CAUTIONS:

- **The time of protection will be shortened in severe weather conditions, heavy precipitation rates or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.**
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **Fluids used during ground deicing do not provide ice protection during flight.**

TRANSPORT CANADA, MAY 2002

https://www.tc.gc.ca/en/services/aviation/documents/HOT_2002.pdf

2002

Mention of Heat and Application quantity

Transport Canada Holdover Time Guidelines **Winter 2003-2004**

TABLE 1

SAE TYPE I[5] FLUID HOLDOVER GUIDELINES FOR WINTER 2003-2004

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Approximate Holdover Times Under Various Weather Conditions (minutes)								
°C	°F	Frost[2]	Freezing Fog	Very Light Snow[1]	Light Snow[1]	Moderate Snow[1]	Freezing Drizzle[3]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[4]
-3 and above	27 and above	45	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	45	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	45	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	45	5 – 9	7	4 – 7	2 – 4				

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside Air Temperature FP = Freezing Point

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 L/m² (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 During conditions that apply to aircraft protection for ACTIVE FROST.
3 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
4 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
5 Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10°C (18°F) below OAT.

CAUTIONS

- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.**
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **Fluids used during ground deicing do not provide ice protection during flight.**

2003

https://www.tc.gc.ca/en/services/aviation/documents/HOT_2003-04E-O.pdf

Mention of Heat and Application quantity

Transport Canada Holdover Time Guidelines **Winter 2004-2005**

TABLE 1

SAE TYPE I[5] FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT[6]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
°C	°F	Frost[2]	Freezing Fog	Very Light Snow[1]	Light Snow[1]	Moderate Snow[1]	Freezing Drizzle[3]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[4]
-3 and above	27 and above	45	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	45	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	45	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	45	5 – 9	7	4 – 7	2 – 4				

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside Air Temperature FP = Freezing Point

OBSOLETE

NOTES
1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m² (2 gal./100 sq. ft.) must be applied to deiced surfaces. OTHERWISE TIMES WILL BE SHORTER.
2 During conditions that apply to aircraft protection for ACTIVE FROST.
3 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
4 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
5 Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10°C (18°F) below OAT.
6 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.**
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **Fluids used during ground deicing do not provide ice protection during flight.**

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_December_2004-2005-English_Obsolete.pdf

2004

Mention of Heat and Application quantity

Transport Canada Holdover Time Guidelines **Winter 2005-2006**

TABLE 1

SAE TYPE I[3] FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[5]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
				Snow or Snow Grains[1]						
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Very Light	Light	Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	45	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	45	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	45	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	45	5 – 9	7	4 – 7	2 – 4				

NOTES
1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m² (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2005-2006_English_Obsolete.pdf

2005

Mention of Heat and Application quantity

Transport Canada Holdover Time Guidelines **Winter 2006-2007**

TABLE 1

SAE TYPE I[3] FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[5]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
				Snow or Snow Grains[1]						
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Very Light	Light	Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	45	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	45	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	45	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	45	5 – 9	7	4 – 7	2 – 4				

NOTES
1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m² (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

2006

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2006-2007_Obsolete_English.pdf

Mention of Heat and Application quantity

Transport Canada Holdover Time Guidelines **Winter 2007-2008**

TABLE 1

SAE TYPE I[3] FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[5]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Snow or Snow Grains[1] Very Light	Snow or Snow Grains[1] Light	Snow or Snow Grains[1] Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	45	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	CAUTION: No holdover time guidelines exist
below -3 to -6	below 27 to 21	45	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6		
below -6 to -10	below 21 to 14	45	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	45	5 – 9	7	4 – 7	2 – 4				

OBSOLETE

NOTES
1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m² (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Page 6 of 40 October 2007

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2007-08_English_OBSOLETE_Revision_1-0.pdf

2007

Mention of Heat and Application quantity

Transport Canada Holdover Time Guidelines **Winter 2008-2009**

TABLE 1

SAE TYPE I[3] FLUID HOLDOVER GUIDELINES FOR WINTER 2008-2009

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[5]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Snow or Snow Grains[1] Very Light	Snow or Snow Grains[1] Light	Snow or Snow Grains[1] Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	45	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	CAUTION: No holdover time guidelines exist
below -3 to -6	below 27 to 21	45	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6		
below -6 to -10	below 21 to 14	45	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	45	5 – 9	7	4 – 7	2 – 4				

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m² (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Page 6 of 42 July 2008

2008

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2008-09_English_OBSOLETE.pdf

Mention of Heat and Application quantity

Transport Canada Holdover Time Guidelines **Winter 2009-2010**

TABLE 1

SAE TYPE I[3] FLUID HOLDOVER GUIDELINES FOR WINTER 2009-2010

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[5]		Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit	Freezing Fog	Snow or Snow Grains[1] Very Light[6]	Snow or Snow Grains[1] Light[6]	Snow or Snow Grains[1] Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
Below -10	below 14	5 – 9	7	4 – 7	2 – 4				

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/m² (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.
6 Use light freezing rain holdover times in conditions of light snow mixed with light rain.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Page 9 of 46 July 2009

2009

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2009-10_English_OBSOLETE.pdf

No Mention of Heat, or Application quantity

Transport Canada Holdover Time Guidelines **Winter 2010-2011**

TABLE 1

SAE TYPE I FLUID HOLDOVER GUIDELINES FOR WINTER 2010-2011[1]

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Wing Surface	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
			Freezing Fog	Snow, Snow Grains or Snow Pellets			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
Degrees Celsius	Degrees Fahrenheit			Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	Aluminum	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
		Composite	9 – 16	12	6 – 12	3 – 6	8 – 13	4 – 6	1 – 5	
below -3 to -6	below 27 to 21	Aluminum	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
		Composite	6 – 8	11	5 – 11	2 – 5	5 – 9	4 – 6		
below -6 to -10	below 21 to 14	Aluminum	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
		Composite	4 – 8	9	5 – 9	2 – 5	4 – 7	2 – 5		
below -10	below 14	Aluminum	5 – 9	7	4 – 7	2 – 4				
		Composite	4 – 7	7	4 – 7	2 – 4				

NOTES

1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2010-11_English_OBSOLETE.pdf

2010

No Mention of Heat, or Application quantity

Transport Canada Holdover Time Guidelines — Winter 2011-2012

TABLE 1-A

SAE TYPE I FLUID HOLDOVER GUIDELINES ON ALUMINUM WING SURFACES FOR WINTER 2011-2012[1]

This table applies to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit	Freezing Fog	Snow, Snow Grains or Snow Pellets: Very Light[3]	Snow, Snow Grains or Snow Pellets: Light[3]	Snow, Snow Grains or Snow Pellets: Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	CAUTION: No holdover time guidelines exist
below -3 to -6	below 27 to 21	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	5 – 9	7	4 – 7	2 – 4				

NOTES
1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2011-12_English_OBSOLETE.pdf

2011

No Mention of Heat, or Application quantity

Transport Canada Holdover Time Guidelines **Winter 2012-2013**

TABLE 1-A

SAE TYPE I FLUID HOLDOVER GUIDELINES ON ALUMINUM WING SURFACES FOR WINTER 2012-2013[1]

This table applies to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit	Freezing Fog	Snow, Snow Grains or Snow Pellets			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
			Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	CAUTION: No holdover time guidelines exist
below -3 to -6	below 27 to 21	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	5 – 9	7	4 – 7	2 – 4				

NOTES
1 Type I Fluid / Water Mixture is selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2012-13_Revision_1-0_OBSOLETE.pdf

2012

No Mention of Heat, or Application quantity

Transport Canada Holdover Time Guidelines — Winter 2013-2014

TABLE 1-A

SAE TYPE I FLUID HOLDOVER GUIDELINES ON ALUMINUM WING SURFACES FOR WINTER 2013-2014[1]

This table applies to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets: Very Light[3]	Snow, Snow Grains or Snow Pellets: Light[3]	Snow, Snow Grains or Snow Pellets: Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	CAUTION: No holdover time guidelines exist
below -3 to -6	below 27 to 21	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	5 – 9	7	4 – 7	2 – 4				

OBSOLETE

NOTES

1 Type I Fluid / Water Mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2013-14_OBSOLETE.pdf

2013

No Mention of Heat, or Application quantity

Transport Canada Holdover Time Guidelines **Winter 2014-2015**

TABLE 1-A

SAE TYPE I FLUID HOLDOVER GUIDELINES ON ALUMINUM WING SURFACES[1]

This table applies to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3] Very Light[4]	Snow, Snow Grains or Snow Pellets[3] Light[4]	Snow, Snow Grains or Snow Pellets[3] Moderate	Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
-3 and above	27 and above	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	5 – 9	7	4 – 7	2 – 4				

NOTES

1 Type I Fluid / Water Mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the visibility in snow vs. snowfall intensity table (Table 8) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2014-15_Revision_1-0_OBSOLETE.pdf

2014

No Mention of Heat, or Application quantity

Transport Canada Holdover Time Guidelines **Winter 2015-2016**

TABLE 1-A

SAE TYPE I FLUID HOLDOVER TIME GUIDELINES ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF ALUMINUM[1]

This table applies to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (minutes)							
			Snow, Snow Grains or Snow Pellets[3]						
Degrees Celsius	Degrees Fahrenheit	Freezing Fog or Ice Crystals	Very Light[4]	Light[4]	Moderate	Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
-3 and above	27 and above	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	
below -3 to -6	below 27 to 21	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	5 – 9	7	4 – 7	2 – 4				

NOTES

1 Type I Fluid / Water Mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2015-16_EN_Revision_1-0_OBSOLETE.pdf

2015

No Mention of Heat, or Application quantity

Transport Canada Holdover Time Guidelines **Winter 2016-2017**

TABLE 1-A

SAE TYPE I FLUID HOLDOVER TIME GUIDELINES ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF **ALUMINUM**[1]

These holdover times apply to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3] Very Light[4]	Light[4]	Moderate	Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
-3 and above	27 and above	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	CAUTION: No holdover time guidelines exist
below -3 to -6	below 27 to 21	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	5 – 9	7	4 – 7	2 – 4				

NOTES
1 Type I Fluid / Water Mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 7) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

Original Issue Page 20 of 107 Aug. 5, 2016

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2016-17_EN_Original_OBSOLETE.pdf

2016

No Mention of Heat, or Application quantity

Transport Canada Holdover Time Guidelines **Winter 2017-2018**

TABLE 2: HOLDOVER TIMES FOR SAE TYPE I FLUID ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF ALUMINUM

Outside Air Temperature[1,2]	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets[3,4]	Light Snow, Snow Grains or Snow Pellets[3,4]	Moderate Snow, Snow Grains or Snow Pellets[3]	Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
-3°C and above (27°F and above)	0:11 - 0:17	0:18	0:11 - 0:18	0:06 - 0:11	0:09 - 0:13	0:04 - 0:06	0:02 - 0:05	
below -3 to -6°C (below 27 to 21°F)	0:08 - 0:13	0:14	0:08 - 0:14	0:05 - 0:08	0:05 - 0:09	0:04 - 0:06	CAUTION: No holdover time guidelines exist	
below -6 to -10°C (below 21 to 14°F)	0:06 - 0:10	0:11	0:06 - 0:11	0:04 - 0:06	0:04 - 0:07	0:02 - 0:05		
below -10°C (below 14°F)	0:05 - 0:09	0:07	0:04 - 0:07	0:02 - 0:04				

NOTES

1 Type I fluid / water mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 40) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS

- These holdover times apply to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.
- The responsibility for the application of these data remains with the user.
- Takeoff after the longest applicable holdover time has been exceeded is not permitted for Type I fluids.
- The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.
- Fluids used during ground de/anti-icing do not provide in-flight icing protection.

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2017-18_EN_Revision_1_0_OBSOLETE.PDF

2017

No Mention of Heat, or Application quantity

Transport Canada Holdover Time Guidelines **Winter 2018-2019**

TABLE 2: HOLDOVER TIMES FOR SAE TYPE I FLUID ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF ALUMINUM

Outside Air Temperature[1,2]	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets[3,4]	Light Snow, Snow Grains or Snow Pellets[3,4]	Moderate Snow, Snow Grains or Snow Pellets[3]	Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
-3°C and above (27°F and above)	0:11 - 0:17	0:18	0:11 - 0:18	0:06 - 0:11	0:09 - 0:13	0:04 - 0:06	0:02 - 0:05	CAUTION: No holdover time guidelines exist
below -3 to -6°C (below 27 to 21°F)	0:08 - 0:13	0:14	0:08 - 0:14	0:05 - 0:08	0:05 - 0:09	0:04 - 0:06	CAUTION: No holdover time guidelines exist	
below -6 to -10°C (below 21 to 14°F)	0:06 - 0:10	0:11	0:06 - 0:11	0:04 - 0:06	0:04 - 0:07	0:02 - 0:05		
below -10°C (below 14°F)	0:05 - 0:09	0:07	0:04 - 0:07	0:02 - 0:04	CAUTION: No holdover time guidelines exist			

NOTES

1 Type I fluid / water mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 40) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Includes light, moderate and heavy freezing drizzle. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS

- These holdover times apply to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.
- The responsibility for the application of these data remains with the user.
- Takeoff after the longest applicable holdover time has been exceeded is not permitted for Type I fluids.
- The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.
- Fluids used during ground de/anti-icing do not provide in-flight icing protection.

[redacted]

https://www.tc.gc.ca/en/services/aviation/documents/HOT_Guidelines_2018-19_EN_Original_OBSOLETE.PDF

2018

No Mention of Heat, or Application quantity

Transport Canada Holdover Time Guidelines — Winter 2019-2020

TABLE 2: HOLDOVER TIMES FOR SAE TYPE I FLUID ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF ALUMINUM

Outside Air Temperature[1,2]	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets[3,4]	Light Snow, Snow Grains or Snow Pellets[3,4]	Moderate Snow, Snow Grains or Snow Pellets[3]	Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
-3°C and above (27°F and above)	0:11 - 0:17	0:18	0:11 - 0:18	0:06 - 0:11	0:09 - 0:13	0:04 - 0:06	0:02 - 0:05	CAUTION: No holdover time guidelines exist
below -3 to -6°C (below 27 to 21°F)	0:08 - 0:13	0:14	0:08 - 0:14	0:05 - 0:08	0:05 - 0:09	0:04 - 0:06	CAUTION: No holdover time guidelines exist	
below -6 to -10°C (below 21 to 14°F)	0:06 - 0:10	0:11	0:06 - 0:11	0:04 - 0:06	0:04 - 0:07	0:02 - 0:05		
below -10°C (below 14°F)	0:05 - 0:09	0:07	0:04 - 0:07	0:02 - 0:04	CAUTION: No holdover time guidelines exist			

NOTES

1 Type I fluid / water mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 43) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Includes light, moderate and heavy freezing drizzle. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS

- These holdover times apply to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.
- The responsibility for the application of these data remains with the user.
- Takeoff after the longest applicable holdover time has been exceeded is not permitted for Type I fluids.
- The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.
- Fluids used during ground de/anti-icing do not provide in-flight icing protection.

2019

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APPENDIX E

ANALYSIS REPORT:
INVESTIGATION OF HISTORICAL METAR REPORTS TO DETERMINE FREQUENCY OF WEATHER TYPES

CM2480.002

ANALYSIS REPORT: INVESTIGATION OF HISTORICAL METAR REPORTS TO DETERMINE FREQUENCY OF WEATHER TYPES

Summer 2020

Prepared by: Ian Wittmeyer

Reviewed by: Marco Ruggi

August 2020
Final Version 1.0

1. BACKGROUND

METARs are reported for most airports on an hourly basis with special reports (referred to as a SPECI) issued whenever a significant change in weather occurs. The METAR report will include current conditions including present weather conditions. Freely available multi-decade METAR archives now exist on the internet and this allows for a thorough analysis of present weather conditions reported therein. It was recommended that a preliminary analysis of this information be completed as a proof of concept to determine if this data could be used to support future development to the holdover time guidelines. This study goes one step further with an expanded analysis of wintertime weather conditions using cold season METAR data from ASOS sites in the United States and Canada.

2. ANALYSIS METHODOLOGY

METAR data used in this study were sourced from the GTA Surface METAR Data (METAR format) website (https://data.eol.ucar.edu/dataset/100.013) made available by the University Corporation for Atmospheric Research (UCAR) and the National Center for Atmospheric Research (NCAR).

Data was subsetted for the cold season months of November through April, from 2009 through 2019. Only stations with human weather observers and full ASOS capability were included. While some regional airports are included in the study, the focus is largely on busy core airports that experience a meaningful frequency of wintertime precipitation. A total of 65 US and 19 Canadian sites were selected (see Table 2.1). Southern US ASOS sites that see limited frozen precipitation were excluded. Memphis, TN (KMEM) is at the southern extent of this analysis.

The data includes hourly and SPECI reports. Due to the large number of clear or non-precipitation data points, as well as warmer data points not related to aircraft ground deicing, the analysis was further refined to weather conditions (including precipitation and obscuration types) where temperatures are below 2°C. The data were analysed to produce total counts and relative frequency of occurrence for every weather type and combination of types found in the data archive, for all US and all Canadian data respectively. Relative frequency data is calculated from two sets of data: 1) all data (shown as "% of Total Reports Below 2C" in the data tables below), and 2) a subset of all data reporting at least one weather type (shown as "% of Weather Reports Below 2C").

Note there are some incorrectly reported METARs in the database used, however these errors are primarily evident in the least frequent weather types. A full examination of the errors is beyond the scope of this study, but some effort has been placed on mitigating their inclusion in the results.

Table 2.1: List of Weather Stations included in this study

United States				Canada
KALB	KDLH	KMDT	KSLC	CYEG
KAPA	KDSM	KMDW	KSTL	CYFC
KARB	KDTW	KMEM	KSYR	CYHZ
KBDL	KEWR	KMHT	KTEB	CYMX
KBGR	KFSD	KMKE	KTVC	CYOW
KBIL	KFWA	KMKG	KYNG	CYQB
KBOS	KGEG	KMSN	PANC	CYQM
KBTV	KGFK	KMSP	PAFA	CYQR
KBUF	KGRR	KOMA		CYQT
KBWI	KGSO	KORD		CYQX
KCAK	KHPN	KPHL		CYSJ
KCLE	KIAD	KPIT		CYUL
KCMH	KICT	KPTK		CYWG
KCOS	KIND	KPVD		CYXE
KCRW	KISP	KPWM		CYXU
KCVG	KJFK	KRFD		CYYC
KDAY	KLAN	KROA		CYYG
KDCA	KLGA	KROC		CYYT
KDEN	KMCI	KSDF		CYYZ

3. DATA AND RESULTS

3.1 Weather Conditions Below 2°C – to Support HOT Tables

The data tables below report the most frequent weather conditions and combinations; however, data for every possible combination of weather conditions is available in the analysis data files and spreadsheets. Tables of results are presented below for the aggregate US and Canadian results, as well as four example airports (KJFK, CYUL, KSDF, and KMEM). In addition, data tables are provided for an airport with full time human augmentation (KDTW) and a nearby airport that reports part-time augmentation (KARB) in order to quantify the impact of the human augmented observation.

3.2 Aggregate US and Canadian Results

The tables below show the total number of reports for observations with no precipitation or obscuration, and then lists the most frequently reported weather conditions. Relative frequencies are also reported in two ways; for all reports and for reports that include precipitation and/or obscuration types. A comparison of columns 4 and 5 in Table 3.1 and Table 3.2 highlights differences between the most common aggregate US and Canada observations. Table data listed as "NF" in column 5 represent a weather condition not found. Differences in US vs Canadian software algorithms are likely responsible for significant frequency differences for many of the weather conditions listed, and it is recommended that further effort is placed on investigating these differences. Other differences are due to geographical differences.

The results indicate that light snow (-SN) represents the largest frequency of observations containing at least one weather condition below 2°C with a total of 31.46% in the United States compared with 36.61% in Canada. A number of weather types and combinations are present in the Canadian data and not in US data, and vice versa.

A large number of combinations of weather types is possible when considering the range of precipitation types and their intensity levels, as well as obscurations that are reported. In fact, we see that in the data. While only the most frequent types of conditions are shown in the tables below, the total number of types of conditions in the data used in this study is 645 in the US and 896 in Canada (including a few erroneous types from miscoded METARs). Many of these conditions were reported just a handful of times, or less. In fact, only 270 of the 645 US condition types were reported 5 or more times, and approximately 400 of the 896 Canadian types had 5 or more reports (see Table 3.3).

When considering mixed frozen precipitation types that are potentially important in improving HOT guidance, we still see a significant number of combinations reported in the data. If we consider all frozen precipitation types and include freezing fog (an obscuration considered in HOT guidance), there approximately 100 combinations of conditions reported in US METARs (among types reported 5 or more times), and approximately 130 in the Canadian data. A significant percentage of these are not covered by current HOT guidance.

Table 3.1: Frequency Distribution of Weather Conditions Below 2ºC – United States

	United States			Canada
Condition	Total Reports Below 2C	% of Total Reports Below 2C	% of Weather Reports Below 2C	% of Weather Reports Below 2C
	1172941	62.09	N/A	N/A
-SN	225329	11.93	31.46	36.61
-SN BR	202775	10.73	28.31	2.72
BR	93242	4.94	13.02	6.83
BLSN -SN	21324	1.13	2.98	3.08
HZ	16553	0.88	2.31	0.19
RA	16079	0.85	2.25	0.03
FZFG	13316	0.7	1.86	1.66
-RA BR	13061	0.69	1.82	1.34
FZFG SN	11530	0.61	1.61	0.02
-FZDZ BR	6477	0.34	0.9	1.17
-DZ BR	6194	0.33	0.86	0.78
-FZRA BR	6149	0.33	0.86	0.84
-RA	5711	0.3	0.8	1.08
FG	5647	0.3	0.79	0.48
BLSN	4647	0.25	0.65	0.41
SN	4078	0.22	0.57	0.84
-FZRA	3369	0.18	0.47	0.6
FZFG +SN	3351	0.18	0.47	0
SN FG	3348	0.18	0.47	0
BLSN SN	2622	0.14	0.37	0.48
-RA SN BR	2411	0.13	0.34	0.24
BCFG	2391	0.13	0.33	0.17
FZFG -SN	2332	0.12	0.33	0.12
RA BR	2233	0.12	0.31	0.08
-FZDZ	2148	0.11	0.3	0.34
BLSN -SNBR	2101	0.11	0.29	0.01
-SN PL BR	1881	0.1	0.26	0.03
-FZDZ SN BR	1835	0.1	0.26	0
BLSN +SN	1680	0.09	0.23	0.08
BCFG BR	1317	0.07	0.18	0.03
VCFG	1249	0.07	0.17	0.11
-SN RA BR	1235	0.07	0.17	0.01
-DZ	1232	0.07	0.17	0.22
-FZRA PL BR	1206	0.06	0.17	0
+SN	1126	0.06	0.16	0.15
-RA SN	1119	0.06	0.16	0.41
SN BR	1005	0.05	0.14	0
BLSN FZFG SN	805	0.04	0.11	0
UP	789	0.04	0.11	0.03

Table 3.2: Frequency Distribution of Weather Conditions Below 2°C – Canada

	Canada			United States
Condition	Total Reports Below 2C	% of Total Report Below 2C	% of Weather Reports Below 2C	% of Weather Reports Below 2C
	462138	56.21	N/A	N/A
-SN	131824	16.03	36.61	31.46
-SHSN	40185	4.89	11.16	0
DRSN -SN	28843	3.51	8.01	0
BR	24597	2.99	6.83	13.02
DRSN	17783	2.16	4.94	0
BLSN -SN	11102	1.35	3.08	2.98
-SN BR	9804	1.19	2.72	28.31
DRSN -SHSN	8105	0.99	2.25	NF
FZFG	5982	0.73	1.66	1.86
-RA BR	4812	0.59	1.34	1.82
IC	4258	0.52	1.18	0
-FZDZ BR	4213	0.51	1.17	0.9
-RA	3894	0.47	1.08	0.8
-FZRA BR	3029	0.37	0.84	0.86
SN	3023	0.37	0.84	0.57
-DZ BR	2825	0.34	0.78	0.86
VCSH	2649	0.32	0.74	0.01
BR -SN	2618	0.32	0.73	0.01
-FZRA	2147	0.26	0.6	0.47
BLSN -SHSN	1820	0.22	0.51	NF
FG	1727	0.21	0.48	0.79
BLSN SN	1714	0.21	0.48	0.37
BLSN	1478	0.18	0.41	0.65
-RA SN	1476	0.18	0.41	0.16
-SHSN BR	1470	0.18	0.41	NF
DRSN SN	1320	0.16	0.37	NF
-FZDZ	1223	0.15	0.34	0.3
-SG	1072	0.13	0.3	0
FG -DZ	1043	0.13	0.29	0
-FZDZ -SN	1023	0.12	0.28	NF
-FZDZ FZFG	994	0.12	0.28	0.03
BR -DZ	930	0.11	0.26	0
-RA SN BR	863	0.1	0.24	0.34
-FZRA -SN	856	0.1	0.24	NF
-SG BR	814	0.1	0.23	0
BR -RA	813	0.1	0.23	0
-DZ	809	0.1	0.22	0.17
HZ	689	0.08	0.19	2.31
-SHRA	653	0.08	0.18	0

Table 3.3: Summary of Weather Types

	USA	Canada
Total # of individual METAR weather types (2009-2019)	645	896
Number of weather types which were reported in at least 5 METARs (2009-2019)	270	400
Number of mixed precipitation types (including FZFG) reported in at least 5 METARs (2009-2019)	100	130

3.3 Frequency Distributions for Individual Sites

Data from four major airports are presented below. New York's JFK Airport (KJFK) is shown in Table 3.4, Montreal/Trudeau (CYUL) in Table 3.5, Louisville, KY (KSDF) in Table 3.6, and Memphis, TN (KMEM) in Table 3.7. Data tables for KJFK, KSDF and KMEM include a final column of frequency data based on all US aggregate weather reports below 2C for comparison, and Table 3.5 for CYUL includes a column from the aggregate Canada data.

When comparing the individual site results with the aggregate US frequencies in the following four tables, it is apparent there is a wide range of reported frequency for many of the weather conditions listed. The US and Canadian frequencies include a large and diverse set of climatological conditions given the large areas included in this study.

Table 3.4: Frequency Distribution of Weather Conditions Below 2°C – KJFK

	New York/JFK (KJFK)			United States
Condition	Total Reports Below 2C	% of Total Report Below 2C	% of Weather Reports Below 2C	% of Weather Reports Below 2C
	12481	80.99	N/A	N/A
-SN	985	6.39	33.63	31.46
-SN BR	831	5.39	28.37	28.31
-RA BR	106	0.69	3.62	1.82
BR	82	0.53	2.8	13.02
BLSN -SN	73	0.47	2.49	2.98
-RA	61	0.4	2.08	0.8
BLSN FZFG SN	55	0.36	1.88	0.11
-FZRA BR	52	0.34	1.78	0.86
FZFG SN	46	0.3	1.57	1.61
-SN PL BR	45	0.29	1.54	0.26
RA BR	33	0.21	1.13	0.31
-FZRA	33	0.21	1.13	0.47
-FZDZ BR	33	0.21	1.13	0.9
BLSN -SNBR	31	0.2	1.06	0.29
SN FG	29	0.19	0.99	0.47
BLSN FZFG +SN	27	0.18	0.92	0.09
SN	24	0.16	0.82	0.57
HZ	24	0.16	0.82	2.31
-DZ BR	24	0.16	0.82	0.86
FZFG +SN	21	0.14	0.72	0.47
-SN RA BR	20	0.13	0.68	0.17
-RA SN BR	18	0.12	0.61	0.34
-FZRA PL	16	0.1	0.55	0.11
-FZRA PL BR	16	0.1	0.55	0.17
-FZDZ	16	0.1	0.55	0.3
-SN PL	13	0.08	0.44	0.1
-RA PL BR	13	0.08	0.44	0.07
-PL BR	11	0.07	0.38	0.09
-SN RA	10	0.06	0.34	0.04
PL BR	9	0.06	0.31	0.06
FG	9	0.06	0.31	0.79
-PL RA BR	9	0.06	0.31	0.05
-FZRA SN BR	9	0.06	0.31	0.11
BLSN	8	0.05	0.27	0.65
BLSN SN	8	0.05	0.27	0.37
BLSN FZFG -SN	8	0.05	0.27	0.04
-PL RA	7	0.05	0.24	0.04
+SN	7	0.05	0.24	0.16
FZRA BR	6	0.04	0.2	0.1

Table 3.5: Frequency Distribution of Weather Conditions Below 2°C – CYUL

	Montreal/Trudeau (CYUL)			Canada
Condition	Total Reports Below 2C	% of Total Reports Below 2C	% of Weather Reports Below 2C	% of Weather Reports Below 2C
	21415	55.15	N/A	N/A
-SN	8613	22.18	49.46	36.61
DRSN -SN	1903	4.9	10.93	8.01
-SHSN	839	2.16	4.82	11.16
-SN BR	792	2.04	4.55	2.72
DRSN	732	1.89	4.2	4.94
BR	701	1.81	4.03	6.83
BLSN -SN	660	1.7	3.79	3.08
-RA BR	217	0.56	1.25	1.34
-RA	209	0.54	1.2	1.08
BR -SN	185	0.48	1.06	0.73
-FZRA	182	0.47	1.05	0.6
-DZ BR	181	0.47	1.04	0.78
-FZDZ BR	165	0.42	0.95	1.17
DRSN -SHSN	162	0.42	0.93	2.25
-FZRA BR	151	0.39	0.87	0.84
VCSH	135	0.35	0.78	0.74
-RA SN	99	0.25	0.57	0.41
-FZDZ	75	0.19	0.43	0.34
-FZDZ -SN	74	0.19	0.42	0.28
-DZ	69	0.18	0.4	0.22
BLSN SN	61	0.16	0.35	0.48
SN	57	0.15	0.33	0.84
-FZDZ -SN BR	57	0.15	0.33	0.13
BR -DZ	53	0.14	0.3	0.26
HZ	52	0.13	0.3	0.19
FZFG	50	0.13	0.29	1.66
DRSN SN	48	0.12	0.28	0.37
BLSN -SHSN	48	0.12	0.28	0.51
-FZRA -SN	48	0.12	0.28	0.24
-SN HZ	46	0.12	0.26	0.02
-SN PL	44	0.11	0.25	0.12
-SN RA	39	0.1	0.22	0.05
-DZ SN BR	32	0.08	0.18	0.06
-PL SN	28	0.07	0.16	0.11
FG	26	0.07	0.15	0.48
VCSH DRSN	24	0.06	0.14	0.1
-PL BR	22	0.06	0.13	0.05
-SHSN BR	21	0.05	0.12	0.41
BR -RA	20	0.05	0.11	0.23

Table 3.6: Frequency Distribution of Weather Conditions Below 2°C – KSDF

	Louisville, KY (KSDF)			United States
Condition	Total Reports Below 2C	% of Total Reports Below 2C	% of Weather Reports Below 2C	% of Weather Reports Below 2C
	10934	65.68	N/A	N/A
-SN	2034	12.22	35.6	31.46
-SN BR	1414	8.49	24.75	28.31
BR	797	4.79	13.95	13.02
HZ	375	2.25	6.56	2.31
-RA BR	100	0.6	1.75	1.82
-FZRA BR	84	0.5	1.47	0.86
-DZ BR	61	0.37	1.07	0.86
FZFG SN	57	0.34	1	1.61
-FZRA	53	0.32	0.93	0.47
-RA	52	0.31	0.91	0.8
FZFG	44	0.26	0.77	1.86
-DZ	43	0.26	0.75	0.17
-SN PL BR	38	0.23	0.67	0.26
-FZRA PL BR	37	0.22	0.65	0.17
BLSN -SN	35	0.21	0.61	2.98
FG	30	0.18	0.53	0.79
-FZDZ BR	29	0.17	0.51	0.9
FZFG +SN	26	0.16	0.46	0.47
SN	24	0.14	0.42	0.57
-RA SN BR	24	0.14	0.42	0.34
-FZRA SN BR	23	0.14	0.4	0.11
SN FG	21	0.13	0.37	0.47
-SN PL	21	0.13	0.37	0.1
-RA PL BR	20	0.12	0.35	0.07
-PL RA BR	18	0.11	0.32	0.05
RA BR	15	0.09	0.26	0.31
-SN RA BR	15	0.09	0.26	0.17
-RA SN	15	0.09	0.26	0.16
FZRA BR	14	0.08	0.25	0.1
-SN HZ	12	0.07	0.21	0.04
+SN	12	0.07	0.21	0.16
FZRA	10	0.06	0.18	0.03
FZFG -SN	10	0.06	0.18	0.33
-FZRA PL	10	0.06	0.18	0.11
-FZDZ SN BR	9	0.05	0.16	0.26
-FZRA SN	8	0.05	0.14	0.06
-FZRA SN PL	8	0.05	0.14	0.01
-FZDZ	7	0.04	0.12	0.3
PL BR	6	0.04	0.11	0.06

Table 3.7: Frequency Distribution of Weather Conditions Below 2°C – KMEM

Condition	Memphis, TN (KMEM) Total Reports Below 2C	Memphis, TN (KMEM) % of Total Reports Below 2C	Memphis, TN (KMEM) % of Weather Reports Below 2C	United States % of Weather Reports Below 2C
	7126	83.31	N/A	N/A
-SN BR	325	3.8	22.76	28.31
BR	309	3.61	21.64	13.02
-SN	209	2.44	14.64	31.46
-RA BR	70	0.82	4.9	1.82
RA BR	61	0.71	4.27	0.31
-RA	57	0.67	3.99	0.8
-FZRA BR	48	0.56	3.36	0.86
-FZRA	42	0.49	2.94	0.47
HZ	30	0.35	2.1	2.31
-DZ BR	28	0.33	1.96	0.86
-FZDZ BR	22	0.26	1.54	0.9
FZFG SN	17	0.2	1.19	1.61
-PL SN BR	14	0.16	0.98	0.07
FZFG	13	0.15	0.91	1.86
FZRA BR	12	0.14	0.84	0.1
-PL	11	0.13	0.77	0.08
-PL BR	10	0.12	0.7	0.09
-FZRA PL	9	0.11	0.63	0.11
-FZRA PL BR	9	0.11	0.63	0.17
RA	8	0.09	0.56	2.25
PL BR	8	0.09	0.56	0.06
-SN PL BR	8	0.09	0.56	0.26
+RA BR	7	0.08	0.49	0.04
+PL SN BR	7	0.08	0.49	0
TSRA BR	6	0.07	0.42	0.01
-FZDZ	6	0.07	0.42	0.3
GS BR	5	0.06	0.35	0.01
FZRA PL BR	5	0.06	0.35	0.03
+TSRA BR	5	0.06	0.35	0.01
SN FG	4	0.05	0.28	0.47
FZRA	4	0.05	0.28	0.03
FG	4	0.05	0.28	0.79
TSRA	3	0.04	0.21	0
PL	3	0.04	0.21	0.02
PL RA BR	3	0.04	0.21	0.02
GS	3	0.04	0.21	0.01
FZFG +SN	3	0.04	0.21	0.47
-TSRA	3	0.04	0.21	0
-SN RA BR	3	0.04	0.21	0.17

3.4 Comparison of Nearby Stations with Different Human Augmentation Capability

Since there is a range of observational capability at airports across North America, it is perhaps instructive to report a comparison of data from two ASOS stations that are nearly collocated. Detroit International (KDTW) and Ann Arbor Municipal (KARB) are separated by a distance of just 20 miles, and should exhibit similar weather climatologies over long periods of time. Both airports have full ASOS capability. Given the 11-season timeframe of this study, differences in weather type frequency should largely be an indication of the impact of human augmentation/monitoring at the larger airport, KDTW. While automatic weather observations recorded via the ASOS are monitored and augmented around the clock at KDTW, this is the case only ~ 50% of the time at KARB where human augmentation is available primarily just during the daylight hours. While there is a diurnal cycle in some wintertime weather types, comparing frequency of weather reports below 2°C may largely be explained by the different level of human oversight.

Column 4 in Table 3.8 shows the frequency of all observations containing at least one weather type, and column 5 reports the same data from KTDW for comparison. There are significant differences for a number of conditions, most notably light snow and light snow with mist. Freezing fog with either moderate or heavy snow is much more frequently reported at KDTW. A number of much less common weather conditions reported at KDTW are almost never observed at KARB (BLSN –SN, -FZDZ BR, -DZ BR, -SN PL BR, etc). These differences are likely due to the human observer amending the automatically-generated weather observations reported by ASOS.

Column 5 in Table 3.8 shows a lower frequency for most weather types observed at KARB compared to those at KDWT (in column 4). This is further illustrated by comparing the top weather types at KARB in column 4 of Table 3.9 with column 5 data from KDTW. Most KARB weather types are less frequent at KARB than at KDTW. Notably every one of the top weather conditions at KDTW is also present in the data record at KARB. Likewise for KARB when compared to KDTW. Note that frequencies reported as 0 are rounded down and are derived from a non-zero number of reports. The primary result of the comparison of data from these two airports is that human augmentation is likely responsible for a greater diversity and frequency of weather types at KDTW.

Table 3.8: Frequency Distribution of Weather Conditions Below 2ºC – KDTW vs KARB

	Detroit, MI (KDTW)			Ann Arbor, MI (KARB)
Condition	Total Reports Below 2C	% of Total Reports Below 2C	% of Weather Reports Below 2C	% of Weather Reports Below 2C
	18848	57.08	N/A	N/A
-SN	5622	17.03	39.67	20.27
-SN BR	3779	11.44	26.67	35.68
BR	1737	5.26	12.26	32.44
HZ	832	2.52	5.87	2.56
BLSN -SN	482	1.46	3.4	0
-RA BR	269	0.81	1.9	0.9
FZFG SN	208	0.63	1.47	0.53
-FZDZ BR	107	0.32	0.76	0
-FZRA BR	101	0.31	0.71	0.51
FG	84	0.25	0.59	1.36
FZFG +SN	80	0.24	0.56	0.07
FZFG	77	0.23	0.54	2.9
-RA	60	0.18	0.42	0.37
-FZRA	49	0.15	0.35	0.24
SN	45	0.14	0.32	0.02
-DZ BR	43	0.13	0.3	0
-SN PL BR	42	0.13	0.3	0
SN FG	38	0.12	0.27	0.08
RA BR	37	0.11	0.26	0.3
BLSN	33	0.1	0.23	0
BLSN SN	30	0.09	0.21	0
-RA SN BR	26	0.08	0.18	0
-FZDZ	24	0.07	0.17	0
BLSN +SN	18	0.05	0.13	0
FZRA BR	17	0.05	0.12	0.19
MIFG BR	16	0.05	0.11	0
-FZRA PL BR	15	0.05	0.11	0
BLSN FZFG SN	14	0.04	0.1	0
-SN PL	14	0.04	0.1	0
-FZDZ SN BR	14	0.04	0.1	0
-FZDZ SN	13	0.04	0.09	0
+SN	13	0.04	0.09	0
-PL SN BR	12	0.04	0.08	0
-FZRA SN BR	11	0.03	0.08	0
FZRA	10	0.03	0.07	0.07
-SN RA BR	10	0.03	0.07	0
-FZRA PL	10	0.03	0.07	0
+SN FG	9	0.03	0.06	0
FZRA PL BR	8	0.02	0.06	0

Table 3.9: Frequency Distribution of Weather Conditions Below 2°C – KARB vs KDTW

	Ann Arbor, MI (KARB)			Detroit, MI (KDTW)
Condition	Total Reports Below 2C	% of Total Reports Below 2C	% of Weather Reports Below 2C	% of Weather Reports Below 2C
	14574	62.49	N/A	N/A
-SN BR	3122	13.39	35.68	26.67
BR	2838	12.17	32.44	12.26
-SN	1773	7.6	20.27	39.67
FZFG	254	1.09	2.9	0.54
HZ	224	0.96	2.56	5.87
FG	119	0.51	1.36	0.59
-RA BR	79	0.34	0.9	1.9
UP BR	61	0.26	0.7	0.01
FZFG SN	46	0.2	0.53	1.47
-FZRA BR	45	0.19	0.51	0.71
UP	40	0.17	0.46	0.01
-RA	32	0.14	0.37	0.42
RA BR	26	0.11	0.3	0.26
-FZRA	21	0.09	0.24	0.35
FZRA BR	17	0.07	0.19	0.12
SN FG	7	0.03	0.08	0.27
RA	6	0.03	0.07	0.01
FZRA	6	0.03	0.07	0.07
FZFG +SN	6	0.03	0.07	0.56
SQ	4	0.02	0.05	0
-SN BR SQ	4	0.02	0.05	0
FZFG -SN	3	0.01	0.03	0.02
VCTS UP BR	2	0.01	0.02	0
VCTS -RA FG	2	0.01	0.02	0
SN	2	0.01	0.02	0.32
+RA	2	0.01	0.02	0.01
VCTS -RA BR	1	0	0.01	0
TSRA BR	1	0	0.01	0.01
BR -SN	1	0	0.01	0.01
-TSRA BR	1	0	0.01	0.01
-SN FG	1	0	0.01	0.02
-RA FG	1	0	0.01	0.06
+RA FG	1	0	0.01	0
+RA BR	1	0	0.01	0.04

4. CONCLUSIONS AND RECOMMENDATIONS

This analysis has utilized the METAR dataset obtained from UCAR/NCAR to provide some valuable insight into the frequency distribution of weather types.

This study examines a large sample of data collected primarily at the major US and Canadian airports that experience wintertime precipitation. Frequency distributions for aggregate US and Canadian data are and presented for most commonly occurring weather conditions. Additionally, frequency distributions for a small selection of individual sites are presented to show variability and regional differences. Further investigation is needed into the differences in algorithms which produce large differences in the frequency of some weather types reported in the US vs Canada.

Additional insight may be gained by expanding the use of METARS in other countries, and using data from sites with lower levels of observation capability in the U.S. (i.e, AWOS). More focussed analysis could involve investigating the distribution of weather conditions over time at key airports to better determine the duration of weather events.

Further analysis is suggested for mixed precipitation types not currently included in HOT guidance. Likewise, a number of conditions involving mist and fog should be investigated. In summary, our goal is to improve understanding of less common weather conditions not currently included in the HOT guidance.

A proposed plan for moving forward is provided below.

i. Review analysis methodology and modify/expand if necessary.
ii. Meet with TC/FAA to discuss updates to HOT guidance.
iii. Work with TC/FAA to determine which conditions can be associated with existing holdover time guidance, and which conditions need testing or analysis. The end goal is to provide a METAR to HOT Table Condition lookup table providing a comprehensive map that pilots can use.
iv. Issue changes to guidance material as necessary.
v. Report and present on results.

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APPENDIX F

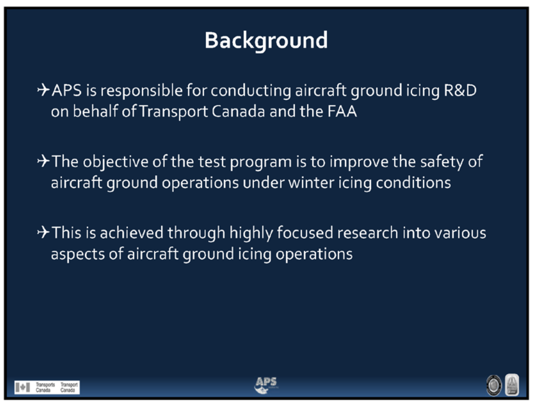
PRESENTATIONS, FLUID MANUFACTURER REPORTS, AND TEST PROCEDURES FOR 2019-20

STANDING COMMITTEE FOR OPERATIONS UNDER ICING CONDITIONS MEETING, OTTAWA, CANADA, OCTOBER 2019

**PRESENTATION:
GROUND ICING RESEARCH PROGRAM PROJECTS AND INITIATIVES**


Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS
Ground Icing Research Program
Projects and Initiatives
SCOUIC, Ottawa, October 30, 2019
Marco Ruggi, Eng., M.B.A., Senior Project Leader


Outline
Background
Projects and Initiatives
– Vertical Stabilizer and High Angle Surfaces
– Ice Pellet Allowance Times
– Snow Allowance Times
– HOTs for Very Cold Snow
– Other Research
Way Forward


Background
APS is responsible for conducting aircraft ground icing R&D on behalf of Transport Canada and the FAA
The objective of the test program is to improve the safety of aircraft ground operations under winter icing conditions
This is achieved through highly focused research into various aspects of aircraft ground icing operations


Major Program Elements
Fluids
Weather
Aircraft Performance
Operations
Sensors
Information Dissemination


Primary Research Facilities
TC/APS MONTREAL AIRPORT (YUL) TEST SITE FACILITY
NRC OTTAWA CLIMATIC ENGINEERING FACILITY
NRC OTTAWA PROPULSION ICING WIND TUNNEL FACILITY (PIWT)

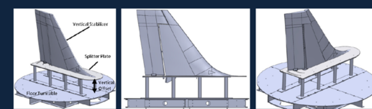

Vertical Stabilizer and High Angle Surfaces

V-Stab Research Program

- Initiated in 2015-16 by FAA, TC, NASA, and APS
- Identified 3 research objectives:
  - Pre-deicing study of contamination on on the tail
  - Post-deicing study of contamination on on the tail
  - Evaluate optimal deicing procedures and mitigation plans
- Study found that:
  - V-Stab generally not contaminated pre-deicing
  - Fluid protection times were generally reduced on V-Stab
  - Contamination is weather dependent (i.e. dry vs. wet snow)
- Additional tests in 2018-19 focusing on mixed conditions

Upcoming V-Stab Research

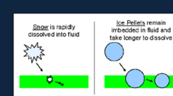
- Wind Tunnel Testing at NRC IWT
  - Salvaged Piper PA34 200T Seneca II tail model
  - NRC design completed and fabrication underway
  - Testing planned for Jan/Feb 2020



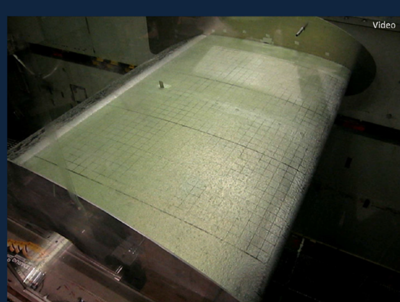
- Tests will include symmetric and asymmetric contamination, and different cross winds

Ice Pellets - Background

- Standard HOT testing does not apply to ice pellets due to different failure mechanism
  - By standard HOT definition, fluid is almost instantly failed due to presence of slow melting ice pellets

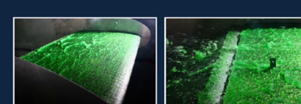


- Since 2004-05, TC/FAA have been conducting yearly or bi-yearly aerodynamic testing to support the development of the ice pellet allowance times

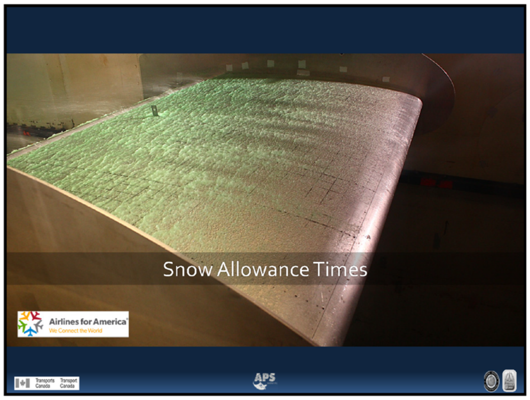


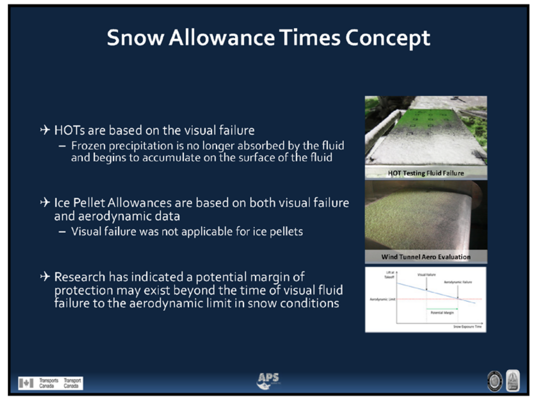
Allowance Time Research

- The focus of the 2017-18/2018-19 research was on:
  - Validating Allowance Times for 7 New Type IV Fluids
  - Evaluating the potential for an EG specific table
  - Developing Low Speed Allowance Times for Type III fluid



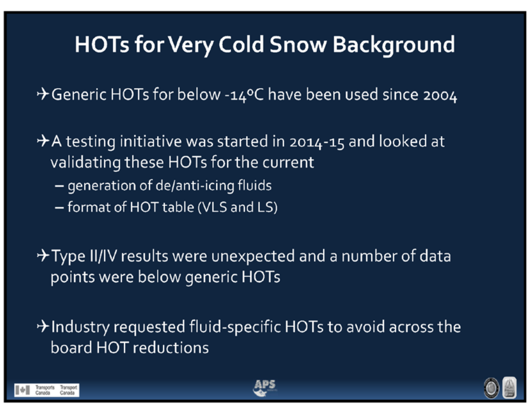
- Continued research is planned for Jan-Feb 2020

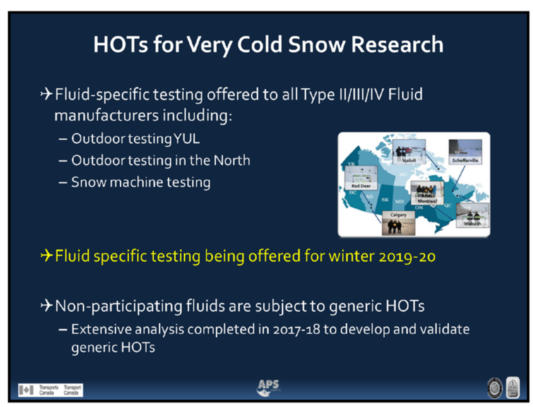

Snow Allowance Times
Airlines for America

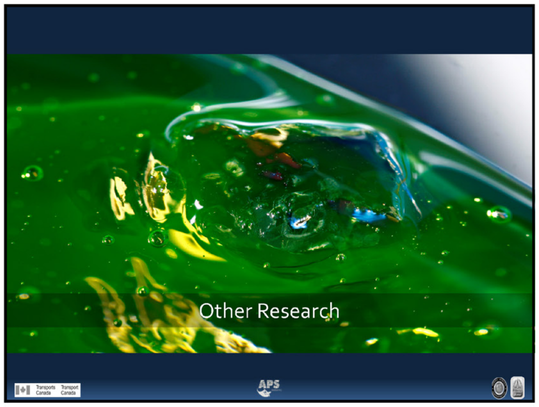

Snow Allowance Times Concept
HOTs are based on the visual failure
– Frozen precipitation is no longer absorbed by the fluid and begins to accumulate on the surface of the fluid
Ice Pellet Allowances are based on both visual failure and aerodynamic data
– Visual failure was not applicable for ice pellets
Research has indicated a potential margin of protection may exist beyond the time of visual fluid failure to the aerodynamic limit in snow conditions
HOT Testing Fluid Failure
Wind Tunnel Aero Evaluation
APS


2018-19 A4A Funded Research
Research imitative was led by A4A
– Contracted APS with support of NRC
– TC/FAA participated as observers
Results indicated that
– Visual failure (and related holdover time) is not always equal to the aerodynamic performance , and
– Some margins may exist dependent on specific variables
Industry discussions are expected to continue to discuss operational implications and way forward
Airlines for America
APS
Canada
NRC CNRC

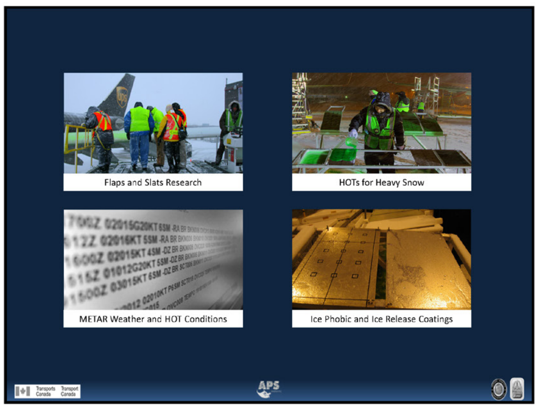

HOTs for Very Cold Snow
APS

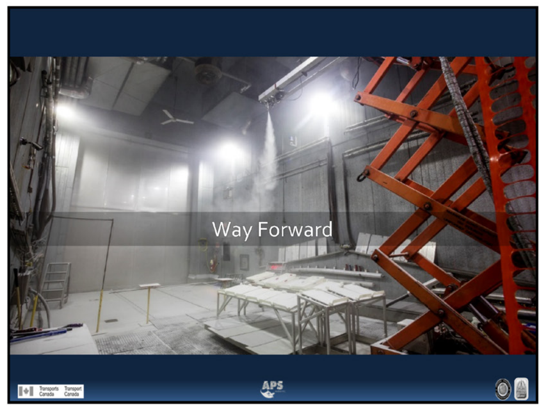

HOTs for Very Cold Snow Background
Generic HOTs for below -14°C have been used since 2004
A testing initiative was started in 2014-15 and looked at validating these HOTs for the current
– generation of de/anti-icing fluids
– format of HOT table (VLS and LS)
Type II/IV results were unexpected and a number of data points were below generic HOTs
Industry requested fluid-specific HOTs to avoid across the board HOT reductions
APS

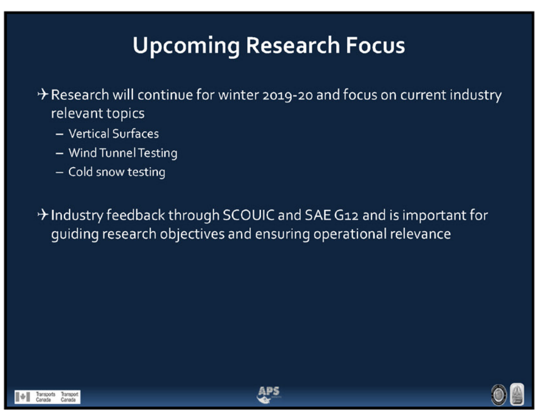

HOTs for Very Cold Snow Research
Fluid-specific testing offered to all Type II/III/IV Fluid manufacturers including:
– Outdoor testing YUL
– Outdoor testing in the North
– Snow machine testing
Fluid specific testing being offered for winter 2019-20
Non-participating fluids are subject to generic HOTs
– Extensive analysis completed in 2017-18 to develop and validate generic HOTs
APS

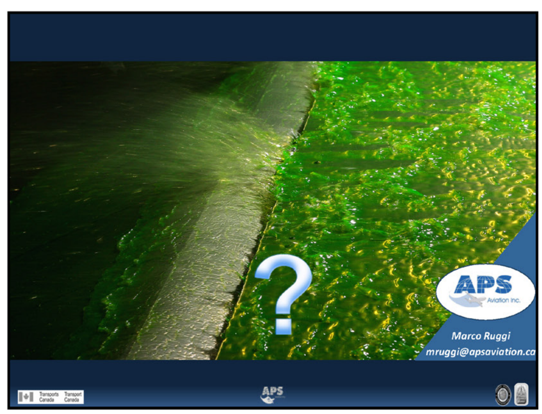

Other Research


Snow Machine Research
(separate presentation)


Flaps and Slats Research
HOTs for Heavy Snow
METAR Weather and HOT Conditions
Ice Phobic and Ice Release Coatings


Way Forward


Upcoming Research Focus
Research will continue for winter 2019-20 and focus on current industry relevant topics
– Vertical Surfaces
– Wind Tunnel Testing
– Cold snow testing
Industry feedback through SCOUIC and SAE G12 and is important for guiding research objectives and ensuring operational relevance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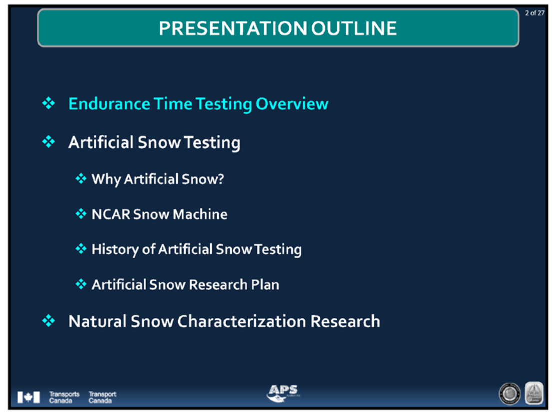
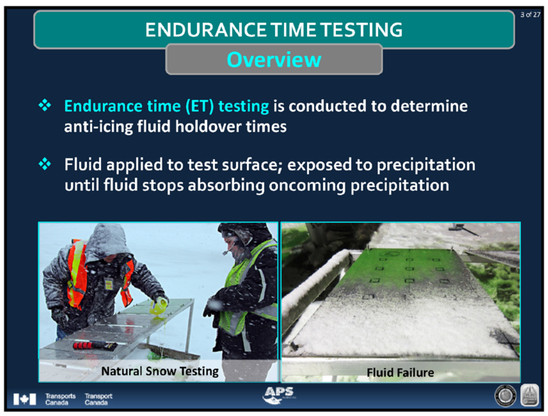
APS
Aviation Inc.
Marco Ruggi
mruggi@apsaviation.ca

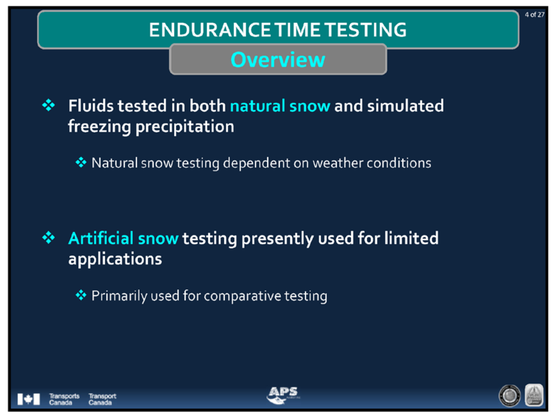
STANDING COMMITTEE FOR OPERATIONS UNDER ICING CONDITIONS
MEETING, OTTAWA, CANADA, OCTOBER 2019

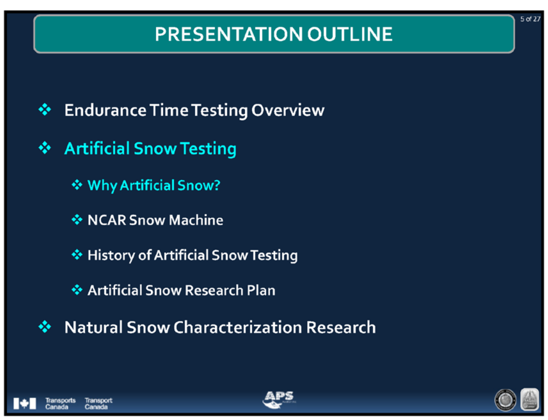
PRESENTATION:
ARTIFICIAL SNOW RESEARCH FOR HOLDOVER TIME DEVELOPMENT


ARTIFICIAL SNOW RESEARCH
FOR HOLDOVER TIME DEVELOPMENT
APS
SCOUIC 2019 · Ottawa, ON – Oct 30th, 2019
Presented By: Benjamin Bernier – APS Aviation


2 of 27
PRESENTATION OUTLINE
Endurance Time Testing Overview
Artificial Snow Testing
Why Artificial Snow?
NCAR Snow Machine
History of Artificial Snow Testing
Artificial Snow Research Plan
Natural Snow Characterization Research


3 of 27
ENDURANCE TIME TESTING
Overview
Endurance time (ET) testing is conducted to determine anti-icing fluid holdover times
Fluid applied to test surface; exposed to precipitation until fluid stops absorbing oncoming precipitation
Natural Snow Testing
Fluid Failure


4 of 27
ENDURANCE TIME TESTING
Overview
Fluids tested in both natural snow and simulated freezing precipitation
Natural snow testing dependent on weather conditions
Artificial snow testing presently used for limited applications
Primarily used for comparative testing


5 of 27
PRESENTATION OUTLINE
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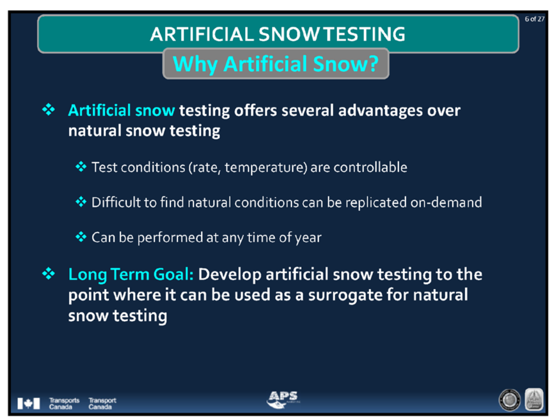
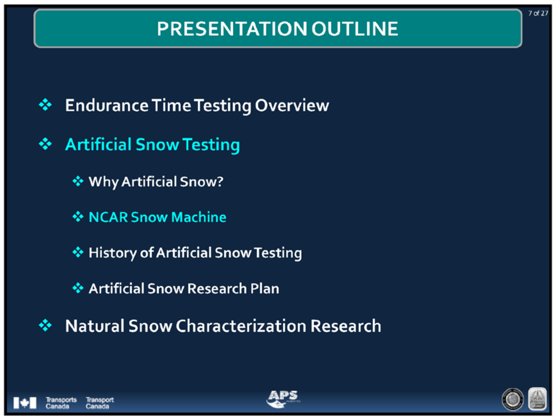

6 of 27
ARTIFICIAL SNOW TESTING
Why Artificial Snow?
Artificial snow testing offers several advantages over natural snow testing
Test conditions (rate, temperature) are controllable
Difficult to find natural conditions can be replicated on-demand
Can be performed at any time of year
Long Term Goal: Develop artificial snow testing to the point where it can be used as a surrogate for natural snow testing


7 of 27
PRESENTATION OUTLINE
Endurance Time Testing Overview
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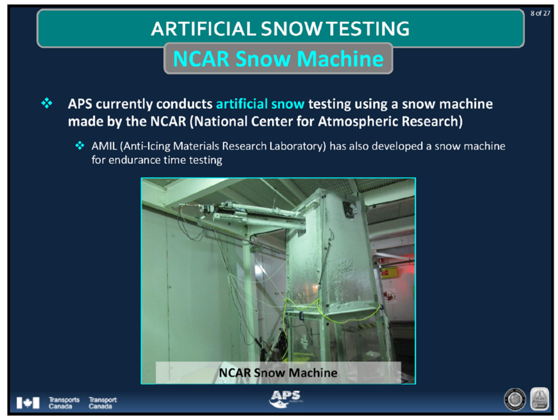
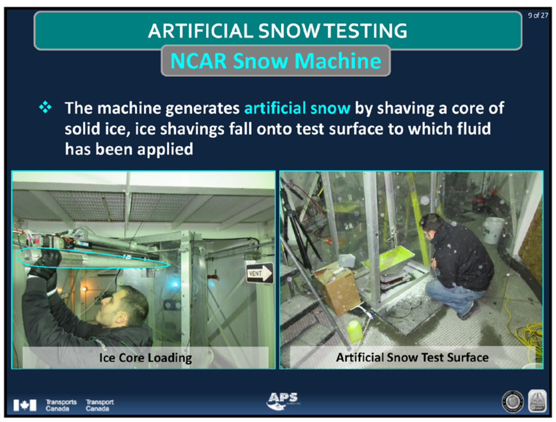
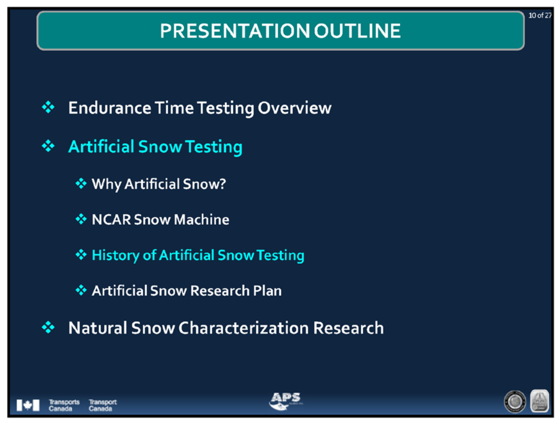
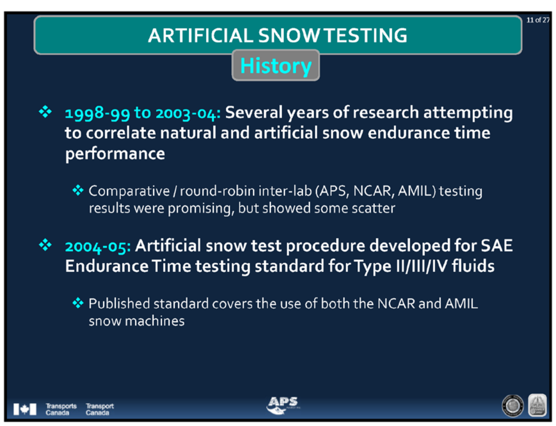
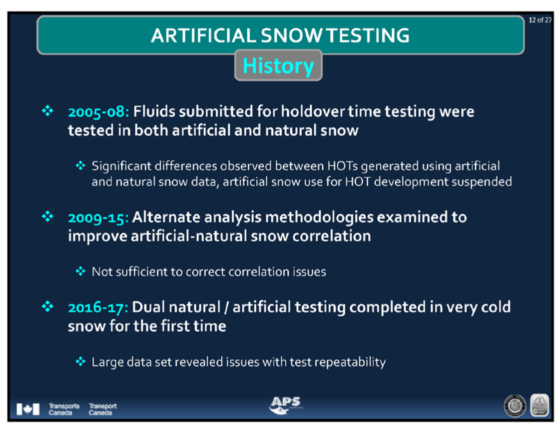
Natural Snow Characterization Research
APS

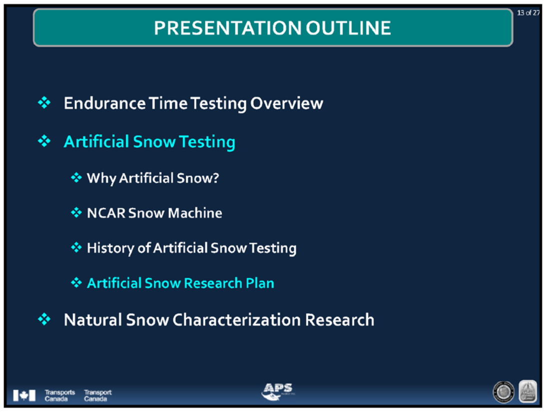

8 of 27
ARTIFICIAL SNOW TESTING
NCAR Snow Machine
APS currently conducts artificial snow testing using a snow machine made by the NCAR (National Center for Atmospheric Research)
AMIL (Anti-Icing Materials Research Laboratory) has also developed a snow machine for endurance time testing
NCAR Snow Machine
APS


9 of 27
ARTIFICIAL SNOW TESTING
NCAR Snow Machine
The machine generates artificial snow by shaving a core of solid ice, ice shavings fall onto test surface to which fluid has been applied
Ice Core Loading
Artificial Snow Test Surface
APS


10 of 27
PRESENTATION OUTLINE
Endurance Time Testing Overview
Artificial Snow Testing
Why Artificial Snow?
NCAR Snow Machine
History of Artificial Snow Testing
Artificial Snow Research Plan
Natural Snow Characterization Research
APS


11 of 27
ARTIFICIAL SNOW TESTING
History
1998-99 to 2003-04: Several years of research attempting to correlate natural and artificial snow endurance time performance
Comparative / round-robin inter-lab (APS, NCAR, AMIL) testing results were promising, but showed some scatter
2004-05: Artificial snow test procedure developed for SAE Endurance Time testing standard for Type II/III/IV fluids
Published standard covers the use of both the NCAR and AMIL snow machines
APS


12 of 27
ARTIFICIAL SNOW TESTING
History
2005-08: Fluids submitted for holdover time testing were tested in both artificial and natural snow
Significant differences observed between HOTs generated using artificial and natural snow data, artificial snow use for HOT development suspended
2009-15: Alternate analysis methodologies examined to improve artificial-natural snow correlation
Not sufficient to correct correlation issues
2016-17: Dual natural / artificial testing completed in very cold snow for the first time
Large data set revealed issues with test repeatability
APS


13 of 27
PRESENTATION OUTLINE
Endurance Time Testing Overview
Artificial Snow Testing
Why Artificial Snow?
NCAR Snow Machine
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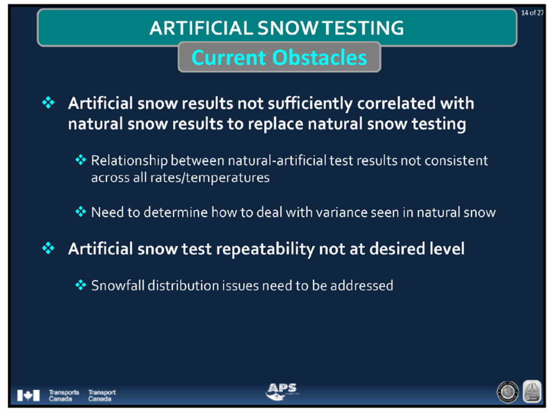
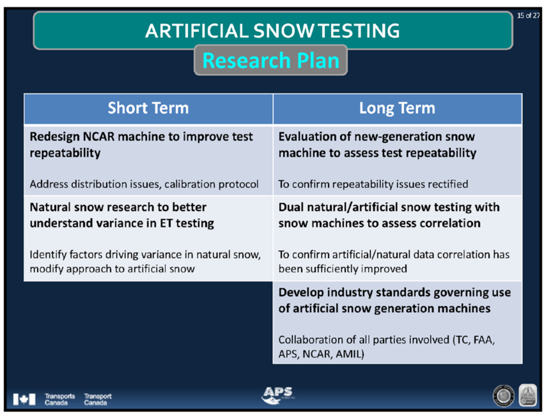
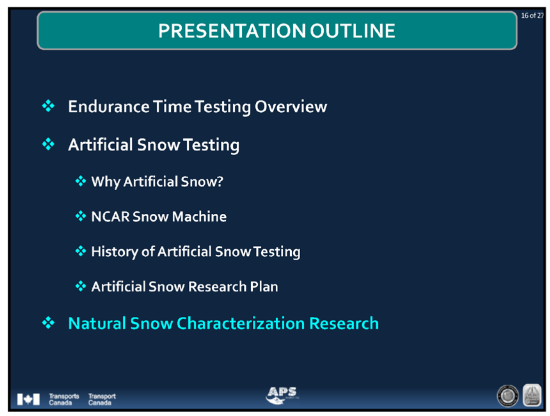
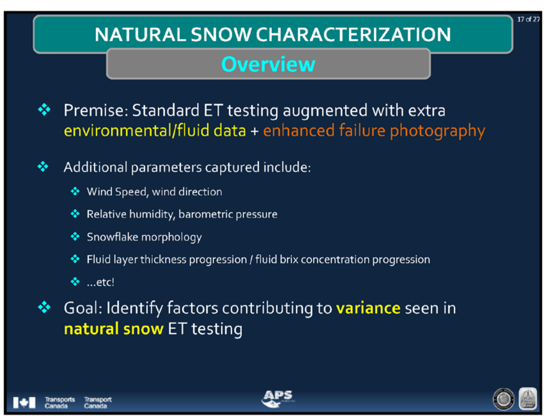
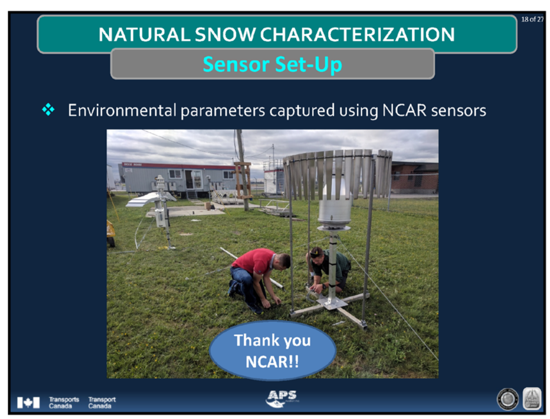
APS

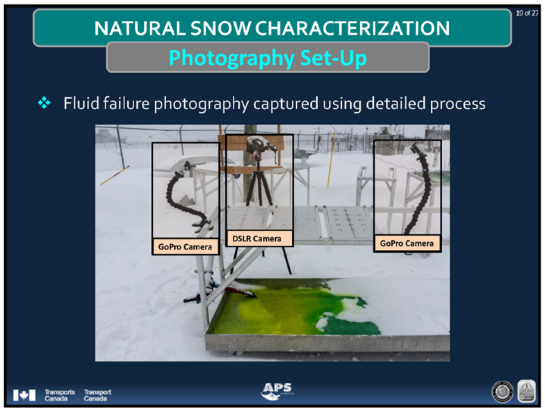

14 of 27
ARTIFICIAL SNOW TESTING
Current Obstacles
Artificial snow results not sufficiently correlated with natural snow results to replace natural snow testing
Relationship between natural-artificial test results not consistent across all rates/temperatures
Need to determine how to deal with variance seen in natural snow
Artificial snow test repeatability not at desired level
Snowfall distribution issues need to be addressed
APS

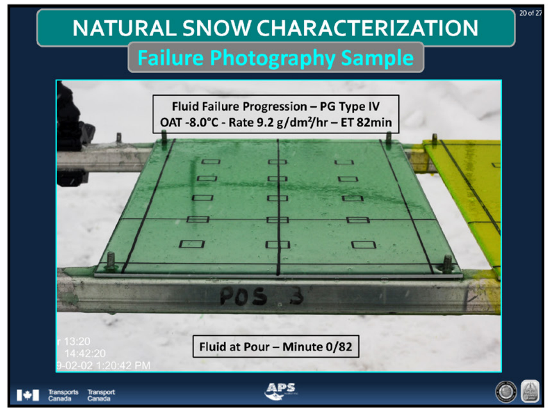

15 of 27
ARTIFICIAL SNOW TESTING
Research Plan
Short Term
Long Term
Redesign NCAR machine to improve test repeatability
Address distribution issues, calibration protocol
Evaluation of new-generation snow machine to assess test repeatability
To confirm repeatability issues rectified
Natural snow research to better understand variance in ET testing
Identify factors driving variance in natural snow, modify approach to artificial snow
Dual natural/artificial snow testing with snow machines to assess correlation
To confirm artificial/natural data correlation has been sufficiently improved
Develop industry standards governing use of artificial snow generation machines
Collaboration of all parties involved (TC, FAA, APS, NCAR, AMIL)
APS

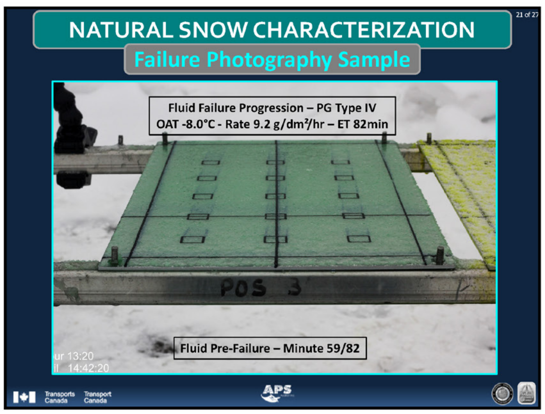

16 of 27
PRESENTATION OUTLINE
Endurance Time Testing Overview
Artificial Snow Testing
Why Artificial Snow?
NCAR Snow Machine
History of Artificial Snow Testing
Artificial Snow Research Plan
Natural Snow Characterization Research
APS

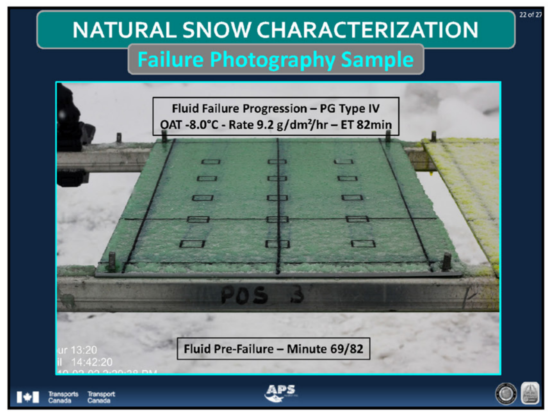

17 of 27
NATURAL SNOW CHARACTERIZATION
Overview
Premise: Standard ET testing augmented with extra environmental/fluid data + enhanced failure photography
Additional parameters captured include:
Wind Speed, wind direction
Relative humidity, barometric pressure
Snowflake morphology
Fluid layer thickness progression / fluid brix concentration progression
...etc!
Goal: Identify factors contributing to variance seen in natural snow ET testing
APS

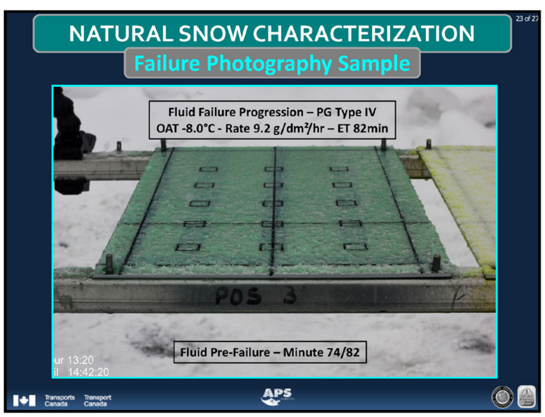

18 of 27
NATURAL SNOW CHARACTERIZATION
Sensor Set-Up
Environmental parameters captured using NCAR sensors
Thank you NCAR!!
APS

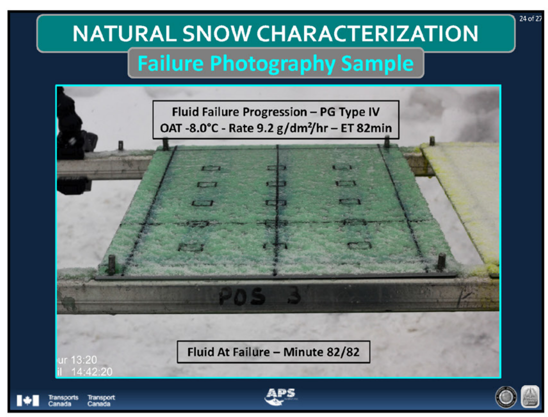

NATURAL SNOW CHARACTERIZATION
Photography Set-Up
Fluid failure photography captured using detailed process
GoPro Camera
DSLR Camera
GoPro Camera
APS

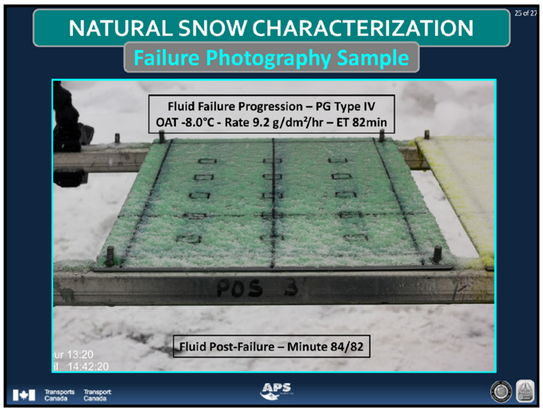

NATURAL SNOW CHARACTERIZATION
Failure Photography Sample
Fluid Failure Progression – PG Type IV
OAT -8.0°C - Rate 9.2 g/dm²/hr – ET 82min
POS 3
Fluid at Pour – Minute 0/82
APS

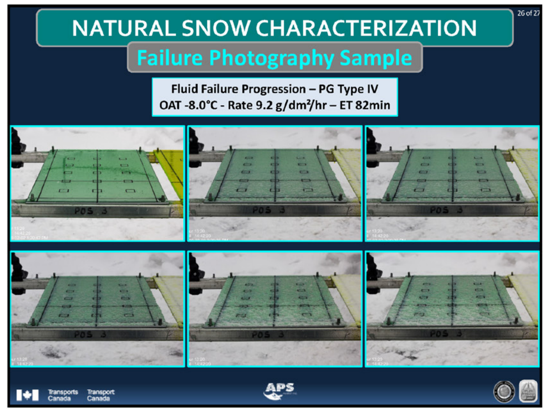

NATURAL SNOW CHARACTERIZATION
Failure Photography Sample
Fluid Failure Progression – PG Type IV
OAT -8.0°C - Rate 9.2 g/dm²/hr – ET 82min
POS 3
Fluid Pre-Failure – Minute 59/82
APS


NATURAL SNOW CHARACTERIZATION
Failure Photography Sample
Fluid Failure Progression – PG Type IV
OAT -8.0°C - Rate 9.2 g/dm²/hr – ET 82min
POS 3
Fluid Pre-Failure – Minute 69/82
APS


NATURAL SNOW CHARACTERIZATION
Failure Photography Sample
Fluid Failure Progression – PG Type IV
OAT -8.0°C - Rate 9.2 g/dm²/hr – ET 82min
POS 3
Fluid Pre-Failure – Minute 74/82
APS


NATURAL SNOW CHARACTERIZATION
Failure Photography Sample
Fluid Failure Progression – PG Type IV
OAT -8.0°C - Rate 9.2 g/dm²/hr – ET 82min
POS 3
Fluid At Failure – Minute 82/82
APS


25 of 27
NATURAL SNOW CHARACTERIZATION
Failure Photography Sample
Fluid Failure Progression – PG Type IV
OAT -8.0°C - Rate 9.2 g/dm²/hr – ET 82min
POS 3
Fluid Post-Failure – Minute 84/82
APS


26 of 27
NATURAL SNOW CHARACTERIZATION
Failure Photography Sample
Fluid Failure Progression – PG Type IV
OAT -8.0°C - Rate 9.2 g/dm²/hr – ET 82min
APS


?
APS
Benjamin Bernier
bbernier@apsaviation.ca

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SAE G-12 HOLDOVER TIME COMMITTEE MEETING, MONTREAL, CANADA, NOVEMBER 2019

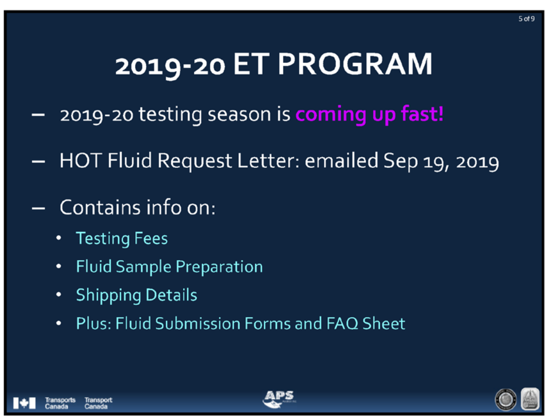
PRESENTATION:
ENDURANCE TIME TESTING PROGRAM WINTER 2019-20

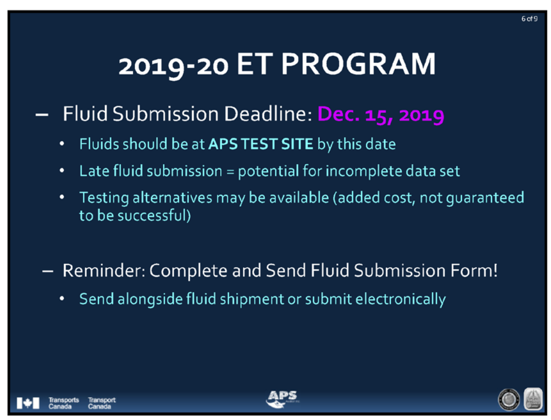

ENDURANCE TIME TESTING PROGRAM
Winter 2019-20
SAE G-12 Holdover Time Committee - Montreal, Canada – November 6, 2019
Presented By: Benjamin Bernier
Prepared by:
APS
Presented on behalf of:
Transports Canada
Transport Canada

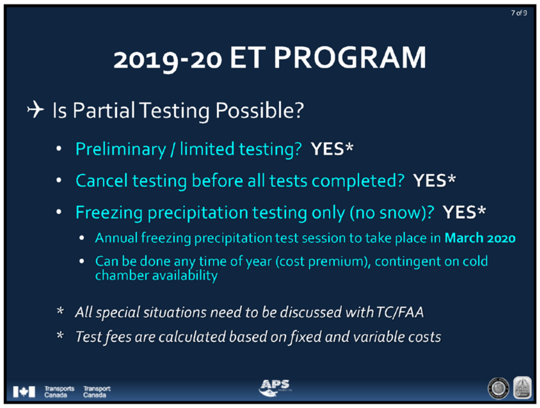

2 of 9
ENDURANCE TIME PROGRAM
APS Aviation is contracted to conduct
HOT Testing on behalf of TC/FAA


3 of 9
ENDURANCE TIME PROGRAM
Natural Snow and Natural Frost Testing
APS Test Site (Montreal, Canada)
Natural Snow
Natural Frost


4 of 9
ENDURANCE TIME PROGRAM
Simulated Freezing Precipitation Testing
NRC-CEF (Ottawa, Canada)
Simulated Freezing Precipitation


5 of 9
2019-20 ET PROGRAM
– 2019-20 testing season is coming up fast!
– HOT Fluid Request Letter: emailed Sep 19, 2019
– Contains info on:
• Testing Fees
• Fluid Sample Preparation
• Shipping Details
• Plus: Fluid Submission Forms and FAQ Sheet


6 of 9
2019-20 ET PROGRAM
– Fluid Submission Deadline: Dec. 15, 2019
• Fluids should be at APS TEST SITE by this date
• Late fluid submission = potential for incomplete data set
• Testing alternatives may be available (added cost, not guaranteed to be successful)
– Reminder: Complete and Send Fluid Submission Form!
• Send alongside fluid shipment or submit electronically


7 of 9
2019-20 ET PROGRAM
Is Partial Testing Possible?
Preliminary / limited testing? YES*
Cancel testing before all tests completed? YES*
Freezing precipitation testing only (no snow)? YES*
Annual freezing precipitation test session to take place in March 2020
Can be done any time of year (cost premium), contingent on cold chamber availability
* All special situations need to be discussed with TC/FAA
* Test fees are calculated based on fixed and variable costs
Transports Canada Transport Canada
APS

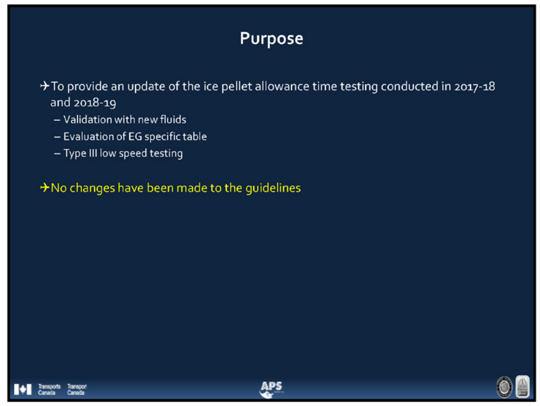

8 of 9
VERY COLD SNOW PROGRAM
– 2019-20 Very Cold Snow Testing
Optional testing for new or existing Type II/III/IV fluids
Participating fluids will receive fluid-specific snow HOTs for temperatures below -14°C down to fluid LOUT
Fluid-specific very cold snow HOTs are generally longer than the generic HOTs
Testing only conducted every second winter, and only if at least two fluids participate
– Confirmation Deadline: Nov. 15, 2019
Written confirmation of participation needed by this date.
– Fluid Submission Deadline: Dec. 15, 2019
Fluids should be at APS TEST SITE by this date
Transports Canada Transport Canada
APS


Questions?
APS
Aviation Inc.
Benjamin Bernier
Junior Project Leader, APS Aviation
bbernier@apsaviation.ca
Transports Canada Transport Canada

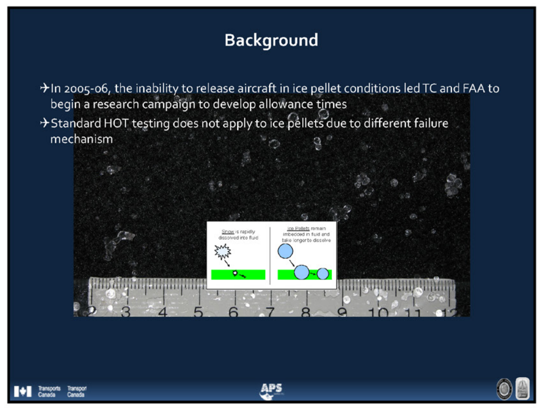
SAE G-12 HOLDOVER TIME COMMITTEE MEETING, MONTREAL, CANADA, NOVEMBER 2019

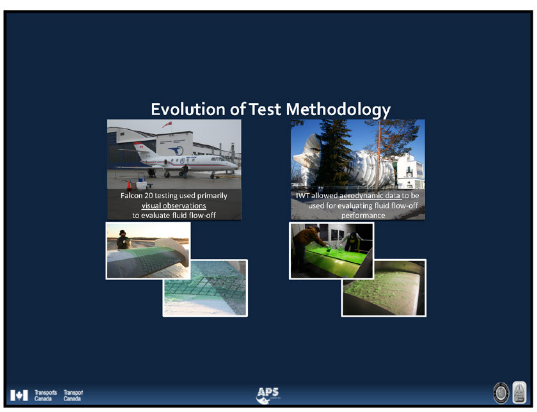
PRESENTATION:
ICING WIND TUNNEL RESEARCH SIMULATING ICE PELLET CONDITIONS

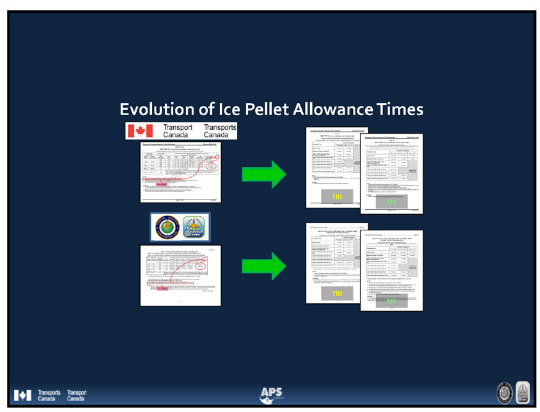

Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS
Aviation Inc
ICING WIND TUNNEL RESEARCH
SIMULATING ICE PELLET CONDITIONS
SAE 12 Holdover Time Committee, Montreal, November 6, 2019
Marco Ruggi, Eng., M.B.A., Senior Project Leader
Transports Canada
Transport Canada
APS

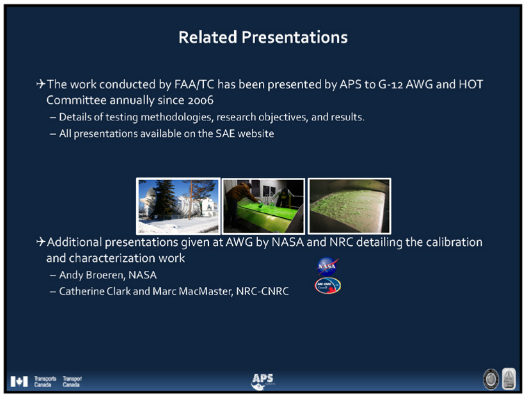

Purpose
✈To provide an update of the ice pellet allowance time testing conducted in 2017-18 and 2018-19
– Validation with new fluids
– Evaluation of EG specific table
– Type III low speed testing
✈No changes have been made to the guidelines
Transports Canada
Transport Canada
APS

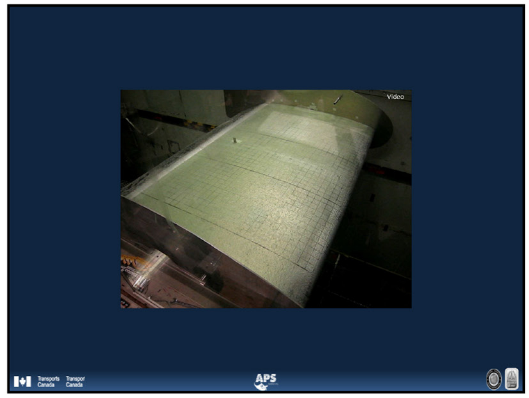

Outline
✈Background and Previous Research
✈Ice Pellet Allowance Time Research
– Validation Testing with New Fluids
– Evaluation of EG Specific Table
– Type III Low Speed Testing
✈Way Forward
Transports Canada
Transport Canada
APS


Background
✈In 2005-06, the inability to release aircraft in ice pellet conditions led TC and FAA to begin a research campaign to develop allowance times
✈Standard HOT testing does not apply to ice pellets due to different failure mechanism
Snow is rapidly dissolved into fluid
Ice Pellets remain imbedded in fluid and take longer to dissolve
2 3 4 5 6 7 8 9 10 11 12
Transports Canada
Transport Canada
APS


Evolution of Test Methodology
Falcon 20 testing used primarily visual observations to evaluate fluid flow-off
IWT allowed aerodynamic data to be used for evaluating fluid flow-off performance
Transports Canada
Transport Canada
APS


Evolution of Ice Pellet Allowance Times
Transport Canada
Transports Canada
Transports Canada
Transport Canada
APS


Related Presentations
The work conducted by FAA/TC has been presented by APS to G-12 AWG and HOT Committee annually since 2006
– Details of testing methodologies, research objectives, and results.
– All presentations available on the SAE website
Additional presentations given at AWG by NASA and NRC detailing the calibration and characterization work
– Andy Broeren, NASA
– Catherine Clark and Marc MacMaster, NRC-CNRC

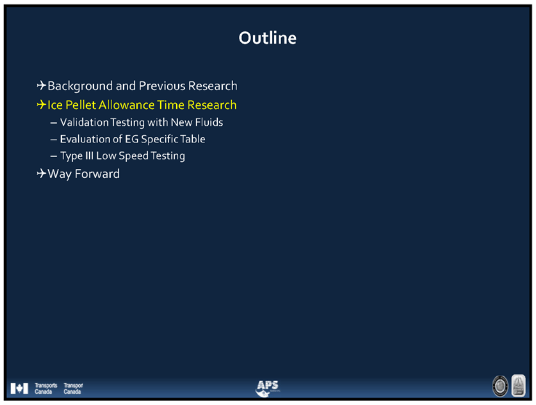

Video

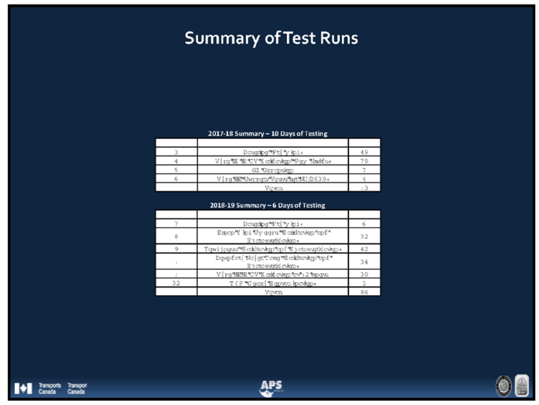

12 Successful Test Campaigns!!!

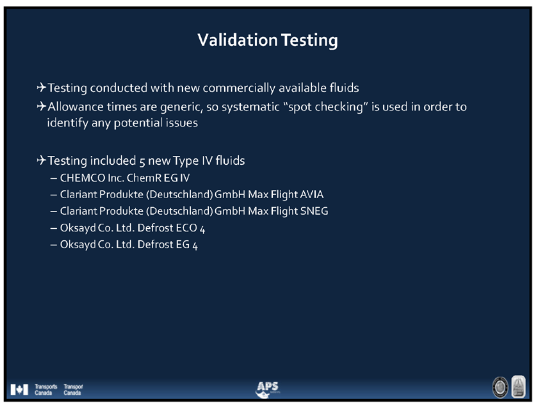

2017-18 Research Team

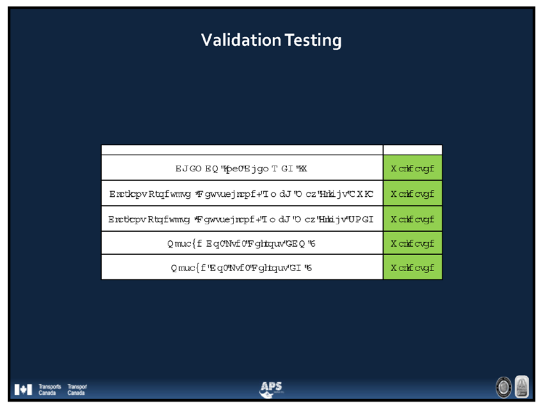

2018-19 Research Team

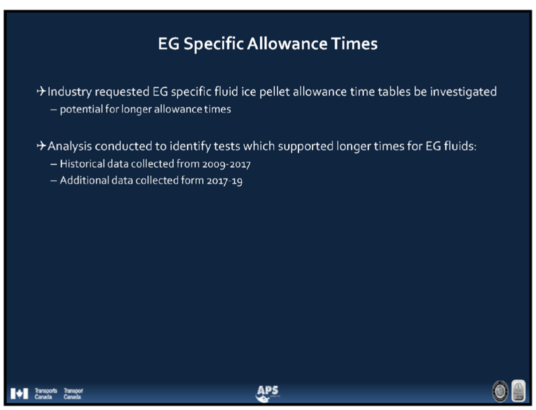

COLLABORATORS
Transport Canada
AMIL
APS
SUPPORTERS
ABAX
ALLCLEAR SYSTEMS
CHEMCO
CLARIANT
CRYOTECH
DOW
Inland
Kilfrost
LNT Solutions
NEWAVE
NORDIX
SAE

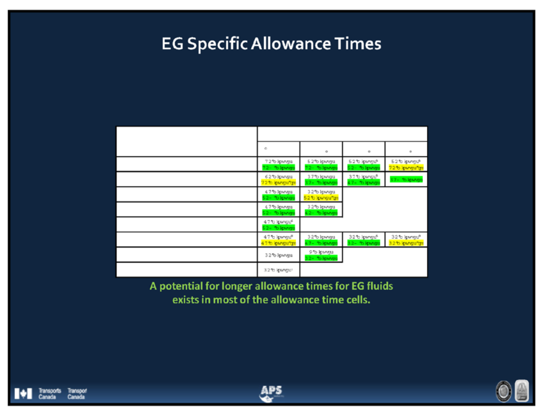

Outline
Background and Previous Research
Ice Pellet Allowance Time Research
– Validation Testing with New Fluids
– Evaluation of EG Specific Table
– Type III Low Speed Testing
Way Forward
APS


Summary of Test Runs
2017-18 Summary – 10 Days of Testing
2018-19 Summary – 6 Days of Testing
APS


Validation Testing
Testing conducted with new commercially available fluids
Allowance times are generic, so systematic "spot checking" is used in order to identify any potential issues
Testing included 5 new Type IV fluids
– CHEMCO Inc. ChemR EG IV
– Clariant Produkte (Deutschland) GmbH Max Flight AVIA
– Clariant Produkte (Deutschland) GmbH Max Flight SNEG
– Oksayd Co. Ltd. Defrost ECO 4
– Oksayd Co. Ltd. Defrost EG 4
APS


Validation Testing
APS

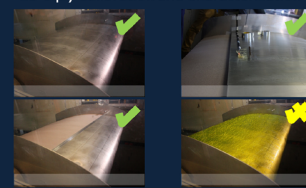

EG Specific Allowance Times
Industry requested EG specific fluid ice pellet allowance time tables be investigated
– potential for longer allowance times
Analysis conducted to identify tests which supported longer times for EG fluids:
– Historical data collected from 2009-2017
– Additional data collected form 2017-19
APS


EG Specific Allowance Times
A potential for longer allowance times for EG fluids exists in most of the allowance time cells.
APS

LS-0417 Calibration and Characterization

- Industry has requested Type III allowance times for lower speed rotations
- The LS-0417 wing is more representative than current RJ model for low rotation speeds of 80 knots
- Calibration and characterization of the LS-0417 wing section was required to:
  - Understand the aerodynamic performance parameters
  - Understand how this effects fluid flow off properties
- Testing is based on new "mid-speed ramp" being proposed by AWG for AS5900

LS-0417 Calibration and Characterization



Type III Low Speed Testing

- Preliminary testing was conducted with:
  - AllClear Systems LLC AeroClear MAX
- Results indicated:
  - Potential for low speed allowance times
  - Potential to expand times
- Further research is pending "mid-speed ramp" approval being proposed by AWG for AS5900

Changes to Allowance Time Tables

- No changes have been made to the guidelines
- Future guidance changes under consideration:
  - *Separate EG allowance time tables for Type IV fluids
  - *Low speed Type III allowance time table

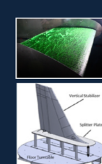
* Works in progress. Changes are pending positive test results.

Outline

- Background and Previous Research
- Ice Pellet Allowance Time Research
  - Validation Testing with New Fluids
  - Evaluation of EG Specific Table
  - Type III Low Speed Testing
- Way Forward

Wind Tunnel Research for 2019-20

- Ice pellet allowance time research
  - Validation with new fluids
  - EG specific times
  - Type III Low Speed
- V-Stab testing
  - New Seneca Piper II Model
- Testing planned for Jan/Feb 2020




Marco Ruggi
mruggi@apsaviation.ca

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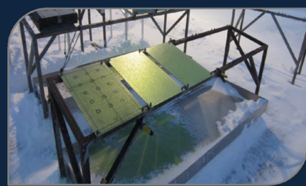
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX), MAY 2020

PRESENTATION:
WINTER 2019-20 ENDURANCE TIME TESTING UPDATE

Joint research led by:

Transports Canada Transport Canada

Conducted by:



WINTER 2019-20

ENDURANCE TIME TESTING UPDATE

SAE 12 Holdover Time Committee, Webex, May 19, 2020

Benjamin Bernier, Project Leader

Purpose

- To provide an overview of the endurance time testing conducted to date in 2019-20
- To provide details concerning the COVID-19 related testing interruption

Outline

- Testing Status – Overview and Communications
- Data Status
  - Natural Snow (Above -14°C) Testing
  - Natural Frost Testing
  - Very Cold Snow Testing
    - Type II/IV
    - Type I
  - Indoor Testing
- Way Forward

Testing Status - Overview

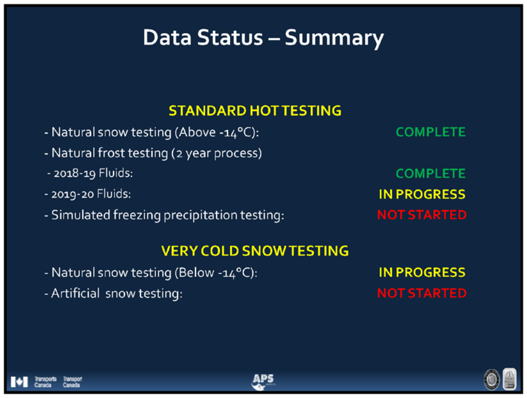
- Multiple Type II/IV fluids were submitted for ET testing in 2019-20
- In early March 2020, several ET testing activities **suspended** as a result of COVID-19
  - Testing-related travel halted due to safety concerns
  - Indoor testing facilities (National Research Council, PMG) closed or operating with restrictions
- Data collection **in progress** as of the **suspension**

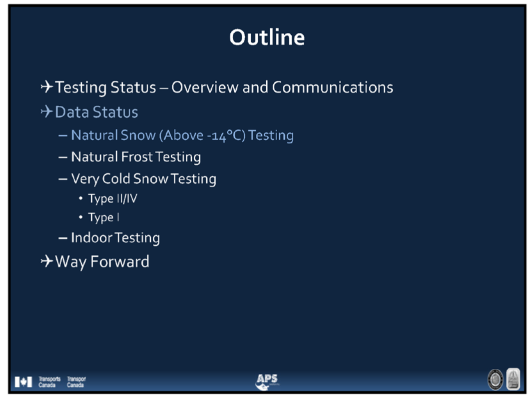
Testing Status - Communications

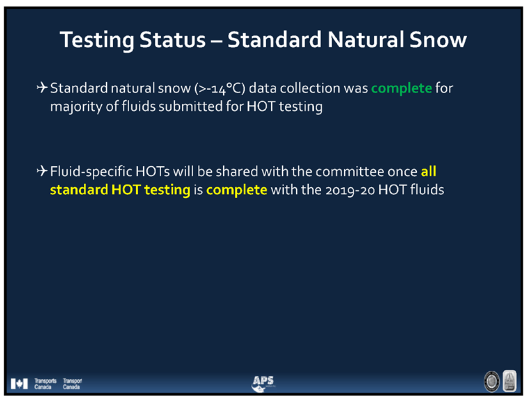
- Fluid manufacturers initially notified of testing suspension on **March 20th, 2020**
  - Email sent by APS on behalf of TC/FAA
  - Follow-up message sent to manufacturers by TC/FAA on **April 14th, 2020** confirming suspension still active
- TC/FAA sent additional communications to SAE HOT Committee on **April 15th, 2020**
  - Message detailed testing facility restrictions, current status of research, timeline for publication of 2020-21 guidance, and plan going forward
- Additional details to be communicated as situation develops further

Outline

- Testing Status – Overview and Communications
- Data Status
  - Natural Snow (Above -14°C) Testing
  - Natural Frost Testing
  - Very Cold Snow Testing
    - Type II/IV
    - Type I
  - Indoor Testing
- Way Forward


Data Status – Summary
STANDARD HOT TESTING
- Natural snow testing (Above -14°C): COMPLETE
- Natural frost testing (2 year process)
- 2018-19 Fluids: COMPLETE
- 2019-20 Fluids: IN PROGRESS
- Simulated freezing precipitation testing: NOT STARTED
VERY COLD SNOW TESTING
- Natural snow testing (Below -14°C): IN PROGRESS
- Artificial snow testing: NOT STARTED
APS


Outline
Testing Status – Overview and Communications
Data Status
– Natural Snow (Above -14°C) Testing
– Natural Frost Testing
– Very Cold Snow Testing
• Type II/IV
• Type I
– Indoor Testing
Way Forward
APS


Testing Status – Standard Natural Snow
Standard natural snow (>-14°C) data collection was complete for majority of fluids submitted for HOT testing
Fluid-specific HOTs will be shared with the committee once all standard HOT testing is complete with the 2019-20 HOT fluids
APS


Outline
Testing Status – Overview and Communications
Data Status
– Natural Snow (Above -14°C) Testing
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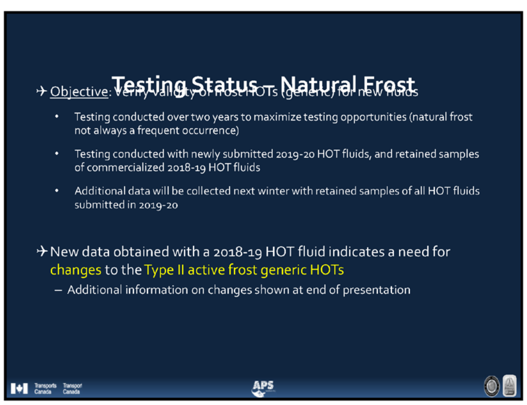
• Type I
– Indoor Testing
Way Forward
APS


Testing Status – Natural Frost
Objective: Verify validity of frost HOTs (generic) for new fluids
• Testing conducted over two years to maximize testing opportunities (natural frost not always a frequent occurrence)
• Testing conducted with newly submitted 2019-20 HOT fluids, and retained samples of commercialized 2018-19 HOT fluids
• Additional data will be collected next winter with retained samples of all HOT fluids submitted in 2019-20
New data obtained with a 2018-19 HOT fluid indicates a need for changes to the Type II active frost generic HOTs
– Additional information on changes shown at end of presentation
APS


Outline
Testing Status – Overview and Communications
Data Status
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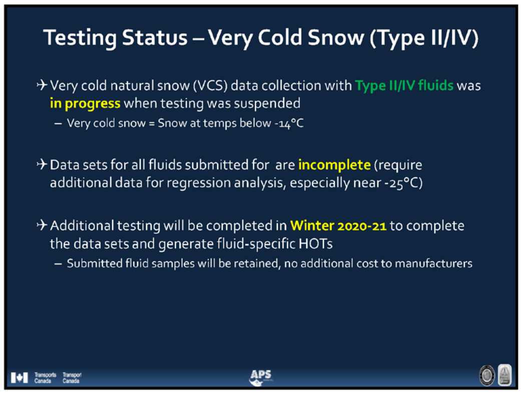
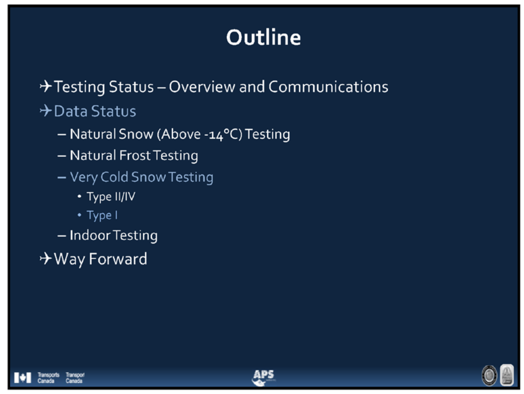
Way Forward
APS


Testing Status – Very Cold Snow (Type II/IV)
Very cold natural snow (VCS) data collection with Type II/IV fluids was in progress when testing was suspended
– Very cold snow = Snow at temps below -14°C
Data sets for all fluids submitted for are incomplete (require additional data for regression analysis, especially near -25°C)
Additional testing will be completed in Winter 2020-21 to complete the data sets and generate fluid-specific HOTs
– Submitted fluid samples will be retained, no additional cost to manufacturers
APS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Testing Status – Overview and Communications
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• Type I
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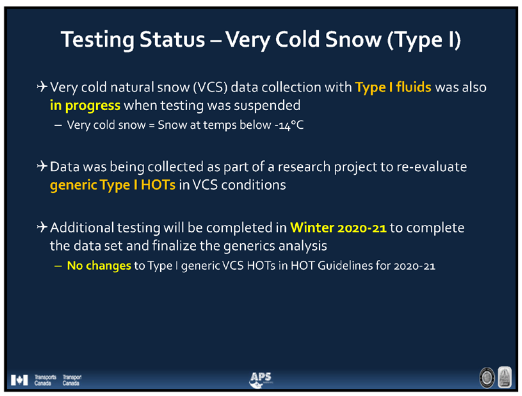
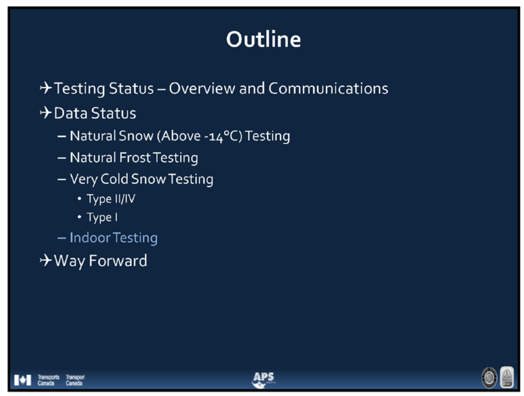
Way Forward
APS


Testing Status – Very Cold Snow (Type I)
Very cold natural snow (VCS) data collection with Type I fluids was also in progress when testing was suspended
– Very cold snow = Snow at temps below -14°C
Data was being collected as part of a research project to re-evaluate generic Type I HOTs in VCS conditions
Additional testing will be completed in Winter 2020-21 to complete the data set and finalize the generics analysis
– No changes to Type I generic VCS HOTs in HOT Guidelines for 2020-21
APS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Testing Status – Overview and Communications
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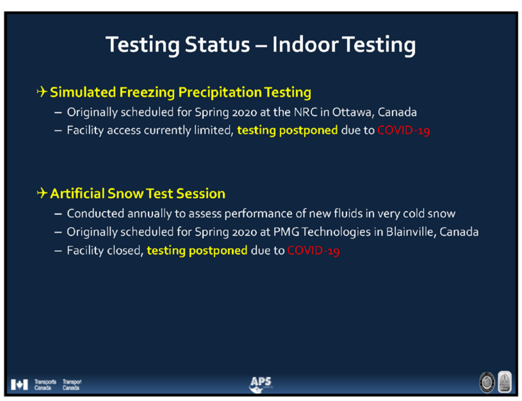
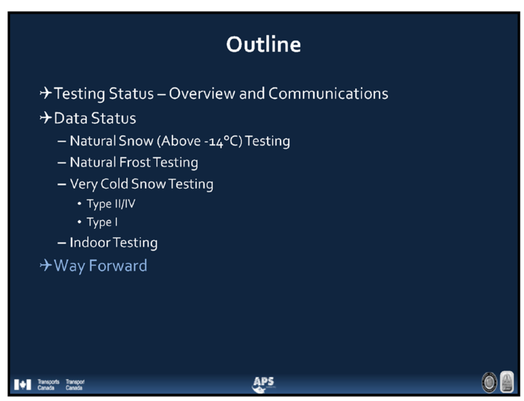
Way Forward
APS


Testing Status – Indoor Testing
Simulated Freezing Precipitation Testing
– Originally scheduled for Spring 2020 at the NRC in Ottawa, Canada
– Facility access currently limited, testing postponed due to COVID-19
Artificial Snow Test Session
– Conducted annually to assess performance of new fluids in very cold snow
– Originally scheduled for Spring 2020 at PMG Technologies in Blainville, Canada
– Facility closed, testing postponed due to COVID-19
APS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• Type I
– Indoor Testing
Way Forward
APS

Way Forward

- Current plan is to finish pending testing activities as soon as COVID-19 situation allows
  - Simulated freezing precipitation testing @ NRC
  - Artificial snow testing @ PMG
  - Note: Very cold natural snow data collection will only resume in Winter 2020-21
- If ET testing and fluid qualification testing (AMIL) resume by June 1st, 2020 new fluid data will be included in the 2020-21 HOT guidelines
  - Testing data, holdover times and impact to generic HOTs will be shared with the HOT committee before data is published
- If testing resumes after June 1st, 2020 - new fluid data will be included in the 2021-22 HOT guidelines

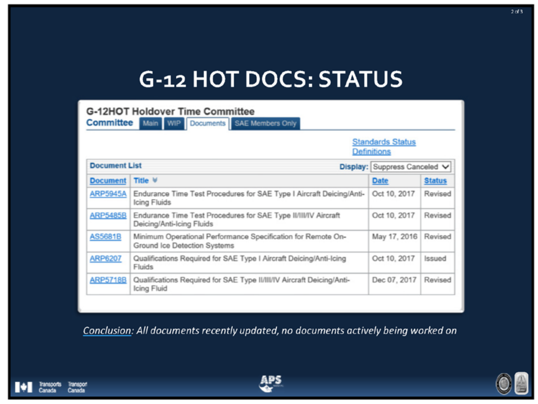
Natural Frost – Impact to Generics

Outside Air Temperature[2,3]	Concentration Fluid/Water By % Volume	Type II
-1°C and above (30°F and above)	100/0	8:00
	75/25	5:00
	50/50	~~3:00~~ 2:00
below -1 to -3°C (below 30 to 27°F)	100/0	8:00
	75/25	5:00
	50/50	1:30
below -3 to -10°C (below 27 to 14°F)	100/0	8:00
	75/25	~~5:00~~ 4:00
below -10 to -14°C (below 14 to 7°F)	100/0	6:00
	75/25	1:00
below -14 to -21°C (below 7 to -6°F)	100/0	~~6:00~~ 3:00
below -21 to -25°C (below -6 to -13°F)	100/0	2:00

SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX), MAY 2020

PRESENTATION:
SAE G-12 HOT COMMITTEE: DOCUMENTS STATUS


SAE G-12 HOT COMMITTEE:
DOCUMENTS STATUS
SAE G-12 Holdover Time Committee – Webex – May 19, 2020
Presented By: Benjamin Bernier, Acting G-12 HOT Secretary
APS


G-12 HOT DOCS: STATUS
G-12HOT Holdover Time Committee
Committee
Main
WIP
Documents
SAE Members Only
Standards Status Definitions
Document List
Display: Suppress Canceled
Document | Title | Date | Status
ARP5945A | Endurance Time Test Procedures for SAE Type I Aircraft Deicing/Anti-Icing Fluids | Oct 10, 2017 | Revised
ARP5485B | Endurance Time Test Procedures for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluids | Oct 10, 2017 | Revised
AS5681B | Minimum Operational Performance Specification for Remote On-Ground Ice Detection Systems | May 17, 2016 | Revised
ARP6207 | Qualifications Required for SAE Type I Aircraft Deicing/Anti-Icing Fluids | Oct 10, 2017 | Issued
ARP5718B | Qualifications Required for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluid | Dec 07, 2017 | Revised
Conclusion: All documents recently updated, no documents actively being worked on
Transports Canada
Transport Canada
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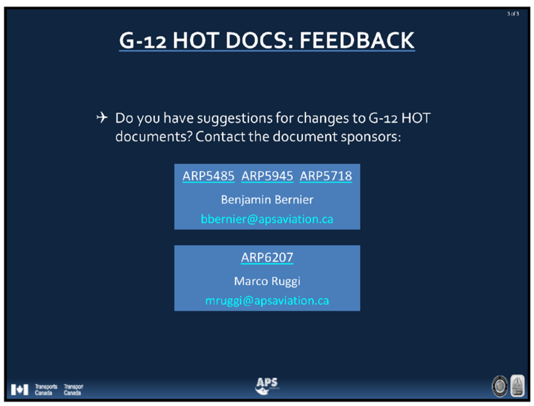
G-12 HOT DOCS: FEEDBACK
Do you have suggestions for changes to G-12 HOT documents? Contact the document sponsors:
ARP5485 ARP5945 ARP5718
Benjamin Bernier
bbernier@apsaviation.ca
ARP6207
Marco Ruggi
mruggi@apsaviation.ca
Transports Canada
Transport Canada
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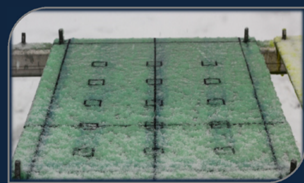
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX), MAY 2020

PRESENTATION:
NATURAL SNOW CHARACTERIZATION TO SUPPORT ARTIFICIAL SNOW RESEARCH 2019-20 APS ACTIVITIES

Joint research led by: Transports Canada Transport Canada

Conducted by: APS Aviation Inc.



NATURAL SNOW CHARACTERIZATION TO SUPPORT ARTIFICIAL SNOW RESEARCH
2019-20 APS Activities

SAE 12 Holdover Time Committee, Webex, May 19, 2020
Dany Posteraro, B. Eng., M. Eng., PhD, Project Leader

Purpose

- To provide an update on the artificial snow research activities conducted by APS in 2019-20

Outline

- Project Background and Research Goals
- Test Methodology
- Testing Summary and Data Processing
- Way Forward
  - Analytical Methodology
  - Future Artificial Snow Research Activities

Project Background

- Goal: Further develop artificial snow endurance time (ET) testing as a tool for holdover time development
  - Increase scope of use, on-demand testing capabilities
- Challenge: Need to improve correlation between natural snow data and artificial snow data
  - Variance observed in natural snow testing impacting ability to correlate data sets
  - Environment contributes to variance seen in natural snow ET testing

Research Goals

- 2019-20 Goal: Identify and characterize environmental parameters influencing anti-icing fluid performance in natural snow
- Approach: Conduct natural snow ET testing with supplemental environmental data collection
  - Investigate effect of specific environmental parameters on fluid ET testing performance

Outline

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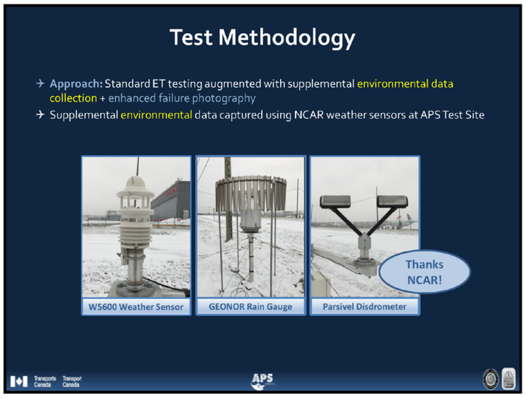
Test Methodology
Approach: Standard ET testing augmented with supplemental environmental data collection + enhanced failure photography
Supplemental environmental data captured using NCAR weather sensors at APS Test Site
WS600 Weather Sensor
GEONOR Rain Gauge
Parsivel Disdrometer
Thanks NCAR!
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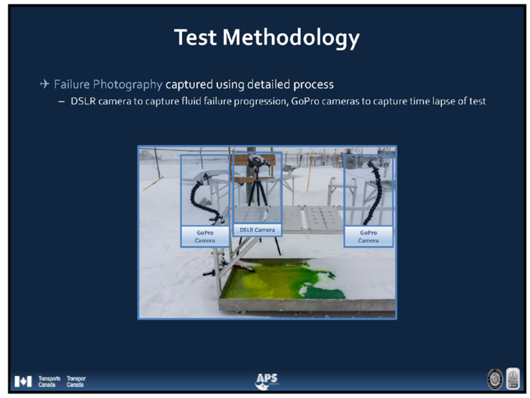
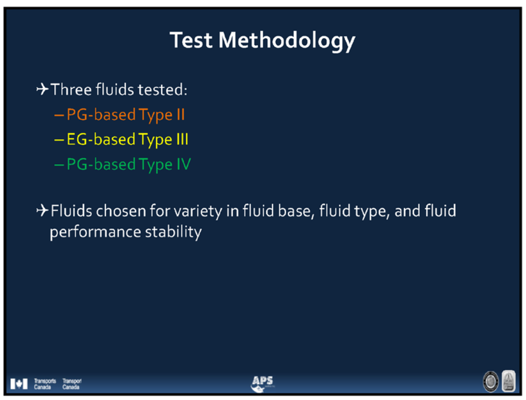
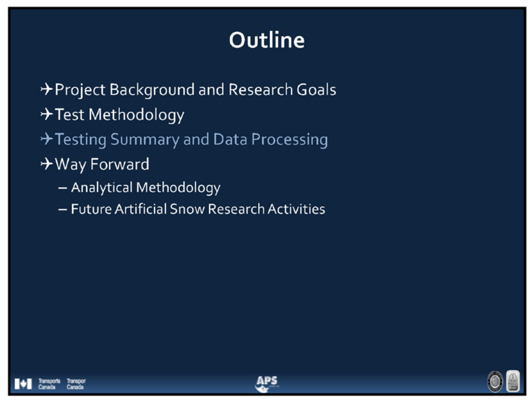

Test Methodology
Failure Photography captured using detailed process
– DSLR camera to capture fluid failure progression, GoPro cameras to capture time lapse of test
GoPro Camera
DSLR Camera
GoPro Camera
APS


Test Methodology
Three fluids tested:
– PG-based Type II
– EG-based Type III
– PG-based Type IV
Fluids chosen for variety in fluid base, fluid type, and fluid performance stability
APS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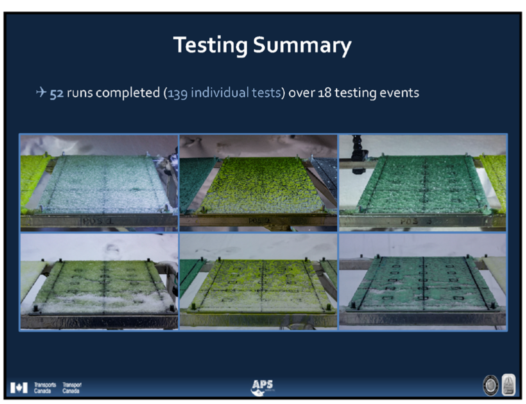
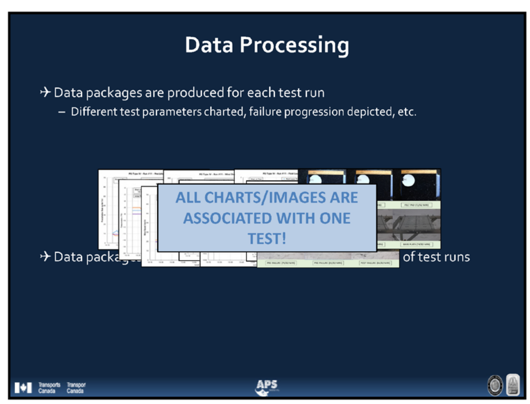
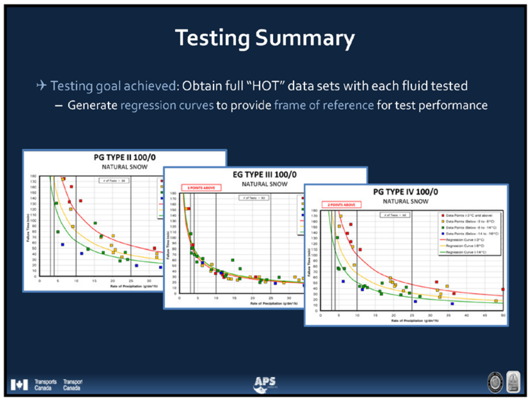
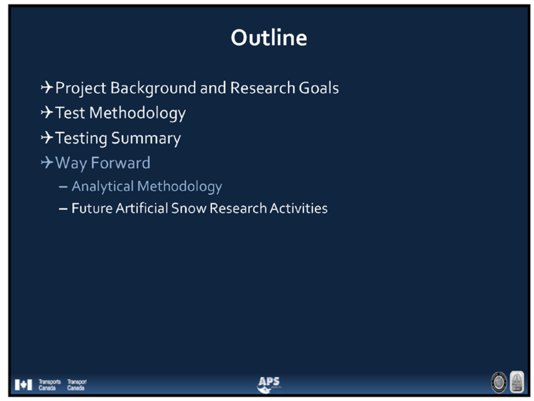

Testing Summary
52 runs completed (139 individual tests) over 18 testing events
APS


Data Processing
Data packages are produced for each test run
– Different test parameters charted, failure progression depicted, etc.
ALL CHARTS/IMAGES ARE ASSOCIATED WITH ONE TEST!
Data packa
of test runs
APS


Testing Summary
Testing goal achieved: Obtain full "HOT" data sets with each fluid tested
– Generate regression curves to provide frame of reference for test performance
PG TYPE II 100/0
NATURAL SNOW
EG TYPE III 100/0
NATURAL SNOW
PG TYPE IV 100/0
NATURAL SNOW
APS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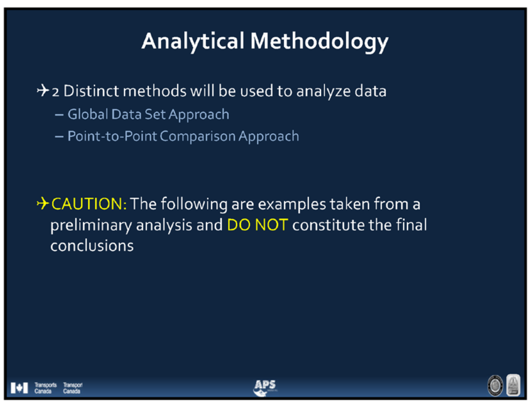
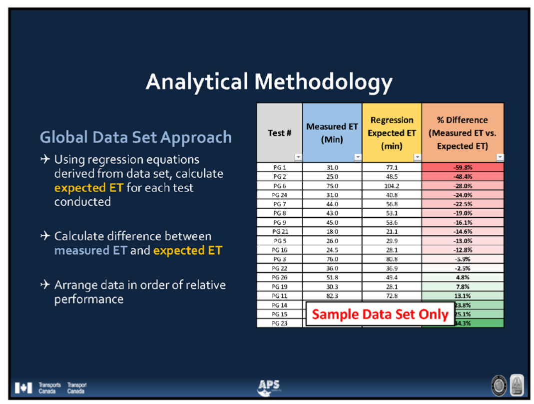
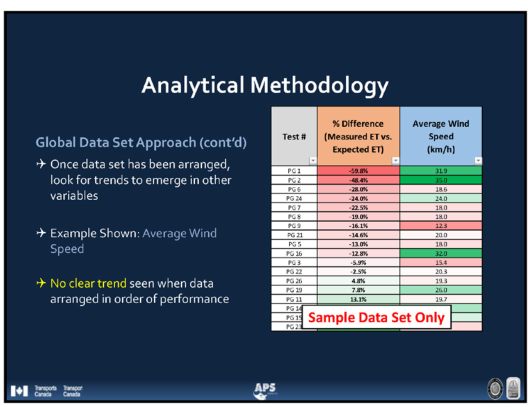
APS


Analytical Methodology
2 Distinct methods will be used to analyze data
– Global Data Set Approach
– Point-to-Point Comparison Approach
CAUTION: The following are examples taken from a preliminary analysis and DO NOT constitute the final conclusions
APS


Analytical Methodology
Global Data Set Approach
Using regression equations derived from data set, calculate expected ET for each test conducted
Calculate difference between measured ET and expected ET
Arrange data in order of relative performance

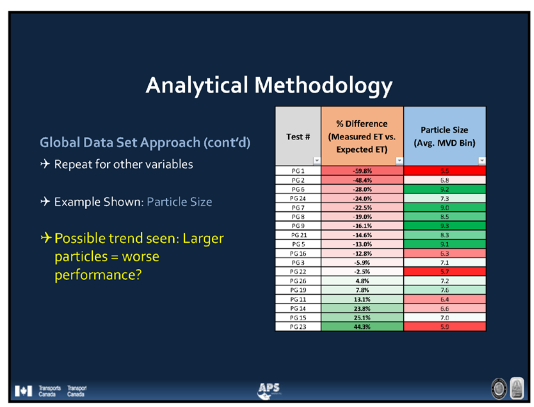
Test #	Measured ET (Min)	Regression Expected ET (min)	% Difference (Measured ET vs. Expected ET)
PG 1	31.0	77.1	-59.8%
PG 2	25.0	48.5	-48.4%
PG 6	75.0	104.2	-28.0%
PG 24	31.0	40.8	-24.0%
PG 7	44.0	56.8	-22.5%
PG 8	43.0	53.1	-19.0%
PG 9	45.0	53.6	-16.1%
PG 21	18.0	21.1	-14.6%
PG 5	26.0	29.9	-13.0%
PG 16	24.5	28.1	-12.8%
PG 3	76.0	80.8	-5.9%
PG 22	36.0	36.9	-2.5%
PG 26	51.8	49.4	4.8%
PG 19	30.3	28.1	7.8%
PG 11	82.3	72.8	13.1%
PG 14	[illegible]	[illegible]	23.8%
PG 15	[illegible]	[illegible]	25.1%
PG 23	[illegible]	[illegible]	44.3%

Sample Data Set Only
APS


Analytical Methodology
Global Data Set Approach (cont'd)
Once data set has been arranged, look for trends to emerge in other variables
Example Shown: Average Wind Speed
No clear trend seen when data arranged in order of performance

Test #	% Difference (Measured ET vs. Expected ET)	Average Wind Speed (km/h)
PG 1	-59.8%	31.9
PG 2	-48.4%	35.0
PG 6	-28.0%	18.6
PG 24	-24.0%	24.0
PG 7	-22.5%	18.0
PG 8	-19.0%	18.0
PG 9	-16.1%	12.3
PG 21	-14.6%	20.0
PG 5	-13.0%	18.0
PG 16	-12.8%	32.0
PG 3	-5.9%	15.4
PG 22	-2.5%	20.3
PG 26	4.8%	19.3
PG 19	7.8%	26.0
PG 11	13.1%	19.7
PG 14	[illegible]	[illegible]
PG 15	[illegible]	[illegible]
PG 23	[illegible]	[illegible]

Sample Data Set Only
APS


Analytical Methodology
Global Data Set Approach (cont'd)
Repeat for other variables
Example Shown: Particle Size
Possible trend seen: Larger particles = worse performance?

Test #	% Difference (Measured ET vs. Expected ET)	Particle Size (Avg. MVD Bin)
PG 1	-59.8%	5.5
PG 2	-48.4%	6.8
PG 6	-28.0%	9.2
PG 24	-24.0%	7.3
PG 7	-22.5%	9.0
PG 8	-19.0%	8.5
PG 9	-16.1%	9.3
PG 21	-14.6%	8.3
PG 5	-13.0%	9.1
PG 16	-12.8%	6.3
PG 3	-5.9%	7.1
PG 22	-2.5%	5.7
PG 26	4.8%	7.2
PG 19	7.8%	7.6
PG 11	13.1%	6.4
PG 14	23.8%	6.6
PG 15	25.1%	7.0
PG 23	44.3%	5.9

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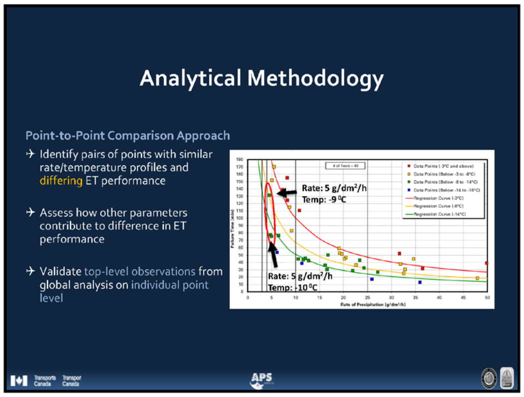
Analytical Methodology
Point-to-Point Comparison Approach
Identify pairs of points with similar rate/temperature profiles and differing ET performance
Assess how other parameters contribute to difference in ET performance
Validate top-level observations from global analysis on individual point level
Rate: 5 g/dm²/h
Temp: -9 ºC
Rate: 5 g/dm²/h
Temp: -10 ºC
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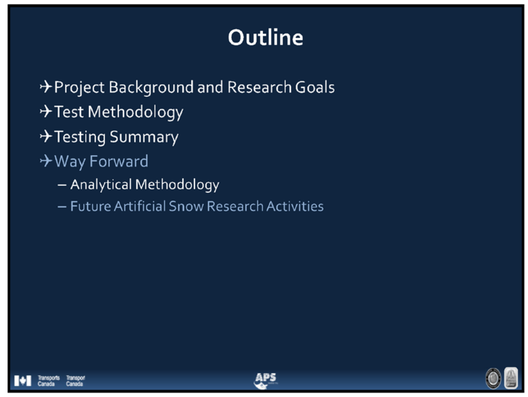
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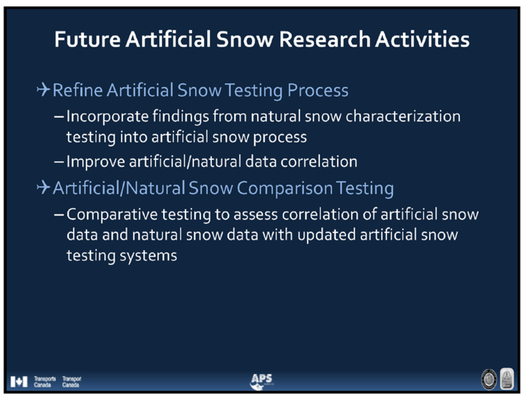
Future Artificial Snow Research Activities
Refine Artificial Snow Testing Process
– Incorporate findings from natural snow characterization testing into artificial snow process
– Improve artificial/natural data correlation
Artificial/Natural Snow Comparison Testing
– Comparative testing to assess correlation of artificial snow data and natural snow data with updated artificial snow testing systems
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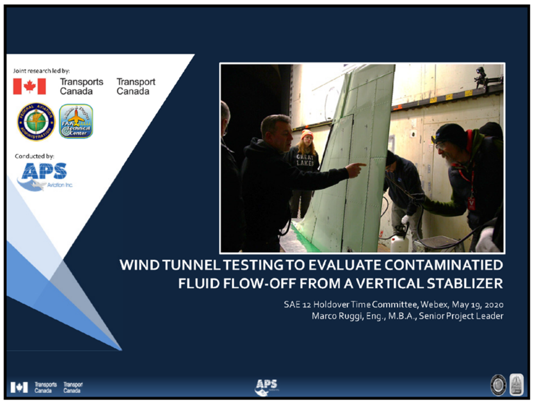
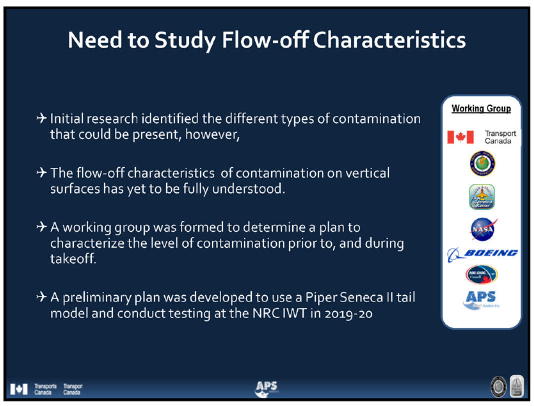
Thank You
APS
Dany Posteraro
dposteraro@apsaviation.ca
APS

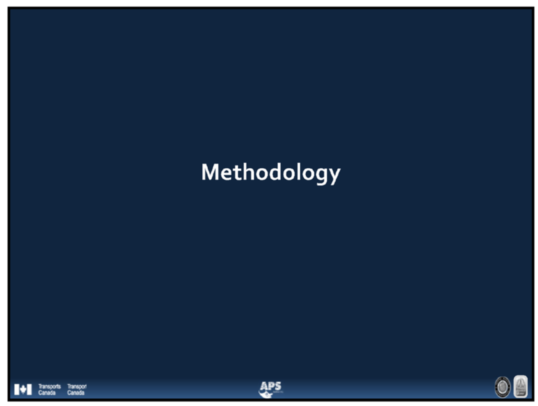
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX), MAY 2020

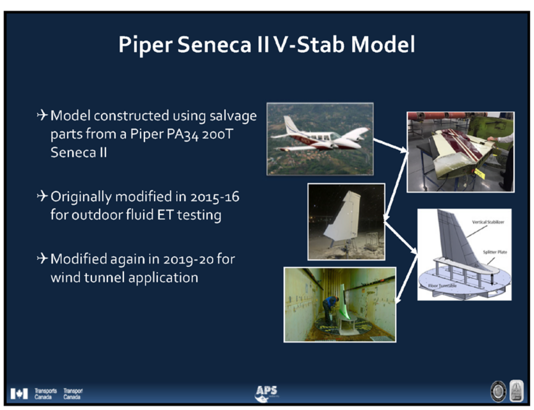
PRESENTATION:
WIND TUNNEL TESTING TO EVALUATE CONTAMINATED FLUID FLOW-OFF FROM A VERTICAL STABILIZER


Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS
WIND TUNNEL TESTING TO EVALUATE CONTAMINATIED FLUID FLOW-OFF FROM A VERTICAL STABLIZER
SAE 12 Holdover Time Committee, Webex, May 19, 2020
Marco Ruggi, Eng., M.B.A., Senior Project Leader
APS


Background and Previous Research
APS


Need to Study Flow-off Characteristics
Initial research identified the different types of contamination that could be present, however,
The flow-off characteristics of contamination on vertical surfaces has yet to be fully understood.
A working group was formed to determine a plan to characterize the level of contamination prior to, and during takeoff.
A preliminary plan was developed to use a Piper Seneca II tail model and conduct testing at the NRC IWT in 2019-20
Working Group
Transport Canada
NASA
BOEING
APS
APS


Methodology
APS


Piper Seneca II V-Stab Model
Model constructed using salvage parts from a Piper PA34 200T Seneca II
Originally modified in 2015-16 for outdoor fluid ET testing
Modified again in 2019-20 for wind tunnel application
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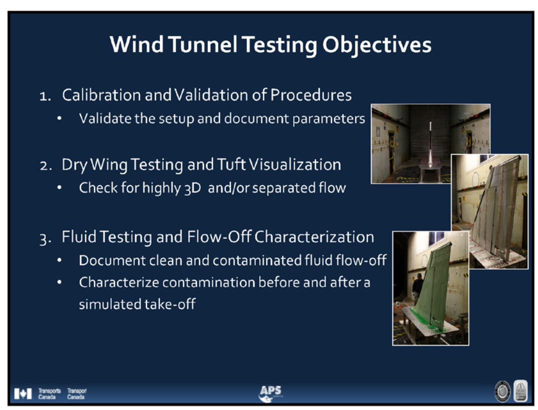
Wind Tunnel Testing Objectives
1. Calibration and Validation of Procedures
• Validate the setup and document parameters
2. Dry Wing Testing and Tuft Visualization
• Check for highly 3D and/or separated flow
3. Fluid Testing and Flow-Off Characterization
• Document clean and contaminated fluid flow-off
• Characterize contamination before and after a simulated take-off
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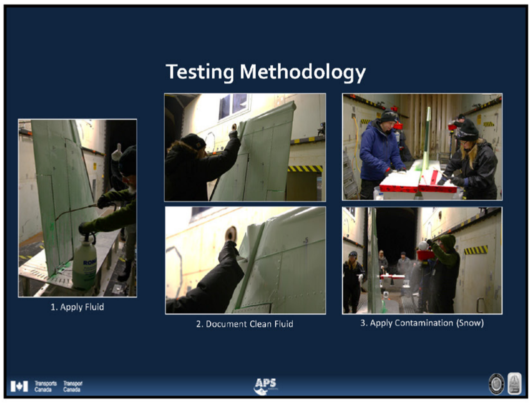
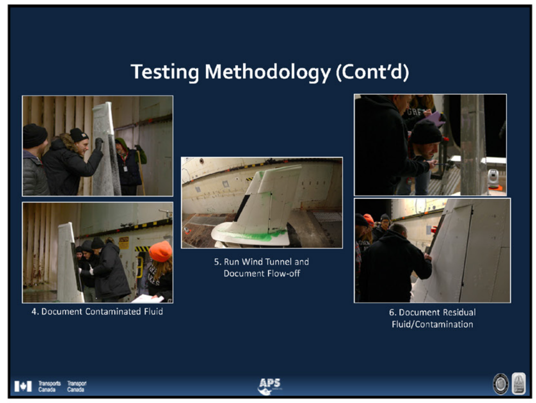
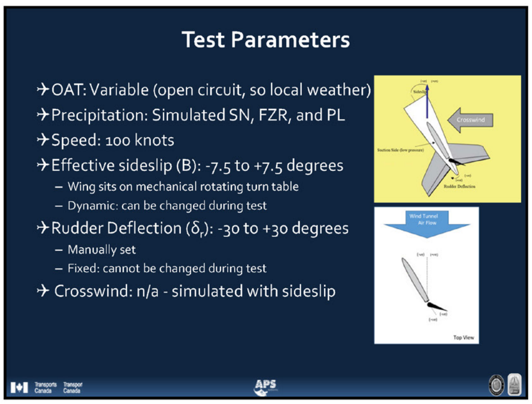
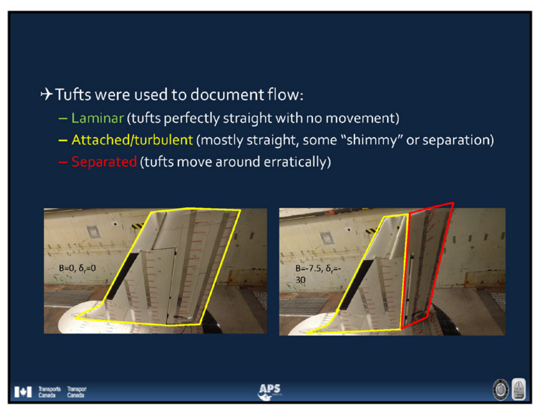

Testing Methodology
1. Apply Fluid
2. Document Clean Fluid
3. Apply Contamination (Snow)
APS

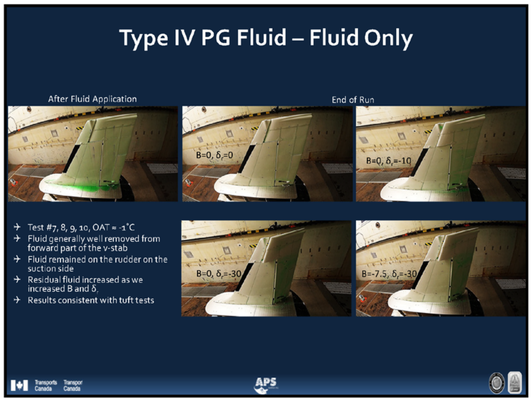

Testing Methodology (Cont'd)
4. Document Contaminated Fluid
5. Run Wind Tunnel and Document Flow-off
6. Document Residual Fluid/Contamination
APS


Test Parameters
OAT: Variable (open circuit, so local weather)
Precipitation: Simulated SN, FZR, and PL
Speed: 100 knots
Effective sideslip (B): -7.5 to +7.5 degrees
– Wing sits on mechanical rotating turn table
– Dynamic: can be changed during test
Rudder Deflection (δr): -30 to +30 degrees
– Manually set
– Fixed: cannot be changed during test
Crosswind: n/a - simulated with sideslip
Crosswind
Wind Tunnel Air Flow
Top View
APS


2019-20 Research Team
APS


Sample of Results
APS


Tufts were used to document flow:
– Laminar (tufts perfectly straight with no movement)
– Attached/turbulent (mostly straight, some "shimmy" or separation)
– Separated (tufts move around erratically)
B=0, δr=0
B=-7.5, δr=-30
APS


Type IV PG Fluid – Fluid Only
After Fluid Application
End of Run
B=0, δr=0
B=0, δr=-10
B=0, δr=-30
B=-7.5, δr=-30
Test #7, 8, 9, 10, OAT ≈ -1°C
Fluid generally well removed from forward part of the v-stab
Fluid remained on the rudder on the suction side
Residual fluid increased as we increased B and δr
Results consistent with tuft tests
Transports Canada
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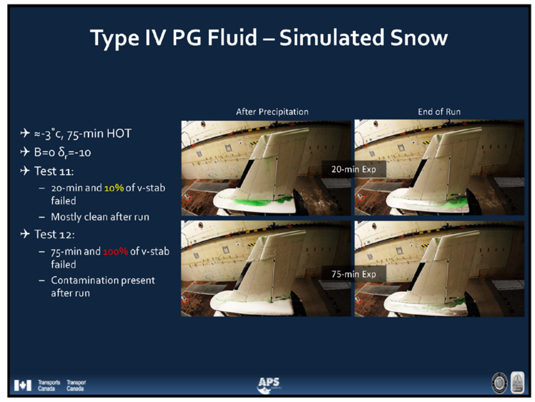
Type IV PG Fluid – Simulated Snow
≈-3°c, 75-min HOT
B=0 δr=-10
Test 11:
– 20-min and 10% of v-stab failed
– Mostly clean after run
Test 12:
– 75-min and 100% of v-stab failed
– Contamination present after run
After Precipitation
End of Run
20-min Exp
75-min Exp
Transports Canada
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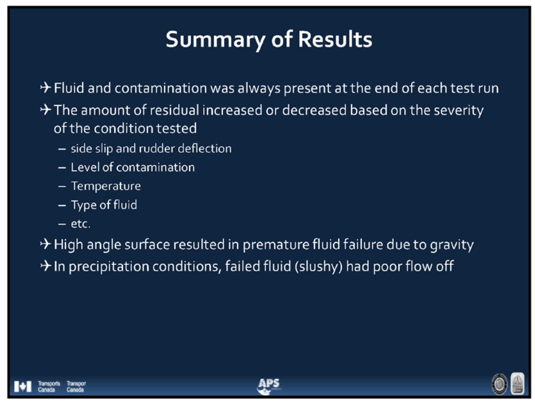
Summary of Results
Transports Canada
APS


Summary of Results
Fluid and contamination was always present at the end of each test run
The amount of residual increased or decreased based on the severity of the condition tested
– side slip and rudder deflection
– Level of contamination
– Temperature
– Type of fluid
– etc.
High angle surface resulted in premature fluid failure due to gravity
In precipitation conditions, failed fluid (slushy) had poor flow off
Transports Canada
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Way Forward
Transports Canada
APS


Way Forward
Continue discussions and analysis with research team
Continue to engage OEMs to ensure relevance of testing results and objectives going forward, and transparency
Develop test plan for additional testing with current setup for winter 2020-21
Develop a long-term research plan incorporating possible new model with added capabilities
Transports Canada
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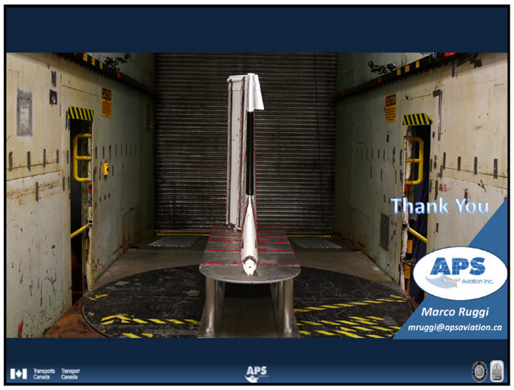
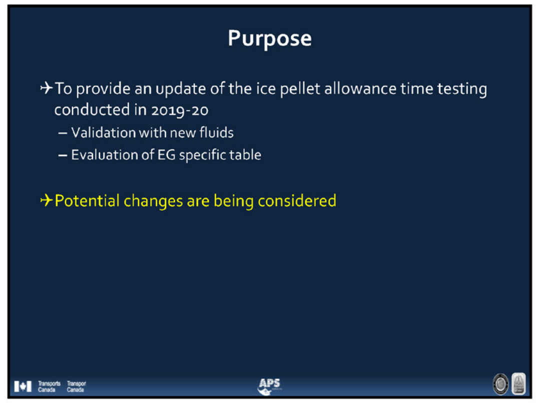

Thank You
APS
Aviation Inc.
Marco Ruggi
mruggi@apsaviation.ca

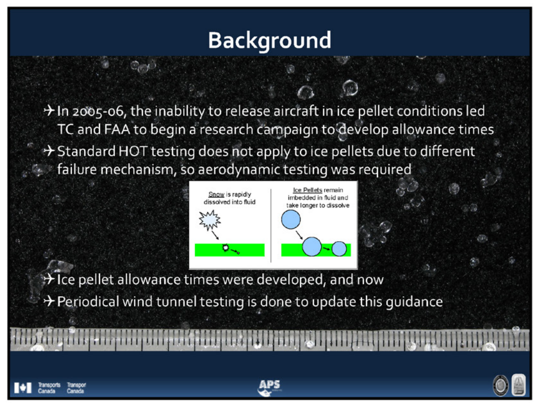
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX), MAY 2020

PRESENTATION:
ICING WIND TUNNEL RESEARCH SIMULATING ICE PELLET CONDITIONS


Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS
ICING WIND TUNNEL RESEARCH
SIMULATING ICE PELLET CONDITIONS
SAE 12 Holdover Time Committee, Webex, May 19, 2020
Marco Ruggi, Eng., M.B.A., Senior Project Leader


Purpose
To provide an update of the ice pellet allowance time testing conducted in 2019-20
– Validation with new fluids
– Evaluation of EG specific table
Potential changes are being considered


Outline
Background and Previous Research
Ice Pellet Allowance Time Research
– Validation Testing with New Fluids
– Evaluation of EG Specific Table
Way Forward


Background
In 2005-06, the inability to release aircraft in ice pellet conditions led TC and FAA to begin a research campaign to develop allowance times
Standard HOT testing does not apply to ice pellets due to different failure mechanism, so aerodynamic testing was required
Ice pellet allowance times were developed, and now
Periodical wind tunnel testing is done to update this guidance


COLLABORATORS
Transport Canada
NASA
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APS
SUPPORTERS
ABAX
ALLCLEAR SYSTEMS
CHEMCO
CLARIANT
CRYOTECH
DOW
Inland
Kilfrost
LNT Solutions
NEWAVE
NORDIX
SAE INTERNATIONAL


2019-20 Research Team

2019-20 Summary of Test Runs

- 8 days of testing between Jan 19 – Feb 7, 2020
  - 3 days with RJ wing for Ice Pellet Validation and Expansion
  - 5 days with Piper Seneca II tail model for V-Stab testing

2019-20 Summary – 8 Days of Testing

3	Dcugnkpg"Vguvu"*Ft{"ykpi+	8
4	Keg"Rgnngv"Cnnqy cpeg"Vko g Xcnkfcvkqp *Pgy "Hnwkfu+	7
5	GI Hnwkfu"/ Gzrcpukqp qh"Cnnqy cpeg"Vko gu	35,
6	X/Uvcd Vguvkpi"ykvj "Piper Seneca II Tail Model**	52
	Vqvcn	76

**7 of 13 tests also served as Validation tests*
*** Discussed in separate presentation*

Validation Testing Results

- Testing conducted with new commercially available fluids
- Allowance times are generic, so systematic "spot checking" done in order to identify any potential issues
- Testing included 1 new Type IV fluid
  - Clariant Produkte (Deutschland) GmbH Safewing EG IV NORTH

Enctkcpv"Rtqfwmvg"*Fgwvuejncpf+"I o dJ "Uchgy kpi "GI "KX "PQTVJ	✓ Xcnkfcvgf

EG Specific Allowance Times

- Industry requested EG specific fluid ice pellet allowance time tables be investigated
  - potential for longer allowance times
- Analysis was conducted to identify tests which supported longer times for EG fluids:
  - Historical data collected from 2009-2017
  - New data collected form 2017-19
  - Additional new data collected in 2019-20

EG Specific Allowance Times (Cont'd)

- Analysis/discussion is on-going to validate the results obtained to date
- Results indicate a potential for longer allowance times for EG fluids in many of the allowance time cells
- Data is supporting development of a separate Ice Pellet Allowance Time Table for EG based fluids
- TC/FAA will be reviewing the data with desire for inclusion into the HOT guidelines

Changes to Allowance Time Tables

- A separate Ice Pellet Allowance Time Table for EG based fluids is being considered
  - Work in progress.
  - Changes are pending more thorough analysis and discussion of results

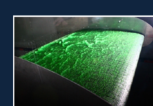
Transport Canada Holdover Time Guidelines Winter 20XX-20XX

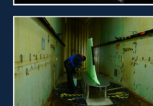
TABLE 42: ALLOWANCE TIMES FOR SAE TYPE IV ETHYLENE GLYCOL (EG) FLUIDS

Precipitation Type	Outside Air Temperature: -5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -22°C
Light Ice Pellets	XX minutes	XX minutes	XX minutes	XX minutes
Light Ice Pellets Mixed with Snow	XX minutes	XX minutes	XX minutes	
Light Ice Pellets Mixed with Freezing Drizzle	XX minutes	XX minutes	Caution: No allowance times currently exist	
Light Ice Pellets Mixed with Freezing Rain	XX minutes	XX minutes		
Light Ice Pellets Mixed with Rain	XX minutes			
Moderate Ice Pellets (or Small Hail)	XX minutes	XX minutes	XX minutes	XX minutes
Moderate Ice Pellets (or Small Hail) Mixed with Freezing Drizzle	XX minutes	XX minutes	Caution: No allowance times currently exist	
Moderate Ice Pellets (or Small Hail) Mixed with Rain	XX minutes			

Wind Tunnel Research Plans for 2020-21

- Ice pellet allowance time research
  - Validation with new fluids
  - Continuation of EG specific times research
  - Type III Low Speed
- V-Stab testing
  - Continued testing with Seneca Piper II Model
- Testing planned for Jan/Feb 2021



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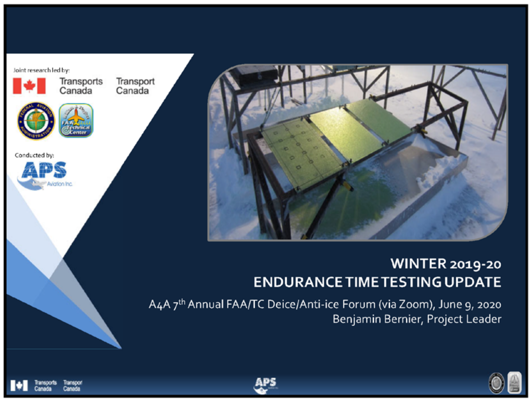
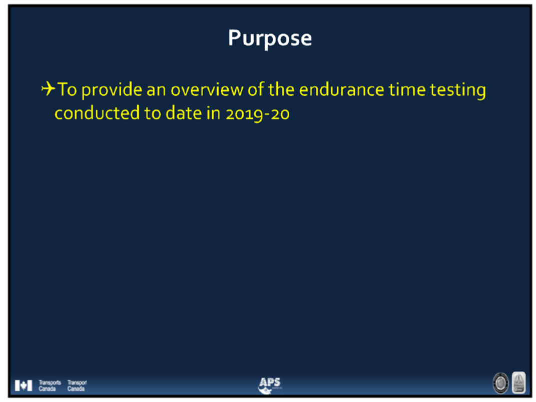
AIRLINES FOR AMERICA GROUND DEICING FORUM, ONLINE (VIA ZOOM), JUNE 2020

PRESENTATION:
WINTER 2019-20 ENDURANCE TIME TESTING UPDATE


Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS
WINTER 2019-20
ENDURANCE TIME TESTING UPDATE
A4A 7th Annual FAA/TC Deice/Anti-ice Forum (via Zoom), June 9, 2020
Benjamin Bernier, Project Leader
APS


Purpose
To provide an overview of the endurance time testing conducted to date in 2019-20
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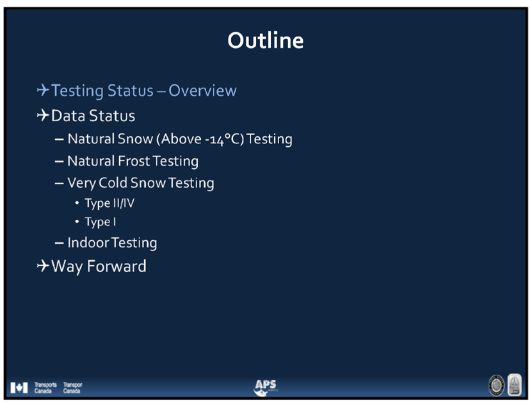
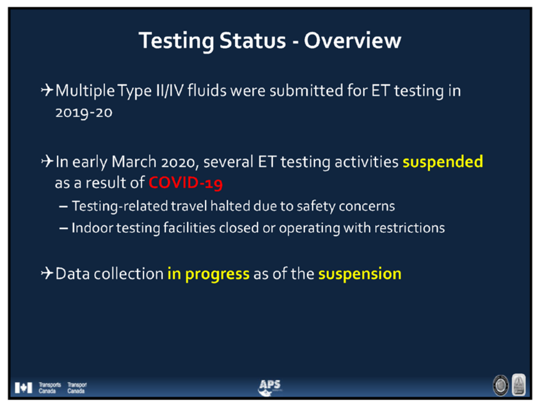

Outline
Testing Status – Overview
Data Status
– Natural Snow (Above -14°C) Testing
– Natural Frost Testing
– Very Cold Snow Testing
• Type II/IV
• Type I
– Indoor Testing
Way Forward
APS


Testing Status - Overview
Multiple Type II/IV fluids were submitted for ET testing in 2019-20
In early March 2020, several ET testing activities suspended as a result of COVID-19
– Testing-related travel halted due to safety concerns
– Indoor testing facilities closed or operating with restrictions
Data collection in progress as of the suspension
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Outline
Testing Status – Overview and Communications
Data Status
– Natural Snow (Above -14°C) Testing
– Natural Frost Testing
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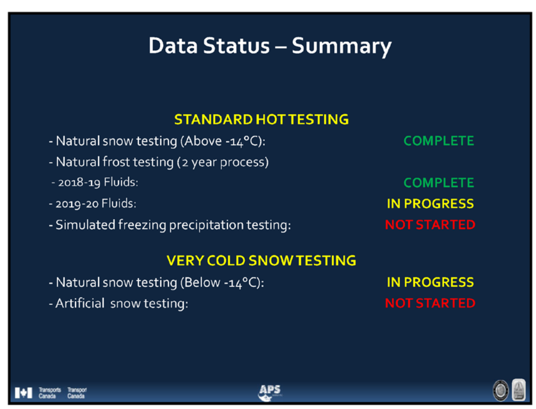
• Type I
– Indoor Testing
Way Forward
APS


Data Status – Summary
STANDARD HOT TESTING
- Natural snow testing (Above -14°C): COMPLETE
- Natural frost testing (2 year process)
- 2018-19 Fluids: COMPLETE
- 2019-20 Fluids: IN PROGRESS
- Simulated freezing precipitation testing: NOT STARTED
VERY COLD SNOW TESTING
- Natural snow testing (Below -14°C): IN PROGRESS
- Artificial snow testing: NOT STARTED
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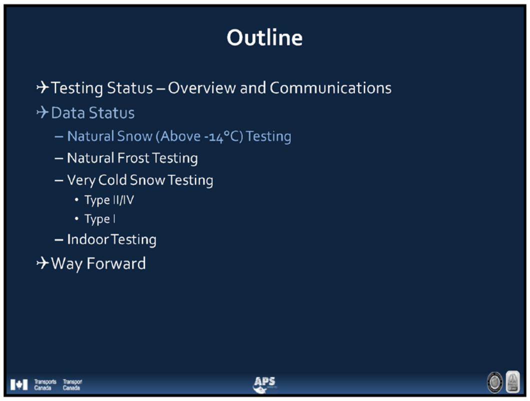
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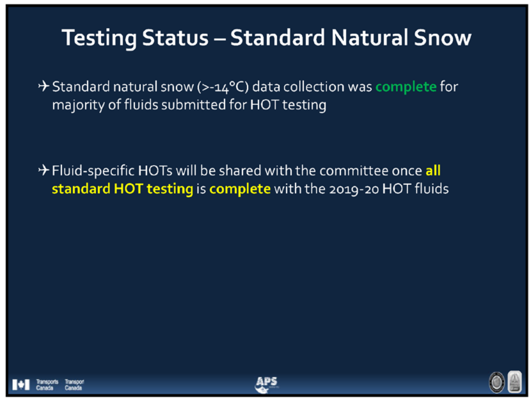
Way Forward
APS


Testing Status – Standard Natural Snow
Standard natural snow (>-14°C) data collection was complete for majority of fluids submitted for HOT testing
Fluid-specific HOTs will be shared with the committee once all standard HOT testing is complete with the 2019-20 HOT fluids
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Outline
Testing Status – Overview
Data Status
– Natural Snow (Above -14°C) Testing
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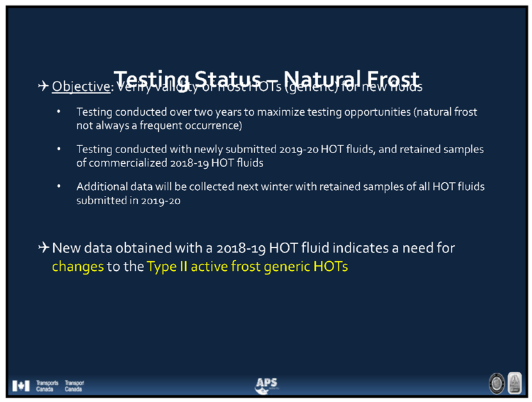
• Type II/IV
• Type I
– Indoor Testing
Way Forward
APS


Testing Status – Natural Frost
Objective: Verify validity of frost HOTs (generic) for new fluids
• Testing conducted over two years to maximize testing opportunities (natural frost not always a frequent occurrence)
• Testing conducted with newly submitted 2019-20 HOT fluids, and retained samples of commercialized 2018-19 HOT fluids
• Additional data will be collected next winter with retained samples of all HOT fluids submitted in 2019-20
New data obtained with a 2018-19 HOT fluid indicates a need for changes to the Type II active frost generic HOTs
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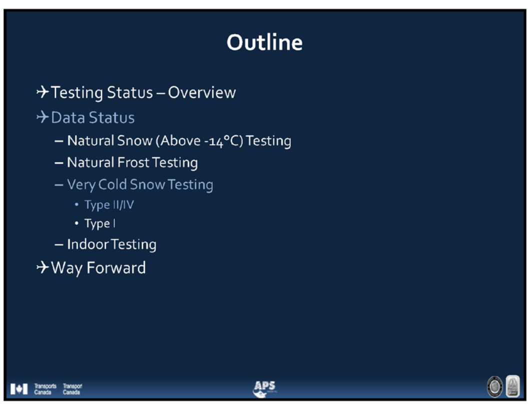
Outline
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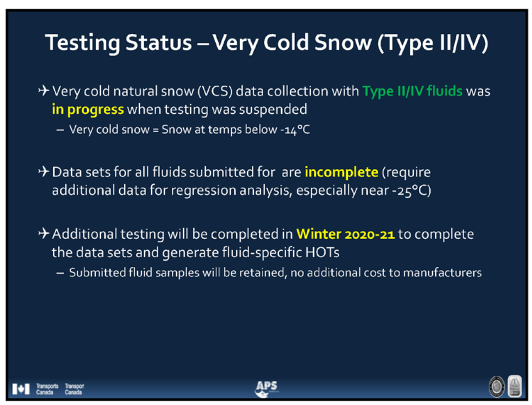
Way Forward
APS


Testing Status – Very Cold Snow (Type II/IV)
Very cold natural snow (VCS) data collection with Type II/IV fluids was in progress when testing was suspended
– Very cold snow = Snow at temps below -14°C
Data sets for all fluids submitted for are incomplete (require additional data for regression analysis, especially near -25°C)
Additional testing will be completed in Winter 2020-21 to complete the data sets and generate fluid-specific HOTs
– Submitted fluid samples will be retained, no additional cost to manufacturers
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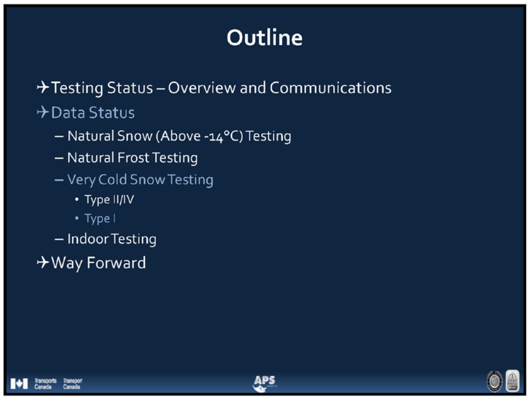
Outline
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• Type II/IV
• Type I
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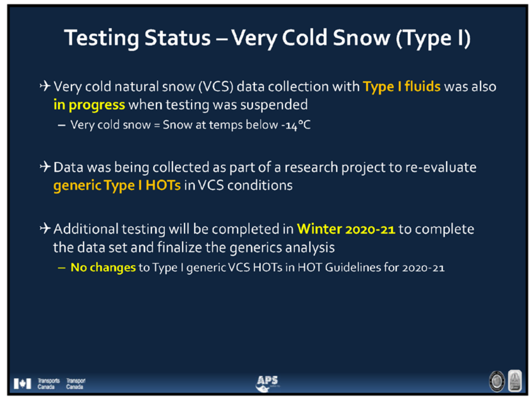
Way Forward
APS


Testing Status – Very Cold Snow (Type I)
Very cold natural snow (VCS) data collection with Type I fluids was also in progress when testing was suspended
– Very cold snow = Snow at temps below -14°C
Data was being collected as part of a research project to re-evaluate generic Type I HOTs in VCS conditions
Additional testing will be completed in Winter 2020-21 to complete the data set and finalize the generics analysis
– No changes to Type I generic VCS HOTs in HOT Guidelines for 2020-21
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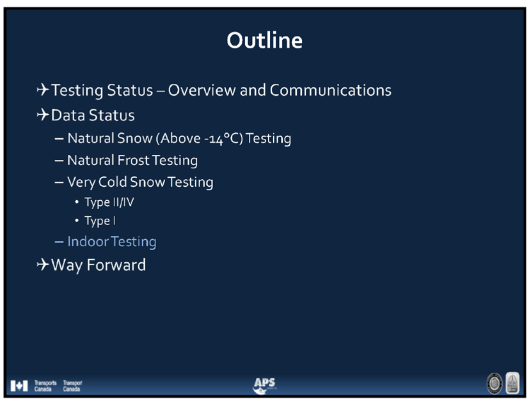
Outline
Testing Status – Overview and Communications
Data Status
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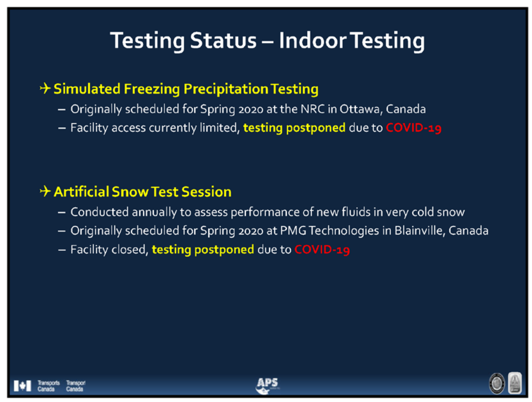
• Type II/IV
• Type I
– Indoor Testing
Way Forward
APS


Testing Status – Indoor Testing
Simulated Freezing Precipitation Testing
– Originally scheduled for Spring 2020 at the NRC in Ottawa, Canada
– Facility access currently limited, testing postponed due to COVID-19
Artificial Snow Test Session
– Conducted annually to assess performance of new fluids in very cold snow
– Originally scheduled for Spring 2020 at PMG Technologies in Blainville, Canada
– Facility closed, testing postponed due to COVID-19
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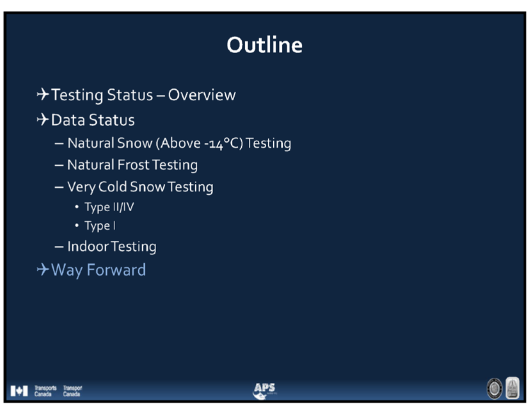
Outline
Testing Status – Overview
Data Status
– Natural Snow (Above -14°C) Testing
– Natural Frost Testing
– Very Cold Snow Testing
• Type II/IV
• Type I
– Indoor Testing
Way Forward
APS


Way Forward
Current plan is to finish pending testing activities as soon as COVID-19 situation allows
– Simulated freezing precipitation testing @ NRC
– Artificial snow testing @ PMG
– Note: Very cold natural snow data collection will only resume in Winter 2020-21
New fluid data will be included in the 2021-22 HOT guidelines
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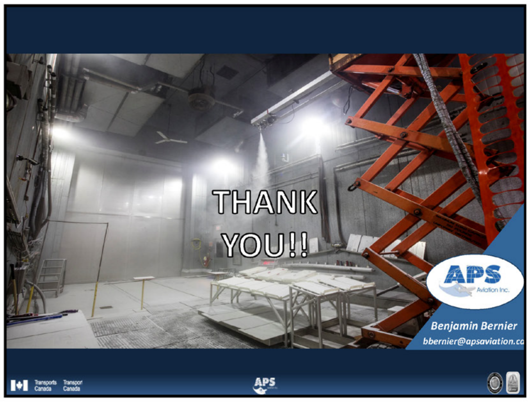
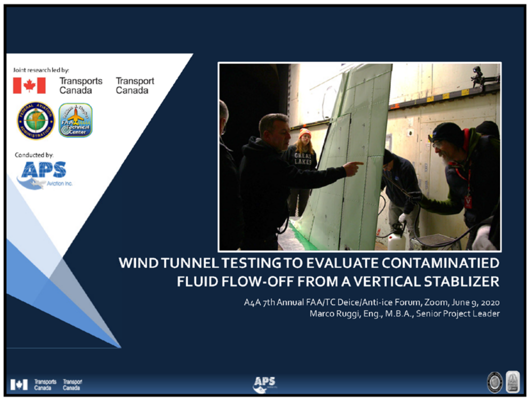


Natural Frost – Impact to Generics

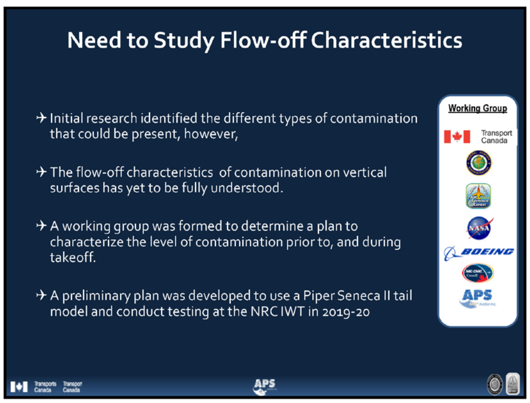
Outside Air Temperature[2,3]	Concentration Fluid/Water By % Volume	Type II
-1°C and above (30°F and above)	100/0	8:00
	75/25	5:00
	50/50	~~3:00~~ 2:00
below -1 to -3°C (below 30 to 27°F)	100/0	8:00
	75/25	5:00
	50/50	1:30
below -3 to -10°C (below 27 to 14°F)	100/0	8:00
	75/25	~~5:00~~ 4:00
below -10 to -14°C (below 14 to 7°F)	100/0	6:00
	75/25	1:00
below -14 to -21°C (below 7 to -6°F)	100/0	~~6:00~~ 3:00
below -21 to -25°C (below -6 to -13°F)	100/0	2:00

AIRLINES FOR AMERICA GROUND DEICING FORUM, ONLINE (VIA ZOOM), JUNE 2020

PRESENTATION:
WIND TUNNEL TESTING TO EVALUATE CONTAMINATED FLUID FLOW-OFF FROM A VERTICAL STABILIZER


Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS
Aviation Inc.
WIND TUNNEL TESTING TO EVALUATE CONTAMINATIED
FLUID FLOW-OFF FROM A VERTICAL STABLIZER
A4A 7th Annual FAA/TC Deice/Anti-ice Forum, Zoom, June 9, 2020
Marco Ruggi, Eng., M.B.A., Senior Project Leader


Background and Previous Research


Need to Study Flow-off Characteristics
Initial research identified the different types of contamination that could be present, however,
The flow-off characteristics of contamination on vertical surfaces has yet to be fully understood.
A working group was formed to determine a plan to characterize the level of contamination prior to, and during takeoff.
A preliminary plan was developed to use a Piper Seneca II tail model and conduct testing at the NRC IWT in 2019-20
Working Group
Transport Canada
BOEING
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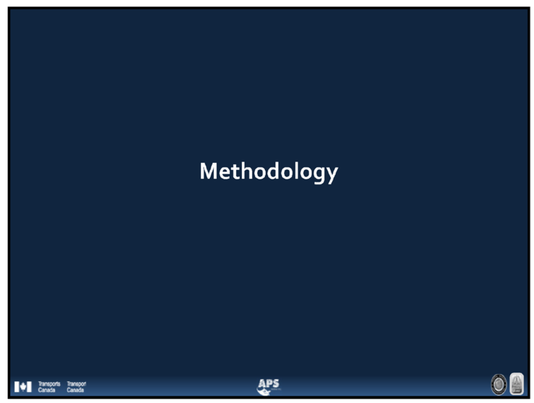
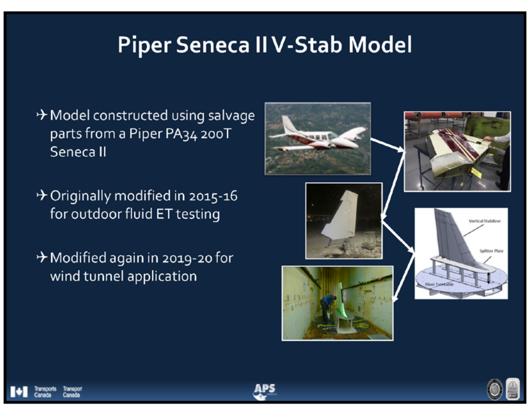
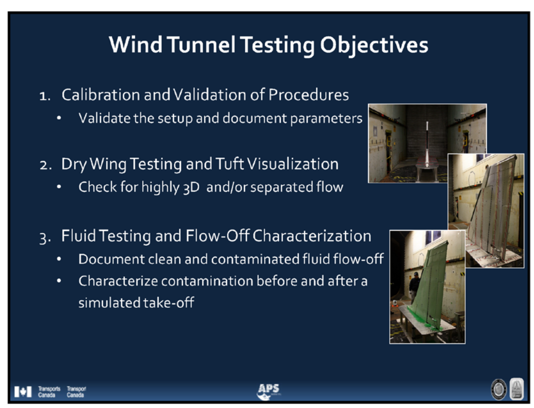
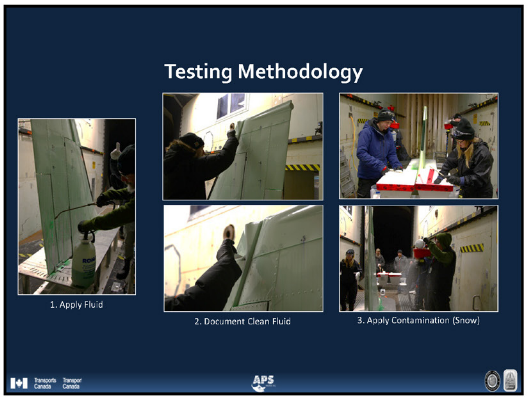
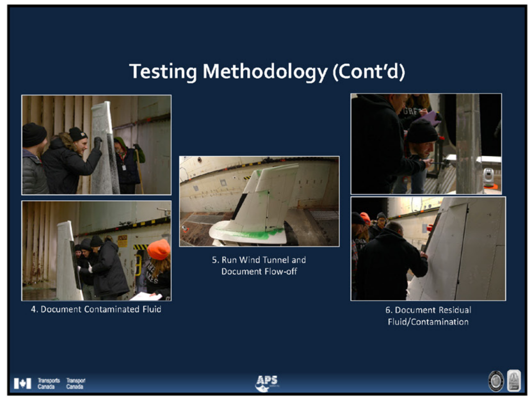
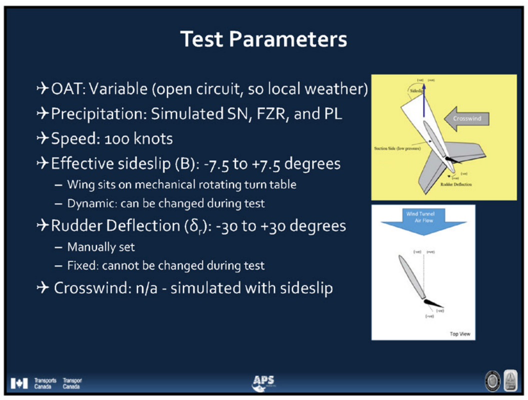

Methodology


Piper Seneca II V-Stab Model
Model constructed using salvage parts from a Piper PA34 200T Seneca II
Originally modified in 2015-16 for outdoor fluid ET testing
Modified again in 2019-20 for wind tunnel application


Wind Tunnel Testing Objectives
1. Calibration and Validation of Procedures
• Validate the setup and document parameters
2. Dry Wing Testing and Tuft Visualization
• Check for highly 3D and/or separated flow
3. Fluid Testing and Flow-Off Characterization
• Document clean and contaminated fluid flow-off
• Characterize contamination before and after a simulated take-off


Testing Methodology
1. Apply Fluid
2. Document Clean Fluid
3. Apply Contamination (Snow)
APS


Testing Methodology (Cont'd)
4. Document Contaminated Fluid
5. Run Wind Tunnel and Document Flow-off
6. Document Residual Fluid/Contamination
APS


Test Parameters
OAT: Variable (open circuit, so local weather)
Precipitation: Simulated SN, FZR, and PL
Speed: 100 knots
Effective sideslip (B): -7.5 to +7.5 degrees
– Wing sits on mechanical rotating turn table
– Dynamic: can be changed during test
Rudder Deflection (δr): -30 to +30 degrees
– Manually set
– Fixed: cannot be changed during test
Crosswind: n/a - simulated with sideslip
Crosswind
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2019-20 Research Team
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Sample of Results
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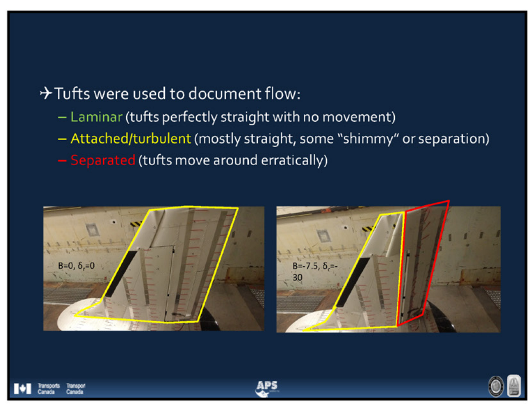
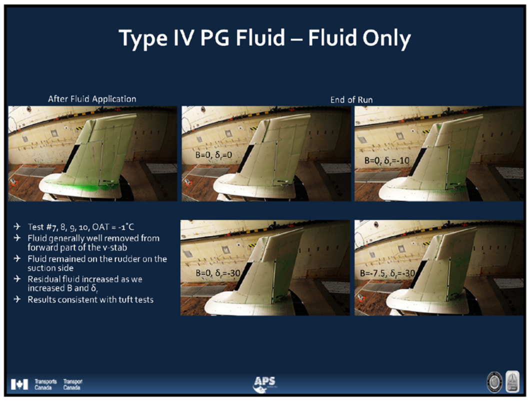

Tufts were used to document flow:
– Laminar (tufts perfectly straight with no movement)
– Attached/turbulent (mostly straight, some "shimmy" or separation)
– Separated (tufts move around erratically)
B=0, δr=0
B=-7.5, δr=-30
APS


Type IV PG Fluid – Fluid Only
After Fluid Application
End of Run
B=0, δr=0
B=0, δr=-10
B=0, δr=-30
B=-7.5, δr=-30
Test #7, 8, 9, 10, OAT ≈ -1˚C
Fluid generally well removed from forward part of the v-stab
Fluid remained on the rudder on the suction side
Residual fluid increased as we increased B and δr
Results consistent with tuft tests
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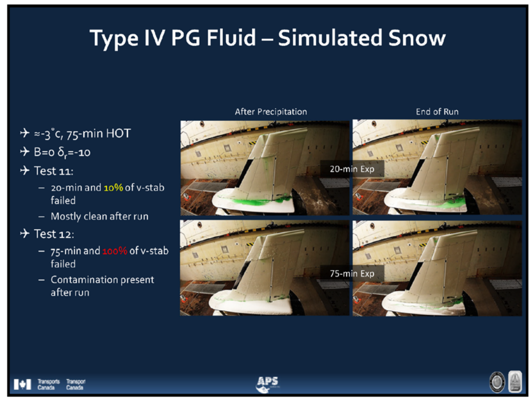
Type IV PG Fluid – Simulated Snow
After Precipitation
End of Run
≈-3˚c, 75-min HOT
B=0 δr=-10
Test 11:
– 20-min and 10% of v-stab failed
– Mostly clean after run
Test 12:
– 75-min and 100% of v-stab failed
– Contamination present after run
20-min Exp
75-min Exp
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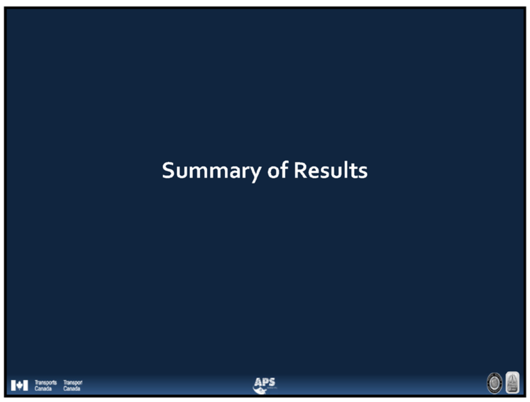
Summary of Results
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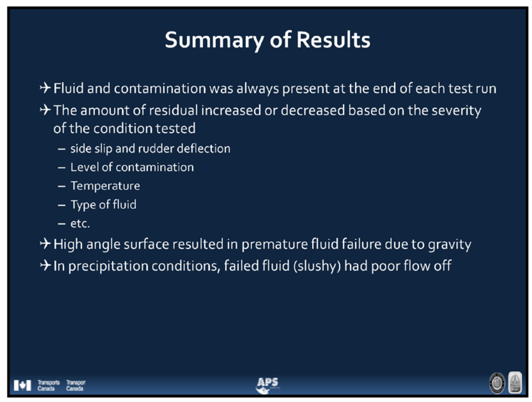
Summary of Results
Fluid and contamination was always present at the end of each test run
The amount of residual increased or decreased based on the severity of the condition tested
– side slip and rudder deflection
– Level of contamination
– Temperature
– Type of fluid
– etc.
High angle surface resulted in premature fluid failure due to gravity
In precipitation conditions, failed fluid (slushy) had poor flow off
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Way Forward
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Way Forward
Continue discussions and analysis with research team
Continue to engage OEMs to ensure relevance of testing results and objectives going forward, and transparency
Develop test plan for additional testing with current setup for winter 2020-21
Develop a long-term research plan incorporating possible new model with added capabilities
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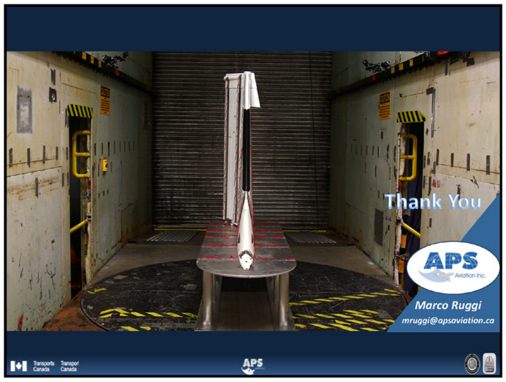
Thank You
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