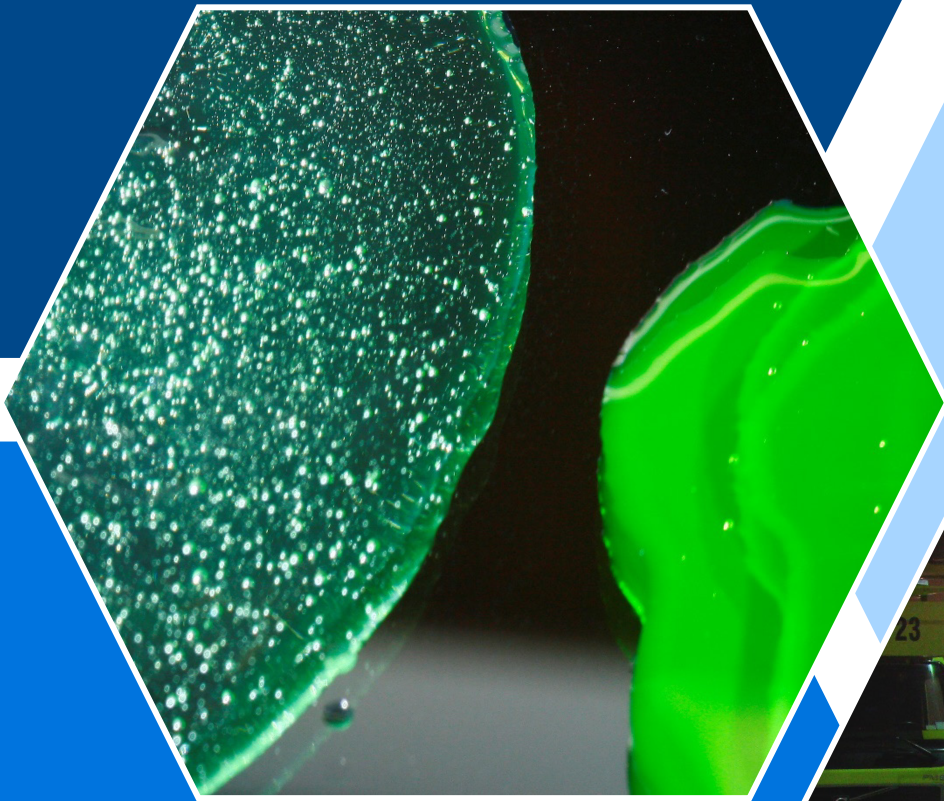
Aviation Inc.

TP 15496E
Final Version 1.0
December 2021



AIRCRAFT GROUND ICING GENERAL RESEARCH ACTIVITIES DURING THE 2020-21 WINTER

Prepared for:

Transport Canada
Innovation Centre

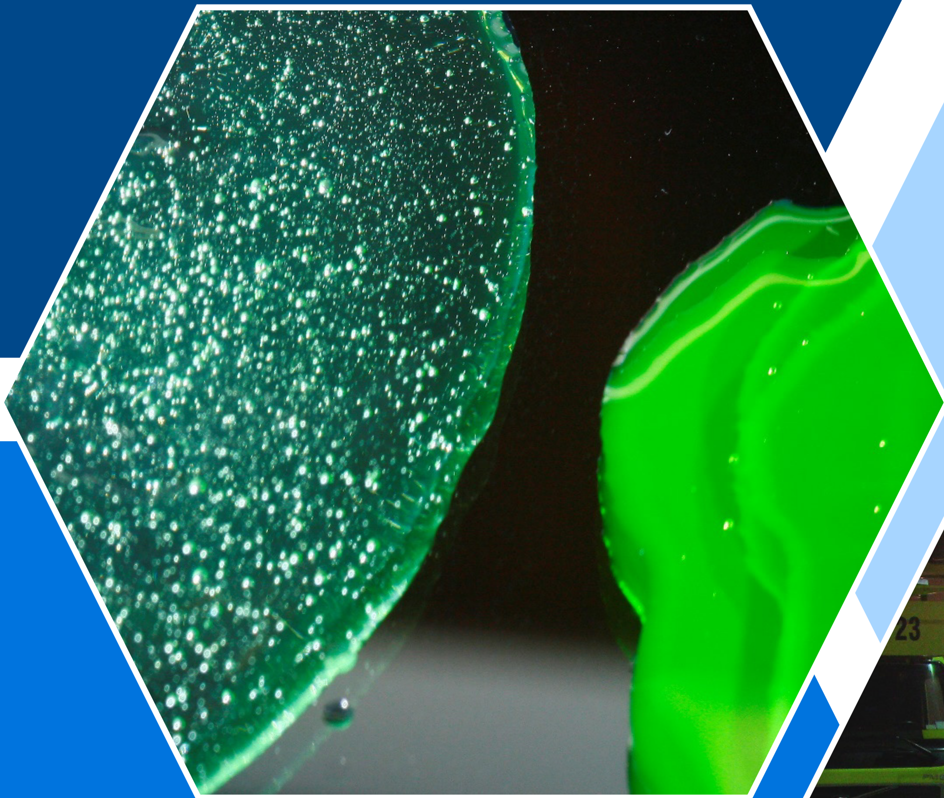
In cooperation with:

Federal Aviation Administration
William J. Hughes Technical Center

Transport Canada
Civil Aviation

Federal Aviation Administration
Flight Standards – Air Carrier Operations

TP 15496E
Final Version 1.0
December 2021



AIRCRAFT GROUND ICING GENERAL RESEARCH ACTIVITIES DURING THE 2020-21 WINTER

Prepared by

APS Aviation Inc.

The contents of this report reflect the views of APS Aviation Inc. and not necessarily the official view or opinions of the Transport Canada Innovation Centre or the co-sponsoring organizations.

Neither the Transport Canada Innovation Centre nor the co-sponsoring organizations endorse the products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

DOCUMENT ORIGIN AND APPROVAL RECORD

Prepared by: APS Aviation Inc.

Reviewed and Approved by:

Aug 17, 2022

John D'Avirro, Eng., PBDM — Date
Vice President, Aviation Services

Un sommaire français se trouve avant la table des matières.

This report was first provided to Transport Canada as Final Draft 1.0 in December 2021.
It has been published as Final Version 1.0 in August 2022.

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, III, and 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 machines 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 finalize the research for the development of degree-specific snow holdover time data;
- To study and support the interpretation of METAR reported weather for determining holdover time table guidance;
- 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 2020-21 are documented in four reports. The titles of the reports are as follows:

- TP 15494E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2020-21 Winter;
- TP 15495E Regression Coefficients and Equations Used to Develop the Winter 2021-22 Aircraft Ground Deicing Holdover Time Tables;
- TP 15496E Aircraft Ground Icing General Research Activities During the 2020-21 Winter; and
- TP 15497E Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2020-21.

In addition, the following interim report is being prepared:

- *Artificial Snow Research Activities for the 2020-21 Winter*.

This report, TP 15496E, has the following objective:

- To document the exploratory research and general activities carried out during the winter of 2020-21.

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, Christopher D'Avirro, John D'Avirro, Peter Dawson, Jaycee Ewald, Noemie Gokhool, Benjamin Guthrie, Peter Kitchener, Diana Lalla, Shahdad Movaffagh, Dany Posteraro, Annaelle Reuveni, Marco Ruggi, Javad Safari, Alexa-Kiran Sareen-Diacoumacos, Niroshaan Sivarajah, James Smyth, Saba Tariq, Charles Wilson, Ian Wittmeyer, and David Youssef.

Special thanks are extended to Antoine Lacroix, Yvan Chabot, 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 and Diana Lalla for *Review of METAR Reported Weather for Determining Holdover Time Guidance*; Dany Posteraro for *Evaluation of Mist Deposition Rates*; Benjamin Bernier for *Development of Degree-Specific Holdover Times for Snow*; Dany Posteraro and Diana Lalla for *Effect of Vibrating Vertical Surfaces on De/Anti-icing Fluids*; Diana Lalla for *Evaluation of Variability in Holdover Time Testing Results – Light Freezing Rain*; Diana Lalla for *Evaluation of the Use of the NRC's Climatic Engineering Facility for Development of Holdover Times*; Benjamin Bernier and Diana Lalla for *Review of "Snowfall Intensities as a Function of Prevailing Visibility" Holdover Time Guidance*; Dany Posteraro and Saba Tariq for *Implementation of Video Streaming Technology for Remote Viewing of Deicing Research Tests*; Diana Lalla and Marco Ruggi for *Documentation of Test Methods and Protocols for Ice Pellet Allowance Time Development*; Diana Lalla and Benjamin Bernier for *Review of Updates Required for SAE Documents ARP5485, ARP5945, ARP5718, and ARP6207*; Dany Posteraro for *COVID-19 Guidelines and Impacts on the 2020-21 Ground Icing Research Program*; Saba Tariq for *Technical Review, Approval, and Publication of Historical Reports*; Chloë Bernier for *Publication of Holdover Time Guidance Materials*; Saba Tariq for *Presentations, Fluid Manufacturer Reports, and Test Procedures for 2020-21*; and Dany Posteraro for *Evaluation of the ACE Research Center as an Alternative Facility for Deicing Research Activities*.

Transport Canada | Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.	2. Project No.	3. Recipient's Catalogue No.
TP 15496E	B14W	

4. Title and Subtitle	5. Publication Date
Aircraft Ground Icing General Research Activities During the 2020-21 Winter	December 2021
	6. Performing Organization Document No.
	300293
7. Author(s)	8. Transport Canada File No.
APS Aviation Inc.	2450-BP-14
9. Performing Organization Name and Address	10. PWGSC File No.
APS Aviation Inc. 6700 Côte-de-Liesse Rd., Suite 102 Montreal, Quebec, H4T 2B5	TOR-7-40103
	11. PWGSC or Transport Canada Contract No.
	T8156-170044/001/TOR
12. Sponsoring Agency Name and Address	13. Type of Publication and Period Covered
Transport Canada Innovation Centre 330 Sparks St., 18th Floor Ottawa, Ontario, K1A 0N5	Final
	14. Project Officer
	Antoine Lacroix

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 2020-21. The activities documented in this report were carried out in addition to the main research projects completed in the winter of 2020-21, which are documented in separate reports. The fifteen activities described in this report are listed below:

1) Review of METAR Reported Weather for Determining Holdover Time Guidance;
2) Evaluation of Mist Deposition Rates;
3) Development of Degree-Specific Holdover Times for Snow;
4) Effect of Vibrating Vertical Surfaces on De/Anti-Icing Fluids;
5) Evaluation of Variability in Holdover Time Testing Results – Light Freezing Rain;
6) Evaluation of the Use of the NRC's Climatic Engineering Facility for Development of Holdover Times;
7) Review of "Snowfall Intensities as a Function of Prevailing Visibility" Holdover Time Guidance;
8) Implementation of Video Streaming Technology for Remote Viewing of Deicing Research Tests;
9) Documentation of Test Methods and Protocols for Ice Pellet Allowance Time Development;
10) Review of Updates Required for SAE Documents ARP5485, ARP5945, ARP5718, and ARP6207;
11) COVID-19 Guidelines and Impacts on the 2020-21 Ground Icing Research Program;
12) Technical Review, Approval, and Publication of Historical Reports;
13) Publication of Holdover Time Guidance Materials;
14) Presentations, Fluid Manufacturer Reports, and Test Procedures for 2020-21; and
15) Evaluation of the ACE Research Center as an Alternative Facility for Deicing Research Activities.

17. Key Words	18. Distribution Statement
METAR, Holdover Time, Guidelines, Mist, Degree-Specific, Vibration, Vertical Surfaces, Variability, NRC, Visibility, Remote Viewing, Allowance Time, SAE, ARP, COVID-19, Reports, Presentations, Procedures, ACE	Available from the Transport Canada Innovation Centre

19. Security Classification (of this publication)	20. Security Classification (of this page)	21. Declassification (date)	22. No. of Pages	23. Price
Unclassified	Unclassified	—	xxvi, 118 apps	—

CDT/TDC 79-005
Rev. 96

Canada

Transports Canada | Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. No de la publication de Transports Canada TP 15496E	2. No de l'étude B14W	3. No de catalogue du destinataire
4. Titre et sous-titre Aircraft Ground Icing General Research Activities During the 2020-21 Winter		5. Date de la publication Décembre 2021 6. No de document de l'organisme exécutant 300293
7. Auteur(s) APS Aviation Inc.		8. No de dossier - Transports Canada 2450-BP-14
9. Nom et adresse de l'organisme exécutant APS Aviation Inc. 6700, Chemin de la Côte-de-Liesse, Bureau 102 Montréal (Québec) H4T 2B5		10. No de dossier - TPSGC TOR-7-40103 11. No de contrat - TPSGC ou Transports Canada T8156-170044/001/TOR
12. Nom et adresse de l'organisme parrain Transports Canada Centre d'innovation 330, rue Sparks, 18ième étage Ottawa (Ontario) K1A 0N5		13. Genre de publication et période visée Final 14. Agent de projet Antoine Lacroix

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 2020-2021. Les activités dont fait état ce rapport ont été effectuées en plus des projets de la recherche principale menés pendant l'hiver 2020-2021, qui sont documentés dans des rapports distincts. Les quinze activités qui font l'objet du présent rapport sont énumérées ci-dessous :

1) Examen des conditions météorologiques signalées par METAR en vue de déterminer les lignes directrices sur les durées d'efficacité ;
2) Évaluation des taux de dépôts brumeux ;
3) Mise au point de durées d'efficacité selon le degré pour la neige ;
4) Effet de la vibration sur les liquides de dégivrage et d'antigivrage appliqués aux surfaces verticales ;
5) Évaluation de la variabilité des résultats d'essais relatifs aux durées d'efficacité – pluie verglaçante légère ;
6) Évaluation du recours à l'installation de génie climatique du CNRC pour l'élaboration de durées d'efficacité ;
7) Examen des lignes directrices sur les durées d'efficacité relatives aux « intensités des chutes de neige en fonction de la visibilité dominante » ;
8) Mise en œuvre de technologies de diffusion vidéo en continu pour l'observation à distance des essais sur le dégivrage ;
9) Documentation des méthodes et des protocoles d'essai encadrant l'élaboration de marges de tolérance dans des conditions de granules de glace ;
10) Examen des mises à jour requises dans les normes ARP5485, ARP5945, ARP5718 et ARP6207 de la SAE ;
11) Lignes directrices relatives à la COVID-19 et répercussions de la pandémie sur le programme de recherche sur le givrage d'aéronefs au sol de 2020-2021 ;
12) Examen technique, approbation et publication de rapports historiques ;
13) Publication de documents d'orientation sur les durées d'efficacité ;
14) Présentations, rapports aux fabricants de liquides et procédures d'essais pour 2020-2021 ; et
15) Évaluation du Centre de recherche ACE en tant qu'installation alternative pour les activités de recherche sur le dégivrage.

17. Mots clés METAR, durées d'efficacité, lignes directrices, brume, selon le degré, vibration, surfaces verticales, variabilité, CNRC, visibilité, observation à distance, marges de tolérance, SAE, ARP, COVID-19, rapports, présentations, procédures, ACE		18. Diffusion Disponible auprès du Centre d'innovation de Transports Canada		
19. Classification de sécurité (de cette publication) Non classifiée	20. Classification de sécurité (de cette page) Non classifiée	21. Déclassification (date) —	22. Nombre de pages xxvi, 118 ann.	23. Prix —

CDT/TDC 79-005
Rev. 96

Canada

EXECUTIVE SUMMARY

This report documents the exploratory research and general activities completed in the winter of 2020-21 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 fifteen activities that were carried out in addition to the main research projects in the winter of 2020-21.

Review of METAR Reported Weather for Determining Holdover Time Guidance (Section 2)

When aircraft are operating in adverse winter conditions, the reported METAR weather conditions may not always have a corresponding condition in the holdover time (HOT) guidance 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 inclusive HOT guidance material. APS undertook a research project including analytical and research activities to support the development of HOT or allowance time guidance for reported METAR weather not currently included in guidance material.

Evaluation of Mist Deposition Rates (Section 3)

Mist is a commonly reported weather phenomenon which can occur alone or with other precipitation types. Although similar to fog, mist is said to be present when the visibility is between 0.6 and 1.2 miles (1-2 km), while fog reduces it to less than 0.6 miles (1 km). With respect to HOTs, mist deposition rates had never been quantified whereas historical data indicates that freezing fog can produce rates between 2 and 5 $g/dm^2/h$. Mist deposition rates were thus determined using the same methodology as used for freezing fog. Results indicated that mist deposition rates for the stationary and taxi tests were 0.2 and 0.3 $g/dm^2/h$ on average, respectively. Although comparable to that of frost, the decision was made to include mist in the “Freezing Fog and Ice Crystals” column of the HOT tables.

Development of Degree-Specific Holdover Times for Snow (Section 4)

In the winter of 2020-21, the development of Degree-Specific Holdover Times (DSHOTs) for snow was completed. This was the continuation of a project initiated in the winter of 2018-19. This resulted in the creation of a database of DSHOTs for snow conditions for all 100/0 Type II, Type III, and Type IV anti-icing fluids. Both TC and the FAA have published versions of the DSHOTs database for use by industry in the upcoming 2021-22 winter season. Additional supporting guidance relating to the use of DSHOTs was also produced and published by both TC and the FAA.

Effect of Vibrating Vertical Surfaces on De/Anti-Icing Fluids (Section 5)

Currently, there is a lack of standardization in the treatment of vertical surfaces. If current operational rules aim to achieve the clean aircraft concept – which requires the tail to have zero adhering frozen contamination – the question remains: How can this be adequately achieved, or appropriately mitigated by operators, to ensure a satisfactory level of safety? The effects of vibration during taxiing on fluid adherence to vertical tail is one of many components, which may need to be considered in future wind tunnel research. To determine if this component is to be included, testing was conducted using a vertical vibrating plate. The taxi vibration profile used was determined using accelerometer data obtained from three reports. The average frequency and amplitude of the vibration was then calculated. For testing conducted with contamination, results showed that in general, the condition of the 80º vibrating plate and the 80º stationary plate at the endurance time of the 10º plate, was approximately the same for each run. Fluid thickness measurements on the 80º vibrating plate and the 80º stationary plate were also similar throughout testing. For the fluid thickness tests conducted without contamination, the thickness measurement on the 80º vibrating plate and the 80º stationary plate were similar throughout each test.

Evaluation of Variability in Holdover Time Testing Results – Light Freezing Rain (Section 6)

APS was requested to study the variability in endurance time test results in simulated light freezing rain conditions. The plan was to conduct testing at the National Research Council Canada (NRC) Climatic Engineering Facility to collect data to assess the variability in endurance time testing results. Outdoor testing at the APS test site was also planned to collect natural light freezing rain data for comparison. No data was collected during the 2020-21 season. Testing scheduled at NRC for fall 2021 was cancelled due to reallocation of project resources to other higher-priority activities. Outdoor testing planned for the APS test site in Montreal was not completed due to absence of suitable freezing rain events this year. If resources become available, it is recommended to pursue testing in the future.

Evaluation of the Use of the NRC's Climatic Engineering Facility for Development of Holdover Times (Section 7)

There have been some questions raised about the validity of the simulated light freezing rain endurance time testing conducted at the NRC climate chamber as part of the development of HOTs.

A review of previous testing methods and results was conducted by APS. Previous full-scale outdoor testing showed a reasonable correlation between ten percent failure on wing and failure on flat plates. As well, comparative testing of the same fluids under natural light freezing rain conditions and simulated conditions at the NRC resulted in similar endurance times.

There have been discrepancies between the results obtained by APS and the Anti-Icing Materials International Laboratory (AMIL) for the same fluids under simulated light freezing rain conditions. In 1998, AMIL presented significantly shorter times, with the APS values substantiated upon retesting. Currently, a fluid manufacturer has claimed that their fluid obtained longer endurance times in light freezing rain tests at the AMIL facility (as compared to the results obtained at the NRC test facility). Significant investment may be required to determine the reason for these varying discrepancies.

Review of "Snowfall Intensities as a Function of Prevailing Visibility" Holdover Time Guidance (Section 8)

In the winter of 2020-21, APS conducted a review of the snowfall intensities as a function of prevailing visibility HOT guidance contained within the TC and FAA HOT Guidelines. The review outlined the existing differences in the two organizations' respective visibility guidance including differences in the table layout and data presentation, differences in the temperature categories within the tables, and discrepancies in the snowfall intensities assigned to certain visibility values. Preliminary analytical work seeking to address and resolve the differences in guidance has begun and is expected to continue in the 2021-22 project year.

Implementation of Video Streaming Technology for Remote Viewing of Deicing Research Tests (Section 9)

The COVID-19 pandemic remained ongoing in Canada during the 2020-21 winter. As a result, multiple COVID-19 guidelines and travel and personnel restrictions were in effect during the testing season and these restrictions varied locally and changed over time. Considering these restrictions, the 2020-21 winter testing was adapted to mitigate exposure risks through an implementation of a virtual remote camera viewing setup as a solution to allow stakeholder participation. This setup included closed-circuit television camera system integration with an online web conferencing platform, which allowed for viewing and evaluation of critical testing activities and technical discussions during testing sessions. The setups were then tried at the NRC climate chamber, NRC Icing Wind Tunnel, Montréal-Pierre Elliot Trudeau International Airport (PET) test facility, PMG Technologies Inc. test facility and Near/Far North testing. Overall, the remote camera viewing setup worked well by providing a high-quality video feed of the testing events to viewers/participants. It is recommended that further improvements be considered to increase quality and effectiveness of the cameras for virtual stakeholder participation in future testing events.

Documentation of Test Methods and Protocols for Ice Pellet Allowance Time Development (Section 10)

In 2020-21, APS carried out work to draft a document detailing the test methods and protocols for ice pellet allowance time development. Prior to the drafting of this new document, the testing protocol and procedures were only documented in technical reports published by APS, NRC, and National Aeronautics and Space Administration. As well, additional information existed only in internal APS procedural documentation or was not documented at all. A copy of the latest draft of the new document is included in this report. Going forward, the document should continue to be further developed and refined. The document developed as part of this project was based upon the format of the SAE International (SAE) Aerospace Recommended Practice (ARP) standards, which provide a comprehensive overview of the data collection and guidance development with respect to HOTs. Consideration should be given to revising the APS document into an SAE ARP document in the future.

Review of Updates Required for SAE Documents ARP5485, ARP5945, ARP5718, and ARP6207 (Section 11)

The objective of the preliminary review was to assess and document proposed changes to the HOT testing standards in support of future revisions. For each document, the proposed changes were categorized and rated on the level of effort required to integrate into the document.

A total of 63 proposed changes to the SAE HOT testing standards were reviewed and documented. Of these changes, 13 are considered critical as they are part of the HOT development process.

It is recommended that the documents are updated in a timely fashion, as resources become available, with the critical changes incorporated at a minimum.

COVID-19 Guidelines and Impacts on the 2020-21 Ground Icing Research Program (Section 12)

COVID-19 guidelines, including several restrictions concerning travel and personnel, which varied substantially from one location to another, and over time, were in effect due to the ongoing pandemic in the 2020-21 winter. Considering these restrictions, the winter testing was adapted to mitigate exposure risks through use of extensive personal protection equipment, implementation of a virtual remote camera viewing setup as a solution to allow stakeholder participation and application of other safety measures. Despite all the restrictions, testing activities undertaken during the winter of 2020-21 were completed. Testing of very cold snow fluids received in 2020-21 will be completed in the winter of 2021-22.

Technical Review, Approval, and Publication of Historical Reports (Section 13)

APS has conducted research related to ground icing, which involved writing and publishing over 213 reports on behalf of TC and the FAA since the early 1990s. 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, 2021, 30 reports remain to be published, excluding the current year reports for 2020-21.

Publication of Holdover Time Guidance Materials (Section 14)

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 2020-21 (Section 15)

APS produced a number of presentations, fluid manufacturer reports, and test procedures for the Winter 2020-21 test program. These are documented in this report.

Evaluation of the ACE Research Center as an Alternative Facility for Deicing Research Activities (Section 16)

In order to increase operational flexibility and acquire added capabilities, TC and the FAA are evaluating a new facility. This facility has three different cold chambers which are available for testing. They are the following:

- The climate wind tunnel;
- The large climate chamber; and
- The small climate chamber.

A feasibility study of this facility should be completed.

This page intentionally left blank.

SOMMAIRE

Le présent rapport documente la recherche exploratoire et les activités d'ordre général effectuées au cours de l'hiver 2020-2021 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 quinze activités effectuées en plus des principaux projets de recherche de l'hiver 2020-2021.

Examen des conditions météorologiques signalées par METAR en vue de déterminer les lignes directrices sur les durées d'efficacité (Section 2)

Il arrive parfois que les conditions météorologiques signalées par METAR ne correspondent pas exactement à celles figurant aux lignes directrices sur les durées d'efficacité permettant le décollage sécuritaire d'aéronefs dans des conditions hivernales défavorables, et cela est particulièrement vrai en présence de conditions mixtes. La mise au point de lignes directrices plus inclusives repose donc sur une bonne compréhension de la signification statistique de la fréquence des conditions météorologiques hivernales signalées par METAR. À cet effet, APS a entrepris un projet de recherche comportant des activités d'analyse et des essais pour soutenir l'élaboration de lignes directrices sur les durées d'efficacité ou les marges de tolérance dans des conditions signalées par METAR, mais ne figurant pas actuellement dans les documents de référence.

Évaluation des taux de dépôts brumeux (Section 3)

La brume est un phénomène météorologique couramment signalé qui peut se produire seul ou avec d'autres types de précipitations. Bien que semblable au brouillard, la brume est dite présente lorsque la visibilité est comprise entre 0,6 et 1,2 mile (1 ou 2 km), tandis que le brouillard la réduit à moins de 0,6 mile (1 km). Les taux de dépôts brumeux n'ont jamais été quantifiés relativement aux durées d'efficacité ; en revanche, les données historiques indiquent que le brouillard verglaçant peut donner lieu à des taux de dépôts de l'ordre de 2 à 5 $g/dm^2/h$. Des taux d'accumulation de brume ont donc été déterminés en appliquant la même méthodologie que celle utilisée pour le brouillard verglaçant. Les résultats indiquent que les taux de dépôts brumeux lors d'essais sur des appareils stationnaires et en circulation sont en moyenne de 0,2 et de 0,3 $g/dm^2/h$, respectivement. Quoique ces résultats soient comparables à ceux pour le givre, il a été décidé d'inclure la brume dans la colonne « Brouillard verglaçant ou cristaux de glace » des tableaux des durées d'efficacité.

Mise au point de durées d'efficacité selon le degré pour la neige (Section 4)

Au cours de l'hiver 2020-2021, l'élaboration de durées d'efficacité selon le degré dans des conditions de neige a été achevée. Ces démarches s'inscrivaient dans la poursuite d'un projet amorcé au cours de l'hiver 2018-2019. Cela a donné lieu à la création d'une base de données sur les durées d'efficacité selon le degré dans des conditions de neige pour l'ensemble des liquides d'antigivrage de type II, III et IV en concentration de 100/0. TC et la FAA ont publié chacune leur version de cette base de données pour utilisation par le secteur au cours de la prochaine saison hivernale de 2021-2022. Des directives complémentaires précisant l'application des durées d'efficacité selon le degré ont également été produites et publiées par ces deux organismes réglementaires.

Effet de la vibration sur les liquides de dégivrage et d'antigivrage appliqués aux surfaces verticales (Section 5)

À l'heure actuelle, le traitement des surfaces verticales ne fait pas l'objet d'une normalisation. Si les normes opérationnelles en vigueur ont pour objectif l'exécution du concept d'aéronef propre – où la queue de l'appareil doit être exempte de contamination par adhérence de givre – la question suivante demeure : Comment les opérateurs peuvent-ils y parvenir ou en réduire les risques adéquatement, et ainsi assurer un niveau de sécurité satisfaisant? Les effets des vibrations durant la circulation sur l'adhérence des liquides aux surfaces verticales de la queue sont l'un des nombreux aspects devant potentiellement être pris en considération dans le cadre de futures recherches en soufflerie. Des essais ont été menés à l'aide d'une plaque vibrante verticale pour déterminer la pertinence de l'ajout de cette composante. Le profil de vibrations de roulement utilisé était basé sur des données d'accéléromètre tirées de trois rapports. La fréquence et l'amplitude moyennes des vibrations ont ensuite été calculées. Les résultats des tests menés en présence de contamination ont démontré qu'en général, l'état des plaques vibrante et fixe de 80º auxquelles on applique des durées d'endurance de la plaque de 10º était approximativement le même pour chaque cycle. Les mesures de l'épaisseur du liquide sur les plaques vibrantes et fixe de 80º ont également été similaires tout au long des essais. Lors d'essais menés sans présence de contamination, les mesures de l'épaisseur du liquide sur ces mêmes plaques se sont également avérées similaires à chaque épreuve.

Évaluation de la variabilité des résultats d'essais relatifs aux durées d'efficacité – pluie verglaçante légère (Section 6)

APS a reçu le mandat d'étudier la variabilité des résultats d'essais relatifs aux durées d'endurance dans des conditions simulées de pluie verglaçante légère. Le plan consistait à mener des tests à l'installation de génie climatique du Conseil national de recherches Canada (CNRC) en vue de recueillir les données nécessaires à l'évaluation demandée. Des essais en plein air menés auprès des sites de tests d'APS étaient également prévus pour obtenir des données comparatives dans des conditions naturelles de pluie verglaçante légère. Aucune donnée n'a toutefois été recueillie au cours de la saison 2020-2021. Les essais prévus au CNRC pour l'automne 2021 ont été annulés en raison de la réaffectation des ressources du projet à d'autres activités prioritaires. En l'absence d'événements de pluie verglaçante adéquats cette année, les essais initialement prévus au site de test d'APS à Montréal n'ont pu être effectués. Si des ressources deviennent disponibles, il est recommandé de poursuivre ces démarches dans le futur.

Évaluation du recours à l'installation de génie climatique du CNRC pour l'élaboration de durées d'efficacité (Section 7)

Certaines questions ont été soulevées quant à la validité des essais sur les durées d'endurance dans des conditions simulées de pluie verglaçante qui ont été menés au sein de la chambre de simulation climatique du CNRC pour l'établissement des durées d'endurance.

APS a procédé à l'examen des méthodes antérieures et des résultats d'essais. Les essais pleine grandeur menés précédemment à l'extérieur présentaient une corrélation raisonnable entre les pertes d'efficacité sur les ailes, à raison de dix pour cent, et celles sur les surfaces planes. De plus, des essais comparatifs menés à l'aide des mêmes liquides dans des conditions naturelles de pluie verglaçante légère, ainsi que des conditions simulées du même type auprès du CNRC ont généré des durées d'endurance similaires.

Des écarts ont été relevés entre les résultats obtenus par APS et ceux du Laboratoire international des matériaux antigivres (LIMA) pour les mêmes liquides dans des conditions simulées de pluie verglaçante légère. En 1998, le LIMA a publié des durées considérablement plus courtes, et les valeurs d'APS ont été corroborées lors des retests. À l'heure actuelle, un fabricant affirme que, lors de tests menés au LIMA dans des conditions de pluie verglaçante légère, l'un de ses liquides a permis l'obtention de durées d'endurance supérieures (comparativement aux résultats recueillis à l'installation du CNRC). Des investissements considérables peuvent s'avérer nécessaires pour expliquer ces écarts variables.

Examen des lignes directrices sur les durées d'efficacité relatives aux « intensités des chutes de neige en fonction de la visibilité dominante » (Section 8)

Au cours de l'hiver 2020-2021, APS a procédé à un examen des durées d'efficacité relatives aux « intensités des chutes de neige en fonction de la visibilité dominante » qui figurent aux lignes directrices de TC et de la FAA. Ces démarches ont révélé la présence d'écarts entre les directives relatives à la visibilité émises respectivement par ces deux organisations, y compris des différences dans la disposition des tableaux et la présentation des données, de même qu'en ce qui a trait aux intensités de chutes de neige attribuées à certains degrés de visibilité. Les travaux d'analyse préliminaire visant à corriger et à résoudre les écarts entre ces lignes directrices ont commencé et devraient se poursuivre au cours de la période annuelle de projets 2021-2022.

Mise en œuvre de technologies de diffusion vidéo en continu pour l'observation à distance des essais sur le dégivrage (Section 9)

Le contexte de pandémie de COVID-19 s'est poursuivi au Canada au cours de l'hiver 2020-2021. Par conséquent, de nombreuses lignes directrices relatives à la COVID-19 et des restrictions concernant les déplacements et le personnel étaient en vigueur au cours de la saison d'essai. De plus, ces restrictions ont varié localement et changé au fil du temps. Compte tenu de ces difficultés, les essais de la période hivernale de 2020-2021 ont été adaptés pour atténuer les risques d'exposition grâce à la mise en œuvre d'un système d'observation à distance par caméra comme solution pour permettre la participation des parties prenantes. Cette approche comprenait l'intégration d'un système de caméras de télévision en circuit fermé à une plateforme de conférence en ligne, qui permettait aux participants d'observer et d'évaluer les activités de test critiques et les discussions techniques au cours des séances d'essais. Cette configuration a également été mise à l'épreuve à la chambre de simulation climatique et à la soufflerie de givrage du CNRC, aux centres d'essais de l'aéroport international Pierre-Elliott-Trudeau de Montréal et de PMG Technologies Inc., et dans le cadre des tests menés dans les régions du pré-Nord et du Grand Nord. Dans l'ensemble, le système d'observation à distance par caméra a bien fonctionné en fournissant une diffusion vidéo de haute qualité des essais aux observateurs et participants. Il est recommandé d'envisager d'autres solutions afin de rehausser la qualité et l'efficacité des caméras et favoriser la participation des parties prenantes virtuelles aux futurs essais.

Documentation des méthodes et des protocoles d'essai encadrant l'élaboration de marges de tolérance dans des conditions de granules de glace (Section 10)

En 2020-2021, APS a effectué des travaux pour rédiger un document détaillant les méthodes et les protocoles d'essai permettant l'élaboration de marges de tolérance dans des conditions de granules de glace. Avant la rédaction de ce nouveau document, les protocoles et les procédures d'essai n'étaient documentés que dans les rapports techniques publiés par APS, le CNRC et la NASA, et, les informations complémentaires n'étaient consignées que dans les directives internes d'APS ou n'étaient pas du tout documentées. Une copie de la dernière version du nouveau document est incluse dans le présent rapport. À l'avenir, ce document sera continuellement bonifié et peaufiné. La version mise au point dans le cadre de ce projet est fondée sur les normes de pratiques recommandées en aérospatiale (*Aerospace Recommended Practice*, ou normes ARP) de la SAE International (SAE) qui fournissent un portrait détaillé de la collecte de données et de l'élaboration de lignes directrices sur les durées d'efficacité. La refonte du document d'APS en norme ARP de la SAE devrait être envisagée dans le futur.

Examen des mises à jour requises dans les normes ARP5485, ARP5945, ARP5718 et ARP6207 de la SAE (Section 11)

L'examen préliminaire avait pour objectif d'évaluer et de documenter les modifications proposées aux normes d'essais relatifs aux durées d'efficacité en vue de révisions futures. Pour chaque document, les changements proposés ont été classés et évalués en fonction du niveau d'effort requis pour procéder à leur intégration au document.

Au total, 63 modifications proposées aux normes d'essai de la SAE relatifs aux durées d'efficacité ont été examinées et documentées. De ce nombre, 13 changements ont été jugés critiques puisqu'ils s'inscrivaient dans le processus d'élaboration des durées d'efficacité.

Il est recommandé que les documents soient mis à jour sans délai, au fur et à mesure que les ressources deviennent disponibles, et qu'au minimum, les changements critiques soient apportés.

Lignes directrices relatives à la COVID-19 et répercussions de la pandémie sur le programme de recherche sur le givrage d'aéronefs au sol de 2020-2021 (Section 12)

De nombreuses lignes directrices relatives à la COVID-19 accompagnées de restrictions concernant les déplacements et le personnel – lesquelles pouvaient varier considérablement d'un endroit à l'autre et au fil du temps – étaient en vigueur en raison du contexte de pandémie qui s'est poursuivi au cours de l'hiver 2020-2021. Compte tenu de ces difficultés, les essais de la période hivernale ont été adaptés pour atténuer les risques d'exposition, notamment par l'utilisation rigoureuse d'équipement de protection individuelle, par la mise en œuvre d'un système d'observation à distance par caméra comme solution pour permettre la participation des parties prenantes, et par l'application d'autres mesures de sécurité. Malgré toutes les restrictions, les activités d'essai entreprises au cours de l'hiver 2020-2021 ont été achevées. Les tests portant sur des liquides reçus en 2020-2021 pour utilisation dans des conditions de neige très froide seront terminés au cours de l'hiver 2021-2022.

Examen technique, approbation et publication de rapports historiques (Section 13)

Depuis le début des années 1990, APS a effectué des études sur le givrage au sol qui ont supposé la rédaction et la publication de plus de 213 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 2021, à l'exception des rapports annuels actuels de 2020-2021, 30 rapports doivent encore être publiés.

Publication de documents d'orientation sur les durées d'efficacité (Section 14)

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 2020-2021 (Section 15)

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 2020-2021. Ceux-ci sont documentés dans ce rapport.

Évaluation du Centre de recherche ACE en tant qu'installation alternative pour les activités de recherche sur le dégivrage (Section 16)

Afin d'accroître la souplesse opérationnelle et d'acquérir des capacités supplémentaires, TC et la FAA évaluent le recours à une nouvelle installation. Celle-ci possède trois chambres froides différentes permettant la réalisation d'essais. En voici la liste :

- Une soufflerie de simulation climatique ;
- Une large chambre de simulation climatique ; et
- Une petite chambre de simulation climatique.

Une étude de faisabilité relative à cette installation doit être effectuée.

CONTENTS Page

LIST OF APPENDICES

LIST OF FIGURES Page

LIST OF TABLES Page

LIST OF PHOTOS Page

LIST OF EQUATIONS Page

GLOSSARY

AC	Advisory Circular
ACE	Automotive Center of Excellence
AMIL	Anti-Icing Materials International Laboratory
APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
AS	Aerospace Standard
AvN	Artificial vs. Natural
CCTV	Closed Circuit Television
CEF	Climatic Engineering Facility
CRM	Common Research Model
DSHOT	Degree-Specific Holdover Time
DSLR	Digital Single-Lens Reflex
EG	Ethylene Glycol
FAA	Federal Aviation Administration
FMH1	Federal Meteorological Handbook No. 1
HOT	Holdover Time
IP	Internet Protocol
IWT	Icing Wind Tunnel
LED	Light Emitting Diode
LOE	Level of Effort
LOUT	Lowest Operational Use Temperature

MSC	Meteorological Service of Canada
MWG	METAR Working Group
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
NVR	Network Video Recorder
OAT	Outside Air Temperature
PET	Montréal-Pierre Elliot Trudeau International Airport
PG	Propylene Glycol
PMG	PMG Technologies Inc.
PPE	Personal Protection Equipment
SAE	SAE International
TC	Transport Canada
VCS	Very Cold Snow
YOW	Ottawa International Airport
YUL/CYUL	Montréal-Pierre Elliot Trudeau International Airport

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 2020-21 in support of the aircraft ground icing research program. Each major project completed as part of the 2020-21 research is documented in a separate individual report. This report documents the remaining general activities and smaller research projects.

1.1 Activities Completed in 2020-21

The general activities and smaller research projects completed in 2020-21 are documented in this report. Each activity is detailed in a separate section as follows (section number in parentheses):

a) Review of METAR Reported Weather for Determining Holdover Time Guidance (Section 2);

b) Evaluation of Mist Deposition Rates (Section 3);

c) Development of Degree-Specific Holdover Times for Snow (Section 4);

d) Effect of Vibrating Vertical Surfaces on De/Anti-Icing Fluids (Section 5);
e) Evaluation of Variability in Holdover Time Testing Results – Light Freezing Rain (Section 6);
f) Evaluation of the Use of the NRC's Climatic Engineering Facility for Development of Holdover Times (Section 7);
g) Review of "Snowfall Intensities as a Function of Prevailing Visibility" Holdover Time Guidance (Section 8);
h) Implementation of Video Streaming Technology for Remote Viewing of Deicing Research Tests (Section 9);
i) Documentation of Test Methods and Protocols for Ice Pellet Allowance Time Development (Section 10);
j) Review of Updates Required for SAE Documents ARP5485, ARP5945, ARP5718, and ARP6207 (Section 11);
k) COVID-19 Guidelines and Impacts on the 2020-21 Ground Icing Research Program (Section 12);
l) Technical Review, Approval, and Publication of Historical Reports (Section 13);
m) Publication of Holdover Time Guidance Materials (Section 14);
n) Presentations, Fluid Manufacturer Reports, and Test Procedures for 2020-21 (Section 15); and
o) Evaluation of the ACE Research Center as an Alternative Facility for Deicing Research Activities (Section 16).

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 referenced in Subsection 1.1, four activities with limited scope were completed during the winter of 2020-21. 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 (AS). In 2020-21, 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 2020-21, in particular, APS provided technical comments for the revision of SAE AS9968A, *Laboratory Viscosity Measurement of Thickened Aircraft Deicing/Anti-icing Fluids with a Viscometer* (1).

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. For the winter of 2020-21, APS attended two online meetings in conjunction with the G-12 biyearly meetings and participated in related group discussions by email.

1.2.3 Changing Snowfall Intensities

During the 2020-21 Winter, APS evaluated the TC and FAA guidance related to changing snowfall intensities vs. holdover time (HOT). It was determined that while guidance exists for TC in the TC report, TP 14052E, *Guidelines for Aircraft Ground Icing Operations (Sixth Edition)* (2) on reassessing HOTs with changing snowfall intensity, similar guidance did not exist for the FAA. APS assisted the FAA in adding this guidance to Subsection 8a in FAA N 8900.594, *Revised FAA-Approved Deicing Program Updates, Winter 2021-2022* (3), which was published in August 2021.

1.2.4 V-Stab Common Research Model

During the winter of 2020-21, APS participated in discussions with the SAE G-12 and regulators related to the design of a new common research model (CRM) vertical stabilizer. APS provided support for the design, procurement, and construction of the model, including providing analysis, research, and testing as required. The new CRM is expected to be built in the fall of 2021 and be ready for calibration and characterization testing in December 2021 and for fluid and contamination testing in January 2022.

This page intentionally left blank.

2. REVIEW OF METAR REPORTED WEATHER FOR DETERMINING HOLDOVER TIME GUIDANCE

This section describes the ongoing work conducted by APS Aviation Inc. (APS) in 2020-21 aimed at interpreting METAR reported weather for determining the applicable holdover time (HOT) or allowance time guidance for conditions not currently addressed in the guidance material.

2.1 Background

METARs are provided for most airports on an hourly basis, with special reports (referred to as SPECIs) issued whenever a significant change in weather occurs. When aircraft are operating in adverse winter conditions, the METAR reported weather conditions may not always have a corresponding condition in the HOT guidance 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 inclusive HOT guidance material.

2.2 Previous Work

In the 2019-20 year, a multi-airport METAR analysis was conducted; further information can be found in the Transport Canada (TC) report, TP 15452E, *Aircraft Ground Icing General Research Activities During the 2019-20 Winter* (4). This study examined a large sample of METAR data collected primarily at major airports in the United States and Canada that encounter winter precipitation. The multi-airport analysis provided insights for prioritizing the development of appropriate HOT guidance material for conditions where guidance may be limited or missing.

2.3 Objective

The general objective of this project is to support the development of HOT or allowance time guidance for METAR reported weather conditions not currently included in the guidance material.

2.4 Summary of Analytical and Research Activities

To reach this objective, several activities were undertaken by APS to support TC and the Federal Aviation Administration (FAA). These individual activities are described in Subsections 2.4.1 to 2.4.3.

2.4.1 METAR Working Group

To support and direct this project, a METAR Working Group (MWG) was formed that included technical experts and meteorologists from the FAA, TC, APS, and National Center for Atmospheric Research (NCAR).

The MWG was responsible for overseeing tasks performed primarily by APS and NCAR and for providing strategic direction for the development of the supporting analytical and research activities. This analysis and research will be the foundation for future HOT guidance from TC and the FAA. In addition, the findings may also encourage governing weather agencies to change policies and procedures in support of ground icing operations. Figure 2.1 provides a conceptual representation of the project process being followed to support the development of this guidance.

The first meeting of the MWG was held in November 2020, and regular meetings were held near-monthly from November 2020 to September 2021 for a total of ten meetings, with the expectation that these meetings would continue into the next year. APS was responsible for organizing, leading, and preparing presentation material for the MWG meetings. A summary of the MWG activities was provided by the FAA at the SAE International (SAE) May 2021 G-12 HOT web conference.

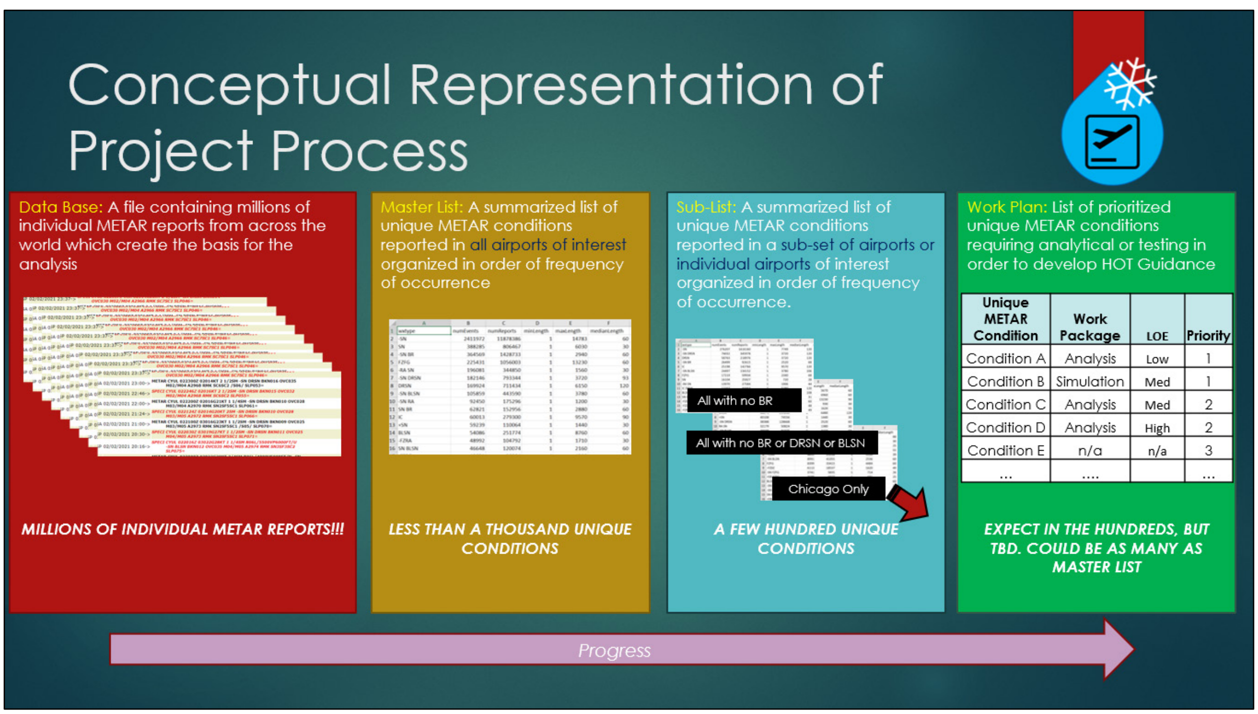


Figure 2.1: Conceptual Representation of Project Process

2.4.2 Master List Analysis

One of the primary activities identified by the MWG was the development of a "Master List." This master list would summarize unique METAR conditions reported in all airports of interest, organized in order of frequency of occurrence. The activity was started by both APS and NCAR, but ultimately the MWG decided that NCAR should be responsible for this activity due to their ease of access to the database. Therefore, NCAR was tasked with leading the development of a master list going forward. The list contains 20 years of historical METAR data, including mixed conditions, and encompasses all weather below 2ºC and freezing/frozen precipitation above 2ºC. The Excel file managed by NCAR was distributed to the MWG regularly, triggered by updates to the data. An extract of the master list from NCAR's file version 2.3.1 (dated August 2021) has been included in Appendix B for reference. This extract contains the three most relevant columns of the data under analysis.

Sub-lists were also created from the master list for specific analytical requirements. One such sub-list, which became a main point of discussion for guidance development, contains all conditions with greater than 20 reported occurrences, excluding descriptors and obscurations such as mist, fog, blowing snow, and drifting snow, which were addressed separately (see the following Subsection 2.4.3). This sub-list is included in Appendix B and also contains the three most relevant columns of data under analysis. It includes 150 different mixed-phase conditions, which were reviewed individually by APS and independently by the meteorologists of the MWG. (Note: There were 164 conditions in file version 2.3 [dated May 2021], which were reduced to 150 in version 2.3.1 [dated August 2021]). For each condition, a work plan, level of effort (LOE), known industry request for guidance, expected potential HOT guidance, and potential timeline were noted. As well, liquid water equivalents for combined conditions were estimated, but further discussion and potential research are required for confirmation.

Multiple strategies were proposed by APS to the MWG for advancing research and analysis of the cases identified in this sub-list. A copy of the presentation is included in Appendix C. The following four strategies were proposed to organize future work:

1. Based on frequency of occurrence (most to least);
2. Based on research packages (to benefit from economies of scale);
3. Based on the LOE required (from analytical to long-term research); and
4. Based on specific airports or locations, using any modified version of the above.

An independent meeting was also held with only the meteorologists of the MWG to determine how best to proceed. Ultimately, the MWG agreed that starting with research packages (Strategy #2; see Figure 2.2) would be the most appropriate of the different strategies proposed. The list of 164 conditions was grouped into 14 research packages based on similarity of conditions, and it was agreed that this framework would be the foundation for future research plans.

Figure 2.2: Research Strategy Based on Packages

2.4.3 Additional Analysis or Research Activities

In addition to the analysis of the master list, several weather conditions were analysed in further detail, as explained below.

2.4.3.1 Mist

Mist (BR) is frequently reported as an obscuration either alone or with other precipitation conditions. A separate study was conducted to measure the deposition rates of mist and provide recommendations for HOT guidance. The details of this research are included in Section 3 of this report.

It was recommended that testing continue to collect rate of deposition data in active BR conditions to validate this new guidance.

2.4.3.2 Fog and Freezing Fog

Fog (FG) is treated as an obscuration as it is defined as very small droplets suspended in the air that do not fall to the ground; therefore, no precipitation rate is reported for FG by the Federal Meteorological Handbook No. 1 (FMH1) or the Manual of Surface Weather Observations Standards. While FG is not considered a precipitation condition, the droplets may deposit on aircraft surfaces and, for that reason, freezing fog (FZFG) HOTs were developed. At the 1997 Chicago SAE G-12 HOT Committee meeting, it was agreed that the lower and upper HOTs for FZFG should be evaluated at rates of 5 $g/dm^2/h$ and 2 $g/dm^2/h$, respectively. The FZFG HOTs currently apply only when FZFG is reported alone, and no HOTs exist for FZFG reported with other precipitation conditions.

It was recommended that testing be conducted in conjunction with BR testing to collect rate of precipitation data in active FG or FZFG conditions to validate the current rates.

2.4.3.3 Mixed Snow and Freezing Fog

Industry expressed concerns with HOT guidance related to conditions of snow mixed with freezing fog (SNFZFG) and provided details in an Airlines for America presentation submitted to the FAA. As a result, the FAA requested that APS evaluate the feasibility of developing preliminary guidance analytically for HOTs in mixed snow and freezing fog conditions.

At the request of the FAA, APS analysed the potential to provide abbreviated HOTs for Type II and IV fluids in light SNFZFG based on existing data. Several possibilities were explored. One scenario was to use the worst-case HOT values of both freezing fog and snow as a conservative option; however, it was determined that further research is required to make recommendations due to the complexities with liquid water equivalencies and non-linear fluid endurance time performances.

It was recommended that testing be conducted to validate any potential HOT recommendations prior to publication to ensure safety. It is expected this testing will occur during the 2021-22 winter testing season, tentatively planned to take place at the National Research Council Canada (NRC) Climatic Engineering Facility in Ottawa, Ontario.

2.4.3.4 Blowing Snow and Drifting Snow

Blowing snow (BLSN) and drifting snow (DRSN) are defined as snow lifted by wind at a height of more than or less than 1.8 m, respectively. BLSN or DRSN can occur with snow or other precipitation conditions. It is yet to be determined if BLSN or DRSN increases the total effective rate of precipitation on aircraft surfaces, considering wing heights for most aircraft are within the range of DRSN or BLSN. Preliminary research has been performed; however, this activity has been paused due to other priorities.

2.4.3.5 Light Snow and Drizzle

Industry requested that regulators include guidance for light snow mixed with drizzle (-SNDZ) conditions. Existing guidance for very light or light snow mixed with rain (-SNRA) already exists and recommends using the same HOTs as for light freezing rain (-FZRA). A detailed review of -SNRA data was conducted by APS to validate expanding the existing guidance to include -SNDZ. Two options were considered: using freezing drizzle (FZDZ) or light freezing rain (-FZRA) HOTs for -SNDZ. Following discussions with TC and the FAA, it was determined that the existing data was sufficient to adopt the more conservative option of using -FZRA HOTs for -SNDZ; however, testing would be required to validate the use of FZDZ HOTs for -SNDZ. A copy of the analysis and presentation to TC and the FAA is included in Appendix D.

As a result of this analysis, the note in the HOT tables was updated from “Use light freezing rain HOTs in conditions of very light or light snow mixed with light rain” to “Use light freezing rain HOTs in conditions of very light or light snow mixed with light rain or drizzle.”

If longer HOTs are required, it is recommended that testing be conducted to provide more specific data to allow for longer HOT guidance.

2.5 Future Activities

The analysis and research activities performed as part of this project have demonstrated the potential for more comprehensive HOT guidance. It is expected that the MWG will continue to develop and expand HOT guidance for mixed precipitation conditions. In addition, testing is planned for mist and fog/freezing fog conditions to document the rate of precipitation and for mixed snow and freezing fog conditions to develop HOTs for future inclusion in the regulatory guidance.

3. EVALUATION OF MIST DEPOSITION RATES

This section documents the work completed during the winter of 2020-21 related to the investigation of mist deposition rates.

3.1 Background

Mist (METAR code BR) is a commonly reported weather phenomenon. Mist is considered an obscuration rather than a precipitation type and can be reported alone or with other precipitation conditions such as snow and freezing rain. In terms of visibility, mist can reduce visibility to between 0.6 and 1.2 miles (1 and 2 km); by comparison, fog reduces it to less than 0.6 miles (1 km).

Mist is similar to freezing fog as they are both considered obscurations; however, holdover times (HOTs) exist specifically for freezing fog but not for mist. Historical research simulating an aircraft taxi in freezing fog indicated that deposition rates can increase significantly when involving motion; consequently, freezing fog rates of 2 to 5 g/dm²/h were selected for developing HOTs. For more information concerning this study, see Subsection 2.9 of the Transport Canada (TC) report, TP 13826E, *Aircraft Ground De/Anti-icing Fluid Holdover Time Development Program for the 2000-01 Winter* (5).

The deposition rates for mist have never been quantified from a HOT perspective.

3.2 Objective

The objective of this study was to determine the range of deposition rates that occur naturally in conditions of mist alone. This research was required to develop HOT guidance for mist.

3.3 Mist Forecasting

The following is a list of winter weather conditions that were targeted when trying to forecast mist conditions for testing purposes.

- Surface visibility greater than or equal to 5/8 mile (≈1 km) and less than 7 miles (≈11 km).
- Outside air temperature (OAT) less than 2°C: Most mist observations are at temperatures above -4°C, with many occurring near 0°C. Mist is also infrequently reported at temperatures colder than -4°C.

- High relative humidity greater than 90 percent (best if closer to 100 percent).
- Overcast sky cover: A low ceiling suggests more robust mist (below 800 ft [≈240 m]).
- No precipitation concurrent with mist (for the purpose of this research).
- Sustained wind speed less than 9 knots (≈15 km/h).
- Helpful if precipitation occurs before the expected period of mist.

An analysis of historical METAR reports from CYUL was conducted to determine the ideal time for the occurrence of mist or fog alone. It was found that the beginning of winter, early mornings, and temperatures around the freezing point (0°C) are the most favourable winter conditions. More details on this analysis can be found in Appendix E.

3.4 Testing Procedure

During the winter of 2020-21, mist tests were carried out at the APS Aviation Inc. (APS) test facility in Montreal. As this study was comparative, mist deposition rates were captured simultaneously using two measurement methods. These methods simulated a taxiing and a stationary aircraft, respectively. Both testing methods were conducted using the standard precipitation collection pan used for HOT testing. For the first method (taxiing), the rate pan was mounted on the top of a test vehicle, as seen in Photo 3.1, and driven for 30 minutes at approximately 30 km/h. The second method (stationary) was performed using the standard method of collecting precipitation rates (using a test stand), as seen in Photo 3.2.

Generally, the tests began on the hour in coordination with issued METAR reports. The targeted METARs were ones that indicated mist was present and confirmed as visible by the researcher, as seen in Photo 3.3. However, in some instances, mist was visually observed but not reported by METAR, as seen in Photo 3.4. Therefore, a decision was made to conduct testing for all events that forecasted mist (within reason) and if it was visually observed, regardless of mist being reported or not reported by METAR. For a more detailed description of the methodologies employed during mist testing, refer to Appendix F.

3.5 Data Collected

The following subsections describe the data that was collected during the Winter 2020-21 testing season. In total, 37 tests were conducted at YUL, Ottawa International Airport (YOW), and Montréal–Mirabel International Airport. Of the

37 tests, 14 occurred with mist being visibly present regardless of being reported by METAR. These tests were included in the analysis and are presented below.

The remaining 23 tests were conducted on December 4 and 5, 2020, and on January 13 and 15, March 10 and 21, and April 7, 2021, where mist was neither visually present nor reported by METAR. Collection for these tests was done due to previous mist forecasts. On average, the precipitation rates ranged from 0 to 0.06 g/dm^2/h according to both test methods. These positive rates may have been obtained from mist and/or any other type of precipitation (e.g., light freezing rain, freezing drizzle). Due to the unknown form of precipitation, these 23 tests were excluded from the analysis.

3.5.1 Tests with Visible Mist and Mist Reported by METAR

In total, six tests were conducted with mist being visible and reported by METAR during the 2020-21 testing season. Table 3.1 below presents a summary of the data collected.

3.5.2 Tests with Visible Mist and Mist Not Reported by METAR

In total, eight tests were conducted with mist being visible but *not* reported by METAR during the 2020-21 testing season. Table 3.2 below presents a summary of the data collected.

Table 3.1: Log of Data Collected – Tests with Visible Mist and Mist Reported by METAR

Test No.	Date	Observed Weather	Visual Verification of Mist at Start (Y/N)	Simulated Taxi Start Time (hh:mm)	Simulated Taxi End Time (hh:mm)	Taxi Distance (km)	Average Taxi Velocity (km/h)	Simulated Taxi Rate (g/dm²/h)	Simulated Stationed Start Time (hh:mm)	Simulated Stationed End Time (hh:mm)	Simulated Stationed Rate (g/dm²/h)	Difference in Test Rate (Taxi - Stationary)	OAT (°C)	RH (%)	Visibility (km)	Wind Speed (km/h)	Location	Comments
9	14-Jan-21	Mist	No	16:35	17:05	15.0	28.0	**0.10**	16:35	17:05	**0.00**	**0.10**	1.0	87	9.7	9	YUL	Mist reported but not confirmed visually
18	15-Jan-21	Mist	Yes	06:15	06:45	15.0	28.0	**0.40**	06:15	06:45	**0.30**	**0.10**	-3.0	93	4.8	13	YUL	–
21	15-Jan-21	Mist	Yes	n/a	n/a	n/a	n/a	**n/a**	00:10	00:35	**0.08**	**n/a**	0.0	93	4.0	6	YOW - M46	–
22	15-Jan-21	Mist	Yes	n/a	n/a	n/a	n/a	**n/a**	01:08	01:38	**0.13**	**n/a**	-1.0	93	4.8	6	YOW - M46	–
23	15-Jan-21	Mist	Yes	01:58	02:34	13.7	23.3	**0.23**	02:00	02:34	**0.13**	**0.10**	-1.0	93	3.2	6	YOW - M46	–
24	15-Jan-21	Mist	Yes	02:58	03:34	14.1	23.6	**0.29**	03:00	03:36	**0.15**	**0.15**	-1.0	93	4.0	6	YOW - M46	–

Table 3.2: Log of Data Collected – Tests with Visible Mist and Mist NOT Reported by METAR

Test No.	Date	Observed Weather	Visual Verification of Mist at Start (Y/N)	Simulated Taxi Start Time (hh:mm)	Simulated Taxi End Time (hh:mm)	Taxi Distance (km)	Average Taxi Velocity (km/h)	Simulated Taxi Rate (g/dm²/h)	Simulated Stationed Start Time (hh:mm)	Simulated Stationed End Time (hh:mm)	Simulated Stationed Rate (g/dm²/h)	Difference in Test Rate (Taxi - Stationary)	OAT (°C)	RH (%)	Visibility (km)	Wind Speed (km/h)	Location	Comments
10	14-Jan-21	Nil	Yes	21:15	21:45	15.0	29.0	**n/a**	21:15	21:45	**0.10**	**n/a**	0.0	93	16.0	9	YUL	Spilled Fluid
11	14-Jan-21	Nil	Yes	22:05	22:35	15.0	28.0	**0.30**	22:05	22:35	**0.10**	**0.20**	0.0	93	16.0	11	YUL	–
12	14-Jan-21	Nil	Yes	23:30	00:03	15.0	28.0	**0.30**	23:30	00:03	**0.10**	**0.20**	0.0	93	16.0	7	YUL	–
13	15-Jan-21	Nil	Yes	00:45	01:15	14.8	29.0	**0.20**	00:45	01:15	**0.20**	**0.00**	0.0	93	16.0	7	YUL	–
14	15-Jan-21	Nil	Yes	01:45	02:15	14.8	29.0	**0.20**	01:45	02:15	**0.30**	**-0.10**	-1.0	93	16.1	11	YUL	–
15	15-Jan-21	Nil	Yes	03:10	03:40	15.0	28.0	**0.20**	03:10	03:40	**0.20**	**0.00**	-2.0	93	12.9	7	YUL	–
16	15-Jan-21	Nil	Yes	04:15	04:35	15.0	28.0	**0.30**	04:15	04:35	**0.20**	**0.10**	-2.0	93	12.9	11	YUL	–
17	15-Jan-21	Nil	Yes	05:15	05:45	15.0	29.0	**0.40**	05:15	05:45	**0.30**	**0.10**	-2.0	100	12.9	7	YUL	–

3.6 Data Analysis

The following subsections describe the analysis conducted using all data collected during the 2020-21 testing season. As seen from the test logs in Subsections 3.5.1 and 3.5.2, the data collected was separated into two sections and analysed.

3.6.1 Tests with Visible Mist and Mist Reported by METAR

The data where mist was visible and reported by METAR is shown in Figure 3.1. Note that in Tests #9, #21, and #22 only the taxi or stationary data was captured.

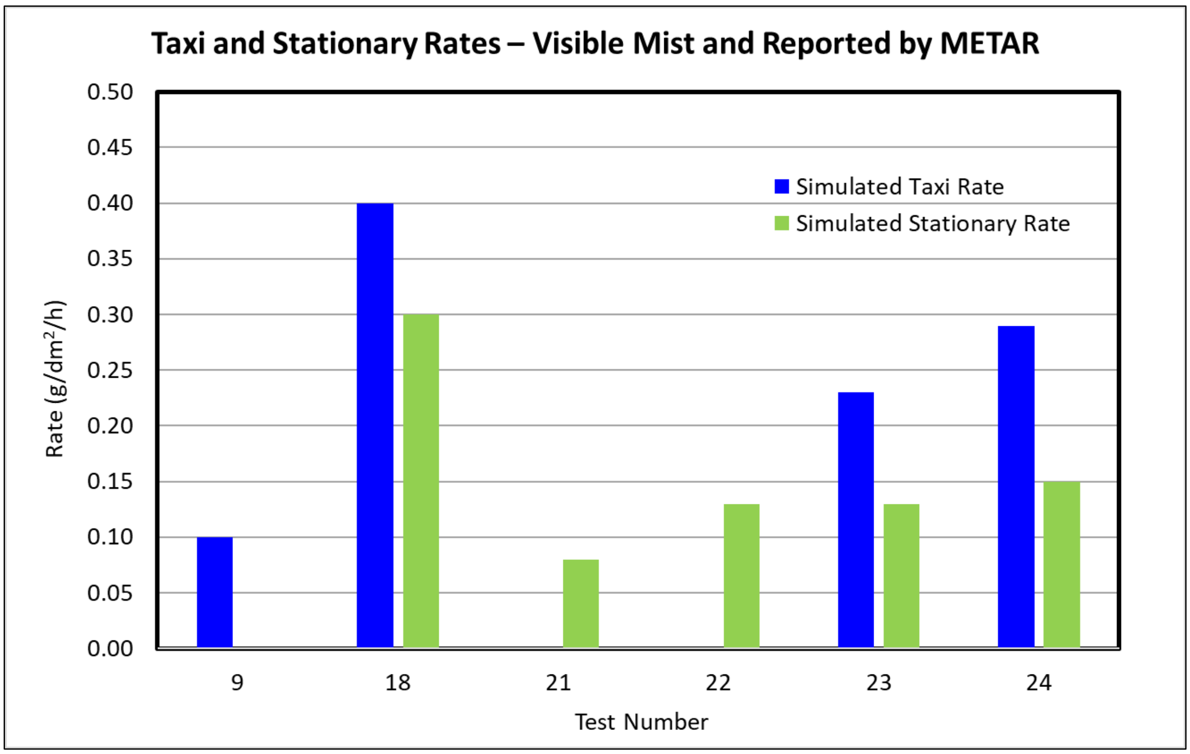


Figure 3.1: Tests with Visible Mist and Mist Reported by METAR

It should be noted that one event (Test #9 in Table 3.1 and Figure 3.1) was observed where the METAR reported mist that was not visually confirmed by the researcher. Although visual confirmation of mist was not possible, the liquid water equivalent confirmed its presence, and this data was thus included in the analysis.

3.6.2 Tests with Visible Mist and Mist Not Reported by METAR

Tests conducted when mist was visible but *not* reported by METAR are shown in Figure 3.2. Note that in Test #10 only the stationary data was captured.

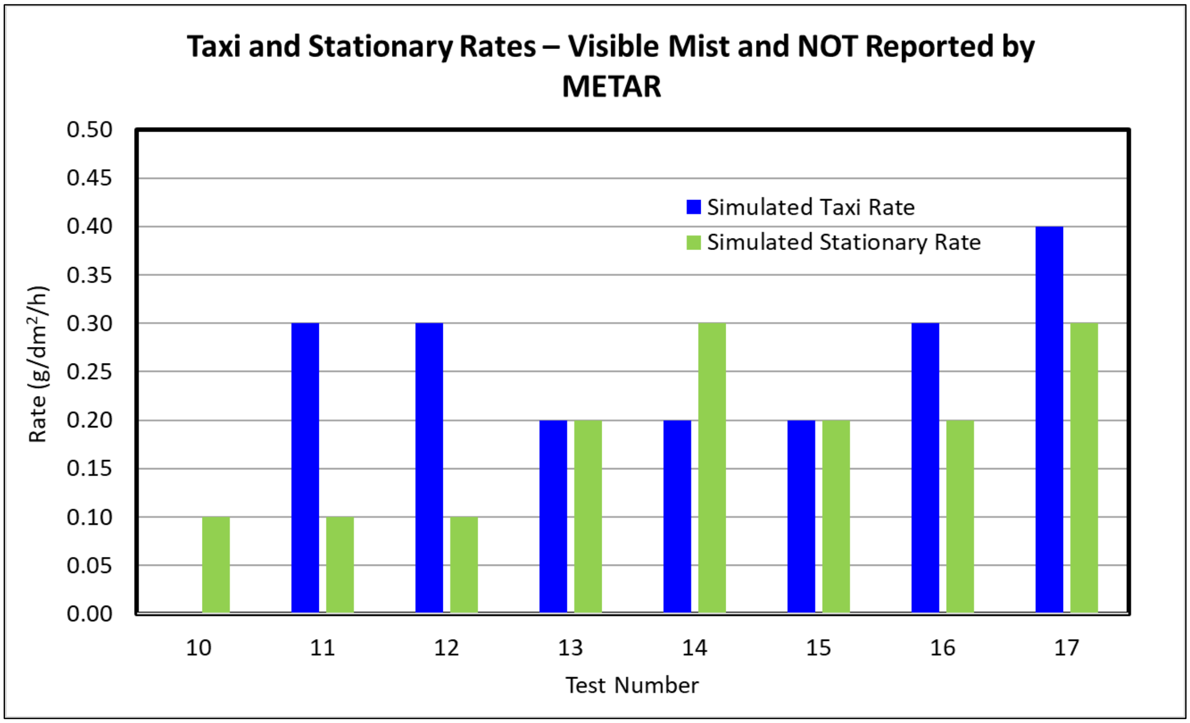


Figure 3.2: Tests with Visible Mist and Mist Not Reported by METAR

3.6.3 Discussion on Observations

There are two important observations that can be made from Figure 3.1 and Figure 3.2:

- A positive rate is obtained for both the stationary and taxiing tests, which confirms a deposition of precipitation; and
- On average, the taxiing rate is greater than the stationary rate by a factor of 1.7.

On some occasions during the testing campaign, it was not possible to obtain both the stationary and taxiing rates due to unforeseen circumstances (e.g., rate fluid spillage, unexpected testing occasions). Generally, the range in rates obtained for both the stationary and taxiing methods varied between 0.08 to 0.4 $g/dm^2/h$. The average rates obtained for only the stationary tests was approximately 0.2 $g/dm^2/h$, while the average rate for the taxiing tests was approximately 0.3 $g/dm^2/h$. Table 3.3 summarizes the findings.

Table 3.3: Summary of Mist Deposition Rate Testing Data

	Number of Tests	Rate Range ($g/dm^2/h$)	Simulated Stationary Average Rate ($g/dm^2/h$)	Simulated Taxi Average Rate ($g/dm^2/h$)	Difference (Taxi – Stationary) ($g/dm^2/h$)
Mist Visible and Reported by METAR	6	0.08 – 0.4	0.13	0.26	0.13
Mist Visible but Not Reported by METAR	8	0.1 – 0.4	0.19	0.27	0.08
Combined Average	–	–	**0.16**	**0.27**	**0.11**

As seen in Table 3.3, the difference between the simulated taxiing and the simulated stationary experiments were approximately 0.11 $g/dm^2/h$ on average. This is expected as the catch factor of the 10° angle rate pan when in motion increases as compared to a stationary rate pan. This difference validates the present testing protocol. It should also be noted that this difference should be considered when determining HOT guidance for freezing mist.

3.6.4 HOT Guidance for Operations in Freezing Mist Conditions

As previously described in Subsection 3.3, the formation of mist occurs when specific weather parameters (humidity, temperature, wind speed, et cetera) are favourable. As a weather phenomenon, mist can be present and reported by METAR at any given temperature. Freezing mist, on the other hand, is never reported by METAR; however, it can occur when mist is present at 0°C (32°F) and below. Freezing mist is also best confirmed by observation. Therefore, for the purposes of HOT development and guidance, freezing mist is of concern.

The range of rates observed during this study suggests that the liquid water content of freezing mist is comparable to that of frost and is an order of magnitude less than all other precipitation conditions, as seen in Figure 3.3. The highest mist rates that occurred during the testing (limited to YUL) were 0.4 $g/dm^2/h$; however, this could increase in areas with valleys or near bodies of water. This deposition rate is still greater than the maximum rate of frost, 0.31 $g/dm^2/h$, observed historically (according to available APS data collected over two decades).

Therefore, erring on the side of caution, TC and the Federal Aviation Administration decided to include freezing mist as part of the "Freezing Fog and Ice Crystals" column of the HOT tables. The associated rate of precipitation for this column is 2 to 5 g/dm²/h, well above the expected rate of freezing mist. The HOT Guidelines were updated accordingly, and an example is illustrated in Figure 3.4 of the generic Type IV HOT table. It is important to note that mist must be reported alone to use the HOTs in the "Freezing Fog, Freezing Mist, or Ice Crystals" column. If mist is reported mixed with another precipitation condition, these HOTs do not apply and mist could be treated as an obscuration.

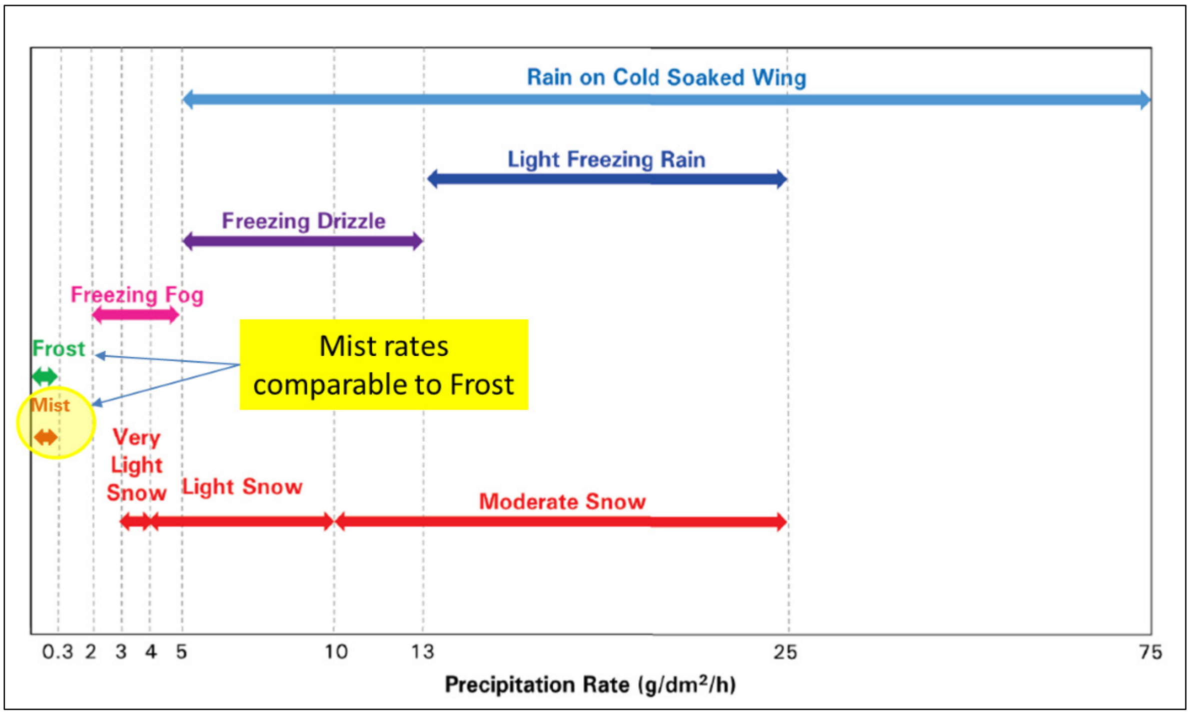


Figure 3.3: Precipitation Rates Related to HOT Guidelines

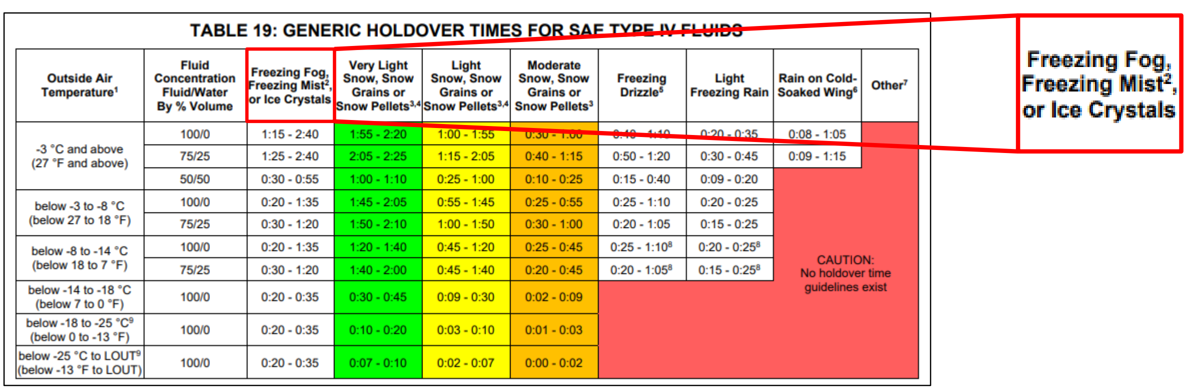


TABLE 19: GENERIC HOLDOVER TIMES FOR SAE TYPE IV FLUIDS

Outside Air Temperature[1]	Fluid Concentration Fluid/Water By % Volume	Freezing Fog, Freezing Mist[2], 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)	100/0	1:15 - 2:40	1:55 - 2:20	1:00 - 1:55	0:30 - 1:00	0:40 - 1:10	0:20 - 0:35	0:08 - 1:05	CAUTION: No holdover time guidelines exist
	75/25	1:25 - 2:40	2:05 - 2:25	1:15 - 2:05	0:40 - 1:15	0:50 - 1:20	0:30 - 0:45	0:09 - 1:15	
	50/50	0:30 - 0:55	1:00 - 1:10	0:25 - 1:00	0:10 - 0:25	0:15 - 0:40	0:09 - 0:20		
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:20 - 1:35	1:45 - 2:05	0:55 - 1:45	0:25 - 0:55	0:25 - 1:10	0:20 - 0:25		
	75/25	0:30 - 1:20	1:50 - 2:10	1:00 - 1:50	0:30 - 1:00	0:20 - 1:05	0:15 - 0:25		
below -8 to -14 °C (below 18 to 7 °F)	100/0	0:20 - 1:35	1:20 - 1:40	0:45 - 1:20	0:25 - 0:45	0:25 - 1:10[8]	0:20 - 0:25[8]		
	75/25	0:30 - 1:20	1:40 - 2:00	0:45 - 1:40	0:20 - 0:45	0:20 - 1:05[8]	0:15 - 0:25[8]		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:20 - 0:35	0:30 - 0:45	0:09 - 0:30	0:02 - 0:09				
below -18 to -25 °C[9] (below 0 to -13 °F)	100/0	0:20 - 0:35	0:10 - 0:20	0:03 - 0:10	0:01 - 0:03				
below -25 °C to LOUT[9] (below -13 °F to LOUT)	100/0	0:20 - 0:35	0:07 - 0:10	0:02 - 0:07	0:00 - 0:02				

Figure 3.4: Example of Inclusion of Freezing Mist in the Generic HOT Table

3.7 Summary

Mist deposition rates were determined using the standard HOT methodology. For the conditions tested, the mist accretion rate was found to be 0.2 $g/dm^2/h$ on average for the stationary tests. The taxiing tests increased this accretion rate to 0.3 $g/dm^2/h$, on average. The range in mist rates was thus calculated to be from 0.08 to 0.4 $g/dm^2/h$. This range is comparable to, but still greater than, the maximum rate of frost observed within the last two decades. Therefore, to ensure operational safety, freezing mist was added to the "Freezing Fog and Ice Crystals" column of the generic and fluid specific HOT tables and not to that of the active frost HOT table.

3.8 Recommendations

For the winter of 2021-22, it is recommended to continue collection of mist deposition rate data to substantiate the results obtained to date. Consideration should be given to other strategic locations with potential for higher mist intensities to capture the most conservative cases (e.g., valleys). Testing should also be expanded to include freezing fog conditions as well. To expand the data set, testing in fall during warmer temperatures to capture mist and fog rates above freezing is also recommended. The results from this testing will support a related research project currently being investigated dealing with mixed-phase icing research.

Procedural recommendations primarily from the May 2021 SAE International G-12 HOT Committee were provided by industry. The group proposed the procedural changes below be considered for future mist testing in 2021-22.

- Testing should be conducted using an additional rate pan for both the stationary and the taxiing methods. This pan is to be used without fluid as the catching medium and is to rely solely on the aluminum pan. The rationale is that the rate fluid used may be absorbing more mist than would be deposited on an untreated taxiing or stationary aircraft.
- Temperature measurements of the rate pans' surfaces should be included in the procedure to confirm that mist is present and not frost.
- Before-and-after photos of each test should be taken of the rate pans and the environment with sufficient lighting (e.g., with a lamp post) to verify that mist is actively present and not frost.
- The particle size of the mist should be determined to quantify and confirm its presence.
- Fog deposition rates should be conducted to substantiate historical test results of 2 to 5 $g/dm^2/h$.

Photo 3.1: Method 1 – Simulated Taxiing Aircraft

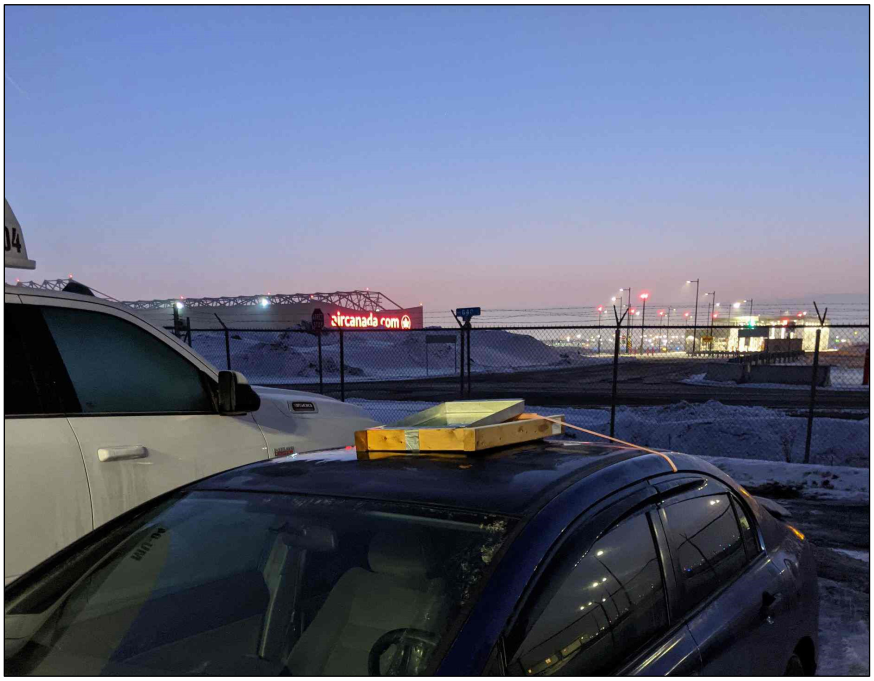


Photo 3.2: Method 2 – Simulated Stationary Aircraft

**Photo 3.3: Mist Visible – Reported by METAR
(January 15, 2021 – Ottawa, Ontario)**

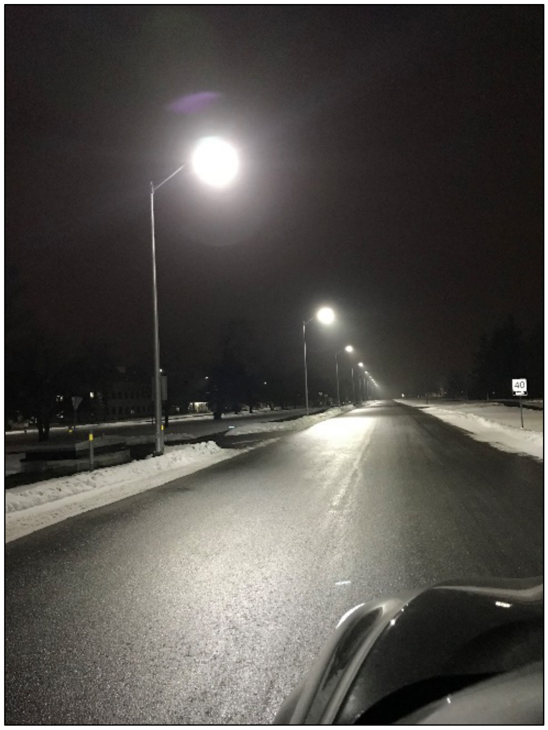


**Photo 3.4: Mist Visible – Not Reported by METAR
(January 15, 2021 – Montreal, Quebec)**

4. DEVELOPMENT OF DEGREE-SPECIFIC HOLDOVER TIMES FOR SNOW

This section documents the work carried out by APS Aviation Inc. (APS) in support of the development of Degree-Specific Holdover Times (DSHOTs) for snow. This project was initiated in the winter of 2018-19 and was completed in the winter of 2020-21.

4.1 Background

Fluid-specific snow holdover times (HOTs) are derived from natural snow endurance time test data collected in a range of temperatures. The data sets for each fluid are analysed using multi-variable regression analysis, and specific coefficients corresponding to the effects of precipitation rate and temperature are determined for each fluid. This regression information is then used to calculate the snow HOTs for specific rate and temperature combinations.

Within a standard fluid-specific HOT table, snow HOTs are provided for specific temperature ranges (i.e., below -3°C to -8°C). Within a given temperature range, the HOT provided is calculated using the coldest temperature in the range. HOT values are not published for every temperature because it is neither practical nor user-friendly to include this amount of information in the HOT tables published by Transport Canada (TC) and the Federal Aviation Administration (FAA). However, as HOTs generally increase as temperature increases, there is an operational advantage to be gained by providing this data to operators (see example in Figure 4.1).

The adoption of electronic flight bags and the advent of apps that provide HOTs electronically have made it possible to provide HOTs for every temperature within a range in a user-friendly format. As a result, TC and the FAA chose to develop and publish databases of DSHOTs for snow. This section documents the development of these databases and their associated guidance documents.

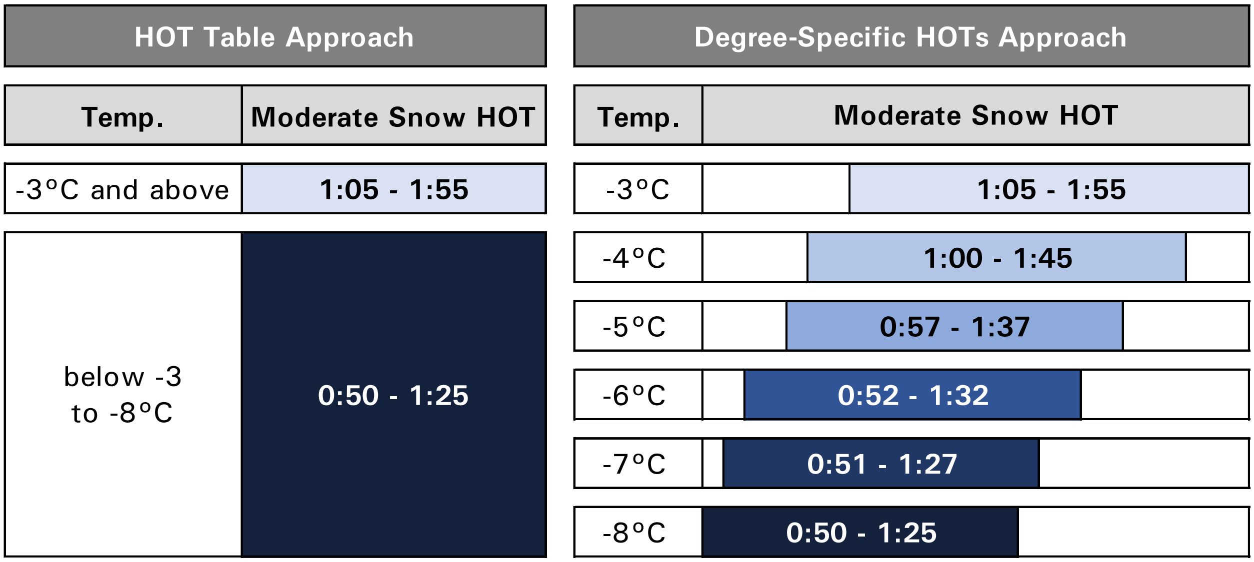


Figure 4.1: Example of HOT Table vs. Degree-Specific HOTs Approaches

4.2 Previous Work

The development of DSHOTs was initiated in 2018-19. Details concerning the development work conducted in previous years can be found in the following TC reports:

1. TP 15427E, *Aircraft Ground Icing General Research Activities During the 2018-19 Winter* (6); and
2. TP 15452E, *Aircraft Ground Icing General Research Activities During the 2019-20 Winter* (4).

These reports document the analyses and regulatory discussions that were essential in determining the content of the final, published DSHOTs databases. For reference, this research was referred to in previous years as temperature-specific HOTs.

4.3 Objective

The objective of this project was to finalize the development of the DSHOTs databases and to support the publication of the related guidance documents.

4.4 DSHOTs Databases

This subsection describes the final, published DSHOTs databases and the methodology to determine the DSHOT values that populate them.

4.4.1 General Information

The TC and FAA DSHOTs databases exist in the form of Excel workbooks containing a series of worksheets corresponding to each of the 100/0 Type II, III, and IV anti-icing fluids listed in the TC/FAA 2021-22 HOT Guidelines.

Each fluid-specific worksheet contains an expanded set of snow precipitation HOTs. For a given fluid, the databases contain HOTs calculated at degree decrements (in °C) ranging from "1°C and above" to the fluid's lowest operational use temperature (LOUT). DSHOTs are provided for precipitation rates of 3, 4, 10, and 25 g/dm²/h. These precipitation rates correspond with the lower and upper precipitation rate boundaries for very light snow (3 to 4 g/dm²/h), light snow (4 to 10 g/dm²/h), and moderate snow (10 to 25 g/dm²/h) used in the TC/FAA HOT Guidelines.

An example of a fluid-specific worksheet from the 2021-22 TC DSHOTs database is shown below in Table 4.1.

The DSHOT database values are derived from the same natural snow test data used to calculate the snow HOTs in the TC/FAA HOT Guidelines. For a given fluid within the databases, the DSHOT values were calculated using the standard snow HOT regression equation and the fluid's snow HOT regression coefficients.

The equation used to treat snow data is as follows:

$t = 10^{I} R^{a} (2-T)^{b}$, where:

t = Time (minutes);

R = Rate of precipitation (g/dm²/h);

T = Temperature; and

I, a, b = Fluid-specific snow HOT regression coefficients.

To account for the dynamic nature of meteorological conditions that may shift between METAR reports, the temperature used in the calculation of all of the values within the DSHOTs databases includes a -1°C degree buffer. For example, DSHOTs listed for an ambient temperature of -4°C have been calculated using a temperature input of -5°C. This -1°C buffer was determined to be sufficient to provide a continued level of safety assurance while still ensuring that the DSHOTs provide expanded HOTs for snow conditions [see TP 15427E (6)].

Finally, the calculated DSHOT values were rounded to the nearest minute (or down to the nearest minute if the raw value was less than 10 minutes). DSHOT values were also capped at either 180 minutes (FAA) or 120 minutes (TC).

Table 4.1: ABAX ECOWING AD-2 – TC DSHOTs Database Sheet

Fluid Name	Ambient Temperature (°C)	Snow DSHOT Rate = 3 g/dm²/h	Snow DSHOT Rate = 4 g/dm²/h	Snow DSHOT Rate = 10 g/dm²/h	Snow DSHOT Rate = 25 g/dm²/h
ABAX ECOWING AD-2	1 and above	120	120	97	50
ABAX ECOWING AD-2	0	120	120	86	45
ABAX ECOWING AD-2	-1	120	120	80	41
ABAX ECOWING AD-2	-2	120	120	75	39
ABAX ECOWING AD-2	-3	120	120	71	37
ABAX ECOWING AD-2	-4	120	120	68	35
ABAX ECOWING AD-2	-5	120	120	65	34
ABAX ECOWING AD-2	-6	120	120	63	33
ABAX ECOWING AD-2	-7	120	118	61	32
ABAX ECOWING AD-2	-8	120	115	59	31
ABAX ECOWING AD-2	-9	120	112	58	30
ABAX ECOWING AD-2	-10	120	109	57	29
ABAX ECOWING AD-2	-11	120	107	56	29
ABAX ECOWING AD-2	-12	120	105	54	28
ABAX ECOWING AD-2	-13	120	103	53	28
ABAX ECOWING AD-2	-14	120	101	52	27
ABAX ECOWING AD-2	-15	30	20	7	2
ABAX ECOWING AD-2	-16	30	20	7	2
ABAX ECOWING AD-2	-17	30	20	7	2
ABAX ECOWING AD-2	-18	30	20	7	2
ABAX ECOWING AD-2	-19	15	9	3	1
ABAX ECOWING AD-2	-20	15	9	3	1
ABAX ECOWING AD-2	-21	15	9	3	1
ABAX ECOWING AD-2	-22	15	9	3	1
ABAX ECOWING AD-2	-23	15	9	3	1
ABAX ECOWING AD-2	-24	15	9	3	1
ABAX ECOWING AD-2	-25	15	9	3	1
ABAX ECOWING AD-2	-26	7	5	1	0
ABAX ECOWING AD-2	-27	7	5	1	0

4.4.1.1 Generic DSHOTs Information

Generic Type II and Type IV DSHOTs have also been provided within specific worksheets. The generic DSHOT values represent the shortest DSHOT for a given fluid type (either Type II or Type IV) at the specified temperature and snow intensity. This approach is equivalent to the development of the generic Type II and Type IV tables for the TC/FAA HOT Guidelines.

4.4.1.2 Flaps-Adjusted DSHOTs Information

Adjusted DSHOTs for anti-icing operations where flaps and slats are deployed prior to de/anti-icing have also been provided for all 100/0 Type II, III, and IV fluids. The “flaps-adjusted” DSHOTs are available on separate sheets within the databases (and are clearly indicated as such).

The adjusted DSHOTs were determined by multiplying the uncapped, rounded standard DSHOT values by 76 percent and rounding the resulting figures to the nearest whole minute.

4.4.2 Database Exceptions

There are certain cells within the DSHOTs databases for which DSHOT values could not be determined. These include cells for which no standard HOT information exists and cells for which the underlying standard HOT information is not derived through regression analysis.

These exceptions and how they are handled within the databases are described within this subsection.

4.4.2.1 Type II Fluids Without Very Light Snow and Light Snow HOTs

Certain Type II fluid-specific HOT tables do not include information for very light snow or light snow. Correspondingly, these fluids have only been provided with DSHOT values for moderate snow (precipitation rates of 10 $g/dm^2/h$ and 25 $g/dm^2/h$).

4.4.2.2 Generic Snow HOTs Below -14°C

Fluids that have not undergone supplemental very cold snow (VCS) endurance time testing are provided with generic snow HOTs for temperatures below -14°C. These generic VCS HOT values were not derived through regression analysis, and as such specific DSHOTs cannot be determined in these cases. As a result, the corresponding cells within the DSHOTs databases have been populated with the appropriate generic VCS HOT values.

4.4.2.3 Fluid-Specific HOTs Below -25°C for Fluids with LOUT <-29.0°C

Fluid-specific snow HOTs below -25°C for fluids with LOUTs below -29.0°C are determined using comparative artificial snow testing (as opposed to natural snow testing). As these values are not derived through regression analysis, specific DSHOTs cannot determined in these cases. As a result, the corresponding cells within the DSHOTs databases have been populated with the applicable standard HOT table values for all temperatures below -25°C.

4.4.2.4 Fluids with Temperature-Independent Endurance Time Performance

Certain anti-icing fluids have been found to demonstrate temperature-independent endurance time performance. Correspondingly, the HOTs for these fluids are not affected by changing temperature and unique DSHOT values cannot be produced for these fluids. As a result, the corresponding cells within the DSHOTs databases have been populated with the applicable standard HOT table values for these fluids.

4.4.3 TC/FAA DSHOTs Database Differences and Publication Details

Although both organizations have published separate versions of the DSHOTs database, the DSHOT values within each version of the database differ only due to the different capping rules employed by each organization. TC caps all snow DSHOTs at 120 minutes; the FAA caps all snow DSHOTs at 180 minutes.

The TC and FAA versions also differ in that each database includes a general information sheet with an excerpt of the organization-specific guidance material related to DSHOTs (see Subsection 4.5).

4.4.3.1 Publication by Transport Canada

The TC DSHOT database was published in August 2021, and a copy is available by request through the following website:

- https://tc.canada.ca/en/aviation/general-operating-flight-rules/holdover-time-hot-guidelines-icing-anti-icing-aircraft/degree-specific-holdover-time-dshot-database

The TC DSHOT database is available in both English and French.

4.4.3.2 Publication by the Federal Aviation Administration

The FAA database was published in August 2021 and is available for download from the following website:

- https://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/deicing/

4.5 Supporting Guidance

In addition to the DSHOTs database files, both TC and the FAA have published supporting guidance to advise industry on the proper use of DSHOTs.

4.5.1 Transport Canada Guidance – Advisory Circular 700-061

TC published Advisory Circular (AC) 700-061, *Degree-Specific Holdover Times* (7), in July 2021. This document informs industry on the analytical background of the DSHOTs database and outlines specific conditions (related to data management, data presentation, and procedures) that operators must adhere to if they are implementing DSHOTs into their ground icing program.

A copy of AC 700-061 has been included with this report as Appendix G.

4.5.2 FAA Guidance – N 8900

The FAA included their DSHOT-specific guidance within the most recent update to their N 8900 series guidance document.

An excerpt of the N 8900 document containing the relevant DSHOT guidance has been included with this report as Appendix H.

4.6 Conclusions

The DSHOTs databases were finalized and published by both TC and the FAA for use by industry in the upcoming winter of 2021-22.

Supporting guidance documents instructing industry on proper use of DSHOTs were also published by both TC and the FAA.

4.7 Recommendations

It is recommended that the DSHOTs database publications be updated annually to reflect changes made to the annual TC and FAA HOT guidance publications.

It is recommended that future analysis be performed to evaluate the feasibility of developing DSHOTs in snow conditions for Type I fluids and dilute (75/25 and 50/50) anti-icing fluids.

It is recommended that future analysis be performed to evaluate the feasibility of developing DSHOTs for the freezing precipitation conditions that are listed within the HOT Guidelines.

5. EFFECT OF VIBRATING VERTICAL SURFACES ON DE/ANTI-ICING FLUIDS

This section describes the preliminary work conducted to evaluate the effects of vibration during taxi on fluid protection when applied to vertical surfaces with and without contamination.

5.1 Background

Currently, there is a lack of standardization in the treatment of vertical surfaces. Some operators in the United States and Canada exclude the treatment of vertical surfaces, including the tail, while others only consider treatment in ongoing freezing precipitation. Some reports have also indicated that treatment of the tail may worsen takeoff performance as the anti-icing fluid on the tail may lead to increased accumulation of contamination in active precipitation conditions.

Current Transport Canada (TC) and Federal Aviation Administration (FAA) rules and regulations require that critical surfaces be free of contamination prior to takeoff. The vertical stabilizer is defined as a critical surface by both TC and the FAA. However, from a regulatory implementation and enforcement standpoint, there is currently no standardized guidance that offers inspectors a means to determine if an air operator is complying with operational rules. If current operational rules aim to achieve the clean aircraft concept – which requires the tail to have zero adhering frozen contamination – the question remains: How can this be adequately achieved, or appropriately mitigated by operators, to ensure a satisfactory level of safety?

The research conducted to date has demonstrated the variability in the fluid protection times and characteristics of contamination that can be present on vertical surfaces. Further research would provide a better understanding of the influence of the different variables, including the rate and type of precipitation, wind conditions, and other meteorological conditions.

The effect of vibration during taxiing on fluid applied to vertical surfaces had yet to be evaluated prior to this research campaign. The following describes the preliminary results from the 2021-22 research that evaluates the effects of vibration during taxi on fluid protection when applied to vertical surfaces with and without contamination. The results will provide direction for future testing and wind tunnel trials.

NOTE: For the purpose of this report, the vibration considered is the natural excitation caused by aircraft taxiing at low speed on uneven pavement with dampening by the shock absorbers of the landing gear, with emphasis on the resulting low-frequency, high-amplitude vertical motion. The parameters simulated are based on literature research described in more detail in section 5.3.1 below.

5.2 Objective

The objective of this research was to evaluate the effects of vibration during taxiing on fluid adherence when applied to vertical surfaces with and without contamination.

5.3 Test Methodology

The following methodology was employed to determine the effects of vibration during taxiing on fluid protection time when applied to vertical surfaces.

5.3.1 Determination of Parameters Used to Simulate Vibration During Taxi

To simulate the effects of vibration during taxiing on fluid protection time when applied to vertical surfaces, representative targets were chosen for vibration frequency and amplitude based on available data.

Accelerometer data from three reports was used to calculate average frequency and amplitude of the vibration. Two reports were referenced from one FAA study, the Airport Pavement Roughness Study conducted by Cherokee CRC, LLC with the FAA: DOT/FAA/TC-18/8, *Boeing 737-800 Final Surface Roughness Study Data Collection* (8), and DOT/FAA/TC-18/13, *Airbus A330-200 Final Surface Roughness Study Data Collection* (9). The study modelled profiles from real-world airport surfaces of varying roughness, recording resulting cockpit acceleration in both a Boeing 737-800 and an Airbus A330-200 flight simulator. The data from the taxiway profile with the highest level of roughness and consequently highest vibration acceleration was chosen as the most conservative case to test.

Another study reviewed was by the DLR (German Aerospace Center) and was conducted on a Dornier DO 228-101, as documented in the report *Taxi Vibration Testing – An Alternative Method to Ground Vibration Testing of Large Aircraft* (10). In this case, accelerometers were installed on an aircraft that was pulled by a tractor along the taxiway.

The data from the above-mentioned reports was analysed and the basic parameters for the proposed testing were derived. A simple harmonic motion profile was estimated from the complex vibration of the recorded accelerometer data (see Figure 5.1). The root-mean-square of the acceleration data was used to calculate the simple harmonic motion using Equation 5.1 and Equation 5.2. The frequency was estimated by calculating the average time interval between peaks in acceleration.

$$RMS\ of\ recorded\ data = \frac{a}{\sqrt{2}}$$

Equation 5.1: Root-Mean-Square Acceleration

Where:

a = calculated peak acceleration.

$$d = \frac{a}{(2\pi f)^2}$$

Equation 5.2: Peak Displacement

Where:

d = displacement;

f = frequency; and

a = calculated peak acceleration.

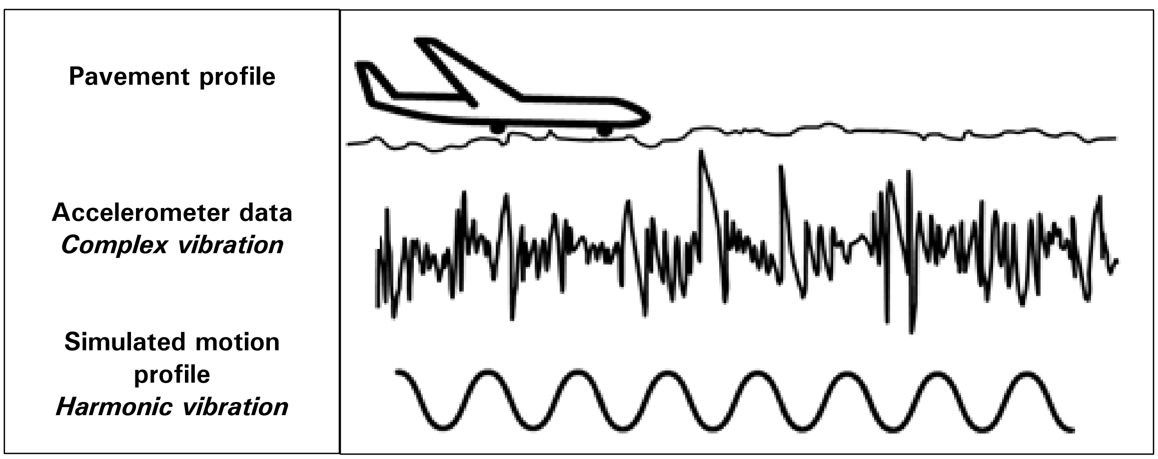


Figure 5.1: Simulated Motion Profile Schematic

The summary of this data is included in Table 5.1.

Table 5.1: Summary of APS Calculated Vibration Parameters Based on Literature Review

Aircraft	Taxi speed (km/h)	Vibration Frequency (Hz)	Vibration Amplitude (mm)
Boeing 737-800 Simulator	37	3.1	5.3
Airbus A330-200 Simulator	37	3.5	2.6
Dornier DO 228-101	"slow speed"	2.3	5

Based on the results of this analysis, the mechanism selected to best simulate the vibration on a test plate was a reciprocating linear actuator with a motor operating at 200 rpm (3.3 Hz) with a displacement of 5 mm (see Figure 5.2).

Figure 5.2: Reciprocating Linear Actuator

5.3.1.1 Procedure: Endurance Time Testing

To evaluate the effects of vibration on the fluid protection times when applied to vertical surfaces, a test plate positioned at 80° was made to vibrate by means of a reciprocating linear actuator (see Figure 5.2) installed on the test stand, and the fluid performance was compared to that of fluid applied to a non-vibrating 80º test plate and a standard 10º plate. Figure 5.3 depicts the setup used. A detailed test procedure is available in Appendix I. Tests were conducted in natural snow.

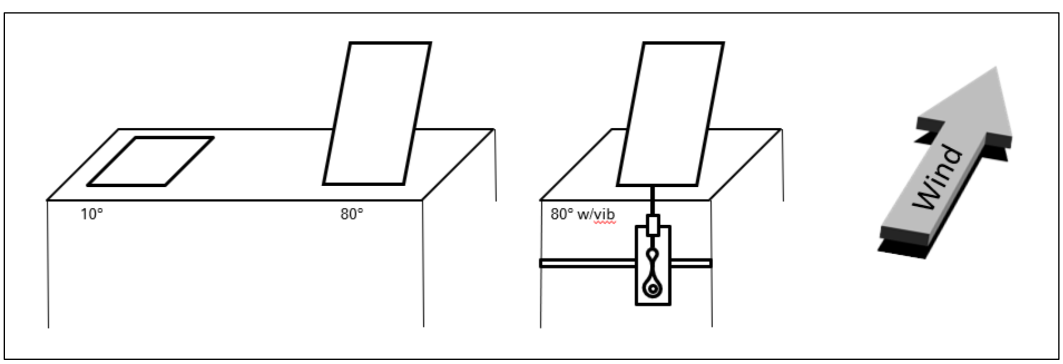


Figure 5.3: Outdoor Testing Setup

5.3.1.2 Procedure: Comparative Fluid Thickness Tests

The objective of this activity was to conduct tests to characterize and compare fluid thickness decay profiles following application on a 10º plate, 80º plate, and vibrating 80º plate. Tests were conducted with Type I and Type IV fluids, and measurements were taken over a 30-minute period. The standard thickness testing procedure was followed. A detailed test procedure is available in Appendix I.

5.4 Comparative Endurance Time Testing Results

A total of six tests with Type IV fluid [three with propylene glycol (PG) and three with ethylene glycol (EG)] were conducted. The endurance times of each plate were determined, and two comparisons were made. The first comparison was between the endurance times of the 80º vibrating plate and the 80º stationary plate. Final contamination thickness measurements were also taken at their respective fluid failures and compared. The second comparison was between the state (contamination present or not) of the 80º vibrating plate and the 80º stationary plate at the standard 10º endurance time, which represents a typical endurance time on a wing surface. It is important to note that progression data of each plate was also documented, and only pertinent information was considered during data analysis. The results of each test (Run #1 to Run #6) are shown in Figure 5.4, Figure 5.5, Figure 5.6, Figure 5.7, Figure 5.8, and Figure 5.9, while Figure 5.10 provides more details regarding Run #6. An overall testing summary is presented in Table 5.2 and Table 5.3.

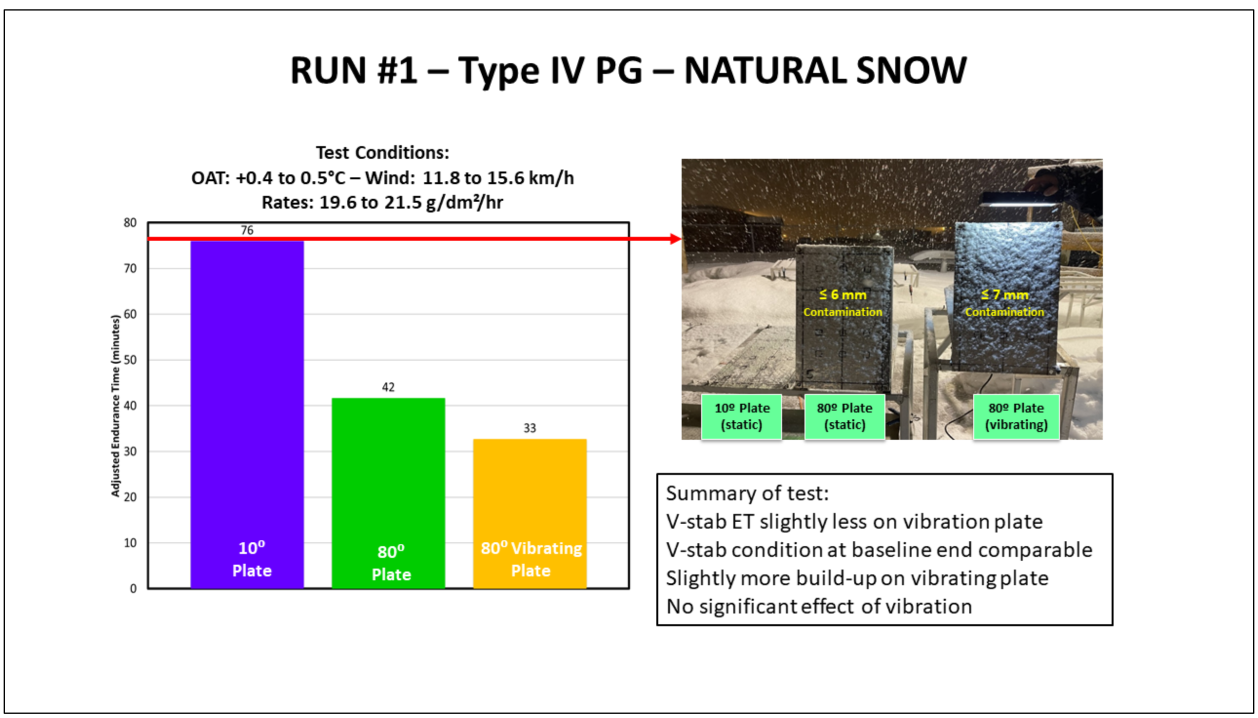


Figure 5.4: Summary of Run #1 – Type IV PG in Natural Snow

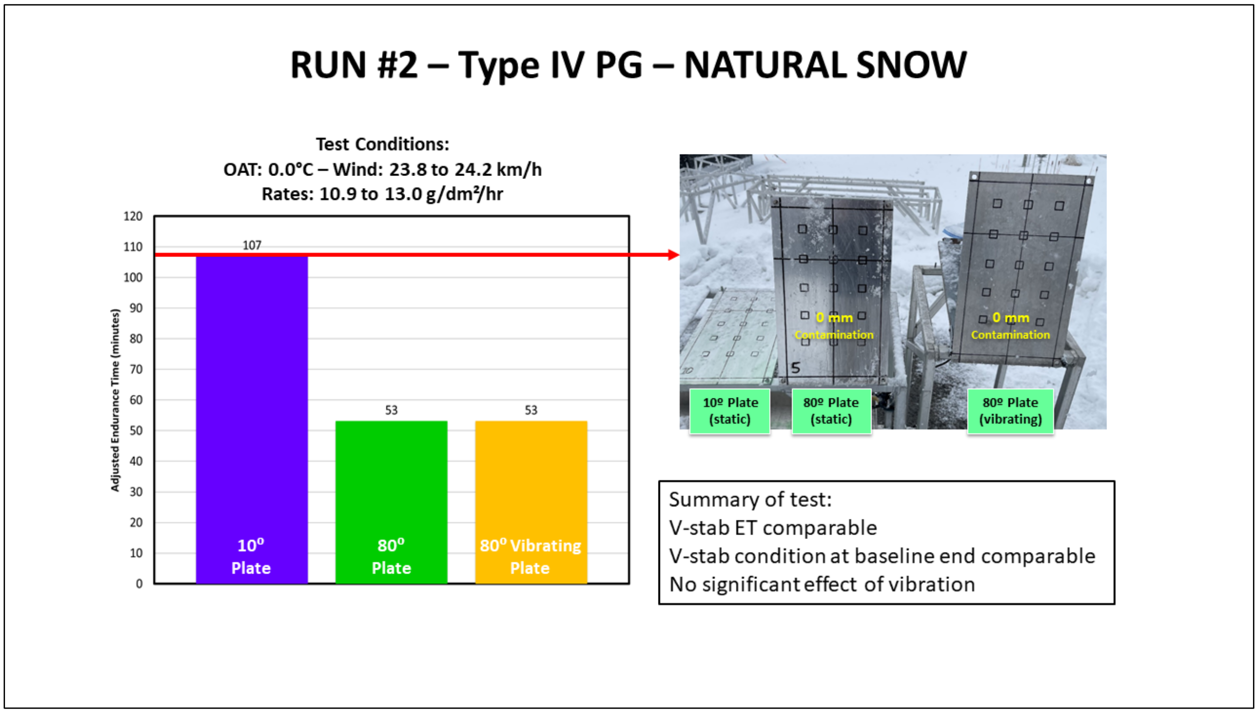


Figure 5.5: Summary of Run #2 – Type IV PG in Natural Snow

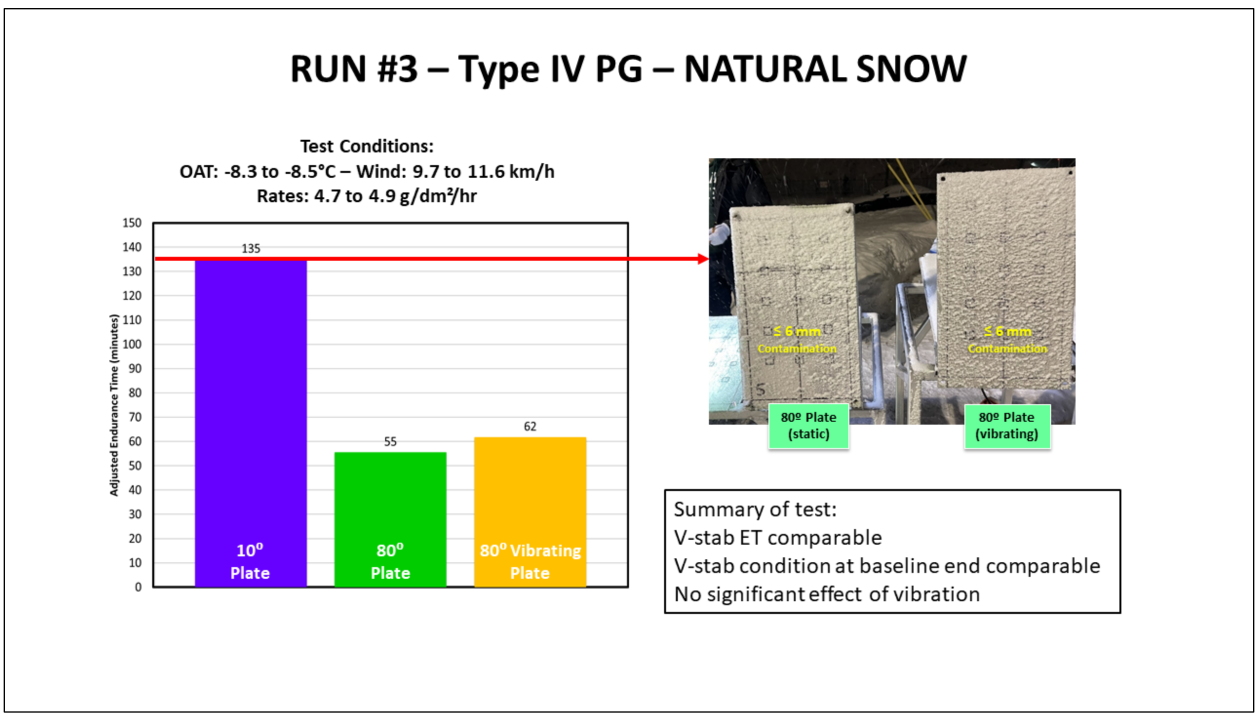


Figure 5.6: Summary of Run #3 – Type IV PG in Natural Snow

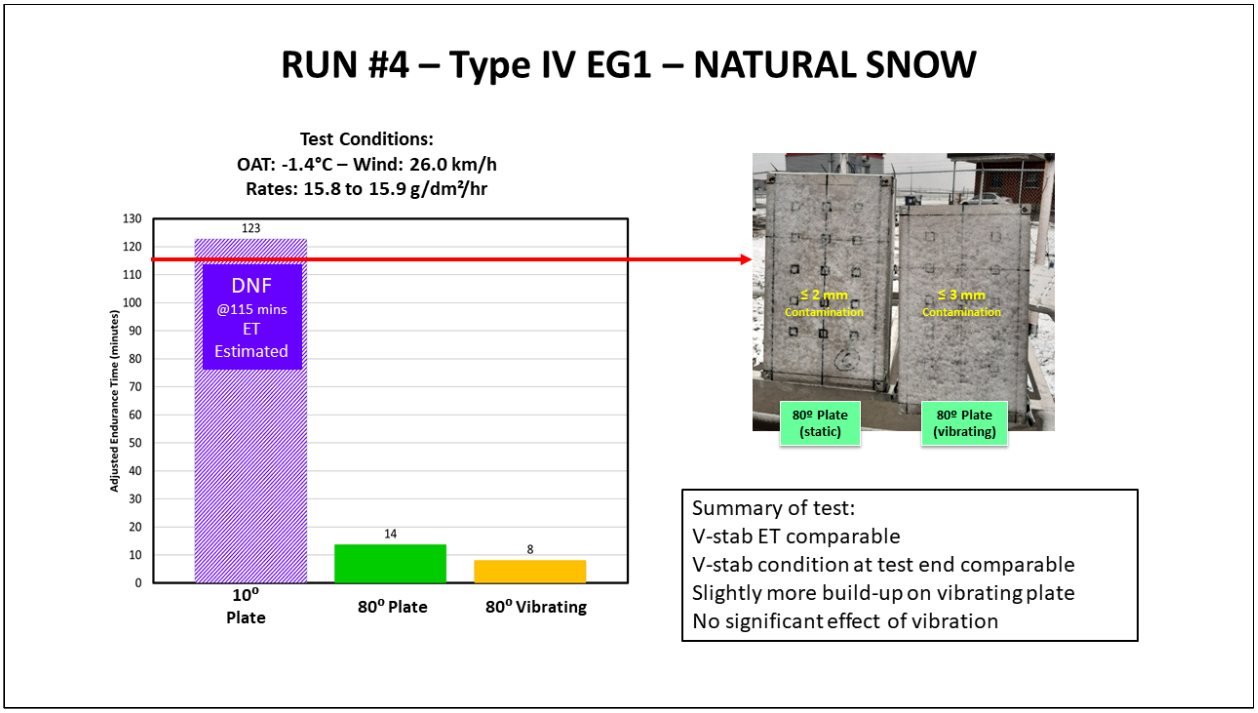


Figure 5.7: Summary of Run #4 – Type IV EG1 in Natural Snow

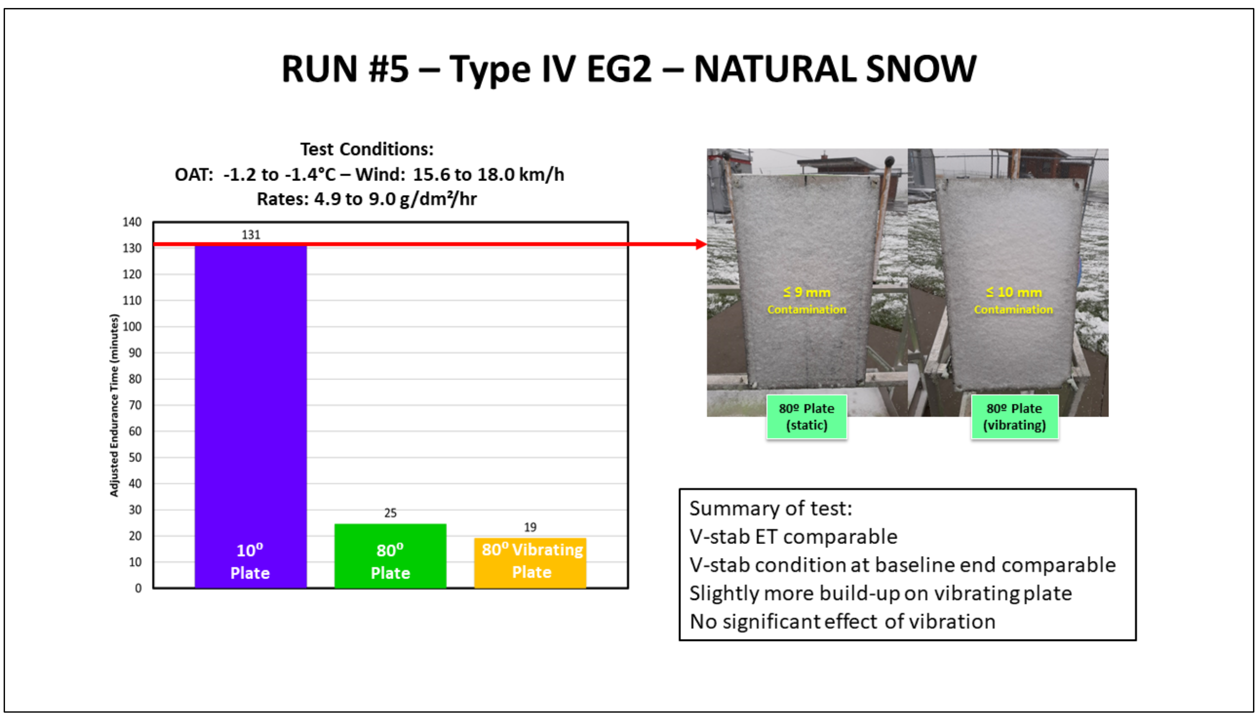


Figure 5.8: Summary of Run #5 – Type IV EG2 in Natural Snow

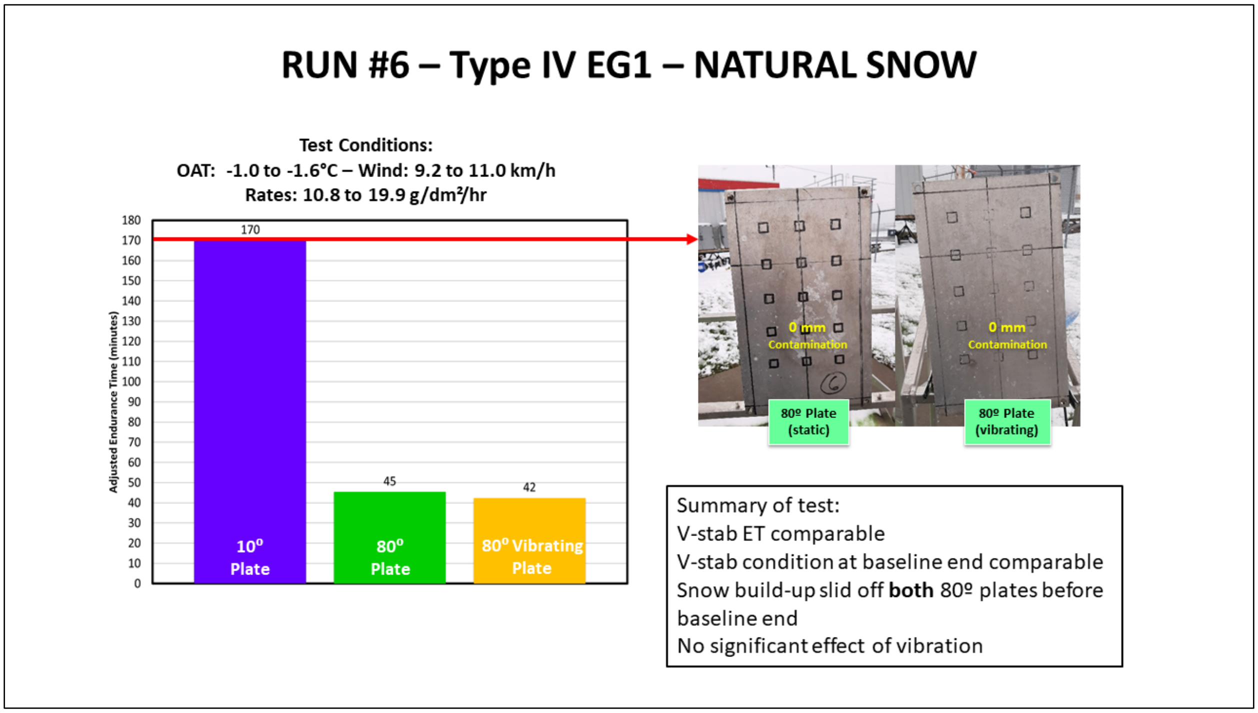


Figure 5.9: Summary of Run #6 – Type IV EG1 in Natural Snow

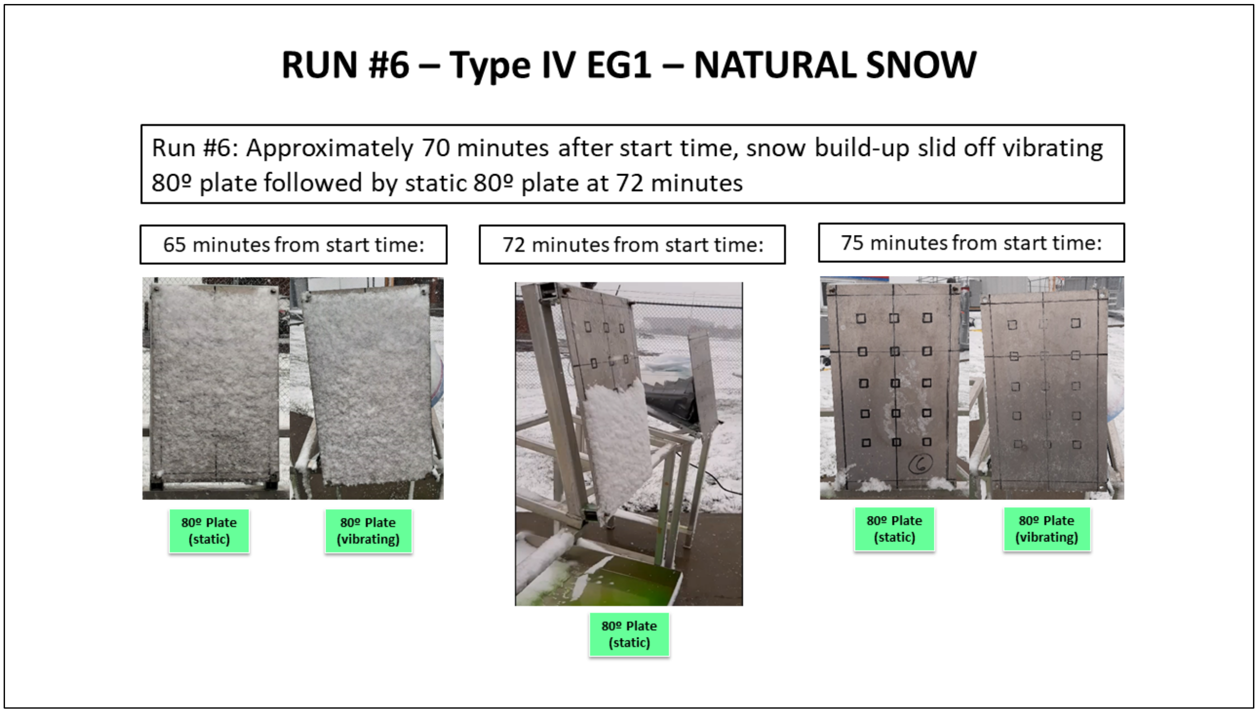


Figure 5.10: Run #6 – Vertical Plates Snow Build-Up Run-Off

Table 5.2: Summary of Endurance Time Results

	10° Plate Avg. ET	80° Static Plate Avg. ET	80° Vibrating Plate Avg. ET	Number of Tests
Type IV PG	100%	49%	46%	3
Type IV EG	100%	19%	15%	3
Combined Type IV	**100%**	**34%**	**31%**	**6**

Table 5.3: Summary of Contamination Present at 10° Plate Failure

	10° Plate Avg. Thickness	80° Static Plate Avg. Thickness	80° Vibrating Plate Avg. Thickness	Number of Tests
Combined Type IV	2.2 mm	3.8 mm	4.2 mm	6

For Run #1 to Run #6, as seen in Figure 5.4 to Figure 5.10, when comparing the 80° vibrating plate to the 80° stationary plate, the endurance times were determined to be statistically equivalent and within 5 percent of each other. The trend was for the endurance times of the vibrating 80° plate to be slightly less than the stationary 80° plate, with the exception of Run #2, where the times were equal, and Run #3, where the endurance time of the 80° vibrating plate was slightly longer than that of the stationary.

The thickness measurement of each plate five minutes into each run was also recorded. The data was consistent throughout all runs and showed that the result for the 80° vibrating plate was similar to that of the 80° stationary plate. The 10° plate was also consistently greater than the vertical plates, which is expected and in line with the longer endurance times recorded.

Final contamination thickness measurements were recorded for all three test plates (80° vibrating, 80° stationary, and standard 10°) at the endurance time of the 10° plate. The results showed that the final thickness measurements of the 80° vibrating plate and the 80° stationary plate for all runs were approximately the same. For half of the tests (Runs #1, #4, and #5), the final thickness was slightly greater, by 1 mm, on the 80° vibrating plate compared to the 80° stationary plate. However, for all tests, both vertical plates were generally within 10 percent of each other. The average thicknesses at failure are summarized in Table 5.3.

In general, the condition of both the 80º vibrating plate and the 80º stationary plate at the endurance time of the 10º plate was approximately the same for each run. The results are summarized in Table 5.2 and Table 5.3.

Run #6 was the only test in which a non-typical occurrence was observed, whereby 70 minutes into the test the snow build-up on the 80º vibrating plate slid off, as seen in Figure 5.10. At 72 minutes (two minutes later), the snow build-up on the 80º stationary plate also slid off. This is most likely due to the outside air temperature and wet snow, which were close to the freezing point and contained a large amount of water, respectively. The large amount of wet snow around the freezing point and adhering to the plate was too heavy for the adhesive forces to withstand. In other words, the force of gravity acting on the wet snow overcame the adhesive forces between the snow and the aluminum plate and resulted in snow run-off, as seen in Figure 5.10.

For more details on the data captured during each test, a complete log can be found in Appendix J.

5.5 Comparative Fluid Thickness Testing Results

A total of four fluid thickness tests were conducted with no precipitation to determine if the fluid thickness of the 80º plate was affected by vibration. Of the four tests, one Type I fluid, two PG Type IV fluids, and one EG Type IV fluid were evaluated. As illustrated below, the 80º vibrating plate was compared to the stationary 80º plate and to the standard 10º plate throughout each test. The results for each test are shown in Figure 5.11, Figure 5.12, Figure 5.13, Figure 5.14, and Figure 5.15.

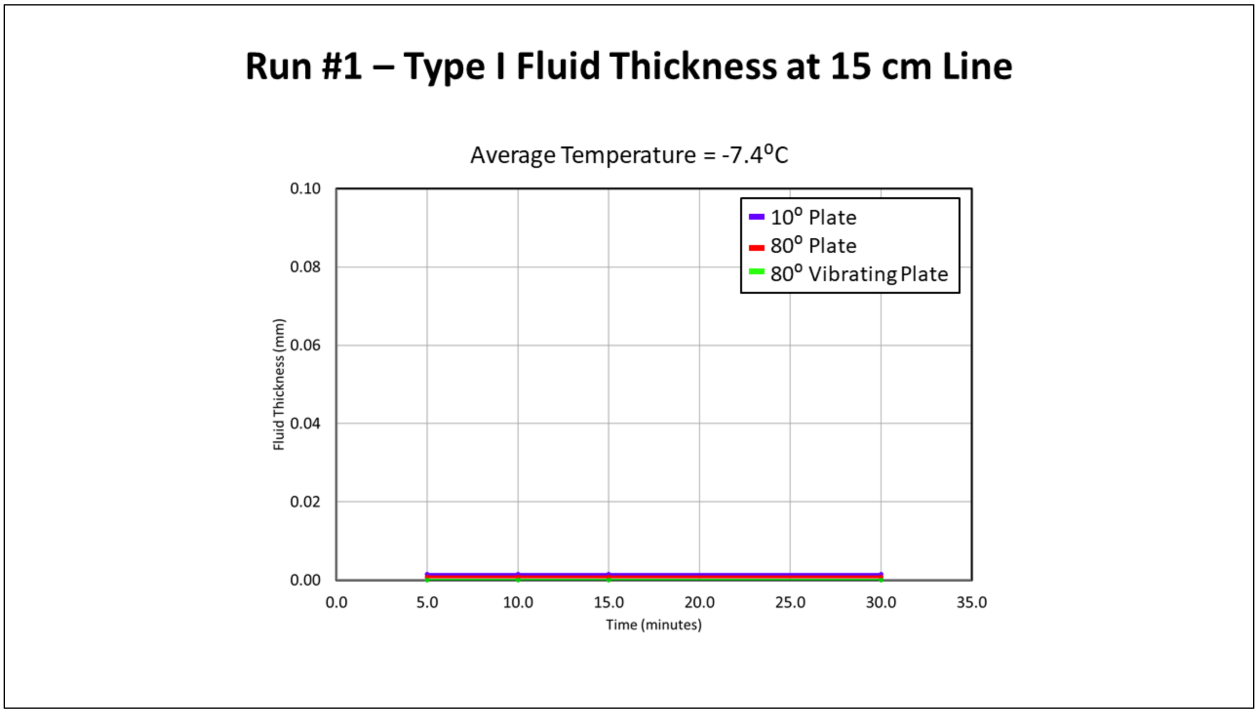


Figure 5.11: Run #1 – Type I Fluid Thickness Test

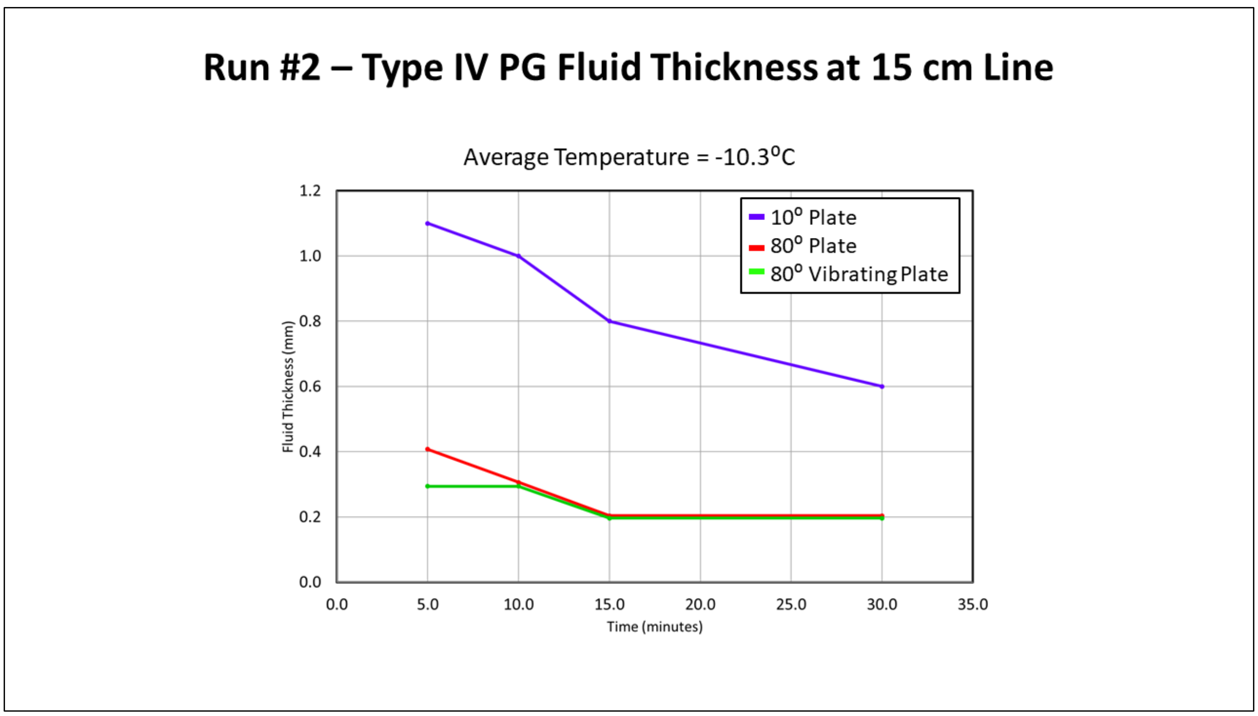


Figure 5.12: Run #2 – Type IV PG Fluid Thickness Test

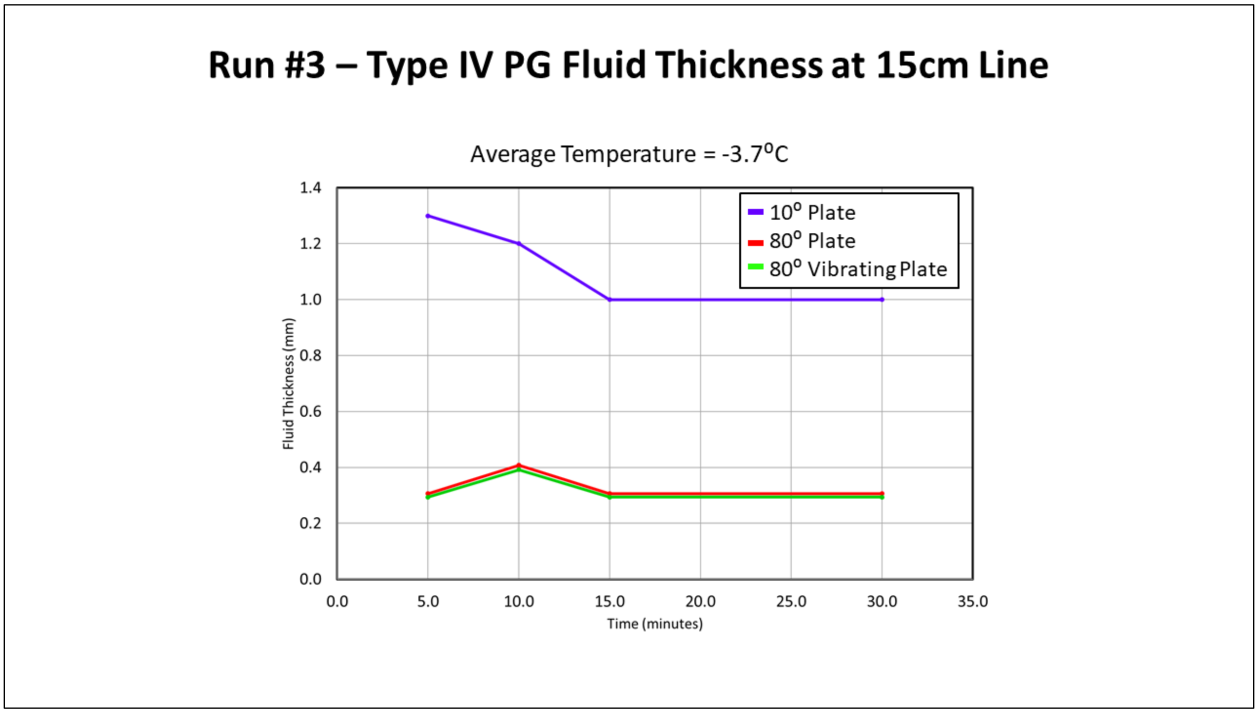


Figure 5.13: Run #3 – Type IV PG Fluid Thickness Test

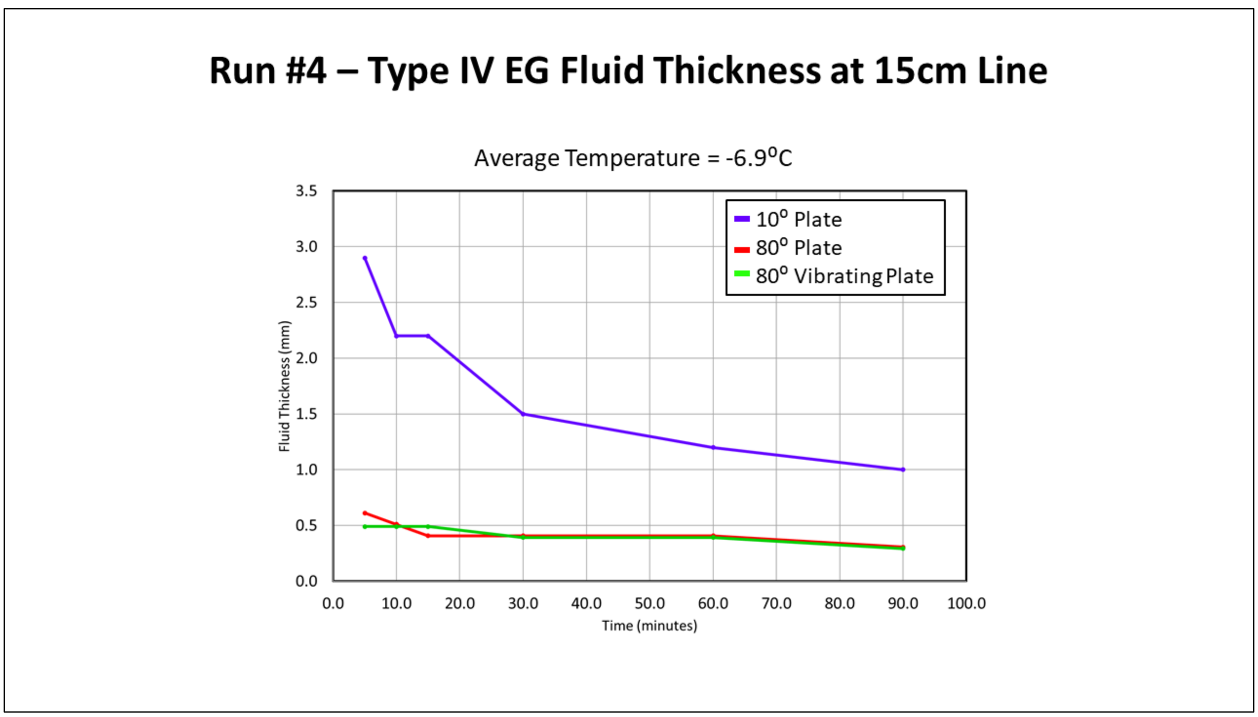


Figure 5.14: Run #4 – Type IV EG Fluid Thickness Test

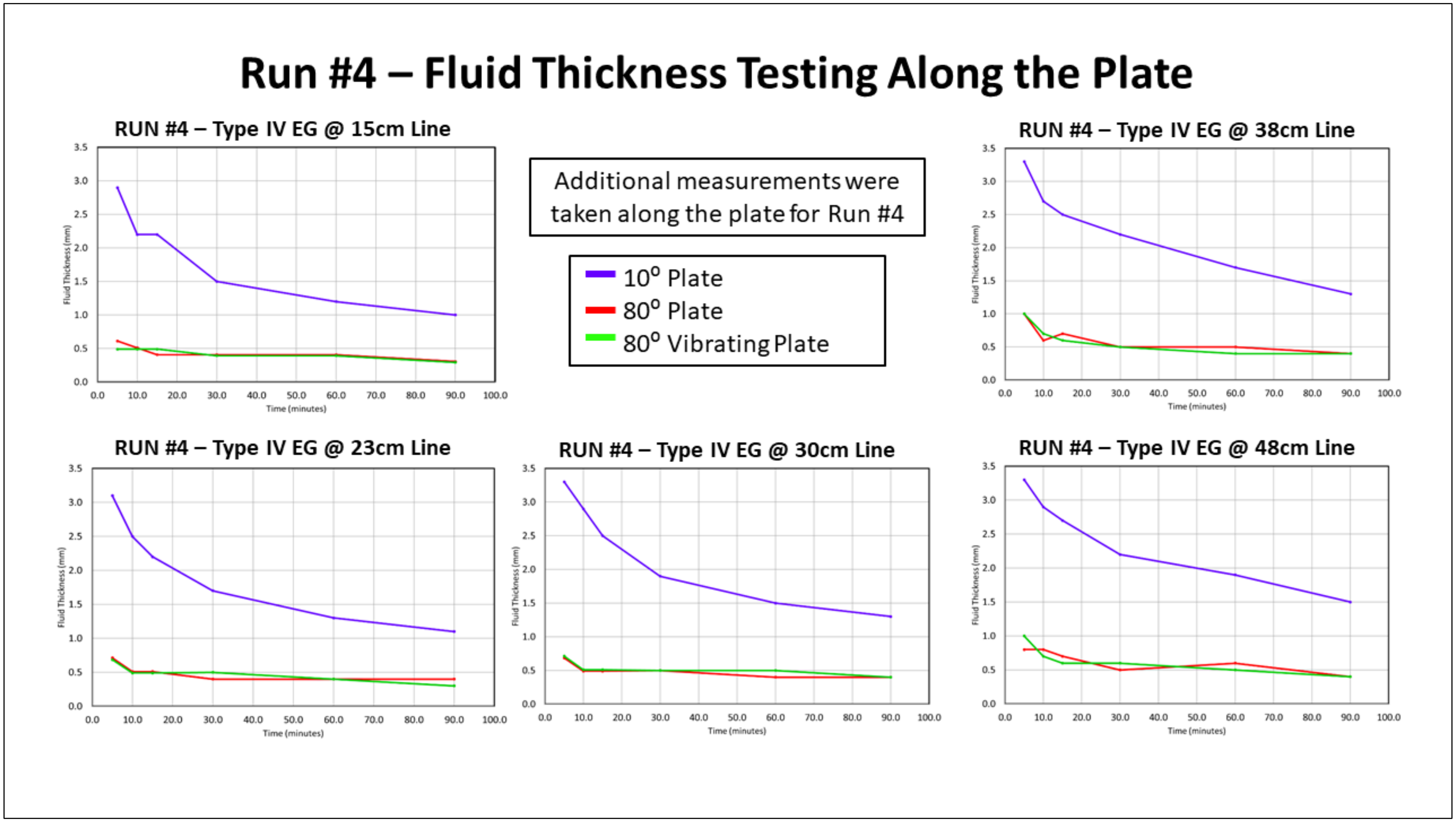


Figure 5.15: Run #4 – Type IV EG Fluid Thickness Test at Various Positions

For each of the four tests conducted, the fluid thickness was measured at the 15 cm line. Measurements were taken until a steady state was achieved. For both the Type I and Type IV PG tests, the test duration was 30 minutes, while for the Type IV EG test, the duration was 90 minutes.

Due to the nature of the Type I fluid and its low viscosity, the results seen in Figure 5.11 were as expected. The fluid thicknesses on each of the three test plates (80º vibrating, 80º stationary, and standard 10º) were essentially equivalent and less than 0.1 mm. Thus, the effect of vibration on Type I fluid was negligible.

The two PG thickness tests had similar results, where the 80º plate was not affected by vibration. When comparing both the 80º vibrating plate and 80º stationary plate, the fluid thicknesses were essentially the same. The 10º plate resulted in a thicker fluid due to the lower angle made with the horizontal surface. However, the 10º plates from Run #2 and Run #3 had a final thickness measurement of 0.6 mm and 1 mm, respectively. This was likely due to Run #3 having an initial fluid thickness greater than that of Run #2.

It is important to note that although the fluid thickness differed slightly for both Run #2 and Run #3, the results seen in Figure 5.12 and Figure 5.13 indicate that the 80º vibrating plate is equivalent to the 80º stationary plate.

The EG thickness test demonstrated the same trend as observed with the PG fluids, except with a much greater fluid thickness throughout the test. This difference in fluid thickness is due to the cooler fluid temperature, which results in a greater fluid viscosity when applied to the plate. Figure 5.14 depicts the fluid thicknesses measured, demonstrating that the 80º vibrating plate is equivalent to the 80º stationary plate. To further validate this claim, thickness measurements throughout the test from multiple locations along the plate were also recorded. Figure 5.15 shows that, regardless of thickness measurement location, the fluid thickness is comparable for both the 80º vibrating plate and 80º stationary plate.

For more details on the data recorded during each test, a complete log can be found in Appendix J.

5.6 Summary of Observations

The following final observations were made:

- Fluid endurance time performance is comparable for both the 80º vibrating and 80º stationary plates;

- Presence of slush or frozen contamination on 80º vibrating and 80º stationary plates at the standard 10º plate failure was also comparable; and
- Fluid thickness tests supported the comparative endurance time results in the following ways:
  - 80º vertical plate thickness is much less than the standard 10º plate; and
  - 80º stationary and 80º vibrating plates have comparable thickness profiles.

5.7 Recommendations

A total of six endurance time comparison and four comparative fluid thickness tests were conducted during the 2020-21 winter season. Preliminary results indicated that vibration is not an important consideration for de/anti-icing fluid performance on vertical surfaces. Based on this finding, vibration is likely not required as a consideration for wind tunnel testing. The National Research Council Canada common research model can thus proceed without modifications for vibration.

Although the preliminary findings seem to be consistent, additional flat plate testing would be useful to substantiate results due to the limited tests conducted. Therefore, further testing is recommended for the winter of 2021-22.

Additional recommendations from the Aerodynamic Working Group were provided during the May 2021 SAE International G-12 conference. The group proposed that the following measures should be considered if future flat plate testing is to occur.

- Dry plate testing (no fluids) to evaluate if vibration has any benefits on surfaces not treated with fluids.
- Ground roll vibration (which may be higher than taxi vibration) to evaluate if the extra forces impact how fluid and contamination adhere to vertical surfaces.
- Auxiliary power unit and engine vibration to evaluate if the extra forces impact how fluid and contamination adhere to vertical surfaces.
- Wet/dry snow testing with temperatures ≈-2ºC to evaluate if there are differences in regard to the vibrating and non-vibrating plate results.
- Amplitude of vibrations sensed by the tail compared to that of the cockpit to validate initial assumptions made. Appropriate testing fluids should also be considered.

This page intentionally left blank.

6. EVALUATION OF VARIABILITY IN HOLDOVER TIME TESTING RESULTS – LIGHT FREEZING RAIN

This section describes the work planned by APS Aviation Inc. (APS) for the winter of 2020-21 to investigate variability in endurance time results for light freezing rain conditions.

6.1 Background

Since the early 1990s, tests have been conducted by APS at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) under simulated freezing rain conditions.

APS was requested to study the variability in endurance time test results in simulated light freezing rain conditions. The plan was to conduct testing at the NRC CEF to collect data to assess the variability in endurance time testing results as outlined below. Outdoor testing at the APS test site was also planned to collect data for comparison.

In addition, a review of historical full-scale and natural light freezing rain data collection was completed. This historical data was compared to simulated light freezing rain data collected at the NRC. This work is documented in Section 7 of this report.

6.2 Objective

The objective was to assess the variability in endurance time testing results in simulated light freezing rain conditions at the NRC CEF. This is the first phase of a multi-phase project, which is planned to include additional phases in subsequent years for other simulated precipitation conditions such as freezing fog and freezing drizzle.

6.3 Test Methodology

An estimated eight days of testing at the NRC CEF was planned for endurance time testing with four anti-icing reference fluids of varying fluid type (Type II PG, Type III EG, Type IV EG, and Type IV PG) under the following simulated conditions:

- Light Freezing Rain, -3°C, 13 g/dm²/h;

- Light Freezing Rain, -3°C, 25 g/dm²/h;
- Light Freezing Rain, -10°C, 13 g/dm²/h; and
- Light Freezing Rain, -10°C, 25 g/dm²/h.

Outdoor testing at the APS test site was also planned for the same four anti-icing reference fluids, with a goal of at minimum three testing events.

6.4 Data Collected

No data was collected during the 2020-21 season. Testing scheduled at the NRC for the fall of 2021 was cancelled due to reallocation of project resources to other, higher-priority activities. Outdoor testing planned for the APS test site in Montreal was not completed due to the absence of suitable freezing rain events this season.

6.5 Recommendations

If resources become available, it is recommended to pursue light freezing rain testing in the future.

7. EVALUATION OF THE USE OF THE NRC'S CLIMATIC ENGINEERING FACILITY FOR DEVELOPMENT OF HOLDOVER TIMES

There have been some questions raised about the validity of the simulated light freezing rain endurance time testing conducted at the National Research Council Canada (NRC) climate chamber as part of the development of holdover times (HOTs) used by pilots during winter operations. A fluid manufacturer is questioning the validity of the light freezing rain test data obtained at the NRC; this manufacturer claims to have obtained longer endurance times at another facility. A review of previous testing methods and results was conducted by APS Aviation Inc. (APS).

7.1 Background

Since the early 1990s, tests have been conducted by APS at the NRC Climatic Engineering Facility (CEF) under simulated freezing rain conditions. Testing parameters and procedures were developed and further refined over several years with substantial investment in the facility and equipment by the NRC, Transport Canada (TC), and the Federal Aviation Administration (FAA).

The sprayer assembly has been optimized to provide improved uniformity over the test bed area. Nozzles and fluid pressures are calibrated to obtain representative droplet sizes and rates. Droplet sizes are measured using the dye stain method to ensure that the appropriate median volume diameter is achieved. Accurate measurement of precipitation rate is crucial to calculate endurance time. During tests, rates are continuously monitored to ensure icing intensity is within specification. HOTs for light freezing rain conditions are developed following the methods outlined in the SAE International (SAE) Aerospace Recommended Practice 5485B, *Endurance Time Test Procedures for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluids* (11).

To compare the fluid failure time measured indoors at the NRC to that measured in natural conditions outdoors, several tests were planned for natural freezing rain in the winter of 2020-21. Unfortunately, there were no freezing rain events at the APS outdoor test site in Montreal this season.

7.2 Full-Scale Outdoor Testing (1995-97)

During the development of the light freezing rain testing methodology, tests were conducted under natural conditions outdoors on an aircraft wing and on flat plates. Specifically, in the 1995-96 winter season, two full-scale tests were conducted on a DC-9-30 wing with simultaneous tests on standard flat plates. See the TC report, TP 12901E, *Aircraft Full-Scale Test Program for the 1995-1996 Winter – Type IV* (12) for the full report on the 1995-96 full-scale testing. As well, in the 1996-97 winter season, a full-scale outdoor test was conducted in freezing rain conditions on a B-737 wing and a standard flat plate. See the TC report, TP 13131E, *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1996/97 Winter* (13) for the full report on the 1996-97 full-scale testing. The full-scale tests showed a reasonable correlation between 10 percent failure on wing and failure on flat plates (see Appendix K). This result was in line with the extensive natural snow correlation work on flat plates and wings, which was the basis for acceptance of the flat plate test procedure.

7.3 Comparative Testing of Natural vs. Simulated Conditions (1995-97)

In those same years (1995-97), tests were conducted with multiple Type IV fluids (Ultra, Ultra+, Hoechst, and Octagon) at the NRC CEF under simulated precipitation conditions as well as outdoors under natural conditions. Failure times recorded during the outdoor natural light freezing rain tests were consistent with those recorded at the CEF (see Appendix K for charts recreated from the original 1995-97 data). Details of the comparative tests can be found in TP 13131E (13).

7.4 Differing Results for Light Freezing Rain HOTs (1998 and 2019)

In 1998, the Anti-Icing Materials International Laboratory (AMIL) presented data for three neat Type IV fluids suggesting significantly lower HOTs in light freezing rain than those presented by APS the same year (7 vs. 20 minutes for two fluids and 10 vs. 30 minutes for one fluid). Tests were repeated by APS on those fluids in the presence of SAE G-12 HOT Subcommittee co-chairs and a representative from the AMIL. The results obtained were identical to those presented by APS initially. Details can be found in the TC report, TP 13477E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1998-99 Winter* (14).

More recently, in 2019, there was a question from a fluid manufacturer related to the results of light freezing rain testing conducted by APS at the NRC CEF. The manufacturer had the same fluid tested at the AMIL under light freezing rain conditions. The results from the AMIL were significantly longer HOTs than those recorded by APS.

In addition, supplemental testing in light freezing rain conditions was conducted in August 2017 for a Type IV fluid at the request of the fluid manufacturer, as they questioned the endurance time results obtained at the NRC facility in March/April of the same year. As a control, a Type II fluid was also re-tested. The supplemental tests on the Type II fluid yielded results consistent with the results obtained with the same fluid in March/April 2017, indicating that the methodology generated repeatable results. The data review and supplemental testing conducted in August with the control fluid suggested that there was no strong evidence that the results from the March/April testing were invalid. The variations in the expected performance of the Type IV fluid were likely a result of the changes observed in the viscosity over time.

7.5 Conclusions

Simulated light freezing rain HOT testing methods and facilities have been developed and refined since the early 1990s by TC, the FAA, APS, and the NRC. Equipment has been optimized for producing representative sizes and rates of simulated precipitation as well as for the accurate measurement of those precipitation rates.

Previous outdoor testing under natural precipitation conditions has validated that the fluid failure times under simulated conditions are similar to those under natural conditions. This was evaluated with full-scale outdoor testing, which showed a reasonable correlation between 10 percent failure on wing and failure on flat plates, and with comparative testing of the same fluids under natural light freezing rain conditions outdoors and simulated conditions at the NRC.

In 1998, the AMIL had presented light freezing rain endurance time test results obtained at their facility that were significantly shorter than test results obtained with the same fluids at the NRC test facility. When tests were repeated, the results confirmed the accuracy and repeatability of the results obtained at the NRC. In 2017, supplemental testing was requested to validate light freezing rain endurance time results obtained at the NRC facility. The results again demonstrated that the methodology generated repeatable results. More recently, in 2019, a fluid manufacturer claimed that their fluid obtained longer endurance times in light freezing rain tests at the AMIL facility compared to those obtained at the NRC facility. Significant investment may be required to determine the reason for their discrepancies, as the endurance time results from the NRC facility have been repeatedly validated for the development of light freezing rain HOTs.

This page intentionally left blank.

8. REVIEW OF "SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY" HOLDOVER TIME GUIDANCE

This section describes the work completed by APS Aviation Inc. (APS) in 2020-21 to review the existing snowfall intensity vs. visibility holdover time (HOT) guidance.

8.1 Background

Pilots determine snowfall intensity as part of the HOT determination process by using visibility as a reference point. Transport Canada (TC) and the Federal Aviation Administration (FAA) provide guidance on this determination through a "Snowfall Intensities as a Function of Prevailing Visibility" reference table published within their respective HOT Guidelines. These tables (referred to as the "visibility tables") allow pilots to estimate the snowfall intensity category using the current visibility, temperature, and lighting conditions.

Each organization publishes its own separate version of the visibility table. The current TC visibility table was developed following analysis conducted by APS in 2002-03. This analysis is documented in the TC report, TP 14151E, *Relationship Between Visibility and Snowfall Intensity* (15). The current FAA visibility table was developed using multiple sources of data and analysis [including TP 14151E (15)].

The two visibility tables contain several differences in both their respective formats as well as in the snowfall intensities assigned to sets of environmental conditions. These differences can create situations in which differing HOT guidance is provided depending on which organization's table is used. This fact has been noted by several Canadian air operators, who have in turn asked TC for clarification (as the TC guidance tends to be more conservative than the FAA guidance where discrepancies exist).

In recent years, TC and the FAA have attempted to harmonize their respective ground deicing guidance wherever possible. It was determined that efforts should be made to evaluate the feasibility of harmonizing the differences in the two organizations' visibility tables.

8.2 Objectives

The objectives of this project were to review the existing TC/FAA visibility tables and associated guidance, to categorize the differences between the two tables, and to begin the analytical work necessary to support future changes to the tables (with the goal of harmonizing the guidance).

8.3 Current TC/FAA Visibility Guidance

The current TC visibility table is shown below in Figure 8.1. The current FAA visibility table is shown below in Figure 8.2.

TABLE 50: SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY[1]

Lighting	Temperature Range		Visibility in Snow in Statute Miles (Metres)			
	°C	°F	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1 (≤1600)	>1 to 2½ (>1600 to 4000)	>2½ to 4 (>4000 to 6400)	>4 (>6400)
	Below -1	Below 30	≤3/4 (≤1200)	>3/4 to 1½ (>1200 to 2400)	>1½ to 3 (>2400 to 4800)	>3 (>4800)
Daylight	-1 and above	30 and above	≤½ (≤800)	>½ to 1½ (>800 to 2400)	>1½ to 3 (>2400 to 4800)	>3 (>4800)
	Below -1	Below 30	≤3/8 (≤600)	>3/8 to 7/8 (>600 to 1400)	>7/8 to 2 (>1400 to 3200)	>2 (>3200)

NOTES

1 Based on: *Relationship between Visibility and Snowfall Intensity* (TP 14151E), Transportation Development Centre, Transport Canada, November 2003; and *Theoretical Considerations in the Estimation of Snowfall Rate Using Visibility* (TP 12893E), Transportation Development Centre, Transport Canada, November 1998.

Figure 8.1: Current Transport Canada Visibility Table

TABLE 50: SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY

Time of Day	Temp.		Visibility in Statute Miles (Meters)									
	Degrees Celsius	Degrees Fahrenheit	≥ 2 1/2 (≥ 4000)	2 (3200)	1 3/4 (2800)	1 1/2 (2400)	1 1/4 (2000)	1 (1600)	3/4 (1200)	1/2 (800)	≤ 1/4 (≤ 400)	
Day	colder/equal -1	colder/equal 30	Very Light	Very Light	Very Light	Light	Light	Light	Moderate	Moderate	**Heavy**	Snowfall Intensity
	warmer than -1	warmer than 30	Very Light	Light	Light	Light	Light	Moderate	Moderate	**Heavy**	**Heavy**	
Night	colder/equal -1	colder/equal 30	Very Light	Light	Light	Moderate	Moderate	Moderate	Moderate	**Heavy**	**Heavy**	
	warmer than -1	warmer than 30	Very Light	Light	Moderate	Moderate	Moderate	Moderate	**Heavy**	**Heavy**	**Heavy**	

NOTE 1: This table is for estimating snowfall intensity. It is based upon the technical report, “The Estimation of Snowfall Rate Using Visibility,” Rasmussen, et al., Journal of Applied Meteorology, October 1999 and additional in situ data.

NOTE 2: This table is to be used with Type I, II, III, and IV fluid guidelines.

NOTE 3: The use of Runway Visual Range (RVR) is not permitted for determining visibility used with the holdover tables.

NOTE 4: Some METARS contain tower visibility as well as surface visibility. Whenever surface visibility is available from an official source, such as a METAR, in either the main body of the METAR or in the Remarks (“RMK”) section, the preferred action is to use the surface visibility value.

NOTE 5: If visibility from a source other than the METAR is used, round to the nearest visibility in the table, rounding down if it is right in between two values. For example, .6 and .625 (5/8) would both be rounded to .5 (1/2).

HEAVY = Caution—No Holdover Time Guidelines Exist

During snow conditions alone, the use of Table 50 in determining snowfall intensities does not require pilot company coordination or company reporting procedures since this table is more conservative than the visibility table used by official weather observers in determining snowfall intensities.

Because the FAA Snowfall Intensities Table, like the FMH-1 Table, uses visibility to determine snowfall intensities, if the visibility is being reduced by snow along with other forms of obscuration such as fog, haze, smoke, etc., the FAA Snowfall Intensities Table does not need to be used to estimate the snowfall intensity for HOT determination during the presence of these obscurations. Use of the FAA Snowfall Intensities as a Function of Prevailing Visibility Table under these conditions may needlessly overestimate the actual snowfall intensity. Therefore, the snowfall intensity being reported by the weather observer or automated surface observing system (ASOS), from the FMH-1 Table, may be used.

Figure 8.2: Current Federal Aviation Administration Visibility Table

8.4 Differences Between the TC and FAA Visibility Guidance

This subsection describes the differences between the current TC and FAA visibility tables and associated guidance.

8.4.1 Table Layout and Data Presentation

The TC and FAA tables contain several differences in layout and data presentation. These differences are described below.

8.4.1.1 Range Format vs. Look-Up Format

The TC visibility table employs a "range" format, where the snowfall intensity categories are listed as the columns and the applicable visibilities are provided as ranges within these columns. The defined ranges are such that any reported visibility can be assigned to one of the existing ranges.

The FAA visibility table employs a "look-up" format, where individual visibility values are listed as columns and the corresponding snowfall intensities are shown within these columns. If the desired visibility value is not listed within the table, users are directed to use the next-lowest visibility value as their input.

8.4.1.2 Order of Parameters (Lighting, Temperature)

The TC and FAA visibility tables differ in the order in which the lighting and temperature parameters are presented. In the TC table, this is inverted: the night-time values are listed above the day-time values, and the warm-temperature values are listed above the cold-temperature values. In the FAA table, day-time values are listed above night-time values, and cold-temperature values are listed above warm-temperature values.

8.4.1.3 Order of Snowfall Intensities

The TC and FAA visibility tables differ in the order in which the snowfall intensities are presented. In the TC table, this is inverted: the snowfall intensities are listed from heaviest to lightest when reading left to right. In the FAA table, the snowfall intensities are listed from lightest to heaviest when reading left to right.

8.4.1.4 Lighting Condition Terminology

There are variations between the two tables in the terminology used to describe the lighting condition. The TC table describes the lighting condition category as "Lighting" and lists "Darkness" and "Daylight" as subcategories. The FAA table describes the lighting condition category as "Time of Day" and lists "Day" and "Night" as the subcategories.

Although the approach to using the TC/FAA visibility tables is the same (i.e., use a known visibility value as an input and check the table to determine the corresponding snowfall intensity), the net effect of the various table layout and data presentation differences makes the process of employing the two tables different in practice. To reduce potential confusion, it is recommended that TC and the FAA consider adopting a unified format.

8.4.2 Temperature Break

The TC and FAA tables currently differ in the temperature that is used to differentiate the "colder" and "warmer" sets of visibility values. TC currently includes temperatures of -1°C in the "warmer" set of values, whereas the FAA currently includes -1°C in the "colder" set of values. The difference is illustrated below in Figure 8.3.

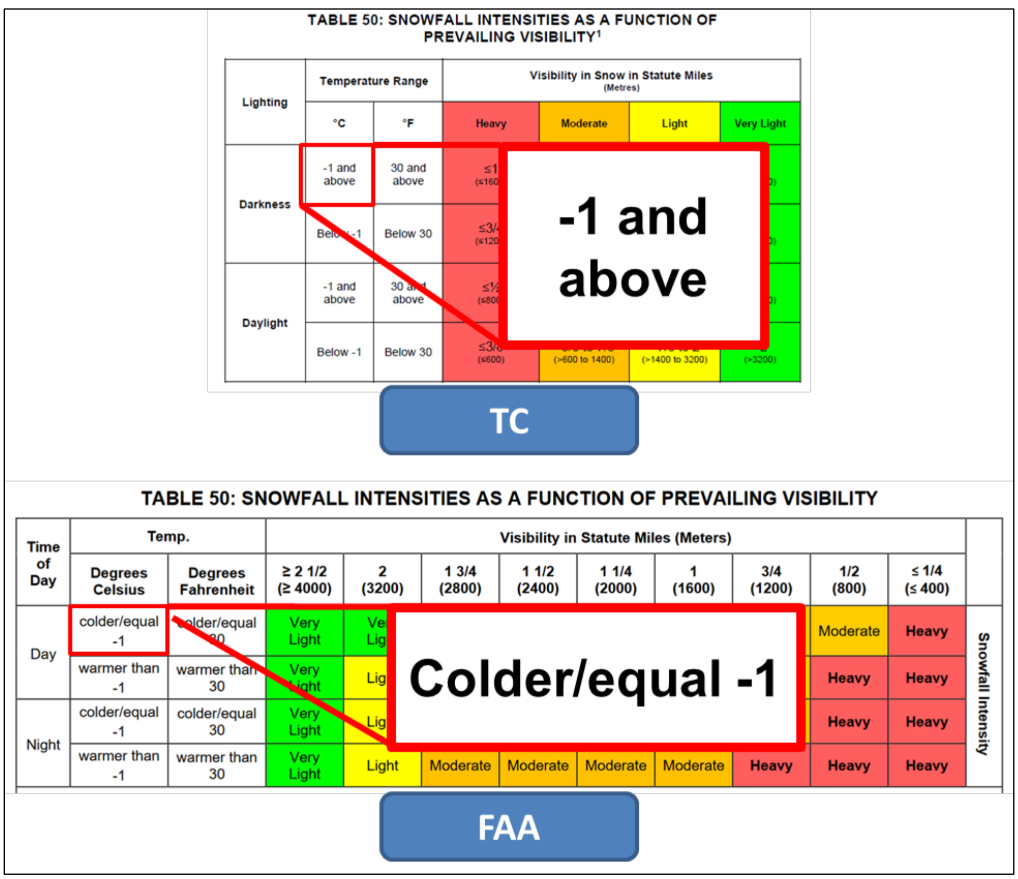


Figure 8.3: Comparison of Temperature Break in TC/FAA Visibility Tables

The snowfall intensities assigned to visibility values in the warmer temperature grouping are generally more conservative (i.e., higher) than the corresponding intensities in the colder temperature grouping. As a result, the guidance provided by each organization for operations at specifically -1°C differs significantly.

Table 8.1 summarizes the visibility table guidance at -1°C for each organization. The visibility values where the two organizations categorize the snowfall intensity differently have been encircled.

Table 8.1: Comparison of TC/FAA Visibility Table Guidance at -1°C

Visibility		Daylight		Darkness	
Statute Miles	Meters	-1°C FAA	-1°C TC	-1°C FAA	-1°C TC
≤ 1/4	≤ 400	Heavy	Heavy	Heavy	Heavy
3/8	600	Heavy	Heavy	Heavy	Heavy
1/2	800	Mod	Heavy	Heavy	Heavy
5/8	1000	Mod	Mod	Heavy	Heavy
3/4	1200	Mod	Mod	Mod	Heavy
7/8	1400	Mod	Mod	Mod	Heavy
1	1600	Light	Mod	Mod	Heavy
1 ¼	2000	Light	Mod	Mod	Mod
1 ½	2400	Light	Mod	Mod	Mod
1 ¾	2800	VLS	Light	Light	Mod
2	3200	VLS	Light	Light	Mod
2 ½	4000	VLS	Light	VLS	Mod
3	4800	VLS	Light	VLS	Light
3 ½	5600	VLS	VLS	VLS	Light
≥ 4	≥ 6400	VLS	VLS	VLS	Light

It is recommended that TC and the FAA consider adopting an equivalent temperature break to reduce the occurrence of situations in which operators are provided differing guidance.

8.4.3 Snowfall Intensity Discrepancies

The TC and FAA tables currently differ in the snowfall intensity assigned to certain specific visibility values. These discrepancies exist due to the differing sources of data considered by each organization during the development of their respective visibility table.

Table 8.2 summarizes the visibility table guidance for each organization. The visibility values where the two organizations categorize the snowfall intensity differently have been encircled.

Table 8.2: Comparison of TC/FAA Visibility Table Values

Visibility		Daylight				Darkness			
Statute Miles	Meters	<-1°C FAA	<-1°C TC	>-1°C FAA	>-1°C TC	<-1°C FAA	<-1°C TC	>-1°C FAA	>-1°C TC
≤ 1/4	≤ 400	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
3/8	600	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
1/2	800	Mod	Mod	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
5/8	1000	Mod	Mod	Heavy	Mod	Heavy	Heavy	Heavy	Heavy
3/4	1200	Mod	Mod	Mod	Mod	Mod	Heavy	Heavy	Heavy
7/8	1400	Mod	Mod	Mod	Mod	Mod	Mod	Heavy	Heavy
1	1600	Light	Light	Mod	Mod	Mod	Mod	Mod	Heavy
1 ¼	2000	Light	Light	Light	Mod	Mod	Mod	Mod	Mod
1 ½	2400	Light	Light	Light	Mod	Mod	Mod	Mod	Mod
1 ¾	2800	VLS	Light	Light	Light	Light	Light	Mod	Mod
2	3200	VLS	Light	Light	Light	Light	Light	Light	Mod
2 ½	4000	VLS	VLS	VLS	Light	VLS	Light	VLS	Mod
3	4800	VLS	VLS	VLS	Light	VLS	Light	VLS	Light
3 ½	5600	VLS	VLS	VLS	VLS	VLS	VLS	VLS	Light
≥ 4	≥ 6400	VLS	VLS	VLS	VLS	VLS	VLS	VLS	Light

For the visibility values where discrepancies exist, the FAA generally assigns a less restrictive (i.e., lower) snowfall intensity than TC.

It is recommended that TC and the FAA re-examine the areas of their respective table where these noted snowfall intensity discrepancies exist. Consideration should be given to making revisions, where appropriate, to reduce the occurrence of situations in which operators are provided differing guidance.

8.4.4 Obscuration Guidance

The TC and FAA tables currently differ in the guidance provided for operations in which a secondary obscuration (fog, mist, etc.) is present.

The FAA provides the following guidance for handling obscuring weather in their visibility table:

> *Because the FAA Snowfall Intensities Table, like the FMH-1 Table, uses visibility to determine snowfall intensities, if the visibility is being reduced by snow along with other forms of obscuration such as fog, haze, smoke, etc., the FAA Snowfall Intensities Table does not need to be used to estimate the snowfall intensity for HOT determination during the presence of these obscurations. Use of the FAA Snowfall Intensities as a Function of Prevailing Visibility Table under these conditions may needlessly overestimate the actual snowfall intensity. Therefore, the snowfall intensity being reported by the weather observer or automated surface observing system (ASOS), from the FMH-1 Table, may be used.*

By contrast, the TC visibility table does not currently contain specific guidance for use of the visibility table when an obscuration is present. TC does provide guidance concerning this situation within the TC report, TP 14052E, *Guidelines for Aircraft Ground Icing Operations (Sixth Edition)* (2), which reads as follows:

> *Rarely, there may be circumstances where the METAR/SPECI reported visibility or flight crew observed visibility is substantially reduced due to obscuration conditions such as fog, mist, freezing fog, freezing mist, dust, haze, or smoke. These obscuration conditions contribute very little to the overall catch rate at the wing surface and using the "Snowfall Intensities as a Function of Prevailing Visibility" Table, would likely overestimate the snow fall intensity.*
>
> *Under these conditions and with a careful assessment by the flight crew to ensure that the obscuration conditions are not concealing significant snowfall intensities, the METAR/SPECI reported snowfall intensity can be used.*

8.5 Preliminary Analysis in Support of Harmonization

This subsection describes the analytical work that was begun in support of harmonizing the TC and FAA visibility tables.

8.5.1 Attempted Expansion to TP 14151E Visibility Analysis Database

The TC visibility table (and, to a lesser extent, the FAA visibility table) was based on the analysis documented in TP 14151E (15).

The analysis contained a database of precipitation rate measurements (collected by APS) and the associated reported visibility values taken from a sensor installed at the Meteorological Service of Canada (MSC) weather station adjacent to the APS test site. The database contained over 700 hours of data collected over a seven-year period (from 1995-96 to 2001-02), and this data was used to determine what snowfall intensities were associated with specific reported visibilities.

To address the issue of the differing values within the TC/FAA visibility tables, consideration was given to expanding the original APS visibility analysis by adding additional precipitation rate data collected by APS in more recent years. It was discovered, however, that the visibility sensor from which the original visibility data had been collected was no longer in use at the MSC weather station (visibility is now being measured by a human observer). As a result, it was determined that adding more recent data to the original database would not be feasible.

8.5.2 Review of TP 14151E Visibility Analysis Database

An analytical review of the initial visibility database from TP 14151E (15) began in 2020-21 with the goal of identifying possible improvements to the analysis that could in turn support changes to harmonize the TC and FAA visibility tables.

Several possible areas for further investigation have been identified, including the three below.

8.5.2.1 Removal of Possible Mixed Precipitation Data Points

It is believed that some of the data within the database may have been collected during mixed precipitation events (not pure snow events). Several of these data points have been identified by reexamining the underlying weather data associated with the high precipitation rate outliers in the database. The inclusion of mixed precipitation data within the database has resulted in more conservative snowfall intensities being assigned to specific visibilities, as non-snow components of mixed precipitation events (i.e., ice pellets, rain) generally have less of an impact on visibility than snow for an equivalent precipitation rate.

8.5.2.2 Adjustments to Risk Tolerance

The original table value recommendations derived from the analysis in TP 14151E (15) were selected using a very tight risk tolerance; for safety purposes, emphasis was placed on ensuring that the visibility table would not result in accidental underestimation of snowfall intensity. The result was a conservative set of values that can often lead to the *overestimation* of the snowfall intensity at specific visibilities. The analytical review being conducted is evaluating the impacts of adjusting the allowable risk of underestimation, with the goal of improving the overall accuracy of the table values.

8.5.2.3 Alternative Analysis Methodology

The original methodology employed a regression analysis that considered visibility as the independent variable from which the dependent variable (precipitation rate/snowfall intensity) could be predicted. It can, however, be argued that precipitation rate should be considered the independent variable, as it is the snowfall intensity that determines visibility (and not vice versa). The analysis could be repeated using the same database with precipitation rate as the independent variable and the results compared.

The analytical review of the TP 14151E (15) database is presently ongoing, and work is expected to continue in 2021-22.

8.6 Recommendations

It is recommended that TC and the FAA continue work to address the differences within their respective visibility guidance table. Specifically, the analytical review of the database from TP 14151E (15) should be completed, and consultations should be held to determine what changes can be made to the existing visibility tables in support of harmonization.

Where possible, changes should be considered to minimize the occurrence of situations where operators using different versions of the visibility tables would receive differing snowfall intensity guidance as a result.

This page intentionally left blank.

9. IMPLEMENTATION OF VIDEO STREAMING TECHNOLOGY FOR REMOTE VIEWING OF DEICING RESEARCH TESTS

This section documents the work conducted by APS Aviation Inc. (APS) to allow virtual participation during 2020-21 testing events. This was achieved through the implementation of a remote camera viewing setup to overcome travel and personnel limitations encountered during the ongoing COVID-19 pandemic.

9.1 Introduction

The COVID-19 pandemic has forced many industries to adjust their working environment in unprecedented ways. In a very short period, businesses had to overcome many obstacles to remain viable. Although the airline industry was required to temporarily halt international travel and significantly reduce domestic operations, the aviation industry, in particular the aviation safety sector, continued to operate with restrictions.

Pandemic-imposed restrictions required APS to operate in exceptional ways. One major obstacle that needed an immediate solution was travel and personnel capacity restrictions. As in previous years, wind tunnel and climate chamber testing were to be conducted at the National Research Council Canada (NRC) facilities in Ottawa, Ontario. To overcome personnel capacity restrictions, remote cameras were installed so that stakeholders, mainly Transport Canada, the Federal Aviation Administration (FAA), and APS, could observe and discuss tests being conducted. Similarly, cameras were also installed at the Montréal-Pierre Elliott Trudeau International Airport (PET) and PMG Technologies Inc. (PMG) test facilities, while an iPhone© 12 Pro Max was used for Near/Far North testing.

9.2 Objective

The primary objective of this project was to evaluate the different needs of test locations affected and launch remote viewing platforms at finalized locations. To this end, APS conducted the following set of activities:

- Evaluating the project needs for different test locations;
- Identifying and sourcing the appropriate professionals, equipment, and technology;
- Performing initial trials during Winter 2020-21 testing activities at the finalized test locations;
- Modifying or purchasing additional equipment as required; and
- Launching the remote viewing platform for clients and management.

9.3 Preliminary Equipment Evaluation

APS was tasked with formulating a temporary solution for virtual stakeholder and APS team participation (possibly multiple solutions for different locations) that was high quality and transportable. Consequently, multiple preliminary discussions were held to evaluate testing locations and analyse viable remote viewing solutions for each location. The following options were discussed as part of the preliminary analysis conducted:

- Acquisition of technology that can be moved around (transportable technology);
- Acquisition of technology for specific sites (fixed technology); and
- Engaging professional services (i.e., a camera crew) that can travel to different testing locations.

9.3.1 Site and Equipment Evaluation for Remote Viewing Capability

9.3.1.1 PET Test Site

At the PET test site, a camera system was already in place with internet protocol (IP) wired cameras fixed manually on posts that covered two testing angles. An iOS application titled "Guarding Vision©" was utilized to view the camera angles; this application was designed to work with digital video recorders, network video recorders (NVRs), and IP cameras (basic/high-definition quality, zoom-in feature, et cetera). The system was further investigated for capabilities to livestream specific camera angles directly from Guarding Vision©.

As a result of the preliminary evaluation conducted for the PET test site, two potential solutions were identified.

- Potential Solution #1: Provide stakeholders separate access to Guarding Vision©; specific camera angles could be provided and switched on/off or potentially moved upon request.
- Potential Solution #2: Create a livestreaming event using an appropriate software (i.e., Microsoft Teams©, SlingStudio©).

9.3.1.2 Icing Wind Tunnel (IWT)/Climatic Engineering Facility (CEF)/PMG

As a result of the preliminary evaluation conducted for the IWT, CEF, and PMG sites, two potential solutions were identified.

- Potential Solution #1: Provide stakeholders access to the remote viewing of testing events through installation of a *Travel Pack Security Camera System*, based on the new PET test site security system, to provide a transportable, turnkey, and pre-configured technology; further requirements for in-house training, equipment, and software may be needed.
- Potential Solution #2: Provide stakeholders access to the remote viewing of testing events through a camera crew setup and livestreaming, requiring installation and setup of approximately four-to-six cameras and livestreaming capability of two or more weeks.

9.3.1.3 Near/Far North Testing

As a result of the preliminary evaluation conducted for the Near/Far North test sites, one potential solution was identified.

- Potential Solution: Provide stakeholders access to the remote viewing of testing events through installation of a *Travel Pack Security Camera System*, based on the new PET test site security system, to provide a transportable, turnkey, and pre-configured technology; further requirements for in-house training, equipment, and software may be needed.

9.4 Camera Implementation

High-resolution cameras were necessary for stakeholders and APS team members to virtually take part in and provide guidance for testing being conducted. The five testing locations that included the use of cameras to capture the tests and/or to provide a means of verification of fluid failures are as follows:

- NRC Wind Tunnel in Ottawa, Ontario;
- NRC Climate Chamber in Ottawa, Ontario;
- PET Test Facility in Montreal, Quebec;
- PMG Test Facility in Blainville, Quebec; and
- Remote Near/Far North Locations throughout Canada.

9.4.1 NRC Wind Tunnel

The following subsections describe the implementation of closed-circuit television (CCTV) cameras at the NRC IWT.

9.4.1.1 Overview

Seven CCTV cameras with a 2.8 mm wide angle view and one NVR receiver were purchased from Advanced Services in Montreal, Quebec. Each CCTV camera had a 4K resolution.

Five iPad© Pros were also purchased from Apple© to view the livestream of tests being conducted. Audio and video conferencing communication was made available between parties using Microsoft Teams©.

To successfully implement the use of cameras at the NRC IWT, trials were first conducted at the PET test facility. A mock test was conducted to determine if the receiver and the internet were able to withstand the demand of multiple users, zooming, and video playback capabilities.

The two platforms offered with the NVR receiver were as follows:

- A website accessible on laptops only through Internet Explorer; and
- The Guarding Vision© application.

Preliminary results showed that the cameras were able to effectively stream a high-quality image but became unstable when using the website due to its complexity. By comparison, the app-based version proved a much more stable and user-friendly experience. Therefore, the decision was made to use Guarding Vision©.

Prior to conducting this research, each camera was positioned outside of the wind tunnel as follows:

- Cameras #1 and #3 were positioned on the northside window for viewing the wing;
- Cameras #2 and #4 were positioned on the southside window for viewing the wing;
- Camera #5 was positioned in the northside area and trained on a computer display viewing current test data;
- Camera #6 was mounted on a hand-held arm for specific viewing capabilities; and
- Camera #7 was positioned in the northside area and trained on a computer display viewing the day's test plan.

Figure 9.1, Figure 9.2, and Figure 9.3 illustrate the position of the cameras at the NRC IWT.

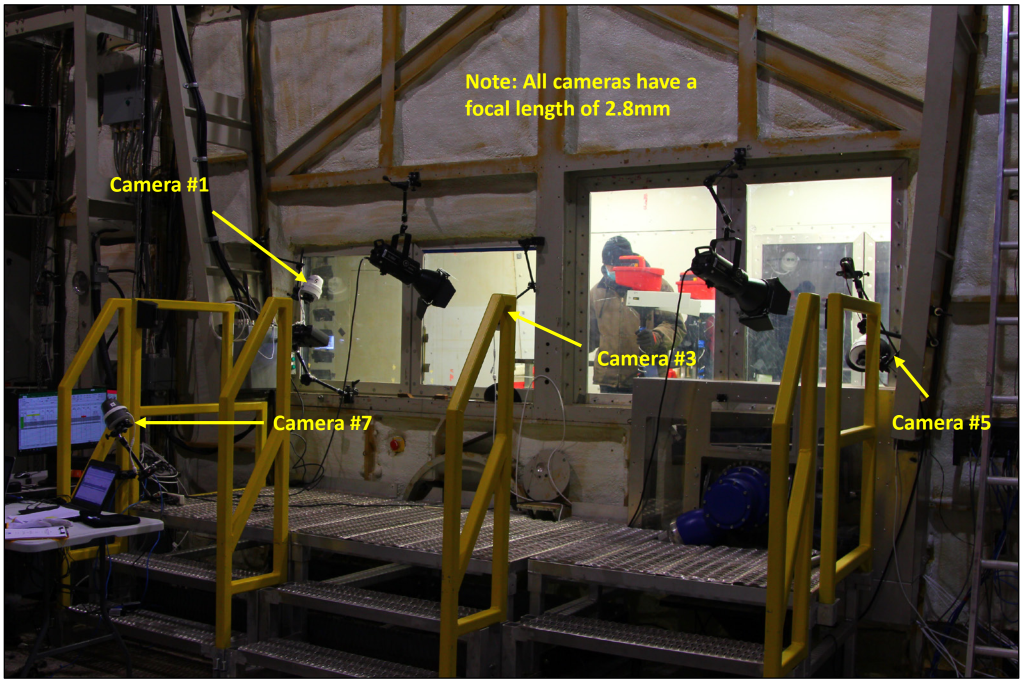


Figure 9.1: Location of Cameras – North Side of Wind Tunnel

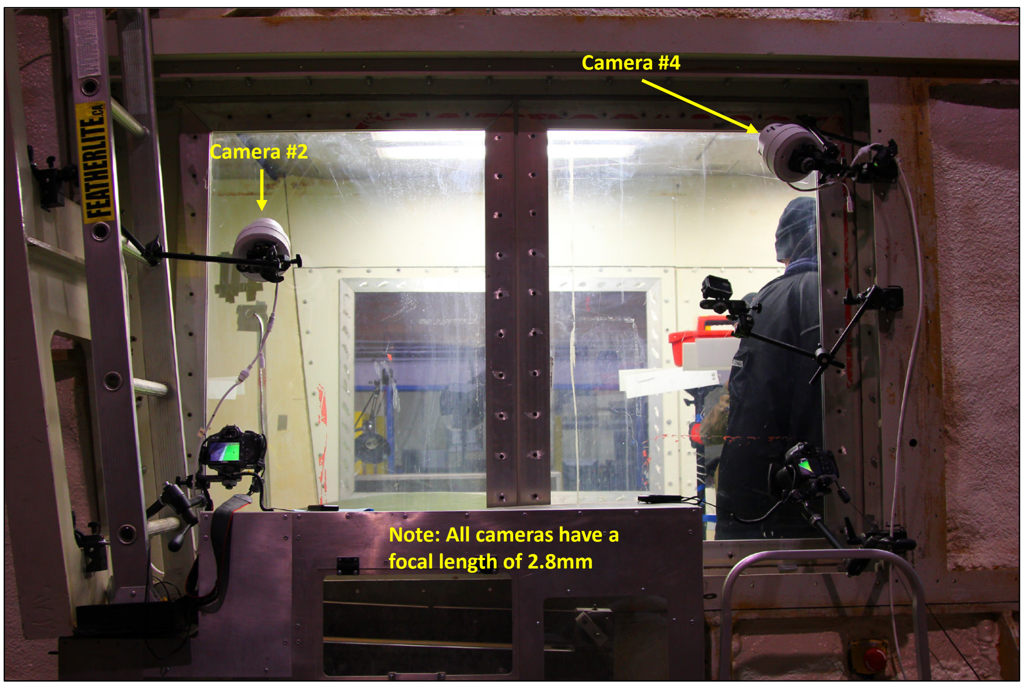


Figure 9.2: Location of Cameras – South Side of Wind Tunnel

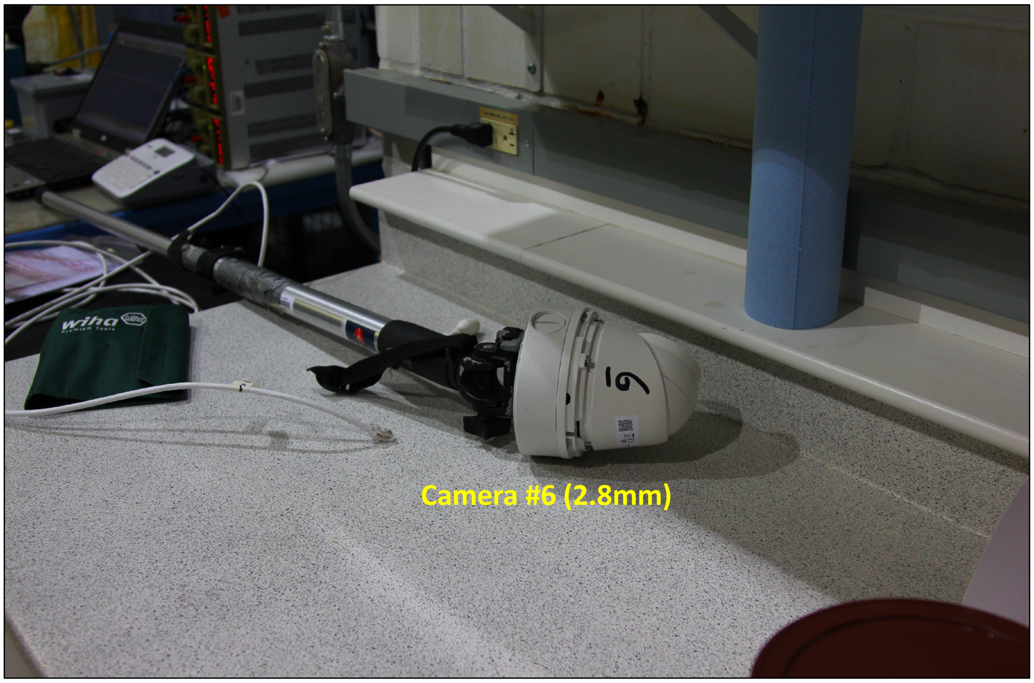


Figure 9.3: Camera #6 Mounted on a Hand-Held Arm for Specific Viewing

9.4.1.2 Observations and Data Storage

Two minor technical issues were encountered while testing:

- The malfunctioning of some cameras; and
- Livestreaming issues.

The malfunction of certain video cameras was due to the flashes from the digital single-lens reflex (DSLR) cameras, which were also installed in the same location. As the DSLR cameras were operating, the flashes interfered with the CCTV cameras, causing the video image to pixelate. This issue was resolved by replacing the flashes with light-emitting diode (LED) flood lights next to the viewing windows.

The streaming issues encountered were mostly the “freezing” of screens since the upload speed of the internet connection could not keep up with the demand of multiple users. The process of livestreaming places a high demand on the amount of data needed to be transferred to enable a high-resolution picture.

The video data was overwritten in a first-in-first-out format, which had a capacity to record a few days’ worth of data. Therefore, at the start of each testing session, the previous days’ data was backed up on an external hard drive and archived for future reference.

9.4.1.3 Conclusion

The camera system provided a suitable platform for clients and personnel unable to attend live testing due to COVID-19 restrictions to be actively involved in the testing process. Overall, all parties involved agreed that the system functioned well. The high-quality resolution provided sufficient detail of the wing and fluid failures for all viewers.

9.4.1.4 Recommendations

Internet connection was the most problematic element of the testing at the NRC IWT. For this reason, it is recommended that an alternative internet provider be used for subsequent testing events. Camera upgrades should also be considered and may aid in resolving connectivity issues.

9.4.2 NRC Climate Chamber

The following subsections describe the implementation of CCTV cameras at the NRC CEF. Note that some equipment used at the NRC IWT was used at the NRC climate chamber.

9.4.2.1 Overview

Four cameras were used at the NRC climate chamber. Of the four cameras, two were 2.8 mm in focal length and two were 8 mm. Initially, the implementation of remote cameras at the NRC climate chamber was to be achieved by clamping "Manfrotto Magic© Arms" to the test stand and angling the camera to provide an adequate video feed of the test plates. Preliminary tests conducted at the PET test facility showed that the Manfrotto Magic© Arms, along with all the required wiring needed for camera usage, interfered with the testing process. It was then decided that the best course of action would be to mount the cameras on the walls of the climate chamber using the Manfrotto Magic© Arms.

Accounting for the dimensions of the climate chamber, two cameras (one 2.8 mm and one 8 mm) were positioned in the front of the test stand while the other two cameras were positioned in the back, representing the northeastern and southwestern wall of the chamber, respectively. Preliminary results showed that this setup was acceptable as it provided sufficient coverage of most test plates. Figure 9.4 displays the positions of the cameras at the NRC climate chamber.

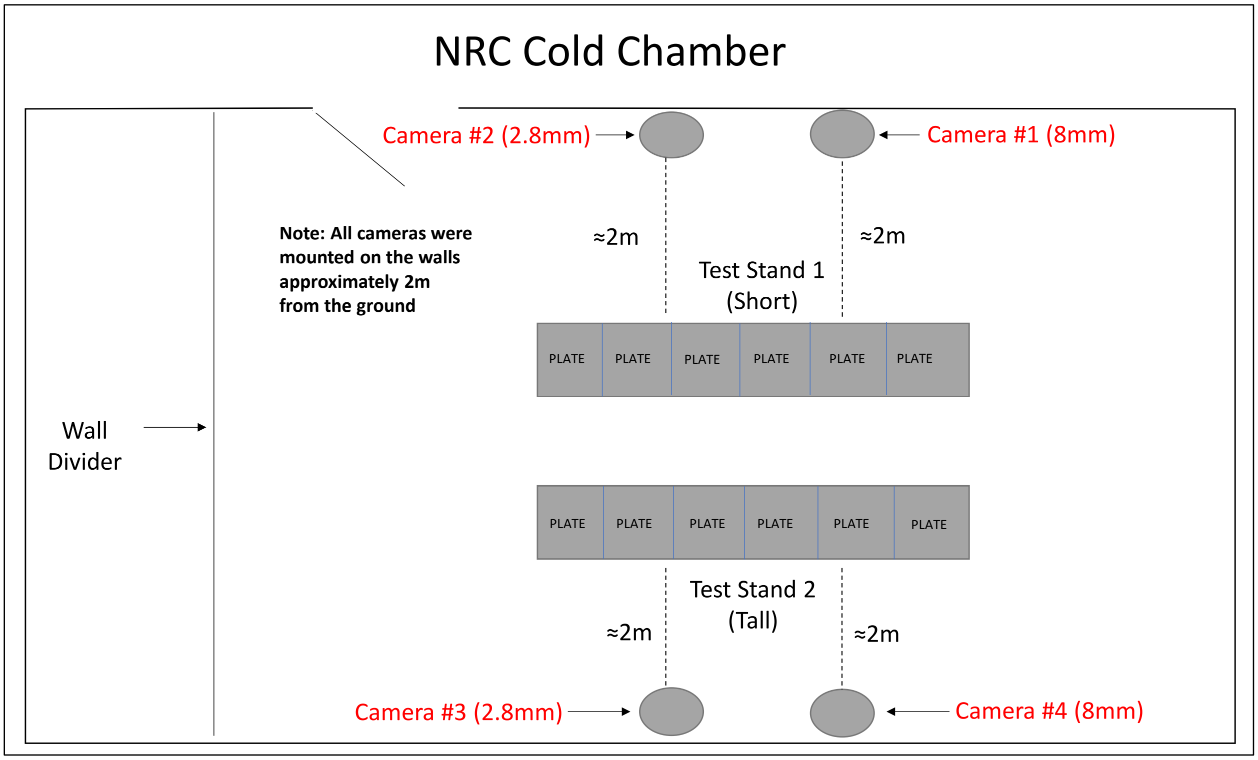


Figure 9.4: Camera Locations at the NRC Climate Chamber

9.4.2.2 Observations and Data Storage

Two issues were encountered while testing:

- Image clarity; and
- Image quality (depending on precipitation being tested).

In general, the image quality was very good during most precipitation conditions [freezing rain (ZR), freezing drizzle (ZD), cold-soak wing (CSW)]. However, testing with freezing fog (ZF) posed a challenge. The dispersion of supercooled vapour particles in the air makes it difficult to see the test plates (loss of granularity). During these instances, image clarity also became an issue. The feed was too dark to view a clear image due to the density of the freezing fog. In the future, this issue may be resolved by additional lighting in the area around the test stand.

The feed from each test session was saved on an external hard drive and archived for future reference. All pertinent test data was collected following the standard protocols and procedures with the addition of the livestreaming data.

9.4.2.3 Conclusion

The camera system provided a suitable platform to observe the test plates while testing in freezing precipitation conditions. Overall, the systems functioned well. The high-quality resolution provided sufficient detail of the test stand and test plates in most conditions.

9.4.2.4 Recommendations

The recommendations below should be considered for future testing.

- The cameras should be better protected from freezing precipitation. A camera cover or umbrella should be used to protect all camera lenses.
- The camera system needs to be positioned at strategic locations to get better angles to view the test stand as a whole. Additional cameras could also be considered.
- Lighting is particularly important for image clarity. Freezing fog posed a problem. It is recommended that additional and/or different types of lighting be incorporated into the setup.

  The image quality was sufficient; however, greater detail would improve it, especially when determining fluid failures. It is recommended that additional 2.8 mm cameras, mechanical arms, and/or tripods be incorporated into the setup so that the viewer can control the camera remotely while using zoom capabilities.

9.4.3 Natural Snow Testing at the PET Test Facility

The following subsections describe the implementation of CCTV cameras at the PET test facility. Equipment similar to that used at the NRC IWT was used at the PET test facility. In instances where the CCTV cameras did not provide the image details needed, an iPhone© 12 Pro Max was used as a backup.

9.4.3.1 Overview

Four cameras were used at the PET test facility. All cameras had an optical focal length of 2.8 mm. The cameras were positioned at strategic locations so that the holdover time (HOT) and the artificial vs. natural (AvN) test stands were visible to provide support for fluid failure verifications. Figure 9.5 displays a schematic representation of the camera locations at the PET test facility.

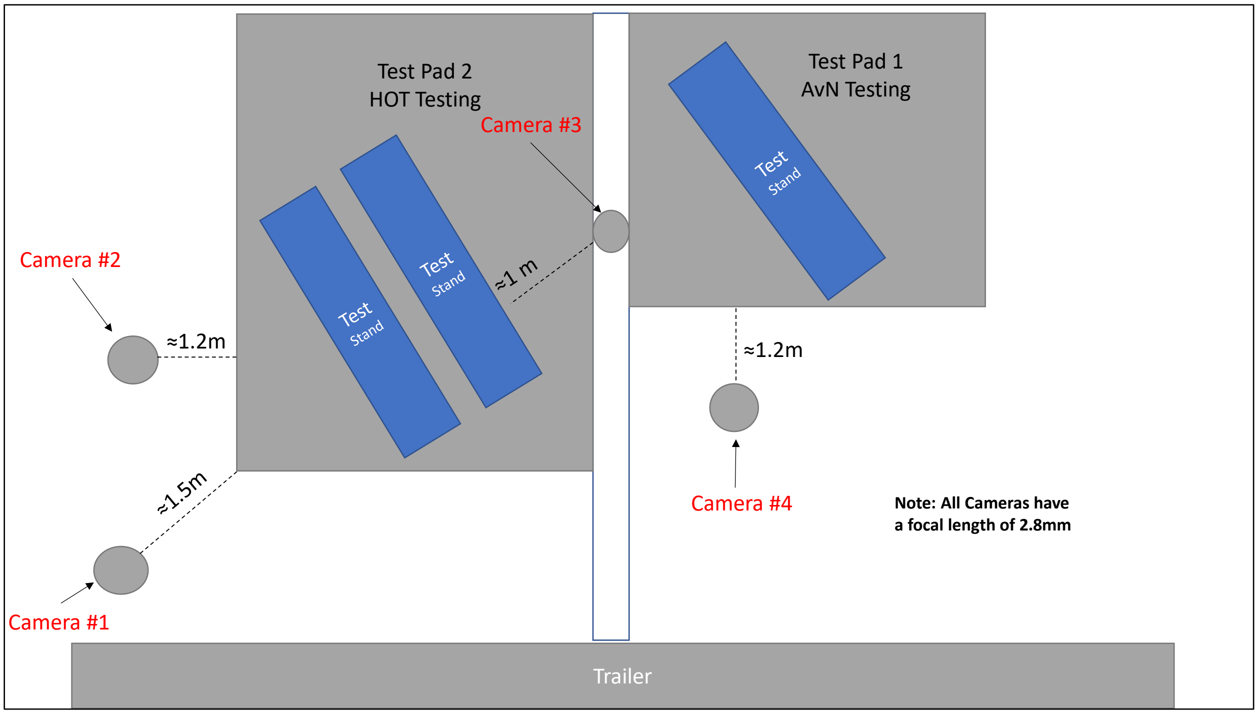


Figure 9.5: Schematic Representation of Camera Locations at the PET Test Facility

9.4.3.2 Observations

Two issues were encountered while testing.

- The camera setup could not adapt to changing conditions. For example, if the wind direction changed during a test event, the test stand orientation was repositioned accordingly; however, the camera system could not be reorientated as it was in a fixed position.
- On some occasions, the camera system did not provide the high-quality image needed to confirm fluid failures due to picture degradation caused by image zoom. Communication was therefore made with on-site staff for confirmation via the iPhone© 12 Pro Max.

The camera system was set up to provide the best-possible detailed imaging of the test stands and plates. The high-resolution cameras provided the high-quality video needed to view most of the test plates and capture most fluid failures during testing. However, on some occasions, the iPhone© 12 Pro Max was needed for verification. This was done by positioning the iPhone© approximately 1 to 2 ft away from the back end of the test stand at an angle of 20 to 30 degrees (with the horizontal) above the test plate. The iPhone© 12 Pro Max provided the high-quality image details needed due to its autofocus capabilities and because, being a hand-held device, it was easily adaptable to determine fluid failures.

9.4.3.3 Recommendations

The recommendations below are proposed for future testing.

- The camera system needs to be positioned at strategic locations to view all test plates in both a zoomed configuration and as a whole while testing in any direction. Additional 8 mm cameras should be considered to achieve this.
- Another camera could be considered for AvN testing since only one camera is currently available. The addition of another camera can add zooming capabilities.
- A preliminary blind study should be conducted to verify if using the camera system can substitute for in-person fluid failure calls. This can be done during one-to-three events in the winter of 2021-22. A test plan should be established along with the necessary data points to be recorded.

9.5 Near/Far North Testing

The following section describes the process used with the iPhone© 12 Pro Max during Near/Far North testing throughout Canada.

9.5.1.1 Overview

An iPhone© 12 Pro Max was used for video conferencing (Facetime) during fluid failure verifications.

CCTV cameras were initially considered for use in Near/Far North testing; however, it was quickly determined that the size and amount of equipment needed rendered them impractical while traveling.

Preliminary testing conducted at the PET test facility showed that the iPhone© 12 Pro Max was the best available option for video streaming of fluid failure verifications. Using this iPhone© made it possible to view the test plates at different angles, which is key when determining fluid failures.

9.5.1.2 Observations

No issues were encountered when using the iPhone© 12 Pro Max in Near/Far North testing, except in some remote locations where Wi-Fi capability was limited.

With regards to data storage, no streaming data was recorded during Near/Far North testing due to the lack of recording capabilities while using Facetime on the iPhone© 12 Pro Max.

9.5.1.3 Conclusion

The iPhone© 12 Pro Max provided a useful platform to verify fluid failures while testing in the Near/Far North. Being a hand-held device with autofocus capability, it was easily adaptable to all needed angles and provided sufficient detail of the fluid failures during all conditions.

9.5.2 PMG Testing

The following subsections describe the implementation of CCTV cameras at the PMG test facility in Blainville, Quebec. Similar equipment used at the NRC IWT was used at the PMG test facility.

9.5.2.1 Overview

Four cameras were used. Of the four cameras, two were 2.8 mm in focal length and two were 8 mm.

Each of the cameras was mounted either adjacent to an artificial snow machine to view the test plate and enable fluid failure verification or on a steel beam within the cold chamber to view the translator and ice core. Figure 9.6 displays the position of the cameras at the PMG test facility.

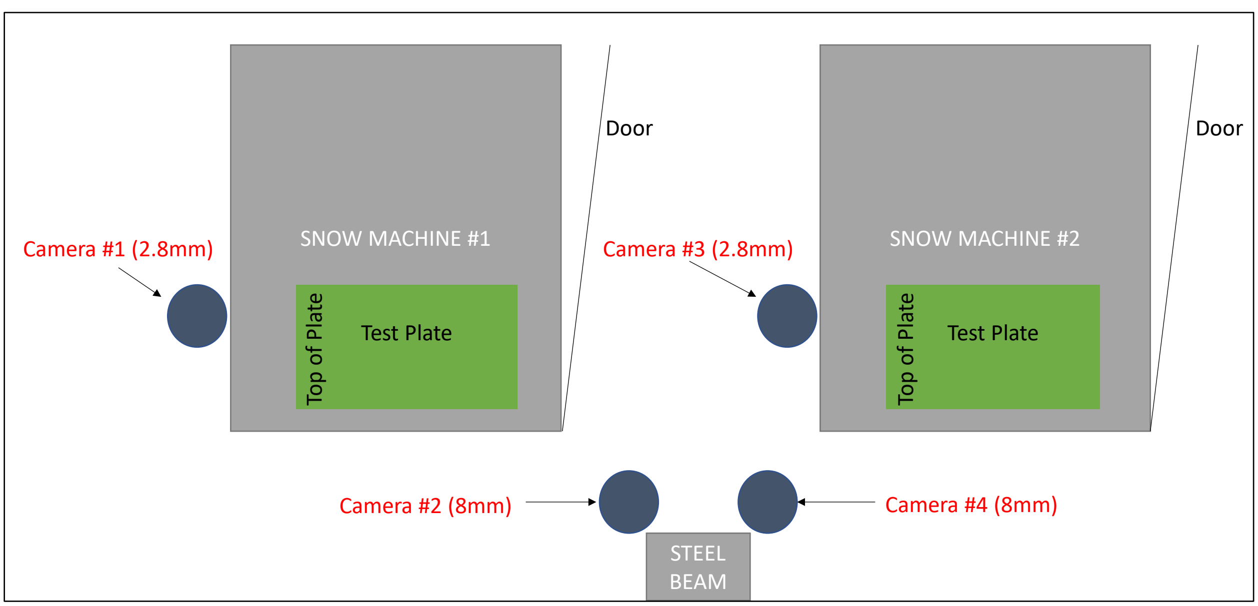


Figure 9.6: Schematic Representation of Camera Locations at PMG Technologies

9.5.2.2 Observations

Two issues were encountered while testing:

- Image clarity; and
- Image quality.

During some instances, image clarity became an issue. The feed was too dark to view a clear image. The issue was resolved by additional LED lighting in the area around the test plate.

Image quality was a major issue due to the lack of transparency through the artificial snow machine enclosure. Installing the cameras inside of the enclosure was not possible as space was limited and snow accumulation would block the video feed. Given the time available to complete this project, this issue was not resolved.

9.5.2.3 Conclusion

The CCTV camera system could have provided a useful platform to verify fluid failures while conducting artificial snow testing. However, it was only utilized for a few tests as the image quality was negatively impacted due to the snow machine enclosure. Improvements to the camera system would be needed for subsequent testing events.

9.5.2.4 Recommendations

The recommendations below are proposed for future testing.

- LED spotlights should be installed to increase image clarity. These lights should be placed around the test plate or within the enclosure.
- A hole should be considered in the plexiglass enclosure so that the camera can be directed at the test plate without obstruction.
- A small camera, if available, could be positioned inside the snow machine enclosure above the plate at a specific height and angle to assist failure call verifications.

9.6 Overall Review and Recommendation

In general, the implementation of remote cameras for testing at all designated locations can be considered a success. Within a short period of time, the temporary solutions to personnel capacity restrictions for all stakeholders were resolved. In fact, the technology worked so well that the setup will be resumed with upgrades and modifications, providing additional capabilities for the 2021-22 testing season. Table 9.1 summarizes the video streaming solutions and the proposed modifications moving forward.

Table 9.1: Proposed Modifications to Video Streaming Solutions

		Solution	Proposed Modifications
Location	PET Test Site	CCTV + iPhone	Add more cameras and/or reposition existing ones.
	Wind Tunnel	CCTV	Improve internet connection and/or upgrade camera system.
	NRC Chamber	CCTV	Add more cameras or reposition existing ones; install covering for camera lenses; possibly add mechanical arms; improve lighting.
	PMG Technologies Site	CCTV	Make a hole in the artificial snow machine enclosure or position a small camera within the enclosure; improve lighting.
	Near / Far North Remote Test Sites	iPhone(s)	–

10. DOCUMENTATION OF TEST METHODS AND PROTOCOLS FOR ICE PELLET ALLOWANCE TIME DEVELOPMENT

This section describes the work performed in 2020-21 to draft a document detailing the test methods and protocols for ice pellet allowance time development. A copy of the latest draft of the document is included in Appendix L.

10.1 Background

Due to their physical characteristics, ice pellets can become partially or fully embedded in aircraft ground anti-icing fluids and can take longer to melt compared to snow or other forms of precipitation. For this reason, the visual indicators used in endurance time testing of other precipitation types [which result in holdover times (HOTs)] cannot be applied to ice pellets.

A test protocol for wind tunnel testing was developed in 2006 and further refined over subsequent years to provide operational guidance in ice pellet conditions. The test protocol uses a combination of aerodynamic fluid flow-off performance of ice pellet–contaminated fluids in combination with visual inspection and evaluation of a wing model test surface. The resulting guidance derived from this testing is referred to as “allowance times,” which are published as part of the yearly HOT Guidelines.

Prior to the drafting of this new document, the testing protocol and procedures were only documented in technical reports published by APS Aviation Inc. (APS), the National Research Council Canada (NRC), and the National Aeronautics and Space Administration. As well, additional information existed only in internal APS procedural documentation or was not documented at all. It was recommended that the ice pellet testing protocol and procedures be formally recorded in one comprehensive document to serve as a reference for ongoing research and historical record.

10.2 Objective

The objective is to record the test protocol and procedures related to ice pellet allowance time development in one comprehensive document.

10.3 Methodology

To develop the comprehensive document, the following activities were performed by APS:

- Conducted a historical review of documented methods and procedures related to ice pellet allowance time testing;

- Identified information gaps;
- Worked with associated testing professionals to acquire and develop missing documentation related to testing activities; and
- Developed a comprehensive document including or referencing relevant data, procedures, methodologies, technical drawings, et cetera.

The document developed as part of this project was based upon the combined formats of the SAE International (SAE) Aerospace Recommended Practice (ARP) 5485B, *Endurance Time Test Procedures for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluids* (11), and ARP5718B, *Qualifications Required for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluid* (16), which provide a comprehensive overview of the data collection and guidance development with respect to HOTs. The formats were modified accordingly to be applicable to the ice pellet allowance time data collection and guidance development and were included in one standalone document.

10.4 Conclusions

Based on the historical reviews and discussions with technical experts, a final draft of the document was developed and can be found in Appendix L. The ice pellet testing protocols and procedures have now been recorded in one comprehensive document to serve as a reference for ongoing research and historical record.

10.5 Recommendations

The following subsections recommend future modifications to the document.

10.5.1 Further Development of Ice Pellet Allowance Time Manual

The document should continue to be further developed and refined. Consideration should be given to revising the APS document into an SAE ARP document in the future.

10.5.2 Updates to Internal Testing Procedures

In developing the document, additional sections were developed to fill identified information gaps in the internal procedures. The internal procedures will be updated to reflect the newly identified information. The internal procedures are developed prior to testing each year and published in the yearly technical reports.

11. REVIEW OF UPDATES REQUIRED FOR SAE DOCUMENTS ARP5485, ARP5945, ARP5718, AND ARP6207

This section documents the work carried out by APS Aviation Inc. (APS) in support of the updates required for the following SAE International (SAE) Aerospace Recommended Practice (ARP) documents:

1. ARP5485B, *Endurance Time Test Procedures for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluids* (11);
2. ARP5945A, *Endurance Time Test Procedures for SAE Type I Aircraft Deicing/Anti-Icing Fluids* (17);
3. ARP5718B, *Qualifications Required for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluid* (16); and
4. ARP6207, *Qualifications Required for SAE Type I Aircraft Deicing/Anti-Icing Fluids* (18).

11.1 Background

APS has been instrumental in the development of SAE aerospace standards related to test protocols for endurance time testing of aircraft de/anti-icing fluids. These include ARP5485B (11) and ARP5945A (17).

APS has also contributed to the development of the standards related to the qualification of de/anti-icing fluids. These include ARP5718B (16) and ARP6207 (18).

APS personnel serve as sponsors of the above-mentioned documents and are therefore responsible for their periodic review (SAE requires a review within five years) and updates. The proposed changes are presented to the SAE G-12 holdover time (HOT) committee for balloting, and new revisions of the documents are subsequently published.

11.2 Objective

The objective of this preliminary review was to assess and document proposed changes necessary to the HOT testing standards [ARP5485B (11), ARP5945A (17), ARP5718B (16), and ARP6207 (18)] in support of a future revision.

11.3 Work Plan

For each document, proposed changes were categorized and rated by the level of time and effort required to integrate them into the document. These changes may come from industry feedback, updates to testing methodology, regulatory changes, et cetera. Types of proposed changes include the following:

- Correction of typos;
- Changes to clarify existing text (no change to methodology);
- Updates to information reflecting changes to methodology currently employed; and
- Suggested changes to testing methodology.

11.4 Results

The following subsections summarize the updates proposed for each document.

11.4.1 ARP5485

ARP5485B (11) outlines the endurance time testing practices for Type II, III, and IV aircraft de/anti-icing fluids. Upon reviewing the document and related communications, a list of 20 potential changes were identified.

Table 11.1: Summary of Proposed Changes to ARP5485

Type of Change	# of Items
Correction of "typos"	1
Changes to clarify existing text (no change to methodology)	3
Updates to information (reflecting updates to methodology currently employed)	8
Suggested changes to testing methodology	8
Total	**20**

Of the list of 20, there were five items identified as critical. One example of information to be added to reflect changes currently employed in the HOT development process is the "Very Cold Snow" (VCS) testing methodology used to determine fluid-specific HOTs in snow below -14°C.

11.4.2 ARP5945

ARP5945A (17) outlines the endurance time testing practices for Type I aircraft de/anti-icing fluids. Upon reviewing the document and related communications, a list of 12 potential changes were identified.

Table 11.2: Summary of Proposed Changes to ARP5945

Type of Change	# of Items
Correction of "typos"	2
Changes to clarify existing text (no change to methodology)	3
Updates to information (reflecting updates to methodology currently employed)	6
Suggested changes to testing methodology	1
Total	**12**

No critical items were identified for ARP5945A (17).

11.4.3 ARP5718

ARP5718B (16) outlines the requirements to qualify Type II, III, and IV aircraft de/anti-icing fluids. Upon reviewing the document and communications, a list of 21 potential changes were identified.

Table 11.3: Summary of Proposed Changes to ARP5718

Type of Change	# of Items
Correction of "typos"	1
Changes to clarify existing text (no change to methodology)	2
Updates to information (reflecting updates to methodology currently employed)	16
Suggested changes to testing methodology	2
Total	**21**

Of the list of 21, eight changes were identified as critical for ARP5718B (16). As with ARP5485B (11), information related to the development of VCS HOTs is to be added or updated. As well, changes to the structure of the HOT tables are considered critical, including updates to the temperature rows, which have been further divided at -8°C and -18°C. Lastly, the application of the adjustment factor for "Flaps-Adjusted" HOTs is considered a critical update.

11.4.4 ARP6207

ARP6207 (18) outlines the requirements to qualify Type I aircraft de/anti-icing fluids. Upon reviewing the document and communications, a list of 10 potential changes were identified.

Table 11.4: Summary of Proposed Changes to ARP6207

Type of Change	# of Items
Correction of "typos"	2
Changes to clarify existing text (no change to methodology)	1
Updates to information (reflecting updates to methodology currently employed)	6
Suggested changes to testing methodology	1
Total	**10**

No critical items were identified for ARP6207 (18).

11.5 Conclusions and Recommendations

A total of 63 proposed changes to the SAE HOT testing standards were reviewed and documented. Of these changes, 13 are considered critical as they are part of the HOT development process.

It is recommended that the documents should be updated in a timely fashion, as resources become available, with the critical changes incorporated at a minimum.

12. COVID-19 GUIDELINES AND IMPACTS ON THE 2020-21 GROUND ICING RESEARCH PROGRAM

This section describes the COVID-19 guidelines and the resulting impacts on the 2020-21 ground icing research program.

12.1 Introduction

The COVID-19 pandemic has forced many industries to adjust their working environment in unprecedented ways. In a very short period, businesses had to overcome many obstacles to remain viable. Although the airline industry was required to temporarily halt international travel and significantly reduce domestic operations, the aviation industry, in particular the aviation safety sector, continued to operate with restrictions.

Pandemic-imposed restrictions required APS Aviation Inc. (APS) to operate in exceptional ways due to restrictions on travel and facility capacity for personnel. As in previous years, holdover time (HOT), wind tunnel, and climate chamber testing were to be conducted at the Montréal-Pierre Elliott Trudeau International Airport and at the National Research Council Canada (NRC) testing facilities. Many safety measures were implemented to mitigate the risk of exposure to COVID-19, including personal protective equipment (PPE), cleaning stations, and hand sanitizer. COVID-19 screening and special paperwork demonstrating intent for travel were required in certain instances. To overcome personnel capacity restrictions, remote cameras were installed so that stakeholders, mainly from Transport Canada (TC), the Federal Aviation Administration (FAA), and APS, could observe and discuss the tests being conducted. As of the writing of this report, the pandemic is still ongoing and is expected to continue throughout the 2021-22 winter testing season.

12.2 Objective

The objective was to provide information relating to the impacts of COVID-19 on the 2020-21 ground icing research program.

12.3 COVID-19 and the Ground Icing Research Program

The COVID-19 pandemic was a limiting factor in Canada during the 2020-21 winter testing season. Multiple COVID-19 guidelines and restrictions were in effect during the testing season. As previously mentioned, these guidelines and restrictions included PPE, cleaning stations, hand sanitizers, and personnel restrictions. To make matters worse, restrictions varied locally and changed over time. This significantly complicated all testing requirements for the ground icing research program. The non-exhaustive list below indicates specific restrictions in Canada by province or region.

- Montreal:
  - Testing facilities remained open but with capacity restrictions.
- Ottawa:
  - Testing facilities operated with reduced capacity and other safety measures in place.
- Northern Territories:
  - Travel required advance notice, negative COVID tests, and local governmental approval; and
  - Some areas were not available for travel due to quarantine requirements.
- Other Provinces:
  - Travel was generally possible without advance notice; however, specific restrictions existed depending on the province.

12.4 Ground Icing Research Program for Winter 2020-21

Despite the restrictions mentioned in Subsection 12.3, TC and the FAA conducted a full testing and research program in Winter 2020-21. However, due to late fluid receipt as well as COVID-19 travel restrictions, very cold snow (VCS) data collection for fluids submitted in 2020-21 are expected to be completed during the Winter 2021-22 testing season. Table 12.1 summarizes the research activities and status as of September 2021.

Table 12.1: Summary of Research Activities as of September 2021

Activity	Testing Location	Testing Status
HOT Testing 2020-21 Fluids and 2019-20 Fluids	Montreal Airport Test Site Ottawa (U88 Facility) Blainville (PMG Facility)	COMPLETE
Very Cold Snow Testing 2019-20 Fluids (Continuation of Testing)	Far North (Various)	COMPLETE
Very Cold Snow Testing 2020-21 Fluids	Far North (Various)	IN PROGRESS
	Blainville (PMG Facility)	COMPLETE
Wind Tunnel Research	Ottawa (M46 Facility)	COMPLETE
Other Research Activities	Montreal Airport Test Site Ottawa (U88 Facility) Far North (Various)	COMPLETE

12.5 COVID-19 Safety Measures

Throughout the winter of 2020-21, testing was adapted to mitigate COVID-19 risks and to meet regional safety requirements, as exemplified in Photo 12.1. These requirements included, but were not limited to, the following:

- Reduced staffing and on-site visitor access;
- Modified testing schedules to meet facility restrictions;
- Mandatory face covering for all testing personnel;
- Additional cleaning and disinfection of workspaces and testing equipment; and
- Two-meter distance between all personnel whenever possible.

12.5.1 COVID-19 Mitigation Plans

To ensure safety, mitigation plans were prepared for all test facilities and for travel. All personnel involved were advised prior to their implementation. Mitigation plans for all procedures for the following listed locations were developed and provided to the staff:

- APS Test Site – Hazard Assessment and Return to Work Instructions;

- PMG Technologies (PMG) – Hazard Assessment and Return to Work Instructions;
- NRC Climate Chamber – Hazard Assessment and Return to Work Instructions;
- NRC Propulsion Icing Wind Tunnel – Hazard Assessment and Return to Work Instructions; and
- Remote Testing – Special Instructions for Air and Truck Travel.

12.6 Remote Viewing Solutions

To adapt to the personnel restrictions, remote viewing equipment was implemented as a temporary solution to allow stakeholders (TC and the FAA) and APS staff to participate during testing. A closed-circuit television system was coupled with an online web conferencing platform so that high-quality video feed could be uploaded and broadcasted to stakeholders. The setup thus allowed for viewing and evaluation of critical testing activities and for technical discussions during testing sessions. Photo 12.2 illustrates the system when in use at the NRC wind tunnel, with a camera facing the wing section, the laptop screen views of the web conferencing platform, and an iPad© screen view of the platform with cameras facing the wing section during testing.

12.7 COVID-19 – Potential Future Impacts

The impacts of the pandemic on the 2021-22 ground icing research program are dependent on numerous factors, which include COVID-19 variants, vaccine rollout, and vaccine passports. At the time of this writing, the vaccine rollout has significantly progressed in Canada; however, much work still needs to be completed before a return to "normalcy." The expectation is that restrictions in 2021-22 will be less impactful than those in 2020-21.

Planning for the 2021-22 winter season will proceed normally but with caution. The standard testing activities are currently at low risk of disruption. The modified testing protocols, which have already been developed and employed during the pandemic, will continue to be used. Even so, the risk presently remains moderate for activities requiring Far North travel (i.e., VCS testing).

12.8 Summary

The following is a summary of the work completed or in progress for 2020-21.

- All standard HOT testing was completed for fluids submitted in 2019-20 and 2020-21.
    - HOTs for these fluids were included in the 2021-22 HOT Guidelines.
- VCS testing was completed for fluids submitted in 2019-20 and is in progress for fluids submitted in 2020-21.
    - 2019-20 cold snow fluids have received new fluid-specific VCS HOT values in their respective tables.
    - Data collection for 2020-21 cold snow fluids is to be completed in the winter of 2021-22.

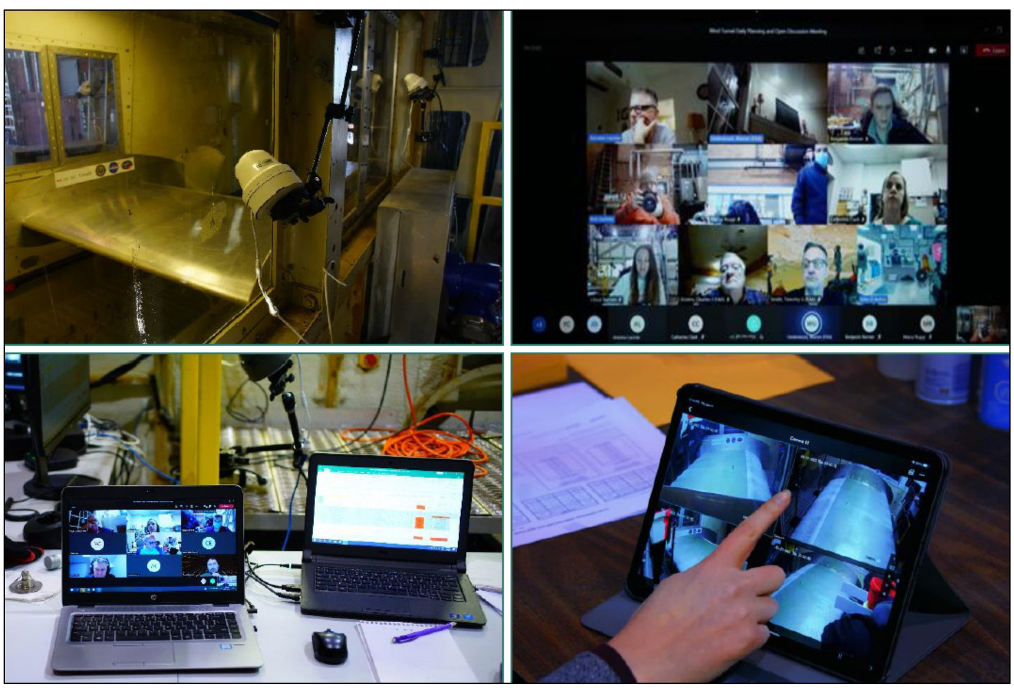
12.9 Way Forward

Planning for the upcoming 2021-22 ground icing research program is expected to proceed as normal but with caution, and it will take into consideration any COVID-19 restrictions that are in place. The expectation is that the 2021-22 restrictions will be less impactful than or equivalent to those in 2020-21. Overall, testing and research activities should at minimum proceed at the same level as in 2020-21.

This page intentionally left blank.

Photo 12.1: Mitigating the Risk of COVID-19 with PPE

Photo 12.2: Remote Viewing Platform



This page intentionally left blank.

13. 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.

13.1 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.

13.2 Objective

The objective of this project for 2020-21 was to handle up to 24 reports, with the aim to accelerate approximately 6 to 10 unpublished reports to the Final Draft 2.0 stage and to publish approximately 12 to 14 remaining 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 up to 24 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.

13.3 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 13.1 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.

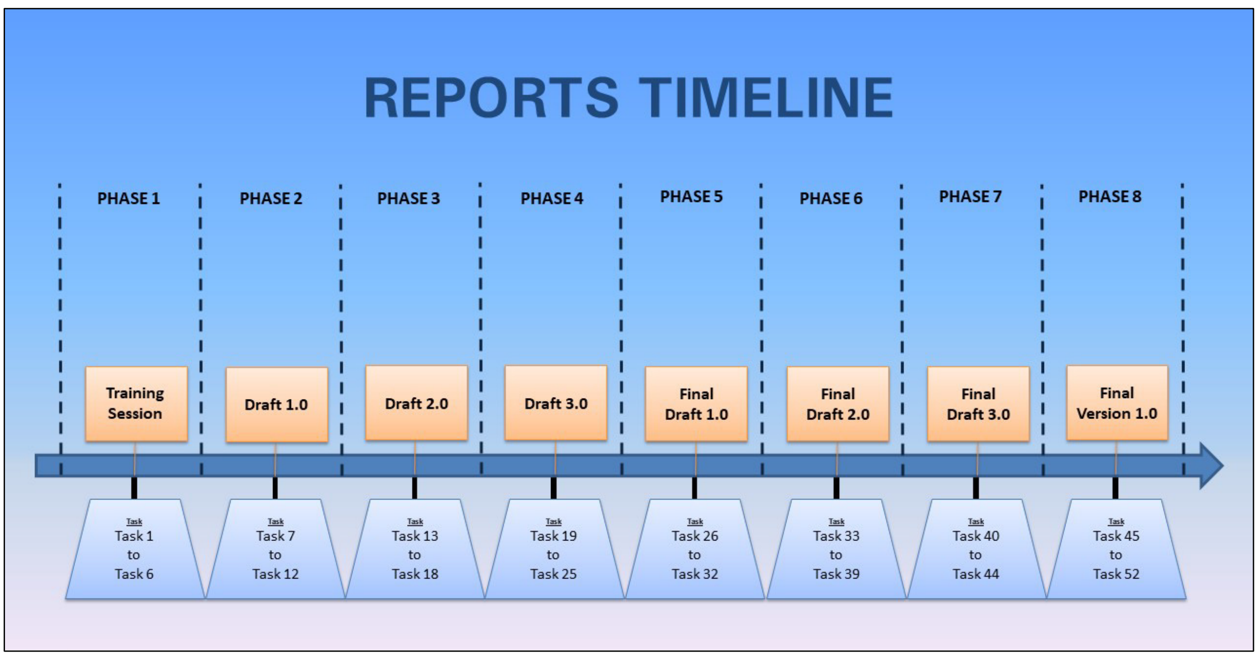


Figure 13.1: Reports Management Process

For 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 the TC report, TP 15374E, *Aircraft Ground Icing General Research Activities During the 2016-17 Winter* (19).

For 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 the TC report, TP 15398E, *Aircraft Ground Icing General Research Activities During the 2017-18*

Winter (20). These reports were published and delivered to TC and the FAA as Final Version 1.0 via “WeTransfer” and USB drives.

For 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 the TC report, TP 15427E, *Aircraft Ground Icing General Research Activities During the 2018-19 Winter* (6). These reports were published and delivered to TC and the FAA as Final Version 1.0 via “WeTransfer” and USB drives.

For 2019-20, APS accelerated a total of six unpublished reports to Final Draft 2.0 stage and published a total of 14 reports. The details of these reports published in 2019-20 are provided in the TC report, TP 15452E, *Aircraft Ground Icing General Research Activities During the 2019-20 Winter* (4). The 14 published reports were delivered to TC and the FAA as Final Version 1.0 via “WeTransfer” and USB drives.

For the year 2020-21, APS accelerated a total of eight unpublished reports to Final Draft 2.0 stage and published a total of 15 reports; the published reports are displayed in Table 13.1. The 15 published reports were delivered to TC and the FAA as Final Version 1.0 via “WeTransfer” and USB drives.

13.3.1 Overall Publication Status of Technical Reports

The overall status of the reports as of October 31, 2020, was as follows:

- Published reports: 137;
- Non-published reports: 70; and
- Total reports: 207.

Detailed in Table 13.1, the following 15 historical reports were delivered to TC and the FAA as Final Version 1.0 during 2020-21:

- One report from 2006-07;
- One report from 2008-09;
- Three reports from 2009-10;
- One report from 2010-11;
- One report from 2011-12;
- One report from 2012-13;
- One report from 2013-14; and
- Six reports from 2019-20.

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, 2021, is presented in Table 13.2.

In addition, APS is currently working on five reports for the Winter 2020-21 research activities; these are not included in the totals as of October 31, 2021.

As of October 31, 2021, estimating that APS will accelerate at least six unpublished reports to Final Draft 2.0 stage and publish at least 12 reports per year, it will take approximately four-and-a-half years to clear the backlog.

As of October 31, 2021, the number of published reports, including the reports that are expected to be published, totals 181.

Table 13.1: List of Published Technical Reports (2020-21)

No.	TP Number	Year	Report Title	Category	Latest Version	Publication Date
1	TP 15450E	2019-20	Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2019-20 Winter	HOT	Final Version 1.0	Jul 22, 2021
2	TP 15451E	2019-20	Regression Coefficients and Equations Used to Develop the Winter 2020-21 Aircraft Ground Deicing Holdover Time Tables	Regression	Final Version 1.0	Apr 30, 2021
3	TP 15452E	2019-20	Aircraft Ground Icing General Research Activities During the 2019-20 Winter	G&E	Final Version 1.0	Aug 13, 2021
4	TP 15453E	2019-20	Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2019-20	Ice Pellet	Final Version 1.0	Aug 13, 2021
5	TP 15454E	2019-20	Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a Vertical Stabilizer	V-Stab	Final Version 1.0	Aug 20, 2021
6	TP 15455E	2019-20	Artificial Snow Research Activities for the 2018-19 and 2019-20 Winters	Artificial Snow Research	Final Version 1.0	Oct 31, 2021
7	TP 14778E	2006-07	Flow of Contaminated Fluid from Aircraft Wings: Feasibility Report	IP Feasibility	Final Version 1.0	Aug 24, 2021
8	TP 14939E	2008-09	Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti Icing Fluid Flow-Off Characteristics Winter 2008-09	WT R&D	Final Version 1.0	Aug 24, 2021
9	TP 15057E	2009-10	Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti Icing Fluid Flow-Off Characteristics Winter 2009-10	WT R&D	Final Version 1.0	Aug 24, 2021
10	TP 15160E	2010-11	Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti Icing Fluid Flow-Off Characteristics Winter 2010-11	WT R&D	Final Version 1.0	Aug 24, 2021
11	TP 15233E	2012-13	Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2012-13	WT R&D	Final Version 1.0	Aug 24, 2021
12	TP 15274E	2013-14	Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2013-14	WT R&D	Final Version 1.0	Aug 24, 2021
13	TP 15056E	2009-10	Holdover Times Related to Aircraft Hangar Operations	Hangar	Final Version 1.0	Aug 26, 2021
14	TP 15199E	2011-12	Research to Access the Need for Remote On-Ground Ice Detection Systems (ROGIDS) at End-of-Runway	ROGIDS	Final Version 1.0	Aug 26, 2021
15	TP 15052E	2009-10	Development of Type I Fluid Holdover Times for Use on Aircraft with Composite Surfaces	Composite	Final Version 1.0	Aug 30, 2021

Table 13.2: Overall Status of Reports from 2017-18 to 2020-21

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)	2020-21 (# of reports as of Oct. 31, 2021)
Published Reports	TP reports that are published as Final Version 1.0.	103	123	137	152
Interim Reports Incorporated into a TP Report	Reports initially produced as interim reports and subsequently incorporated into TP reports.	21	22	25	26
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	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	3
Non-Published Reports	TP reports that are still in Draft stages.	64	48	38	29
Interim Reports to Be Published	Reports that have not been assigned TP numbers and may be published.	5	4	2	1
Total Reports Produced	Total number of reports produced by APS.	**198**	**202**	**207**	**213**

13.4 Conclusions

APS has been involved in writing and publishing technical reports on behalf of TC and the FAA since the early 1990s and has prepared over 213 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 six reports to Final Draft 2.0 stage and published 14 reports that were delivered to TC and the FAA as Final Version 1.0. By October 2021, APS accelerated eight reports to Final Draft 2.0 stage and published 15 reports that were delivered to TC and the FAA as Final Version 1.0.

13.5 Recommendations

Since APS has taken a more active role in completing this project, it is recommended that appropriate resources continue to be dedicated to support the publication of the remaining technical reports on a yearly basis.

This page intentionally left blank.

14. PUBLICATION OF HOLDOVER TIME GUIDANCE MATERIALS

This section describes the work APS Aviation Inc. (APS) completed in the winter of 2020-21 in support of Transport Canada (TC) and the Federal Aviation Administration (FAA) holdover time (HOT) guidance materials.

14.1 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 a standard and essential part of winter operations. APS plays a significant role in the preparation and management of these documents.

14.2 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) Maintains a Degree-Specific Holdover Time (DSHOT) database for Type II, III, and IV 100/0 fluids in snow conditions;

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

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

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

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

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

14.3 Winter 2021-22 Holdover Time Guidance Materials

In August 2021, the 2021-22 HOT Guidelines, DSHOTs database, 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 and DSHOTs Database:** TP 15494E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2020-21 Winter* (21); and
2. **Holdover Time Regression Information:** TP 15495E, *Regression Coefficients and Equations Used to Develop the Winter 2021-22 Aircraft Ground Deicing Holdover Time Tables* (22).

The titles of the 2021-22 documents are listed in Table 14.1. Final drafts of the TC and FAA documents were provided to the TC and the FAA publications departments, respectively, for publication on August 4, 2020.

The FAA finalized and published its N 8900 series notice on August 26, 2021.

Table 14.1: 2021-22 HOT Guidance Documents

HOT Guidelines	1. Transport Canada Holdover Time (HOT) Guidelines Winter 2021-2022, Original Issue, August 4, 2021
	2. Guide de Transports Canada sur les durées d'efficacité Hiver 2021-2022, version originale, 4 août 2021
	3. FAA Holdover Time Guidelines Winter 2021-2022, Original Issue, August 4, 2021
DSHOTs Database	4. Transport Canada Degree-Specific Holdover Times, Winter 2021-2022, Original Issue, August 4, 2021
	5. Guide de Transports Canada sur les durées d'efficacité selon le degré Hiver 2021-2022, version originale, 4 août 2021
	6. FAA Degree-Specific Holdover Time Data, Winter 2021-2022, Original Issue, August 4, 2021
Regression Information	7. Transport Canada HOT Guidelines Regression Information Winter 2021-2022, Original Issue, August 4, 2021
	8. Transports Canada Guide des durées d'efficacité Information de régression Hiver 2020-2021, version originale, 7 août 2020
	9. FAA Holdover Time Regression Information Winter 2021-2022, Original Issue, August 4, 2021

14.4 Future Responsibilities

APS will continue contributing to the development of the TC and FAA HOT guidance materials in the winter of 2021-22. Specifically, APS will continue carrying out the tasks listed in Subsection 14.2.

This page intentionally left blank.

15. PRESENTATIONS, FLUID MANUFACTURER REPORTS, AND TEST PROCEDURES FOR 2020-21

This section contains an account of the presentations, fluid manufacturer reports, and test procedures prepared by APS Aviation Inc. (APS) in the winter of 2020-21.

15.1 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 2020-21, APS gave presentations at the following meetings:

1) SAE G-12 Holdover Time (HOT) Committee Meeting, Online (via Webex), November 2020; and
2) SAE G-12 HOT Committee Meeting, Online (via Webex), May 2021.

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 M.

15.1.1 SAE G-12 Holdover Time Committee Meeting, Online (Via Webex), November 2020

The following two presentations were prepared and presented at the SAE G-12 HOT Committee meeting held virtually via Webex in November 2020:

1) 2020-21 Endurance Time Testing Program; and
2) Update: Natural Snow Characterization Supporting Artificial Snow Research.

15.1.2 SAE G-12 Holdover Time Committee, Online (via Webex), May 2021

The following five presentations were prepared and presented at the SAE G-12 HOT Committee meeting held virtually via WebEx in May 2021:

1) Winter 2019-20 + 2020-21 Endurance Time Testing Update;
2) Icing Wind Tunnel Research Simulating Ice Pellet Conditions;

3) Update: Artificial vs. Natural Snow Comparison Supporting Artificial Snow Research;
4) Investigation of Mist Deposition Rates; and
5) Fluid Endurance Times on Vibrating Vertical Surfaces.

15.2 Fluid Manufacturer Reports

As part of the HOT research program, new fluids are tested for HOT performance each year. The data from new fluids that have been commercialized is published in the related Transport Canada (TC) report, TP 15494E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2020-21 Winter* (21), while the non-commercialized fluid reports are provided to the respective fluid manufacturers for internal development purposes.

As a result of the ongoing COVID-19 pandemic, several 2019-20 testing activities were incomplete at the end of the 2019-20 testing season. These outstanding testing activities were completed during the 2020-21 testing season. As a result, fluid manufacturer reports were completed and provided to fluid manufacturers and to TC and the Federal Aviation Administration (FAA) for fluids submitted in both 2019-20 and 2020-21.

15.2.1 Holdover Time Testing Reports 2019-20

The following subsections describe the fluid manufacturer reports produced for fluids submitted in 2019-20.

15.2.1.1 Standard Holdover Time Testing Reports 2019-20

Eleven reports were prepared to document HOT testing conducted in the winter of 2019-20. Copies of these reports were provided to the fluid manufacturers and to the TC and FAA project managers in June 2021.

Six of the reports were for commercialized fluids; these reports can be found in the appendices of TP 15494E (21). Five reports were for experimental fluids.

The eleven reports were for the following fluids:

1) Type II: ROMCHIM ADD-PROTECT NG;
2) Type IV: AllClear ClearWing ECO;

3) Type IV: AVIAFLUID AVIAFlight EG;
4) Type IV: AVIAFLUID AVIAFlight PG;
5) Type IV: CHEMCO ChemR Nordik IV;
6) Type IV: Newave Aerochemical FCY-EGIV; and
7) Five non-commercialized experimental fluids.

A companion document outlining the methodologies used in endurance time testing of Type II, III, and IV fluids was also prepared and provided to the manufacturers. Copies of these methodology reports are included in TP 15494E (21).

15.2.1.2 Very Cold Snow Testing Reports 2019-20

Thirteen reports were prepared to document the very cold snow (VCS) HOT testing conducted in the winter of 2019-20. Copies of these reports were provided to the fluid manufacturers and to the TC and FAA project managers in June 2021.

Ten of the reports were for commercialized fluids; these reports can be found in the appendices of TP 15494E (21). Three reports were for experimental fluids.

The thirteen reports were for the following fluids:

1) Type II: Aviation Shaanxi Cleanwing II;
2) Type IV: AllClear ClearWing ECO;
3) Type IV: AllClear ClearWing EG;
4) Type IV: AVIAFLUID AVIAFlight EG;
5) Type IV: AVIAFLUID AVIAFlight PG;
6) Type IV: CHEMCO ChemR EG IV;
7) Type IV: CHEMCO ChemR Nordik IV;
8) Type IV: Cryotech Polar Guard Xtend;
9) Type IV: Newave Aerochemical FCY 9311;
10) Type IV: Newave Aerochemical FCY-EGIV; and
11) Three non-commercialized experimental fluids.

A companion document outlining the methodologies used in endurance time testing of Type II, III, and IV fluids was also prepared and provided to the manufacturers. Copies of these methodology reports are included in TP 15494E (21).

15.2.2 Holdover Time Testing Reports 2020-21

The following subsections describe the fluid manufacturer reports produced for fluids submitted in 2020-21.

15.2.2.1 Standard Holdover Time Testing Reports 2020-21

Five reports were prepared to document HOT testing conducted in the winter of 2020-21. Copies of these reports were provided to the fluid manufacturers and to the TC and FAA project managers in June 2021.

Three of the reports were for commercialized fluids; these reports can be found in the appendices of TP 15494E (21). Two reports were for experimental fluids.

The five reports were for the following fluids:

1) Type IV: ASGlobal 4Flite EG;
2) Type IV: ASGlobal 4Flite PG;
3) Type IV: JSC RCP Nordix Defrost NORTH 4; and
4) Two non-commercialized experimental fluids.

In addition, one supplemental testing report was prepared for Aviation Shaanxi Cleanwing II. A companion document outlining the methodologies used in endurance time testing of Type II, III, and IV fluids was also prepared and provided to the manufacturers. Copies of these methodology reports are included in TP 15494E (21).

15.2.2.2 Very Cold Snow Testing Reports 2020-21

Three interim reports were prepared to document VCS testing conducted in the winter of 2020-21. These reports are expected be completed and provided to the fluid manufacturers and to the TC and FAA project managers once data collection is complete.

15.3 Test Procedures

Several procedures were developed to guide and support the research team in conducting tests in the winter of 2020-21. Table 15.1 provides the list of the procedures. The procedures have been included as appendices to the Winter 2020-21 reports; the specific reports are listed in the last column of Table 15.1.

Table 15.1: List of Procedures 2020-21

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 2.0 November 2020	HOT
1	1.1	INTERPRETATION OF METAR REPORTED WEATHER FOR DETERMINING HOT TABLE GUIDANCE CONDITION – DEVELOPMENT OF GUIDANCE FOR SELECT CONDITION	Procedure: SIMULATED TAXIING AND STATIONED AIRCRAFT TESTS TO INVESTIGATE THE DEPOSITION RATE OF MIST	Final Version 1.0 December 15, 2020	G&E
2	2.5	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2021	Final Version 1.0 March 16, 2021	HOT
2	2.6	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	OVERALL PROGRAM OF TESTS AT PMG, APRIL 2021	Final Version 1.0 March 11, 2021	HOT
3	3.1	ARTIFICIAL VS. NATURAL CONDITIONS COMPARISON TESTING	Procedure: NATURAL SNOW ENDURANCE TIME TESTING FOR ARTIFICIAL VS. NATURAL CONDITIONS COMPARISON	Final Version 1.0 December 10, 2020	ASR
9	9.1	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
10	10-13	WIND TUNNEL TESTING - COMBINED R&D TESTING INCLUDING TYPE IV VALIDATION AND EG EXPANSION	Procedure: WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS	Final Version 1.0, December 21, 2020	WT
5	5.1	EXPLORATORY RESEARCH AND STANDARD	Procedure: VERTICAL SURFACES TESTING – EFFECT OF VIBRATION DURING AIRCRAFT TAXI ON FLUID AND CONTAMINATION	Final Version 1.0 February 23, 2021	G&E

This page intentionally left blank.

16. EVALUATION OF THE ACE RESEARCH CENTER AS AN ALTERNATIVE FACILITY FOR DEICING RESEARCH ACTIVITIES

This section introduces the Automotive Center of Excellence (ACE) Facility and its potential for conducting future research activities.

16.1 Introduction

Transport Canada (TC) and the Federal Aviation Administration (FAA) have been interested in conducting research at another climatic facility to increase operational flexibility and to acquire added capabilities. The ACE Facility was identified as a potential candidate, and APS Aviation Inc. (APS) was therefore tasked to conduct a feasibility study.

16.2 Overview of Automotive Center of Excellence Facility

The ACE Facility, part of Ontario Tech University and located in Oshawa, Ontario, offers three main chambers of interest where research and development work can be conducted. They are the following:

- Climatic Wind Tunnel (CWT);
- Large Climate Chamber (LCC); and
- Small Climate Chamber (SCC).

According to the ACE Facility, both climate chambers can re-create any weather condition occurring in the world. The CWT is also said to be one of the most sophisticated wind tunnels available. The overall dimensions and relevant operating parameters of all three chambers are indicated below.

CWT

- Length: 20 m;
- Width: 14 m; and
- Height: 8 m.

LCC

- Length: 21 m;
- Width: 6 m; and
- Height: 6 m.

SCC

- Length: 9 m;
- Width: 6 m; and
- Height: 6 m.

Photo 16.1 illustrates the LCC at the ACE Facility.

All three chambers can generate the following operating conditions:

- Temperature range of -40°C to +60°C; and
- Relative humidity of 5 percent to 95 percent.

Within this temperature range, the CWT can generate a maximum wind speed of 300 km/h (162 knots) under controlled humidity levels.

16.3 Capability Comparison to the NRC Climate Chamber

Present research activities are conducted at the National Research Council Canada (NRC) climate chamber in Ottawa, Ontario. The overall dimensions of this facility are as follows:

- Length: 30 m;
- Width: 6 m; and
- Height: 6 m.

The chamber can generate the following operating conditions:

- Temperature range of -46°C to +55°C; and
- Relative humidity of approximately 5 percent to 95 percent.

Although the NRC facility is larger in length and can produce slightly cooler temperatures, most of the work conducted by APS does not require the full length of the chamber, making the ACE Facility a prospective candidate.

16.4 Recommendations

The following three phases are recommended if the ACE Facility is to be considered as a potential testing facility.

1) Visit and Demonstration of the Capabilities of All Three Chambers:
   - APS personnel to visit and observe the demonstrations; and
   - Preliminary determination if freezing precipitation, wind tunnel, and artificial snow machine testing is feasible.
2) In-Depth Evaluation of the ACE Facility by APS Personnel:
   - Including evaluation of rate pan measurements, droplet size, distribution, temperature, repeatability, and stability;
   - Validation of precipitation types (ZF, ZR, ZD, and SN), including mixed conditions and changes of temperatures; and
   - All capabilities related to wind tunnel testing (wind speed, temperature, et cetera).
3) Conduct Testing – Only If Facility Proves Feasible:
   - Test ZF and SN; and
   - May consider other mixed phase testing as needed.

A visit to the ACE facility is presently being organized by TC and the FAA.

This page intentionally left blank.

Photo 16.1: Large Climate Chamber at the ACE Facility

This page intentionally left blank.

REFERENCES

1. SAE International Aerospace Standard 9968A, *Laboratory Viscosity Measurement of Thickened Aircraft Deicing/Anti-icing Fluids with a Viscometer*, July 2021.

2. *Guidelines for Aircraft Ground Icing Operations (Sixth Edition)*, Transport Canada, August 2021, TP 14052E.

3. Federal Aviation Administration N 8900.594, *Revised FAA-Approved Deicing Program Updates, Winter 2021-2022*, August 2021.

4. APS Aviation Inc., *Aircraft Ground Icing General Research Activities During the 2019-20 Winter*, APS Aviation Inc., Transport Canada, Montreal, November 2020, TP 15452E, 38.

5. Campbell, R., Chaput, M., *Aircraft Ground De/Anti-icing Fluid Holdover Time Development Program for the 2000-01 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2001, TP 13826E, 250.

6. 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.

7. Transport Canada Advisory Circular 700-061, *Degree-Specific Holdover Times*, July 2021.

8. Ballew, J., Hudspeth, S., Sparkman, J., Stapleton, D., *Boeing 737-800 Final Surface Roughness Study Data Collection*, FAA, February 2017, DOT/FAA/TC-18/8, 75. Retrieved from https://www.airporttech.tc.faa.gov/Products/Airport-Safety-Papers-Publications/Airport-Safety%20Detail/ArtMID/3682/ArticleID/159/Boeing-737-800-Final-Surface-Roughness-Study-Data-Collection

9. Cherokee CRC, LLC, *Airbus A330-200 Final Surface Roughness Study Data Collection*, FAA, May 2020, DOT/FAA/TC-18/13, 55. Retrieved from https://www.airporttech.tc.faa.gov/Products/Airport-Pavement-Papers-Publications/Airport-Pavement-Detail/ArtMID/3684/ArticleID/2839/Airbus-A330-200-Final-Surface-Roughness-Study-Data-Collection

10. Böswald M., Govers, Y., *Taxi Vibration Testing – An Alternative Method to Ground Vibration Testing of Large Aircraft, ISMA 2008 - International Conference on Noise and Vibration Engineering*, Deutsches Zentrum für Luft-und Raumfahrt e.V. (DLR), Institute of Aeroelasticity, Bunsenstr. 10, 37073 Göttingen, Germany, January 2008, 14.

11. SAE International Aerospace Recommended Practice 5485B, *Endurance Time Test Procedures for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluids*, October 2017.

12. D'Avirro, J., *Aircraft Full-Scale Test Program for the 1995-1996 Winter – Type IV,* APS Aviation Inc., Transportation Development Centre, Montreal, October 1996, TP 12901E, 50.

13. Chaput, M., D'Avirro, J., Dawson, P., Hanna, M., Peters, A., *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1996/97 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, October 1997, TP 13131E, 234.

14. Chaput, M., Hanna, M., Hunt, M., Peters, A., Ruggi, E., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1998-99 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, October 1999, TP 13477E, 278.

15. Bendickson, S., *Relationship Between Visibility and Snowfall Intensity,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2003, TP 14151E, 34.

16. SAE International Aerospace Recommended Practice 5718B, *Qualifications Required for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluid*, December 2017.

17. SAE International Aerospace Recommended Practice 5945A, *Endurance Time Test Procedures for SAE Type I Aircraft Deicing/Anti-Icing Fluids*, October 2017.

18. SAE International Aerospace Recommended Practice 6207, *Qualifications Required for SAE Type I Aircraft Deicing/Anti-Icing Fluids*, October 2017.

19. 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.

20. 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.

21. Bernier, B., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2020-21 Winter*, APS Aviation Inc., Transport Canada, Montreal, November 2021, TP 15494E, 60.

22. Bernier, B., *Regression Coefficients and Equations Used to Develop the Winter 2021-22 Aircraft Ground Deicing Holdover Time Tables*, APS Aviation Inc., Transport Canada, Montreal, November 2021, TP 15495E, 60.

This page intentionally left blank.

APPENDIX A

TRANSPORT CANADA
STATEMENT OF WORK EXCERPT –
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2020-21

TRANSPORT CANADA
STATEMENT OF WORK EXCERPT –
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2020-21

1. Interpretation of METAR Reported Weather for Determining HOT Table Guidance Condition - Development of Guidance for Select Conditions (i.e. CHARACTERIZE RATE OF MIST AND ZF, CHANGING PHASE, ETC)

a) Conduct more refined analysis of historical METAR data, including Europe and Asia.

b) Prepare a project plan to prioritize the development of appropriate guidance.

   i. Examination of obscuration in fog and mist should be emphasized in this study.

   ii. Characterize rate of mist. Testing up to 3 events in Montreal or nearby locations to obtain preliminary information.

   iii. Examine changing phase condition.

   iv. Evaluate duration of changing phase conditions.

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

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

e) Prepare presentation for SAE G-12.

f) Prepare a report.

5. Exploratory Research and Standard (SAE Standards, Preliminary Assessment of Changes for ARP5485, ARP5945, ARP5718, ARP6207, AWG, HOT Committee, 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) Provide support for further development of SAE aircraft ground deicing standards as needed.

c) Provide a preliminary assessment of the changes required for ARP5485, ARP5945, ARP5718, ARP6207 as part of the 5-year review due late 2022.

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

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

Activities added on December 3, 2020 based on TC/FAA request:

f) Evaluate Guidance Related to Changing Intensities vs. HOT

g) Evaluate the Effects of Vibration on V-Stab Fluid Thinning with and Without Contamination

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. S upport 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.

xii. 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.

xiii. Preliminary evaluation of ACE facility's climatic testing capabilities for ground icing research applications.

6. Evaluation of Variability in HOT Testing Results at the NRC Climatic Engineering Facility – Phase 1: Light Freezing Rain

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

This activity is the first phase (light freezing rain) in a proposed multi-year project to investigate variability in HOT testing results. Each phase will consist of a detailed assessment of variability in a specific HOT condition.

a) Conduct endurance time tests in simulated light freezing rain conditions at the NRC CEF with up to four pre-selected reference anti-icing fluids of varying fluid type. The test plan will include testing in all four standard light freezing rain HOT conditions:

i. Light Freezing Rain, -3°C, 13 g/dm²/h

ii. Light Freezing Rain, -3°C, 25 g/dm²/h

iii. Light Freezing Rain, -10°C, 13 g/dm²/h

iv. Light Freezing Rain, -10°C, 25 g/dm²/h

The above-listed conditions will be repeated up to three times each, on different calendar days (total of 12 conditions to be tested). A minimum of 8 data points will be collected with each fluid per condition, per repeat. It is anticipated that eight days of testing will be required to complete the full test plan. A senior member of the APS staff will oversee all failure calls during the testing.

b) Review historical full-scale light freezing rain data collected in 1990s against the NRC light freezing rain data.

c) Collect outdoor light freezing rain data with four reference fluids on three occasions.

d) Analyze the data collected to assess the variability in the endurance time test results obtained in each simulated light freezing rain HOT condition.

e) Report on the findings.

f) Prepare presentation material (as required).

7. Remote Camera Viewing for Failure Call Remote VS. In-Person (and for Wind Tunnel)

a) Evaluate project needs for different test locations.

b) Engage video professional for support in identifying and sourcing appropriate equipment and technology.

c) Acquire equipment or engage long term rental.

d) Conduct trial run at P.E.T. test site.

e) Make modifications as necessary.

f) Perform initial trials during winter 2020-21 testing activities at site, in remote location, and at wind tunnel.

g) Modify or purchase additional equipment as required.

h) Launch remote viewing platform to clients and management.

8. Harmonization of Visibility Table (Including Moderate/Heavy Snow)

a) Review the visibility tables used for Canada and US and determine the differences.

b) Review industry requests for modifications or improvements to the visibility table, including requests related to moderate/heavy snow HOTs.

c) Develop a prioritized plan of potential changes with the goal of harmonizing the Canada and US visibility tables. Meet with TC and FAA to review the plan, adjust accordingly, and develop final list of modifications to be examined.

d) Perform analysis related to each of the proposed changes to the visibility tables to ensure they are validated and substantiated. Reference historical data or reports as required.

e) Mock-up changes for incorporation into the HOT guidelines and review with TC and FAA, and industry as required.

f) Report on the findings and prepare presentation material for the SAE G-12 meetings.

14. V-Stab New Design Construction and Support for 2021-22 Testing

a) Participate in discussions with the SAE G12 and regulators related to the design of a new common research model (CRM) vertical stabilizer. Provide support during the acquisition/construction of the model.

b) Support the discussions as required by providing analysis, research, or testing as required.

c) Manufacture the new CRM vertical stabilizer model with the likely support of NRC.

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

a) Assist TC/FAA to further develop the regulatory guidance needed to support temperature-specific HOT data publication.

b) Update the draft data output.

c) Conduct detailed verification of the updated data output.

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

e) Prepare presentation for SAE G-12.

f) Prepare a report.

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

a) Coordinate and manage the Master List of Reports, the Master 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 6 to 10 additional reports. Coordinate and schedule editorial reviews, technical reviews, and French translation of applicable reports.

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

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

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

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

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

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

17. 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).

18. 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).
f) Provide support for publication of documents.

20. Documentation of Test Methods and Protocols for Ice Pellet Allowance Times – Training Manual

a) Conduct a historical review of documented data and standards related to ice pellet allowance time testing.
b) Identify information gaps and prioritize the documentation plan based on the highest priority needs.
c) Work with associated testing professionals to acquire and develop missing documentation related to testing activities.
d) Develop a comprehensive internal report which will include or reference relevant data, procedures, methodologies, photos, technical drawings, etc.
e) Recommend updates to internal training material accordingly.
f) Recommend updates to SAE G12 standards accordingly.

21. 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.

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.

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.

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.

e) Prepare reports.

22. 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.

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.

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.

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.
e) Prepare reports.

23. Provision for Modification to Testing Procedures, Schedules, Equipment, and Facilities in Order to Comply with COVID-19 Guidelines

a) Review and adapt all existing testing procedures to ensure that processes and personnel requirements are compliant with local COVID-19 guidelines.
b) Adjust testing schedules as needed to comply with personnel restrictions in place due to COVID-19.
c) Purchase health and safety equipment for all testing facilities, including but not limited to masks, visors, gloves, disinfectants, and other cleaning products as needed.
d) Modify testing facilities as needed to ensure workstations provide an adequate standard of safety and comply with distancing regulations.
e) Prepare a report on COVID-19 health and safety measures (as required).

This page intentionally left blank.

APPENDIX B

EXTRACTS FROM MASTER LIST

- Extract from Master List Version 2.3.1
- Extract from Sub-List Version 2.3.1 Primarily Used by MWG for Discussion on Research Focus Going Forward

EXTRACT FROM MASTER LIST VERSION 2.3.1

Weather Type	Number or Events	Number of Reports
BR	3309579	15334013
-SN	2447690	13117053
-RA BR	1398022	3817810
RA BR	567428	1017707
SN	446762	983139
-DZ BR	366880	930206
-SN BR	366345	1438664
FZFG	225954	1058080
+RA BR	198039	346256
-RA SN	196233	345340
-SN RA	92696	175869
+SN	74490	156847
DZ BR	69438	124953
IC	67028	409213
SN BR	63396	155389
-RA DZ BR	59536	112321
-FZRA	49339	105556
-FZDZ	41186	87361
-RA SN BR	37184	74131
RA SN	33218	50532
-SN FZFG	28695	92964
-FZDZ BR	27555	81229
-FZRA BR	26348	67338
SN RA	25050	42983
SN FZFG	22045	45105
-DZ RA BR	21985	44152
-PL	21349	29000
-SN RA BR	20744	40340
-FZRA SN	14190	20796
RA DZ BR	11286	19560
-SN FZRA	8417	12783
-SN FZDZ	7558	18797
-SN PL	6681	11783

Weather Type	Number or Events	Number of Reports
-FZDZ FZFG	6603	18887
FZDZ	6305	11701
PL	6217	10406
IC BR	5952	18646
FZRA	5939	10050
-RA PL	5782	7900
DZ RA BR	5438	8789
-FZDZ SN	5434	11619
+SN FZFG	5432	10645
SN RA BR	5352	10196
RA SN BR	5084	8580
GR	5052	7147
+DZ BR	4971	6378
-IC	4928	10938
FZRA BR	4885	9609
-PL SN	3887	6548
-DZ SN	3819	6370
+FZDZ	3791	7786
-PL BR	3682	6060
+SN BR	3356	5877
+SN RA	3081	5321
-SN PL BR	3051	5795
+RA SN	2724	3896
-FZDZ SN BR	2715	6857
-RA PL BR	2638	4103
FZDZ BR	2503	5879
-DZ SN BR	2499	4474
-FZRA FZFG	2320	4842
-GR	2258	2735
-FZRA SN BR	2249	4089
RA GR	2245	2668
-FZRA PL	2210	3621
IC SN	2085	3683

Weather Type	Number or Events	Number of Reports
-PL FZRA	2003	3729
-FZRA PL BR	1992	3817
-RA GR	1886	2170
-PL RA	1603	2146
GR RA	1458	1668
PL BR	1446	2559
FZDZ FZFG	1370	4526
+RA GR	1230	1451
-PL SN BR	1133	1844
-SN DZ	959	1499
-PL RA BR	945	1402
SN PL	891	1196
IC FZFG	833	1838
FZRA SN	822	1241
+SN RA BR	776	955
-DZ FZFG	728	1389
+RA DZ BR	728	898
-GR RA	717	806
-SN DZ BR	712	1090
+GR	653	758
-RA SN PL	589	771
SN FZRA	579	941
+GR RA	565	655
+FZRA	560	1163
-SN GR	551	775
-RA FZFG	549	847
-SN IC	539	1629
-IC BR	537	1042
PL RA BR	520	736
PL RA	427	535
FZRA PL BR	426	715
-PL SN FZRA	390	625
SN IC	382	509

Weather Type	Number or Events	Number of Reports
RA PL	378	463
-RA PL SN	368	513
GR BR	367	567
SN GR	352	447
FZRA FZFG	346	618
PL SN	330	450
+RA SN BR	318	391
-FZRA DZ	302	381
-SN FZDZ BR	301	572
-FZRA PL SN	290	420
SN FZDZ	266	351
RA PL BR	260	361
-FZDZ PL BR	257	417
-SN FZDZ FZFG	254	521
DZ SN	247	370
PL SN BR	243	376
-FZRA SN PL	238	351
FZDZ SN	238	344
-RA SN PL BR	236	338
-PL FZDZ	224	375
-FZRA PL SN BR	222	374
SN DZ	213	295
SN PL BR	207	434
-RA SN FZFG	207	344
FZRA SN BR	202	328
-DZ PL	201	255
-FZRA DZ BR	201	298
+PL	197	251
FZRA PL	192	299
+RA GR BR	186	217
-RA PL SN BR	186	251
-FZRA SN PL BR	180	305
-FZDZ PL	178	282

Weather Type	Number or Events	Number of Reports
-FZDZ SN FZFG	173	343
-DZ PL BR	163	255
-FZRA FZDZ BR	151	288
-SN RA FZFG	150	260
+GR RA BR	149	172
+PL BR	149	282
-PL RA SN	143	161
-SN PL FZRA	141	222
+SN FZRA	136	195
-PL FZFG	132	204
-FZDZ RA	131	169
SN RA PL	129	147
-GR SN	129	164
+DZ RA BR	128	153
GR SN	127	166
RA IC	124	176
+FZDZ FZFG	122	271
-PL RA SN BR	116	165
GR RA BR	115	128
-RA DZ SN	115	156
RA GR BR	114	129
-SN FZRA BR	114	172
+FZRA BR	104	155
-FZRA FZDZ	102	137
-PL FZRA BR	100	168
SN PL FZFG	96	144
+PL RA BR	96	125
-DZ RA SN	95	131
FZDZ RA	95	104
PL FZRA	93	135
FZDZ SN BR	87	144
DZ FZFG	86	152
-FZDZ RA BR	86	116

Weather Type	Number or Events	Number of Reports
-FZRA SN FZFG	83	131
-GR BR	83	90
GR IC	83	134
-SN RA DZ	80	91
-SN RA PL BR	77	106
-SN PL FZFG	77	163
-FZDZ FZRA	75	83
+SN PL	74	109
-RA IC	71	92
-SN PL RA BR	69	92
-RA GR BR	69	84
-RA SN DZ	67	84
+FZRA SN	67	111
-PL SN RA BR	64	87
-SN RA PL	63	75
SN DZ BR	63	98
-PL SN FZDZ	62	109
+RA PL	60	71
-PL SN RA	59	70
PL FZFG	58	96
DZ SN BR	56	80
-DZ RA SN BR	55	82
-FZDZ PL SN	48	76
-IC FZFG	47	63
FZRA FZDZ	47	48
DZ RA SN	47	55
SN PL RA	46	49
RA FZFG	45	110
-FZDZ FZRA BR	44	84
-DZ SN FZFG	43	66
-RA SN GR	43	50
RA SN PL	42	45
+RA PL BR	41	52

Weather Type	Number or Events	Number of Reports
FZRA PL SN BR	40	57
-SN PL RA	40	49
SN RA FZFG	40	88
-RA IC BR	39	63
+SN GR	39	57
-SN RA GR	38	47
+FZDZ BR	38	43
-RA DZ SN BR	37	55
-SN PL FZDZ	37	63
PL RA SN	37	42
-DZ SN RA	35	41
-SN IC BR	35	69
-PL SN FZFG	35	54
-PL FZRA FZFG	35	67
+GR BR	34	35
DZ PL	34	37
DZ IC	34	51
RA SN GR	34	50
-RA FZDZ	33	39
+PL SN BR	33	54
SN FZDZ BR	33	60
-SN FZRA FZFG	32	41
-PL DZ BR	31	40
-FZDZ PL SN BR	31	46
PL RA SN BR	31	40
+PL RA	30	31
-FZDZ SN PL	30	49
IC SN BR	29	72
+SN PL FZFG	29	46
-DZ GR	28	36
-IC SN	28	65
-FZRA SN FZDZ	27	30
-GR RA BR	26	32

Weather Type	Number or Events	Number of Reports
PL SN FZFG	26	37
SN FZRA BR	26	54
-GR SN RA	25	29
-FZRA FZDZ FZFG	25	55
FZRA DZ BR	25	35
SN DZ RA	23	23
+FZRA PL BR	23	30
RA SN PL BR	23	31
-DZ DZ PL BR	23	23
-DZ FZRA	23	27
RA SN DZ	22	30
-PL FZDZ BR	22	34
DZ SN RA	22	22
+FZDZ RA	22	23
FZRA DZ	22	26
-GR FZFG	22	27
FZRA PL SN	21	25
-SN GR BR	21	35
SN IC BR	21	65
GR FZFG	21	38
-FZDZ SN PL BR	20	36
-SN DZ FZFG	20	37
FZDZ FZRA	20	21
-FZDZ RA SN	20	22
-DZ IC	20	21
RA SN FZFG	20	26
FZDZ PL BR	19	32
-FZRA PL FZFG	19	35
FZDZ SN FZFG	18	33
SN RA DZ	18	22
+PL SN	17	31
FZRA SN PL BR	17	24
PL DZ BR	16	18

Weather Type	Number or Events	Number of Reports
-FZDZ SN FZRA	16	17
-FZRA DZ FZFG	16	23
RA DZ SN	16	20
FZDZ PL	15	20
-GR RA SN	15	20
FZRA SN FZFG	15	20
PL SN RA BR	15	18
-PL DZ	15	21
RA PL SN BR	14	24
SN FZDZ FZFG	14	33
SN GR BR	13	14
-FZDZ RA FZFG	13	14
FZDZ RA BR	13	16
-SN RA DZ BR	13	15
-SN FZDZ FZRA	12	14
RA PL SN	12	13
SN RA GR	12	14
-SN FZRA FZDZ	12	16
SN FZRA FZFG	12	18
RA FZDZ	12	14
-PL DZ SN BR	12	15
-DZ IC BR	11	15
+SN RA PL	11	17
-DZ PL SN	11	13
+GR SN	11	12
PL SN RA	11	13
-SN FZDZ PL	11	11
-RA SN FZDZ	11	13
-DZ SN PL	11	12
PL SN FZRA	10	12
-PL FZDZ FZFG	10	10
PL GR	10	21
-DZ RA PL	10	10

Weather Type	Number or Events	Number of Reports
-RA DZ PL	10	15
-RA RA BR	10	12
+FZDZ SN	10	10
-SN FZRA PL	10	12
SN PL FZRA	10	11
+FZRA FZFG	10	15
FZRA PL FZFG	10	22
DZ GR	9	9
+PL FZFG	9	13
PL DZ	9	10
-SN DZ RA	9	14
DZ RA SN BR	9	9
+SN RA FZFG	9	24
DZ IC BR	9	12
-FZDZ FZRA SN	9	10
DZ PL BR	8	11
+IC	8	16
+DZ SN RA	8	8
RA IC BR	8	24
-SN FZRA PL BR	8	15
DZ FZRA	8	8
-RA DZ FZFG	8	8
GR RA DZ	8	8
+RA IC	8	8
IC RA	7	8
-SN GR RA	7	7
-SN RA FZDZ	7	12
GR RA SN	7	9
PL FZDZ	7	8
-SN DZ RA BR	7	10
-RA DZ PL BR	7	9
RA DZ SN BR	7	9
-RA GR SN	7	10

Weather Type	Number or Events	Number of Reports
+SN DZ	7	9
-SN PL DZ BR	7	11
-FZRA DZ SN	7	7
-SN FZDZ PL BR	6	6
RA GR SN	6	7
+RA FZFG	6	12
-PL FZRA FZDZ	6	9
-DZ GR BR	6	8
-RA SN DZ BR	6	7
SN RA PL BR	6	10
FZRA SN PL	6	8
-DZ RA FZFG	6	6
-GR SN BR	6	9
+DZ SN	6	9
+PL RA SN BR	6	8
-SN DZ PL BR	6	8
-FZDZ PL FZFG	6	9
PL FZRA BR	5	10
SN FZRA FZDZ	5	5
-DZ PL SN BR	5	7
+SN PL BR	5	7
GR SN RA	5	6
+SN FZDZ	5	12
IC PL	5	10
-PL SN FZRA BR	5	6
PL IC	5	9
IC SN FZFG	5	9
+PL SN FZFG	5	7
-SN SN BR	5	15
RA SN FZDZ	5	5
SN PL RA BR	5	5
FZDZ RA SN	5	5
-FZDZ IC BR	4	17

Weather Type	Number or Events	Number of Reports
-SN RA IC	4	4
-SN PL FZRA BR	4	5
-FZDZ FZRA FZFG	4	8
-SN GR FZFG	4	4
-FZDZ PL FZRA	4	4
SN FZRA PL	4	4
-PL FZDZ SN	4	4
-FZDZ IC	4	7
DZ GR BR	4	4
+FZRA PL	4	7
SN GR RA	4	4
+RA PL SN BR	3	3
RA DZ GR	3	3
-DZ SN PL BR	3	4
-DZ PL RA	3	4
-FG FZFG	3	5
-FZRA PL SN FZFG	3	4
-FZRA PL FZDZ	3	3
+RA IC BR	3	3
-DZ DZ BR	3	3
FZDZ IC BR	3	4
PL FZDZ BR	3	4
-FZRA SN PL FZFG	3	6
-FZRA GR	3	3
-RA FZDZ BR	3	4
-IC SN BR	3	4
+RA SN GR	3	3
-DZ SN RA BR	3	3
DZ SN RA BR	3	9
SN RA FZDZ	3	4
GR PL	3	4
-PL FZDZ FZRA	3	3
PL RA FZFG	3	11

Weather Type	Number or Events	Number of Reports
-DZ DZ IC BR	3	4
IC FZRA	3	6
GR SN BR	3	4
RA DZ FZFG	3	3
SN PL FZDZ	3	3
IC GR	3	3
PL FZRA FZFG	2	2
SN FZDZ FZRA	2	2
GR DZ	2	2
-DZ RA IC	2	2
+RA SN FZFG	2	6
RA GR DZ	2	2
-DZ SN GR	2	2
-SN IC FZFG	2	3
-RA DZ PL SN	2	3
+FZRA PL SN BR	2	2
RA PL FZFG	2	2
GR SN FZFG	2	2
+FZRA PL FZFG	2	2
SN IC RA PL	2	2
+RA SN DZ	2	2
FZRA SN FZDZ	2	2
-RA GR PL	2	2
RA SN FZDZ BR	2	3
+DZ PL	2	2
SN RA DZ BR	2	2
-RA RA IC BR	2	3
FZRA SN PL FZFG	2	3
FZRA FZDZ BR	2	2
FZRA DZ FZFG	2	2
DZ PL RA	2	2
-FZRA IC	2	4
DZ RA PL	2	2

Weather Type	Number or Events	Number of Reports
+FZDZ RA SN	2	2
+SN IC	2	3
-FZRA SN IC	2	4
-FZRA FZDZ SN	2	2
+FZRA DZ BR	2	2
FZDZ FZRA BR	2	2
-FZRA FZDZ PL	2	4
+DZ FZFG	2	5
-DZ RA GR	2	2
-FZDZ PL SN FZFG	2	2
IC FZDZ	2	3
-DZ RA PL BR	2	2
FZRA PL SN FZFG	2	2
+SN FZRA BR	2	4
-RA PL FZFG	2	3
FZDZ SN PL	2	3
-SN IC FZDZ FZRA	2	2
SN RA GR BR	2	2
-RA DZ SN GR	1	1
SN IC FZFG	1	1
-RA DZ SN PL BR	1	1
SN FZDZ PL	1	1
FZDZ RA PL	1	1
-FZDZ FZRA PL	1	1
+FZRA PL SN FZFG	1	1
-GR DZ RA	1	1
-SN GR IC	1	1
-FZRA SN DZ	1	2
-IC RA	1	1
SN FZRA DZ	1	1
-SN FZRA DZ BR	1	2
PL FZRA SN BR	1	1
-FZDZ FZRA SN BR	1	6

Weather Type	Number or Events	Number of Reports
FZRA GR	1	1
GR FZRA BR	1	2
IC DZ	1	1
-FZDZ GR BR	1	1
+PL SN RA BR	1	1
SN RA IC	1	1
+RA SN PL BR	1	2
-DZ RA IC BR	1	1
-FZDZ RA SN BR	1	1
PL GR BR	1	4
-GR PL	1	1
-RA GR DZ	1	1
-GR SN RA BR	1	1
-FZDZ SN GR	1	3
-FZDZ GR	1	1
-RA DZ SN PL	1	1
SN IC GR	1	1
-PL GR	1	1
DZ SN PL	1	1
+FZDZ SN FZFG	1	1
+GR FZFG	1	1
DZ SN FZRA BR	1	1
-GR RA PL	1	1
DZ DZ BR	1	1
RA GR SN BR	1	1
+SN GR BR	1	1
RA FZDZ BR	1	2
-FZDZ SN RA	1	1
-GR RA SN BR	1	2
PL GR SN	1	1
DZ FZRA BR	1	1
SN GR RA BR	1	1
+DZ RA SN	1	1

Weather Type	Number or Events	Number of Reports
-SN FZRA DZ	1	1
SN DZ RA BR	1	1
-SNFG FZFG	1	1
+RA SN DZ BR	1	1
IC RA PL	1	1
+RA GR SN	1	1
-SN RA IC BR	1	1
GR PL IC	1	1
DZ SN FZFG	1	1
+RA GR PL	1	1
PL RA IC BR	1	1
RA GR PL	1	2
-DZ DZ PL IC BR	1	1
-FZRA IC BR	1	1
RA DZ GR BR	1	1
+RA RA IC BR	1	1
-GR FZDZ	1	1
SN DZ FZFG	1	2
FZDZ PL SN FZFG	1	1
RA IC SN	1	1
-SN RA PL FZFG	1	1
-DZ RA SN PL	1	2
+RA PL SN	1	1
-DZ IC RA	1	1
-RA DZ GR	1	1
-DZ FZRA BR	1	3
-RA PL GR	1	1
IC PL RA	1	2
SN SN BR	1	1
-DZ DZ RA BR	1	1
-RA SN GR BR	1	1
DZ GR IC	1	1
-RA FZDZ FZFG	1	3

Weather Type	Number or Events	Number of Reports
SN RA FZDZ BR	1	1
+GR FZRA	1	1
DZ PL SN	1	1
FZDZ SN RA BR	1	1
+RA GR DZ	1	1
FZDZ IC	1	1
DZ FZRA SN BR	1	1
SN PL FZRA FZFG	1	1
PL IC BR	1	1
-PL IC	1	1
+SN FZDZ BR	1	1
DZ RA PL BR	1	1
PL SN FZDZ	1	2
-FZDZ RA IC	1	2
RA SN GR BR	1	1
IC PL SN	1	1
-SN FZDZ GR	1	1
-GR DZ	1	1
+IC BR	1	1
-FZRA DZ PL	1	1
-RA SN IC	1	1
GR FZRA	1	1
-RA DZ IC	1	2
RA SN DZ BR	1	1
+FZRA SN BR	1	1
+SN RA DZ	1	1
FZDZ RA SN BR	1	4
FZDZ RA FZFG	1	1
+FZRA SN PL BR	1	3
FZDZ FZRA SN	1	1

This page intentionally left blank.

EXTRACT FROM SUB-LIST VERSION 2.3.1 PRIMARILY USED BY MWG FOR DISCUSSION ON RESEARCH FOCUS GOING FORWARD

Weather Type	Number or Events	Number of Reports
-RA SN	223208	419471
-SN RA	108452	216209
RA SN	37709	59112
SN RA	29557	53179
-SN FZFG	28695	92964
SN FZFG	22045	45105
-FZRA SN	16086	24885
-SN PL	9459	17578
-SN FZRA	8505	12955
-RA PL	8108	12003
-SN FZDZ	7756	19369
-FZDZ SN	7624	18476
-FZDZ FZFG	6603	18887
-DZ SN	5927	10844
+SN FZFG	5432	10645
-PL SN	4905	8392
-FZRA PL	3915	7438
+SN RA	3803	6276
+RA SN	3018	4287
-PL RA	2449	3548
RA GR	2353	2797
-FZRA FZFG	2320	4842
IC SN	2102	3755
-PL FZRA	2076	3897
-RA GR	1946	2254
-SN DZ	1612	2589
GR RA	1564	1796
+RA GR	1388	1668
FZDZ FZFG	1370	4526
SN PL	1080	1630
FZRA SN	1004	1569
PL RA	925	1271
IC FZFG	833	1838

Weather Type	Number or Events	Number of Reports
-RA SN PL	800	1109
-GR RA	741	838
-DZ FZFG	728	1389
+GR RA	694	827
RA PL	632	824
FZRA PL	598	1014
SN FZRA	595	995
-SN GR	572	810
-SN IC	561	1698
PL SN	555	826
-RA FZFG	549	847
-RA PL SN	539	764
-FZRA DZ	495	679
-FZRA PL SN	487	794
-FZDZ PL	419	699
-FZRA SN PL	398	656
SN IC	398	574
-PL SN FZRA	393	631
SN GR	365	461
-DZ PL	355	510
FZRA FZFG	346	618
FZDZ SN	313	488
DZ SN	300	450
SN FZDZ	299	411
SN DZ	271	393
-PL RA SN	255	326
-SN FZDZ FZFG	254	521
-FZRA FZDZ	244	425
-PL FZDZ	244	409
-FZDZ RA	212	285
-RA SN FZFG	207	344
-FZDZ SN FZFG	173	343
-DZ RA SN	150	213

Weather Type	Number or Events	Number of Reports
-SN RA FZFG	150	260
-RA DZ SN	148	211
-SN PL FZRA	144	227
+SN FZRA	138	199
-SN RA PL	137	181
SN RA PL	135	157
-GR SN	133	173
-PL FZFG	132	204
GR SN	130	170
RA IC	128	200
+PL RA	124	156
+FZDZ FZFG	122	271
-FZDZ FZRA	116	167
-PL SN RA	116	157
-RA IC	109	155
FZDZ RA	108	120
-SN PL RA	108	141
+RA PL	100	123
SN PL FZFG	96	144
PL FZRA	96	145
-SN RA DZ	89	106
DZ FZFG	86	152
-FZRA SN FZFG	83	131
GR IC	83	134
+SN PL	79	116
-SN PL FZFG	77	163
-FZDZ PL SN	75	122
-RA SN DZ	73	91
PL RA SN	68	82
+FZRA SN	68	112
RA SN PL	63	76
-PL SN FZDZ	62	110
FZRA PL SN	60	82

Weather Type	Number or Events	Number of Reports
PL FZFG	58	96
DZ RA SN	56	64
SN PL RA	51	54
+PL SN	49	85
FZRA FZDZ	49	50
-IC FZFG	47	63
FZRA DZ	47	61
RA FZFG	45	110
-FZDZ SN PL	45	85
-RA SN GR	44	51
-PL DZ	44	61
-DZ SN FZFG	43	66
DZ IC	43	63
DZ PL	42	48
+SN GR	40	58
SN RA FZFG	40	88
-SN RA GR	38	47
-DZ SN RA	38	44
-SN PL FZDZ	37	64
-RA FZDZ	36	43
-PL SN FZFG	35	54
-PL FZRA FZFG	35	67
RA SN GR	35	51
-DZ GR	34	44
FZDZ PL	33	52
-SN FZRA FZFG	32	41
-IC SN	31	69
-DZ IC	30	36
+SN PL FZFG	29	46
-FZRA SN FZDZ	27	30
+FZRA PL	27	37
-GR SN RA	26	30
PL SN FZFG	26	37

Weather Type	Number or Events	Number of Reports
-FZRA FZDZ FZFG	25	55
RA PL SN	25	37
PL SN RA	25	31
PL DZ	25	28
DZ SN RA	25	31
SN DZ RA	24	24
-DZ FZRA	24	30
RA SN DZ	23	31
FZRA SN PL	23	32
RA DZ SN	23	29
+FZDZ RA	22	23
-GR FZFG	22	27
FZDZ FZRA	21	23
-FZDZ RA SN	21	23
GR FZFG	21	38
RA SN FZFG	20	26
-SN DZ FZFG	20	37
SN RA DZ	20	24

This page intentionally left blank.

APPENDIX C

PRESENTATION:
MIXED PHASE ICING CONDITIONS – STRATEGY MOVING FORWARD

JUNE 10, 2021

Joint research led by:

Transports Canada Transport Canada

Conducted by:

APS Aviation Inc.

Mixed Phase Icing Conditions – Strategy Moving Forward

June 10, 2021
MR,IW,JD

Background

- During April 8, 2021 MWG meeting, APS had the following task
  - APS to review latest sub-list and categorize into "Analysis", "Simulation", "No Capability". If ready before meeting, send to group for review prior to May 27, 2021 meeting.
- May 27, 2021 MWG meeting was rescheduled to June 10, 2021

File Control

- APS referenced file "MixedPhaseV2.3"
  - Descriptors were "scrubbed" from file
- APS provided list of recommendations and updates to the file for NCAR consideration
  - Master list correction, removal of tabs, general info tab etc
- APS performed analysis on the
  - "Mixed_noBR_>20reports" tab
  - "All_singletypes" tab

Analysis Overview

- Fun facts
  - "Mixed_noBR_>20reports" tab has 164 individual mixed phase conditions
  - "All_singletypes" tab has 20 individual conditions
  - Total of 184 conditions need to be reviewed from HOT guidance perspective
- Notes:
  - Descriptors and Obscuration's have been removed by NCAR, therefore will need to be addressed separately i.e. DRSN, BLSN, BR, FG
  - Single conditions mixed with BR were scrubbed but not identified on a separate list, therefore not included in analysis (need to be added back).
  - Didn't address conditions with no freezing/frozen precip.
  - Didn't address <20 reports

Columns Added (in yellow)

wxtype	PILOT INTERPRETATION or WORK PLAN	Applicable "Package"	LOE	LWE Combinations for Simulation	Expected/Potential HOT Guidance	Known Reported Request	Timeline
xxx (164 + 20 total)	Brief summary of what should be interpreted or what needs to be done to develop guidance	#identifying similar research packages	Analytical, Simulation, or Long Term Research	LWE values if testing is required	Initial proposed guidance based on brief discussion. Would need to be validate with analysis, testing, or long term research	If the condition has any supporting industry requests	Optimistic time when this could be completed

Discussed in next slides

Research Packages

- While analysing the 164 + 20 conditions, we identified similarities in the process required to develop guidance
- Those similarities would likely lead to "economies of scale" when developing guidance material
- An initial list was developed for consideration.
- This list may be further expanded or refined as the project progresses.

Research Packages List

	Mixed Phase Conditions	LOE
1	Mixed Conditions with **Ice Pellets (-PL/PL)** Covered by Existing Allowance Times	Done
2	**Light Snow** mixed with **Rain (-SN RA)**	Done
3	**Light Rain** mixed with **Snow (-RA SN)**	Analytical
4	**Moderate Snow** mixed with **Rain (SN RA/RA SN)**	Simulation
5	**Snow (-SN/SN)** mixed with **Freezing Rain (-FZRA/FZRA)**	Simulation
6	**Snow (-SN/SN)** mixed with **Drizzle (-DZ/DZ)**	Analytical
7	**Snow (-SN/SN)** mixed with **Freezing Drizzle (-FZDZ/FZDZ)**	Simulation
8	Mixed Conditions with **Freezing Drizzle/Drizzle (-FZDZ/FZDZ/-DZ/DZ) AND Freezing Rain/Rain (-FZRA/FZRA/-RA/RA)**	Analytical
9	Mixed Conditions with **Freezing Fog (FZFG)**	Analytical or Simulation
10	Mixed Conditions with **Ice Pellets (-PL/PL) NOT** Covered by Existing Allowance Times	Analytical or Simulation
11	Mixed Conditions with **Ice Crystals (-IC/IC)**	Analytical
12	Mixed Conditions with **Hail (-GR/GR)**	Long Term Research
13	Mixed Conditions listed as **heavy**	Long Term Research
14	Triple Condition with **Ice Pellets (-PL/PL)**	Simulation

Research Packages List (Detailed View)

Non-Mixed Phase Conditions			Number of REPORTS	Number of Conditions	Percentage of TOTAL Reports
FOG, BLSN, DRSN			Excluded from list	n/a	n/a
Single Precipitation Conditions (including BR alone)			31343197	19	77.02%
Single Condition Mixed with BR (Become single conditions when BR "scrubbed")			8036774	23	19.75%
Conditions with no freezing/frozen precipitation (DZ/RA)			185926	18	0.46%
Conditions with <20 reports (after BR "scrubbed")			912	189	0.00%

	Mixed Phase Conditions	PILOT INTERPRETATION or WORK PLAN	LOE	Number of REPORTS	Number of Conditions	Percentage of TOTAL Reports	Percentage of Mixed Conditions Reports
1	Mixed Conditions with **Ice Pellets (-PL/PL)** Covered by Existing Allowance Times	USE ALLOWANCE TIMES	Done	55650	9	0.14%	4.9%
2	**Light Snow** mixed with **Rain (-SN RA)**	USE HOT TABLES (recommend use of -FZRA)	Done	216209	1	0.53%	19.2%
3	**Light Rain** mixed with **Snow (-RA SN)**	Should be able to use -FZRA similar to -SN RA condition, but needs to be explicit.	Analytical	419471	1	1.03%	37.3%
4	**Moderate Snow** mixed with **Rain (SN RA/RA SN)**	Current research applies to -RA and -SN, not RA. Testing would be required to provide guidance if possible. High intensity may not make it possible. Maybe RCSW HOT due to rate?	Simulation	112291	2	0.28%	10.0%
5	**Snow (-SN/SN)** mixed with **Freezing Rain (-FZRA/FZRA)**	HOT exists for SN and RA, however not for SN and Freezing Rain. Needs some research.	Simulation	40404	4	0.10%	3.6%
6	**Snow (-SN/SN)** mixed with **Drizzle (-DZ/DZ)**	Current research applies to -RA and -SN, not DZ. Maybe current guidance can be applied to this as conservative estimate? Need to evaluate additive LWE.	Analytical	14276	4	0.04%	1.3%
7	**Snow (-SN/SN)** mixed with **Freezing Drizzle (-FZDZ/FZDZ)**	HOT exists for SN and RA, however not for SN and Freezing Rain (or drizzle). Needs some research.	Simulation	38744	4	0.10%	3.4%
8	Mixed Conditions with **Freezing Drizzle/Drizzle (-FZDZ/FZDZ/-DZ/DZ) AND Freezing Rain/Rain (-FZRA/FZRA/-RA/RA)**	Can RA and DZ co-exist, and possibly in different freezing and frozen state? Is the LWE additive? HOT exists for SN and RA, so maybe could apply?	Analytical	2875	26	0.01%	0.3%
9	Mixed Conditions with **Freezing Fog (FZFG)**	[illegible]	Analytical or Simulation	185235	42	0.46%	16.4%
10	Mixed Conditions with **Ice Pellets (-PL/PL) NOT** Covered by Existing Allowance Times	Needs Allowance Times development	Analytical or Simulation	4723	10	0.01%	0.4%
11	Mixed Conditions with **Ice Crystals (-IC/IC)**	Consider disregarding IC when mixed with SN, or use PL allowance times when mixed with RA or DZ	Analytical	6574	9	0.02%	0.6%
12	Mixed Conditions with **Hail (-GR/GR)**	Allowance times for small hail exist, but not for regular hail. Need research to show larger diameter size hail >5mm is applicable for ATs	Long Term Research	12198	18	0.03%	1.1%
13	Mixed Conditions listed as **heavy**	Heavy condition. Not enough data at this time. Long term effort required	Long Term Research	11449	10	0.03%	1.0%
14	Triplicate Condition with **Ice Pellets (-PL/PL)**	Triple condition, request from UPS for analysis	Simulation	5965	24	0.01%	0.5%
	Subtotal (Mixed_noBR_>20reports)			**1126064**	**164**	**2.77%**	**100.0%**
	TOTAL (including BR and Single Conditions)			**40,692,873**	**413**		

Strategies for Moving Forward

- Our initial review identified 4 potential strategies for moving forward with the research and analysis
  1. Based on Freq of occurrence (most to least)
  2. Based on Research Packages (to benefit from economies of scale)
  3. Based on the LOE required (analytical first up to long term research)
  4. Any modified version from above based on specific airports or locations

Research Strategy #1
Based on Freq of Occurrence

- Go down the list of 164 + 20 and address conditions in order of highest frequency of "reports"
  - Sort the list by reports
  - Address highest frequency first
- Pros: Addresses most commonly occurring conditions
- Cons: Not a structured strategy, and doesn't streamline research efforts

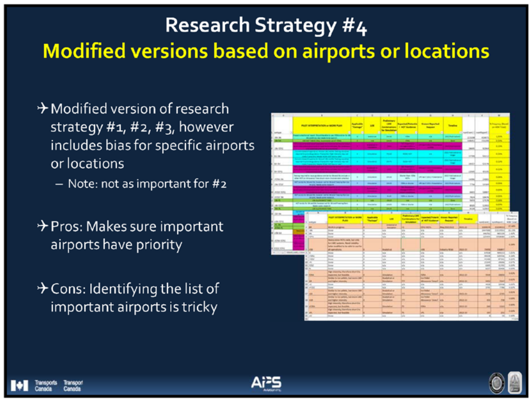
Research Strategy #2
Based on Research Packages

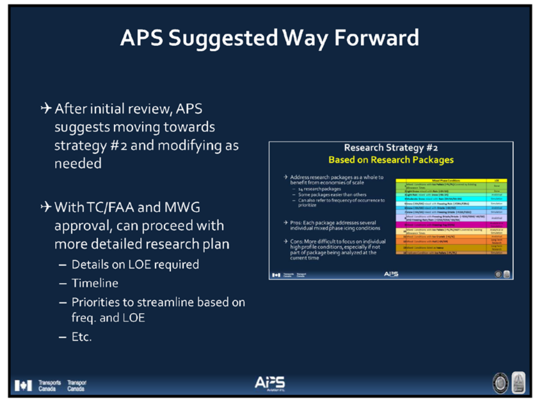
- Address research packages as a whole to benefit from economies of scale
  - 14 research packages
  - Some packages easier than others
  - Can also refer to frequency of occurrence to prioritize
- Pros: Each package addresses several individual mixed phase icing conditions
- Cons: More difficult to focus on individual high profile conditions, especially if not part of package being analyzed at the current time

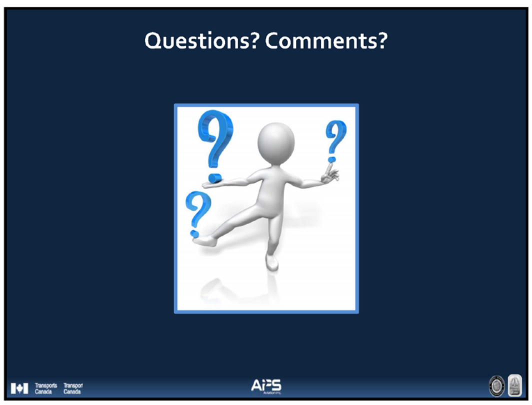
	Mixed Phase Conditions	LOE
1	Mixed Conditions with **Ice Pellets (-PL/PL)** Covered by Existing Allowance Times	Done
2	**Light Snow** mixed with **Rain (-SN RA)**	Done
3	**Light Rain** mixed with **Snow (-RA SN)**	Analytical
4	**Moderate Snow** mixed with **Rain (SN RA/RA SN)**	Simulation
5	**Snow (-SN/SN)** mixed with **Freezing Rain (-FZRA/FZRA)**	Simulation
6	**Snow (-SN/SN)** mixed with **Drizzle (-DZ/DZ)**	Analytical
7	**Snow (-SN/SN)** mixed with **Freezing Drizzle (-FZDZ/FZDZ)**	Simulation
8	Mixed Conditions with **Freezing Drizzle/Drizzle (-FZDZ/FZDZ/-DZ/DZ) AND Freezing Rain/Rain (-FZRA/FZRA/-RA/RA)**	Analytical
9	Mixed Conditions with **Freezing Fog (FZFG)**	Analytical or Simulation
10	Mixed Conditions with **Ice Pellets (-PL/PL) NOT** Covered by Existing Allowance Times	Analytical or Simulation
11	Mixed Conditions with **Ice Crystals (-IC/IC)**	Analytical
12	Mixed Conditions with **Hail (-GR/GR)**	Long Term Research
13	Mixed Conditions listed as **heavy**	Long Term Research
14	Triplicate Condition with **Ice Pellets (-PL/PL)**	Simulation

Research Strategy #3
Based on the LOE required

- Go down the list of 164 + 20 and address conditions in order of Level of Effort (LOE) required
  - Do all the easy "analysis" items first
  - Then do "simulation" activities
  - Then do "long term research"
- Pros: Initial progress will be speedy since will be doing easy ones first
- Cons: May not be addressing higher frequency conditions, especially if they need more LOE


Research Strategy #4
Modified versions based on airports or locations
Modified version of research strategy #1, #2, #3, however includes bias for specific airports or locations
– Note: not as important for #2
Pros: Makes sure important airports have priority
Cons: Identifying the list of important airports is tricky
AiPS


APS Suggested Way Forward
After initial review, APS suggests moving towards strategy #2 and modifying as needed
With TC/FAA and MWG approval, can proceed with more detailed research plan
– Details on LOE required
– Timeline
– Priorities to streamline based on freq. and LOE
– Etc.
Research Strategy #2
Based on Research Packages
AiPS


Questions? Comments?
AiPS

This page intentionally left blank.

APPENDIX D

PRESENTATION:
HOLDOVER TIMES IN CONDITIONS OF SNOW MIXED WITH DRIZZLE

FEBRUARY 23, 2021

Joint research led by: Transports Canada / Transport Canada

Conducted by: APS Aviation Inc.

HOLDOVER TIMES IN CONDITIONS OF SNOW MIXED WITH DRIZZLE

February 23, 2021
Marco Ruggi, Eng., M.B.A., Senior Project Leader

Background

- In 2007-08 and 2008-09, limited testing was conducted to compare ETs of
  - "light snow mixed with light rain" at +1ºC vs. "light freezing rain" at -3ºC
  - 8 comparative tests conducted
- Results
  - -SNRA ET was always longer than -FZRA ET.
  - At failure, adherence was present on both plates.
  - Failure in -SNRA showed characteristics similar to -FZRA , i.e. presence of adherence and erosion of the fluid layer.
  - Adherence was generally similar, or less severe in the case of -SNRA, however, adhered contamination was rougher.
  - -FZRA holdover times seem a good conservative approach for -SNRA; this was in accordance with the AEA recommendation.
  - A footnote was included in all the Type I, II, III and IV fluid tables of the 2009-2010 HOT Guidelines as follows:
    - Use light freezing rain holdover times in conditions of light snow mixed with light rain

Previous Reports and Data

Table 5.1: Light Snow Mixed with Light Rain vs. Light Freezing Rain Endurance Time Tests

Test #	Year	Commercial Fluid	Fluid Dilution	Endurance Time (min)	% Diff in Endurance Time	Precip. Rate (g/dm²/hr)	Temp. (°C)	Precipitation (Type)
RS1-08	2007-08	Fluid A-IV-EG	100	59	16%	25	1	S+R (12+13)
RS1-1-08	2007-08	Fluid A-IV-EG	100	51		25	-3	ZR (25)
RS2-08	2007-08	Fluid B-IV-PG	100	69	13%	25	1	S+R (12+13)
RS2-1-08	2007-08	Fluid B-IV-PG	100	61		25	-3	ZR (25)
RS1-1A	2008-09	Fluid C-IV-PG	100	57	15%	25	1	S+R (12+13)
RS7	2008-09	Fluid C-IV-PG	100	49		25	-3	ZR (25)
RS2-2A	2008-09	Fluid D-IV-PG	100	54	34%	25	1	S+R (12+13)
RS8	2008-09	Fluid D-IV-PG	100	40		25	-3	ZR (25)
RS3-3A	2008-09	Fluid E-II-PG	100	36	23%	25	1	S+R (12+13)
RS9	2008-09	Fluid E-II-PG	100	29		25	-3	ZR (25)
RS4-4A	2008-09	Fluid F-II-PG	100	25	20%	25	1	S+R (12+13)
RS10	2008-09	Fluid F-II-PG	100	21		25	-3	ZR (25)
RS5-5A	2008-09	Fluid G-III-PG	100	16	55%	25	1	S+R (12+13)
RS11	2008-09	Fluid G-III-PG	100	10		25	-3	ZR (25)
RS6-6A	2008-09	Fluid H-IV-PG	50	21	40%	25	1	S+R (12+13)
RS12	2008-09	Fluid H-IV-PG	50	15		25	-3	ZR (25)

Avg %Diff in Fail Time: 27%

Note for NRC Testing: FZRA = ZR, RA = R, FZDZ = ZD, DZ = D

2020-21 Objective

- To determine if the current HOT guidelines can be expanded to include mixed conditions of snow mixed with drizzle
- Analytical approach proposed
  - Review -SNRA data and see if can infer similarities
  - Perform engineering assessment
  - Consider testing only if necessary

Detailed Historical Review of -SNRA

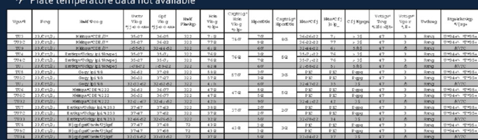
Detailed Review of 2007-08 -SNRA Data

- No adherence data collected
- No additional insights from data review
  - Plate temperature data may be available (to investigate latent cooling). Could be investigated further upon request

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Detailed Review of 2008-09 -SNRA Data

- Adherence in -SNRA tests was never more than at 1" line
  - During 4 of 6 -SNRA tests, no adherence was present at failure
  - Time of first adherence was after fail time of FZRA test
- All -FZRA tests had adherence present at failure (min at 1")
  - Adherence in -FZRA tests was never more than at 3-6" line
- Brix at failure generally lower during -SNRA test than -FZRA (likely linked to OAT)
- Plate temperature data not available



Meteorological Considerations for -SNRA

- When selecting the ratio of rates for SNRA, the following was considered
  - For METAR, the intensity indicator applies to both precipitation types, therefore possible combinations of SN and RA were
    - -SNRA (light snow and light rain) = 10 + 25 g/dm²/h
    - SNRA (moderate snow and moderate rain) = 25 + 75 g/dm²/h
    - +SNRA (heavy snow and heavy rain) = >25 + >75 g/dm²/h
  - METAR of "-SNRA" could mean max of 10 g/dm²/hr SN + 25 g/dm²/hr RA for a total of 35 g/dm²/h, but
  - Because mixed snow and rain is generally from one system and caused by snow melting or rain freezing, the rates should not be additive, so it should be a max of 25 g/dm²/h, and not 35 g/dm²/h
  - NRC tests already calibrated runs with -FZRA at a rate of 13 g/dm²/h, therefore could easily achieve RA at 13 g/dm²/h
  - SN rate could be easily changed, so 12 g/dm²/h was selected to total 25g/dm²/hr (and because 12 g/dm²/h was close enough to -SN upper limit of 10 g/dm²/h)
  - SN and RA rates for the test was 12 g/dm²/h + 13 g/dm²/h, respectively

HOT Considerations for -SNRA

- ETs for -SNRA were on avg 27% longer than -FZRA, therefore
- Using -FZRA HOTs was considered conservative
  - Note: Data showed no adhesion was present on -SNRA test at time of -FZRA failure.
- Using SN HOTs may have also been possible, but would have needed more research to ensure times were appropriate
  - -SNRA time could have been close to -SN times, but not enough data to ensure there is a safety buffer

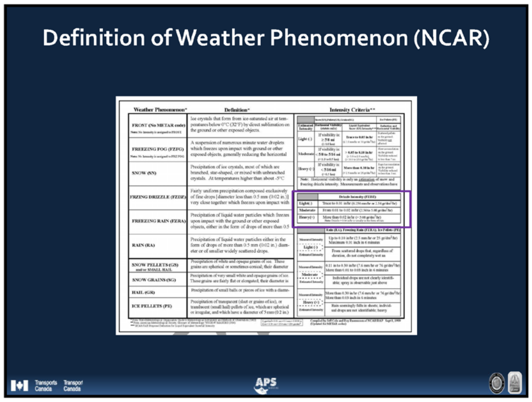
Analytical Considerations for Developing HOTs for Mixed SN and DZ

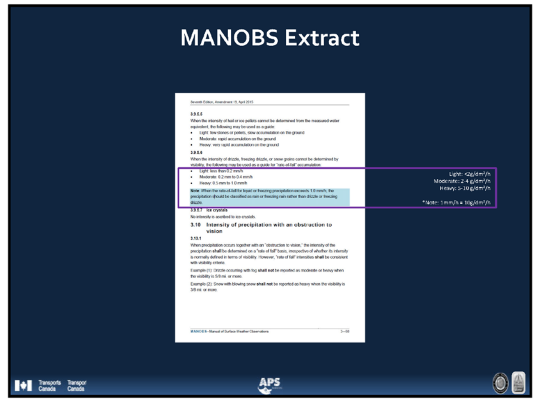
Open Questions

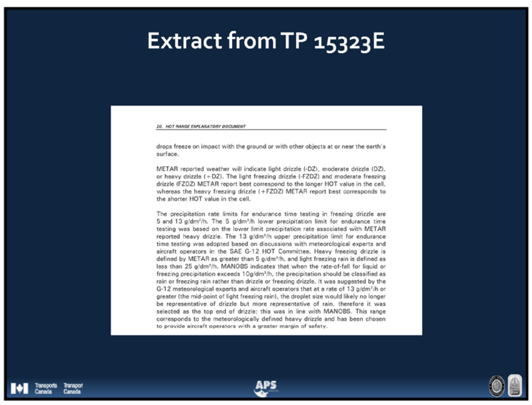
1. What rate intensities for mixed SN and DZ are considered acceptable?
2. What HOT should be linked to mixed SN and DZ ?
3. Is testing required?
4. Are there latent heat effects that need to be considered?

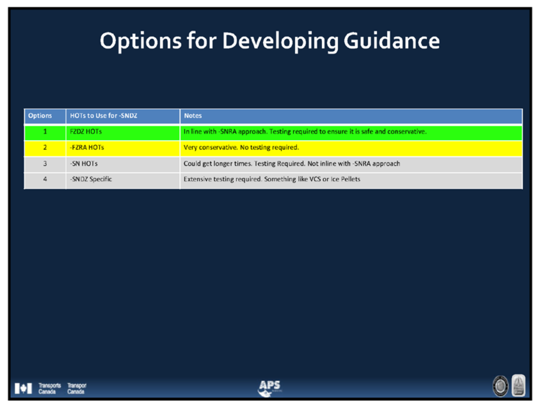
Meteorological Considerations for -SNDZ

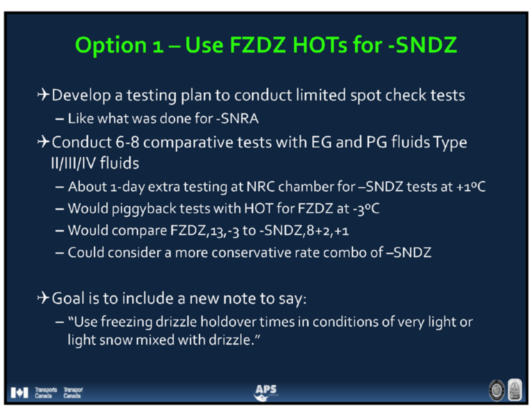
- From a HOT perspective, guidance for all intensities of drizzle are based on heavy drizzle (see extract from TP 15323E).
  - The longer HOT value is associated with the low end of Heavy Drizzle with rate of 5 g/dm²/h
  - The shorter HOT value is associated with high end of Heavy Drizzle with rate of 13 g/dm²/h
  - The HOTs can technically be applied for all intensity descriptors
- For METAR, the intensity indicator applies to both precipitation types, therefore possible combinations are
  - -SNDZ (light snow and light drizzle) = 10 + 2 g/dm²/h
  - SNDZ (moderate snow and moderate drizzle) = 25 + 5 g/dm²/h
  - +SNDZ (heavy snow and heavy drizzle) = >25 + >5-10 g/dm²/h
- Mixed snow and drizzle should be like -SNRA in that it is generally from one system and caused by snow melting or rain freezing, therefore the rates should not be additive
- Therefore, inline with -SNRA testing, -SN and -DZ rates for testing could be 8 g/dm²/h + 2 g/dm²/h for a total LWE of 10 g/dm²/h
  - As a conservative estimate we could consider 8+5 = 13, or 12+13 = 25

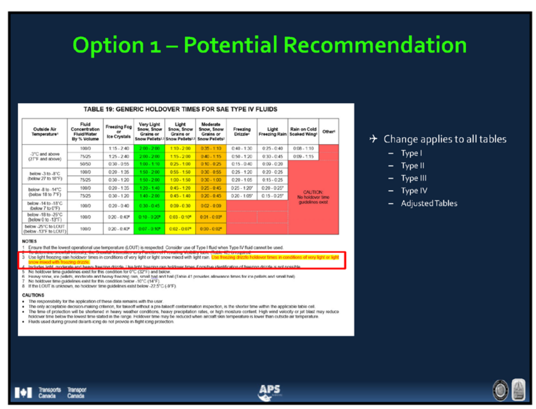

Definition of Weather Phenomenon (NCAR)
APS


MANOBS Extract
APS


Extract from TP 15323E
20. HOT RANGE EXPLANATORY DOCUMENT
drops freeze on impact with the ground or with other objects at or near the earth's surface.
METAR reported weather will indicate light drizzle (-DZ), moderate drizzle (DZ), or heavy drizzle (+DZ). The light freezing drizzle (-FZDZ) and moderate freezing drizzle (FZDZ) METAR report best correspond to the longer HOT value in the cell, whereas the heavy freezing drizzle (+FZDZ) METAR report best corresponds to the shorter HOT value in the cell.
The precipitation rate limits for endurance time testing in freezing drizzle are 5 and 13 g/dm²/h. The 5 g/dm²/h lower precipitation limit for endurance time testing was based on the lower limit precipitation rate associated with METAR reported heavy drizzle. The 13 g/dm²/h upper precipitation limit for endurance time testing was adopted based on discussions with meteorological experts and aircraft operators in the SAE G-12 HOT Committee. Heavy freezing drizzle is defined by METAR as greater than 5 g/dm²/h, and light freezing rain is defined as less than 25 g/dm²/h. MANOBS indicates that when the rate-of-fall for liquid or freezing precipitation exceeds 10g/dm²/h, the precipitation should be classified as rain or freezing rain rather than drizzle or freezing drizzle. It was suggested by the G-12 meteorological experts and aircraft operators that at a rate of 13 g/dm²/h or greater (the mid-point of light freezing rain), the droplet size would likely no longer be representative of drizzle but more representative of rain, therefore it was selected as the top end of drizzle; this was in line with MANOBS. This range corresponds to the meteorologically defined heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety.
APS


Options for Developing Guidance
Options | HOTs to Use for -SNDZ | Notes
1 | FZDZ HOTs | In line with -SNRA approach. Testing required to ensure it is safe and conservative.
2 | -FZRA HOTs | Very conservative. No testing required.
3 | -SN HOTs | Could get longer times. Testing Required. Not inline with -SNRA approach
4 | -SNDZ Specific | Extensive testing required. Something like VCS or Ice Pellets
APS

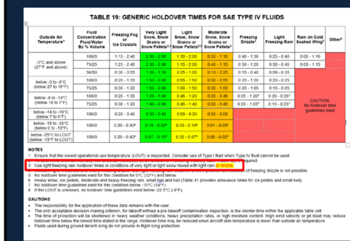

Option 1 – Use FZDZ HOTs for -SNDZ
Develop a testing plan to conduct limited spot check tests
– Like what was done for -SNRA
Conduct 6-8 comparative tests with EG and PG fluids Type II/III/IV fluids
– About 1-day extra testing at NRC chamber for –SNDZ tests at +1ºC
– Would piggyback tests with HOT for FZDZ at -3ºC
– Would compare FZDZ,13,-3 to -SNDZ,8+2,+1
– Could consider a more conservative rate combo of –SNDZ
Goal is to include a new note to say:
– "Use freezing drizzle holdover times in conditions of very light or light snow mixed with drizzle."
APS


Option 1 – Potential Recommendation
TABLE 19: GENERIC HOLDOVER TIMES FOR SAE TYPE IV FLUIDS
Change applies to all tables
– Type I
– Type II
– Type III
– Type IV
– Adjusted Tables
APS

Option 2 – Use FZRA HOTs for -SNDZ

- Conservative approach, but cheapest.
- Reference historical -SNRA testing
  - compared FZRA,25,-3 to -SNRA,12+13,+1
  - showed -SNRA was on average 27% longer
- Using this data for -SNDZ should be conservative
  - -SNRA combined rate of 25 g/dm²/h is double the -SNDZ combined rate of 10 g/dm²/h
  - Droplet size would be different
- Not addressing the G12 request for FZDZ HOT
- Would need to write a position paper based on this describing engineering approach, but no testing required.
- Would change Note 3 to say:
  - "Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain or drizzle."

Option 2 – Potential Recommendation



- Change applies to all tables
  - Type I
  - Type II
  - Type III
  - Type IV
  - Adjusted Tables

Latent Heat Considerations -SNDZ vs. –SNRA If Using –FZRA HOTs

- During the -SNRA tests, there was limited adherence present
- If there was less liquid water from RA (or DZ), this would impart less heat into the plate, and if there was similar levels of dilution, there could be more adhesion as it is expected the plate would cool more (from latent cooling of melting snow)
- This effect would need to be evaluated if developing fluid specific times,
- However, if trying to compare the -SNDZ condition to -FZRA, the LWE would be equal to or less, therefore the longer HOT may provide sufficient buffer

Latent Heat Effects Prediction Analysis -SNDZ vs. –SNRA If Using –FZRA HOTs

Condition	HOT Compared to -FZRA	Adhesion at Failure	Adhesion at -FZRA HOT
Light Freezing Rain (25)	n/a	1-6" line	1-6" line
Light Snow (12) and Rain (13)	27% Longer	0-1" line	None
Light Snow (12) and Drizzle (13)	Estimate 27% longer	Estimate 0-1" line	Estimate None
Light Snow (8) and Drizzle (2)	Estimate >>27% longer	Estimate 0-1" line or worse	Estimate None

Conclusion

- Four options are available to provide guidance for operating in -SNDZ
- Two best options are
  1. Conduct testing to use -FZDZ HOTs for -SNDZ (i.e. HOTs would be 0:40-1:30)
  2. Do engineering analysis to use -FZRA HOTs for -SNDZ (i.e. HOTs would be 0:25-0:40)
- Based on option selected, guidance would be issued accordingly

Notes from Feb 24, 2021 Meeting with TC/FAA/APS

- Presentation was reviewed.
- FAA has strong industry requests for this guidance.
- Group was considering doing Option 1 (FZDZ HOTs), but decided to defer due to ongoing METAR project which will prioritize research into mixed conditions going forward.
- Decision was made to go with Option 2 (-FZRA HOTs) for this year.
- May reconsider testing (Option 1) at a later date.
- Action: APS will include Option 2 (-FZRA HOTs) as part of changes to be addressed in upcoming HOT guideline meetings for inclusion in 2021-22 publication.

APPENDIX E

ANALYSIS REPORT:
INVESTIGATION OF HISTORICAL METAR REPORTS AT CYUL TO DETERMINE FREQUENCY OF FOG AND MIST WITH NO OTHER WEATHER TYPE

300293

ANALYSIS REPORT:

INVESTIGATION OF HISTORICAL METAR REPORTS AT CYUL TO DETERMINE FREQUENCY OF FOG AND MIST WITH NO OTHER WEATHER TYPE

Winter 2020-21

This document was prepared for internal purposes to guide the research planning and preparation.

Prepared by: Ian Wittmeyer

Reviewed by: Marco Ruggi

November 29, 2021
Final Version 1.1

INVESTIGATION OF HISTORICAL METAR REPORTS AT CYUL TO DETERMINE FREQUENCY OF FOG AND MIST WITH NO OTHER WEATHER TYPE

Winter 2020-21

1. OVERVIEW

The goal of this study is to characterize the occurrence of cold weather fog and mist at Montreal Trudeau airport (CYUL) when no other weather type is reported. This study is in support of testing activities planned at CYUL for the winter of 2020-21.

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. Observations were excluded from the study when the temperature was 2°C or higher. Periods of fog and mist were noted by start and end times to determine length of events when no other precipitation or obscuration was present.

Frequency of occurrence of fog and mist is reported by year, month of year, time of day, temperature, and length of event (see all data in Subsection 4.1 for mist and Subsection 4.2 for fog). In addition, the number of events and total event hours are shown in tables for all months in the study and 11 year "climatological" sums are presented by year and month of year.

3. ANALYSIS

3.1 Mist

The frequency of mist at CYUL is quite variable from year to year. See Subsection 4.1 below for total number of METAR observations by year, which range from 25 to 92. There is no obvious trend in the yearly data. Observations by month are highest in December when frequent weather systems occur, and lowest in April when temperatures are more consistently above 1°C. There is a trend toward fewer mist observations at lower temperatures. A large percentage of mist observations are at the warm end, from 1°C to -1°C. There is a general diurnal cycle in frequency with a peak occurrence in the pre-dawn and early morning hours. Most mist events are relatively short lived as the highest frequency of events is less than just a few hours with a peak duration of 1 to 1.5 hours.

Monthly frequency of total event hours is widely variable from month to month and year to year. December sees the greatest number of mist events, as well as total summed hours of mist from all events per month. The highest yearly total frequency was in 2012, while 2011 had the fewest. The characterization of total number of monthly events largely mimics the number of total event hours, with December seeing the highest monthly frequency, and the highest yearly frequency in 2012.

3.2 Fog

There are relatively few observations of fog when no other weather type or obscuration is also reported (see Subsection 4.2 below for all fog data). As with mist, the frequency of fog is highly variable year-to-year and was most prevalent in 2012 and least in 2011 and 2018. Each of those two years saw no events. Fog observations were most frequent in March, and in warmer temperatures, peaking at 1°C. As expected, fog observations also exhibit a diurnal cycle with the highest frequency in the early pre-dawn hours and early morning.

The relatively few fog events were relatively short lived, with almost all events lasting under 90 minutes. There were many cold season months during the 11-year study period with no fog-only events.

4. DATA

4.1 Mist

Table 4.1: Mist – Total Observations by Year (CYUL)

Total Observations by Year	
2009	63
2010	87
2011	25
2012	92
2013	70
2014	65
2015	43
2016	74
2017	89
2018	74
2019	38

Table 4.2: Mist – Total Observations by Month (CYUL)

Total Observations by Month	
11	148
12	214
01	156
02	82
03	106
04	14

Table 4.3: Mist – Total Observations by Temperature (CYUL)

Total Observations by Temperature	
1	225
0	111
-1	81
-2	41
-3	32
-4	42
-5	35
-6	28
-7	11
-8	7
-9	17
-10	16
-11	17
-12	11
-13	5
-14	7
-15	7
-16	2
-17	1
-18	2
-19	2
-20	1
-21	2
-22	4
-23	5
-24	3
-25	4
-26	1

Table 4.4: Mist – Total Observations by Hour of the Day (UTC) (CYUL)

Total Observations by Hour of the Day (UTC)	
00	8
01	13
02	20
03	36
04	39
05	35
06	37
07	43
08	53
09	57
10	50
11	49
12	60
13	44
14	38
15	27
16	19
17	13
18	19
19	17
20	9
21	7
22	14
23	13

Table 4.5: Mist – Number of Events by Duration of Event (Hours) (CYUL)

# of Events by Duration of Event (Hours)	
0-0.33	31
0.33-0.66	30
0.66-1	17
1-1.5	32
1.5-2	21
2-3	23
3-4	9
4-5	8
5-6	11
6-7	3
7-8	3
8-9	1
9-10	3
10-12	2
12-18	
18-24	1
24-100	

Table 4.6: Mist – Number of Event Hours, All Months (CYUL)

# of Event Hours, All Months							
	Nov	Dec	Jan	Feb	Mar	Apr	Total
2009	14.56	15.56	0.2	0	0.23	0	30.56
2010	0.38	23.78	12.48	0	11	0	47.65
2011	0	10.51	0.83	4.26	0	0	15.61
2012	9	15.63	13.51	9.65	7.91	2.18	57.9
2013	4.36	29.35	5	6.65	0.21	0	45.58
2014	0	23.96	4.66	1.78	6	0	36.41
2015	0	2.08	4.06	0	8.96	5	20.11
2016	28.31	2.53	4	2.13	2.2	0	39.18
2017	0	9.55	19.73	2.16	3.2	0	34.65
2018	14.03	1.55	22.4	5.28	2.2	0	45.46
2019	6.26	0	1.13	8.48	9.05	0	24.93
Total	76.93	134.53	88.03	40.41	50.98	7.18	398.08

Table 4.7: Mist – Number of Events, All Months (CYUL)

# of Events, All Months							
	Nov	Dec	Jan	Feb	Mar	Apr	Total
2009	9	3	1	0	1	0	14
2010	1	15	8	0	1	0	25
2011	0	5	1	2	0	0	8
2012	1	6	4	7	7	2	27
2013	2	7	1	3	2	0	15
2014	0	12	4	3	1	0	20
2015	0	1	6	0	4	2	13
2016	8	1	1	4	2	0	16
2017	0	6	11	2	3	0	22
2018	4	1	9	5	2	0	21
2019	2	0	2	3	4	0	11
Total	27	57	48	29	27	4	192

4.2 FOG

Table 4.8: Fog – Total Observations by Year (CYUL)

Total Observations by Year	
2009	11
2010	9
2011	0
2012	24
2013	9
2014	1
2015	11
2016	11
2017	21
2018	0
2019	2

Table 4.9: Fog – Total Observations by Month (CYUL)

Total Observations by Month	
11	20
12	9
01	5
02	16
03	42
04	7

Table 4.10: Fog – Total Observations by Temperature (CYUL)

Total Observations by Temperature	
1	23
0	8
-1	15
-2	5
-3	5
-4	7
-5	5
-6	5
-7	2
-8	4
-9	3
-10	2
-11	6
-12	3
-13	1
-14	1
-15	2
-16	
-17	
-18	1
-19	1
-20	
-21	
-22	
-23	
-24	
-25	
-26	

Table 4.11: Fog – Total Observations by Hour of the Day (UTC) (CYUL)

Total Observations by Hour of the Day (UTC)	
00	
01	
02	1
03	2
04	2
05	3
06	7
07	14
08	13
09	11
10	15
11	11
12	8
13	5
14	4
15	3
16	
17	
18	
19	
20	
21	
22	
23	

Table 4.12: Fog – Number of Events by Duration of Event (Hours) (CYUL)

# of Events by Duration of Event (Hours)	
0-0.33	2
0.33-0.66	5
0.66-1	
1-1.5	2
1.5-2	
2-3	1
3-4	
4-5	
5-6	1
6-7	
7-8	
8-9	
9-10	
10-12	
12-18	
18-24	
24-100	

Table 4.13: Fog – Number of Event Hours, All Months (CYUL)

# of Event Hours, All Months							
	Nov	Dec	Jan	Feb	Mar	Apr	Total
2009	0.55	0	0	0	0.21	0	0.76
2010	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0
2012	0	0	0	0	7.46	0	7.46
2013	0	0	0	0	0.43	0	0.43
2014	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0
2016	3.26	0	0	0	0.46	0	3.73
2017	0	0	0	0	0.58	0	0.58
2018	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0
Total	3.81	0	0	0	9.16	0	12.98

Table 4.14: Fog – Number of Events, All Months (CYUL)

# of Events, All Months							
	Nov	Dec	Jan	Feb	Mar	Apr	Total
2009	1	0	0	0	1	0	2
2010	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0
2012	0	0	0	0	3	0	3
2013	0	0	0	0	1	0	1
2014	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0
2016	3	0	0	0	1	0	4
2017	0	0	0	0	1	0	1
2018	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0
Total	4	0	0	0	7	0	11

This page intentionally left blank.

APPENDIX F

PROCEDURE:
SIMULATED TAXIING AND STATIONED AIRCRAFT TESTS TO INVESTIGATE THE DEPOSITION RATE OF MIST

300293

PROCEDURE:

SIMULATED TAXIING AND STATIONED AIRCRAFT TESTS TO INVESTIGATE THE DEPOSITION RATE OF MIST

Winter 2020-21

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

Prepared by: Dany Posteraro

Reviewed by: Marco Ruggi

APS Aviation Inc.

December 15, 2020
Final Version 1.0

PROCEDURE: SIMULATED TAXIING AND STATIONED AIRCRAFT TESTS TO INVESTIGATE THE DEPOSITION RATE OF MIST

1. BACKGROUND

Mist (METAR code BR) is a commonly reported weather phenomenon. Mist is considered an obscuration rather than a precipitation type and can be reported alone or in conjunction with other weather conditions such as snow, freezing rain, et cetera. In terms of visibility, mist can reduce visibility to between 0.6 and 1.2 miles (1 - 2 km), while fog reduces it to less than 0.6 miles (1 km).

Mist is similar to freezing fog as they are both considered obscurations, however, holdover times (HOTs) exist specifically for freezing fog, but do not for mist. Historical research simulating an aircraft taxi in freezing fog indicated that the deposition rates can increase significantly when in motion; consequently, simulated freezing fog rates of 2 to 5 g/dm²/h were selected for developing HOTs.

The deposition rates for mist have never been quantified from a HOT perspective. This research is required to develop guidance for the appropriate treatment of mist for HOT determination.

2. OBJECTIVE

The objective of this study is to determine the range of deposition rates that occur naturally in mist.

3. TEST PLAN

The collection of mist deposition rates will be done in natural occurring conditions below, or close to freezing temperatures. A total of 3 to 4 testing events are planned for the winter of 2020-21. Additional tests may be considered only if the data collected during certain events is not adequate (i.e. mist did not occur, mixed precipitation, et cetera).

4. MIST FORECASTING

The following list of elements can be considered when trying to forecast mist conditions.

1. Surface visibility greater than or equal to 5/8 mile ($\approx$1 km) and less than 7 miles ($\approx$11 km).
2. Outside air temperature (OAT) < 2°C. Most mist observations are at temperatures above -4°C with many occurring near 0°C. Mist is also infrequently reported at temperatures colder than -4°C.
3. High relative humidity > 90%, best if closer to 100%.
4. Overcast sky cover. Low ceiling suggests more robust mist (below 800 feet i.e. $\approx$240 m).
5. No precipitation concurrent with mist (for the purpose of this research).
6. Sustained wind speed < 9 knots ($\approx$15 km/h).
7. It is helpful if precipitation occurs before the expected period of mist.

An analysis of historical METAR reports from CYUL was conducted to determine the ideal time for the occurrence of mist alone. It was found that the beginning of winter, early mornings, and temperatures around the freeze point (0°C) are the most favourable.

Note: When there is a forecast for mist conditions, start watching the CYUL TAF the day before and check for low wind speeds, overcast sky cover, low ceiling, and duration of potential mist with no precipitation falling. Keep in mind that forecasting may be difficult to predict (similar to frost testing) but can occur at any time of day. Consideration should, therefore, be made to test for extended periods to increase the chances of successful data collection.

5. TESTING PROCEDURE

Tests will be carried out at the APS Aviation Inc. (APS) test facility in Montreal and/or surrounding areas i.e. Mont Saint-Sauveur, Mont Tremblant, et cetera. Testing in the surrounding areas will only be considered if weather conditions at the APS test facility prove insufficient. Mist deposition rates are to be captured simultaneously using two measurement methods. The first and second methods will simulate a taxiing and stationed aircraft, respectively. It should be noted that since this study is comparative research, both measurement methods should be conducted simultaneously.

5.1 Measurement Method 1: Simulation of a Taxiing Aircraft Using a Test Vehicle

The following is the procedure to be followed for testing:

a) Ensure active mist conditions (to be confirmed visually and using the standard rate measurement method) and record meteorological conditions;

b) Using a standard precipitation collection pan (rate pan), pour rate fluid into the pan and record the measured weight (in grams) and test start time (hh:mm:ss) in the electronic rate form. Coordinate the start time of the taxi test with the stationed aircraft test. To ensure that the rate pan is tempered, it should be left outside and covered for 15 minutes prior to the start of measurements;

c) Mount the rate pan on the roof of the test vehicle at a 10° angle as seen in Photo 5.1. Ensure the heating is off and the car is not left running when not in use to prevent air flow disruptions (by a change in air density of the surrounding environment) and in turn, mist deposition;

d) Bring the odometer of the test vehicle to zero;

e) Drive the test vehicle to simulate a typical aircraft taxi, i.e. travel time of approximately 30 minutes at no more than 30 km/h (≈15 km) with appropriate hold periods to simulate a typical taxi. Plan the route as a round trip which ends at the testing station for measuring the rates post test;

f) Determine the visibility using a stationary object i.e. lamp post, et cetera;

g) Document the end time of the test run;

h) Take note of distance travelled on the odometer;

i) Re-weigh the rate pan;

j) Document the trajectory and speed of the test vehicle (iPad™ or iPhone™ GPS™ tracking apps can be useful for this). If no app is available, calculate the average velocity during the test by using the distance travelled during the test and the test end time; and

k) Repeat test if required and if conditions are still appropriate.

***Important**: Due to evaporation of the precipitation in the rate pan, it is important to minimize the amount of time the rate pan is indoors during weighing. Care should be taken to weigh the rate pan and return it back outdoors quickly. Also ensure the scale reads zero (tared) before any measurements are taken.*

Photo 5.1: Example Images of a Rate Pan Installed on a Test Vehicle

5.2 Measurement Method 2: Simulation of a Stationed Aircraft Using the Standard Rate Measurement Method

The following is the procedure to be followed for testing:

a) Ensure active mist conditions (to be confirmed visually and using the standard rate measurement method) and record meteorological conditions;

b) Using a standard precipitation collection pan (rate pan), pour rate fluid into the pan and record the measured weight (in grams) and test start time (hh:mm:ss) in the electronic rate form. Coordinate the start time of the stationed test with the taxi simulation test. To ensure that the rate pan is tempered, it should be left outside and covered for 15 minutes prior to the start of measurements;

c) Place rate pan on test stand for a period of approximately 30 min. Take note that the duration of mist deposition needs to coincide with the taxi simulation test for comparative purposes;

d) Re-weigh the rate pan and record the time; and

e) Repeat steps c and d until the end of testing.

***Important**: Due to evaporation of the precipitation in the rate pan, it is important to minimize the amount of time the rate pan is indoors during weighing. Care should be taken to weigh the rate pan and return it back outdoors quickly. Also ensure the scale reads zero (tared) before any measurements are taken.*

6. EQUIPMENT

The following is the equipment required to conduct the simulated aircraft taxi and stationed tests:

- Test vehicle;
- Two (2) rate pans;
- Weight scale with Styrofoam on top;
- Rate fluid;
- Mounting brackets/bungee cords or tie-downs;
- Data/Rate forms;
- Camera; and
- iPad™ or iPhone™ equipped with GPS™ tracking app (optional).

7. PERSONNEL

One or two people will be required to conduct this test. The simulated aircraft taxi tests will require one (1) person while the stationed tests will require one (1) person as well, however both activities can be coordinated and be done by one person if required.

8. SAFETY

All standard safety precautions are to be followed for this study.

9. DATA FORMS AND SOFTWARE

The standard electronic rate file and the general information data form (shown in Figure 9.1) should be used for this study.

When measuring rates, the taxiing pan should be denoted as “Pan 1” and the stationed pan should be denoted as “Pan 2”.

MIST - SIMULATED TAXIING AND STATIONED AIRCRAFT TESTING

DATE: ____________________ RUN #: ____________________

RECORDED BY: ____________________ SIGNATURE: ____________________

APS DATA

Visual Verification of Mist at Start Yes ☐ No ☐

Simulated Taxi:

Taxi Start (hr:min): ____________ Taxi Stop (hr:min): ____________

Taxi Distance (km) : ____________ Visibility (km) ____________

Rate (g/dm^2/h): ____________ Average Velocity (km/h): ____________

Simulated Stationed:

Start Time (hr:min): ____________ End Time (hr:min): ____________

Rate (g/dm^2/h): ____________

METAR DATA

Observed Weather: ____________ Time (Hr:min): ____________

Temperature (ºC): ____________ Wind Speed (km/h): ____________

Relative Humidity (%): ____________

COMMENTS: ____________________

APS/Library/Projects/300293 (TC Deicing 2020-21)/Procedures/Mist Testing/Data Form - Simulated Taxiing and Stationed Aircraft Testing

Figure 9.1: General Information Data Form

This page intentionally left blank.

APPENDIX G

TRANSPORT CANADA ADVISORY CIRCULAR (AC) 700-061 – DEGREE-SPECIFIC HOLDOVER TIMES

Transport Canada Transports Canada

Advisory Circular

Subject: **Degree-Specific Holdover Times**

Issuing Office:	Civil Aviation, Standards	Document No.:	AC 700-061
File Classification No.:	Z 5000-34 U	Issue No.:	01
RDIMS No.:	17277185 V9	Effective Date:	2021-07-16

Table of contents

Canada

1.0 Introduction

(1) This Advisory Circular (AC) is provided for information and guidance purposes. It describes an example of an acceptable means, but not the only means, of demonstrating compliance with regulations and standards. This AC on its own does not change, create, amend or permit deviations from regulatory requirements, nor does it establish minimum standards.

(2) Operators are expected to follow the means of compliance described in this AC in all respects, unless the Minister approves an acceptable alternate means of compliance.

(3) The conditions on the use of the Degree-Specific Holdover Time (DSHOT) database appear in Appendix A of this AC.

(4) This AC uses mandatory terms such as “shall”, “requirements” and “is/are required” in order to convey the intent of this and other referenced guidance documents. The term “should” is to be understood to mean that the proposed method of compliance must be used, unless an alternate means of compliance has been determined and approved.

(5) The term “operator” in this AC includes operators flying aircraft operated under the *Canadian Aviation Regulations* (CARs) Part VI and Part VII.

1.1 Purpose

(1) The purpose of this document is to:

- (a) provide guidance for the operational approval of the implementation of DSHOT snow data into an operator’s ground icing program (GIP);
- (b) specify that all DSHOT data to be used in operations are to be subjected to a defined evaluation process;
- (c) provide guidance to assist operators, service providers, contractors, and Transport Canada Civil Aviation (TCCA) personnel in evaluating proposed implementation of DSHOT data; and
- (d) provide guidance material and recommendations for Principal Operations Inspectors (POIs) or Civil Aviation Safety Inspectors (CASIs) when evaluating the use of DSHOTs in an operator’s GIP.

1.2 Applicability

(1) This document applies to:

- (a) Canadian air operators holding an air operator certificate (AOC) under Subpart 705 of the (CARs); or
- (b) All other operators not operating under Subpart 705 of the CARs but that have established an aircraft inspection program in accordance to Standard 622 of the *General Operating and Flight Rules Standards* (GOFRS) — Ground Icing Operations.

(2) This document is also applicable to all TCCA personnel, and to individuals and organizations that exercise privileges granted to them under an External Ministerial Delegation of Authority. This information is also provided to the aviation industry at large for educational purposes.

1.3 Description of changes

(1) Not applicable.

2.0 References and requirements

2.1 Reference documents

(1) It is intended that the following reference materials be used in conjunction with this document:

(a) *Aeronautics Act* (R.S.C., 1985, c. A-2)

(b) Part VI, Subpart 02 of the *Canadian Aviation Regulations* (CARs) — Operating and Flight Rules

(c) Standard 622 of the *General Operating and Flight Rules Standards* (GOFRS) — Ground Icing Operations

(d) Transport Canada Publication —TP 14052 — Guidelines for Aircraft Ground Icing Operations

(e) Transport Canada Publication — Holdover Time Guidelines

(f) Transport Canada Publication — Degree-Specific Holdover Time Database

(g) Transport Canada Publication — Regression Information

(h) Transport Canada Publication — TP 15451 — Regression Coefficients And Equations Used To Develop The Winter 2020-21 Aircraft Ground Deicing Holdover Time Tables

(i) SAE International Aerospace Recommended Practice (ARP) 5485 — Endurance Time Test Procedures for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluids

2.2 Cancelled documents

(1) Not applicable.

(2) By default, it is understood that the publication of a new issue of a document automatically renders any earlier issues of the same document null and void.

2.3 Definitions and abbreviations

(1) The following **definitions** are used in this document:

(a) **Data Presentation:** Means the method or means by which the data from the DSHOT database is presented in its final and verified form to the end user of the data. This could be a modified paper holdover time (HOT) table, an electronic presentation of a HOT table, or an electronic application (App) in an electronic flight bag (EFB).

(b) **Degree-Specific Holdover Time:** Means the HOT calculated at degree decrements beginning at 3°C down to the aircraft de/anti-icing fluid (ADF)'s lowest operational use temperature (LOUT). The DSHOT database contains an expanded set of snow precipitation HOTs (very light snow, light snow and moderate snow) for all Type II, III and IV ADFs listed in the TCCA HOT Guidelines.

(c) **Generic Holdover Time:** Is the shortest HOT for a given ADF Type (either Type II or Type IV) within a specified temperature range and for a specific precipitation type and intensity. In the absence of knowing what specific ADF is being used to protect the aircraft, the generic holdover times provide the most conservative values and ensure that the lowest ADF HOT is identified to the flight crew.

(d) **Holdover Time**: Is the estimated time that an application of ADF is effective in preventing frost, ice, or snow from adhering to an aircraft's treated surfaces. HOT is calculated as beginning at the start of the final application of ADF and as expiring when the fluid is no longer effective. A HOT may be one which is published by Transport Canada Civil

Aviation (TCCA) in the holdover timetables or one generated by a Holdover Time Determination System (HOTDS).

(e) **Holdover Time Determination System**: Means a near real-time system that samples a number of atmospheric inputs and uses these in conjunction with HOT regression curves and associated coefficients for ADFs to produce a holdover time determination report (HOTDR). A valid HOTDS will meet the Minimum Assurance Requirements Performance Specifications (MARPS) for HOTDS as set out by the Minister.

(f) **Holdover Time Regression Curve**: Means a graphical representation of data inputs (e.g. temperature, precipitation rate) generated in regression analysis. HOT regression curves may employ one or two coefficients which model fluid behaviour. All HOT regression curves are power law-based.

(g) **Power Law**: means a statistical functional relationship between two variables where a change in one variable yields a proportional relative change in the other variable. Compared to a linear relationship between a variable, power law variables vary as a power of another.

(h) **Regression Analysis**: means a set of statistical methods utilized to estimate the relationship between dependent and/or independent variables. In the context of holdover times, it is used to estimate the relationship between the holdover time of an ADF, outdoor ambient temperature (OAT) and precipitation rate.

(2) The following **abbreviations** are used in this document:

(a) **AC:** Advisory Circular

(b) **ADF:** Aircraft De/Anti-icing Fluid

(c) **ARP:** Aerospace Recommended Practice

(d) **CARs:** *Canadian Aviation Regulations*

(e) **COM:** Company Operations Manual

(f) **DSHOT:** Degree-Specific Holdover Time

(g) **DSHOTDA:** Degree-Specific Holdover Time Data Administrator

(h) **EFB:** Electronic Flight Bag

(i) **FAA**: Federal Aviation Administration

(j) **GIP:** Ground Icing Program

(k) **GOFRS:** *General Operating and Flight Rules Standards*

(l) **HOT:** Holdover Time

(m) **HOTDS:** Holdover Time Determination System

(n) **LOUT:** Lowest Operational Use Temperature

(o) **MARPS:** Minimum Assurance Requirements and Performance Specifications

(p) **METAR:** Meteorological Terminal Air Report

(q) **OAT:** Outdoor Ambient Temperature

(r) **POI:** Principle Operations Inspector

(s) **SAE:** Society of Automotive Engineers

(t) **SOP:** Standard Operating Procedures

(u) **SPECI:** Aviation Special Weather Report

(v) **TCCA**: Transport Canada Civil Aviation

3.0 Background

(1) The Holdover Time (HOT) Guidelines are published annually by Transport Canada Civil Aviation (TCCA). The HOT Guidelines contain a series of tables that provide time estimates on the effectiveness of de/anti-icing fluids (ADF) against freezing or frozen precipitation while an aircraft is on the ground. Holdover times can vary depending on the type of ADF used, the type of precipitation (e.g. snow), rate of precipitation (intensity), and outdoor ambient temperature (OAT).

(2) Within a typical HOT table exists ADF HOTs for various freezing and frozen forms of precipitation, these HOTs are provided for defined temperature ranges (e.g. -3 °C to -8 °C). The HOTs provided within a given temperature range are based on the coldest temperature of that range. Operators can typically determine an ADF's HOT by referencing the published HOT table in combination with meteorological information provided at an airport/station (e.g. METAR/SPECI).

(3) Operators may use as an optional service a HOT Determination System (HOTDS) at certain airports/stations. HOTDS comprise of specialized equipment sited at airports that carry out near real-time sampling of atmospheric inputs (e.g. temperature, precipitation rate and type) and use these in combination with HOT regression curves for specific ADF to produce a HOT determination report (HOTDR). The HOTDR contains pertinent information for flight crew including fluid name, type and the calculated holdover time. HOTDS are required to meet the Minimum Assurance Requirements and Performance Specifications (MARPS) for HOTDS as set out by the Minister in *General Operating and Flight Rules Standards* (GOFRS) 622.11 - Ground Icing Operations.

(4) Typically, a HOTDS will provide more precise HOTs compared to the timetable ranges found in the HOT guidelines given that information is real-time and is not bounded within a temperature range. In the absence of using a HOTDS, an operator uses the HOT information in the tabular format as published by TCCA in the HOT guidelines.

(5) To support extending safe air operations in snow conditions and leverage the similar benefits of HOTDS, a significant amount of analytical work to assess the safety and feasibility of publishing a database of Degree-Specific HOTs (DSHOT) was conducted by TCCA in partnership with the Federal Aviation Administration (FAA).

4.0 Degree-Specific Holdover Time (DSHOT) database

(1) The DSHOT database contains an expanded set of snow precipitation HOTs (very light snow, light snow and moderate snow) for all Type II, III and IV anti-icing fluids listed in the HOT Guidelines. For a given fluid, this expanded set contains HOTs calculated at degree decrements (in °C) down to the ADF's lowest operational use temperature (LOUT). The DSHOT database is an extension of the HOT Guidelines.

(2) Given the dynamic nature of meteorological conditions that may shift between METAR reports, the calculations for all holdover times within the DSHOT database factor in 1 degree colder (-1°C) for all temperatures, with the exception of temperatures warmer than 0°C. This ensures a continued level of safety assurance while overall providing expanded holdover times for snow conditions.

(3) DSHOT data is derived from the same natural snow test data used to calculate the snow cells in the published TCCA HOT Guidelines. The methodology for collection of snow data and the calculation of fluid endurance times are found in SAE International Aerospace Recommended Practice (ARP) 5485 — Endurance Time Test Procedures for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluids.

(4) Snow test data is fitted to a power law curve, which best reflects the behaviour of ADF in relation to two main variables – temperature and precipitation intensity. The general form of the regression equation for snow precipitation is $t = 10^{I} R^{A} (2\text{-}T)^{B}$, where:

(a) t = time (minutes);

(b) R = rate of precipitation (g/dm²/h);

(c) T = temperature (°C); and

(d) I, A, B = coefficients determined from the regression.

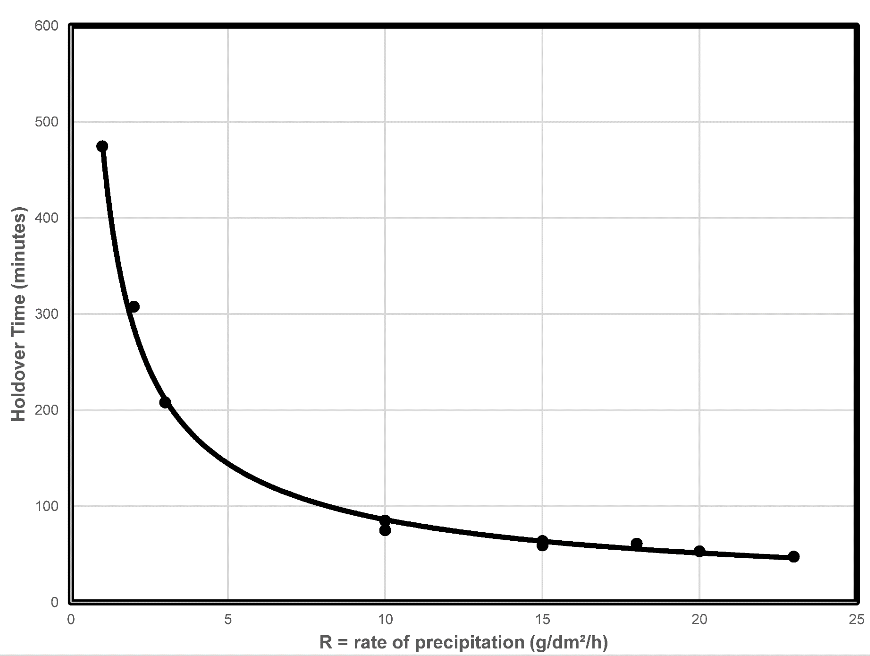
(5) Table 1 provides sample snow data measurements. The resulting power law curve fit yields the following coefficients: I = 3, A = -0.8 and B = -0.3.

Table 1: Sample snow data measurements and resulting holdover times

T = temperature (°C)	R = rate of precipitation (g/dm²/h)	t = Holdover Time (minutes)
-4	20	53
-6	2	308
-8	3	208
-6	10	85
-10	1	475
-10	10	75
-4	23	48
-5	15	64
-3	18	61
-7	15	59

(6) The resulting regression data can be fitted to a curve which provides holdover times for an ADF. Figure 1 provides a visual representation of most ADF regression curves for a given temperature range.

Figure 1: Aircraft De/anti-icing Fluid Regression Curve



(7) Fluid specific DSHOT data is provided for all undiluted Type II, Type III, and Type IV fluids listed within the HOT Guidelines. DSHOT data is also provided in generic format for Type II and Type IV fluids. The generic values for a given fluid type and temperature represent the lowest calculated HOT value of all fluids of that type at the specified temperature.

4.1 Regulatory Framework

(1) In accordance with paragraph 602.11 (4)(b) of the CARs, CARs subpart V of Part VII air operators are required to have an aircraft inspection program in accordance with GOFRS 622.11. Aircraft operated under CARs Part VI or subsections I, II, II, IV of CARs Part VII are required to have an aircraft inspection program if they are unable to immediately inspect their aircraft prior to take-off to determine whether any frost, ice or snow is adhering to an aircraft's critical surfaces.

(2) GOFRS 622.11(3) identifies the aircraft inspection program elements required to be included as part of an operator's ground inspection program (GIP) which includes:

(a) the Operator's Management Plan;

(b) Aircraft Deicing/Anti-icing Procedures;

(c) Holdover Timetables or HOTDR derived from HOTDS;

(d) Aircraft Inspection and Reporting Procedures; and

(e) Training and Testing.

(3) Operators implementing the use of the DSHOT database within their operations must update their aircraft ground icing programs (GIP) in accordance with the guidance of this AC to ensure compliance with GOFRS 622.11(3)(c).

(4) The operator should be able to demonstrate that the use of DSHOT has the equivalent level of workload for flight crew compared to the typical means of using the HOT Guidelines (e.g. paper or an electronic representation of the HOT Guidelines).

5.0 Operator implementation process

(1) Operators incorporating DSHOT into their operations should carefully review the contents of this AC to determine applicable requirements.

(2) From a process perspective it is envisaged that an operator wishing to incorporate DSHOT data will:

(a) decide on the method by which the DSHOT data will be implemented into its GIP;

(b) discuss any implementation concerns with their respective Principal Operations Inspector (POI);

(c) complete all necessary evaluations, document modification, procedures and training modifications as outlined in the appendices of this AC; and

(d) submit changes to Company Operations Manual (COM) and/or GIP to POI for approval.

5.1 Application and structure of this Advisory Circular

(1) This AC provides the conditions and associated guidance applicable to include the DSHOT database as part of an operator's GIP:

(a) Appendix A: Stipulates the conditions for the use of the DSHOT database.

(b) Appendix B: Provides requirements with respect to data management and security of the DHSOT.

(c) Appendix C: Provides guidance with respect to data verification and user validation.

(d) Appendix D: Provides general procedures and training requirements with respect to the DSHOT database.

(e) Appendix E: Features a checklist for the conditions in Appendix A and guidance found in the other Appendices.

6.0 Information management

(1) Not applicable

7.0 Document history

(1) Not applicable

8.0 Contact us

For more information, please contact:

Chief, Commercial Flight Standards Division (AARTF)
E-mail: AARTFInfo-InfoAARTF@tc.gc.ca

We invite suggestions for amendment to this document. Submit your comments to:

Civil Aviation Communications Centre
E-mail: services@tc.gc.ca

Original signed by Andrew Larsen, for

Félix Meunier
Director, Standards
Civil Aviation
Transport Canada

Appendix A — Conditions on the use of the DSHOT database

General

(1) Degree-Specific Holdover Time (DSHOT) data is provided in the form of a reference table listing ('xls' format) on the most recent Transport Canada DSHOT data publication. Separate DSHOT values are provided for standard anti-icing operations and for operations where flaps and slats are deployed prior to de/anti-icing. The data will be obtainable from the Transport Canada website: https://tc.canada.ca/en/aviation/general-operating-flight-rules/holdover-time-hot-guidelines-icing-anti-icing-aircraft.

(2) For each aircraft de/anti-icing fluid ADF included, DSHOT data is provided at all temperatures decrementing down to the ADF's lowest operational use temperature (LOUT). A 1°C safeguard is incorporated in all DSHOT calculations (i.e. all published DSHOT values are calculated using a temperature that is 1°C colder than the listed temperature). This mitigates the dynamic nature of meteorological conditions that may shift between METAR reports and potential temperature decreasing.

(3) DSHOTs are provided for precipitation rates of 3, 4, 10, and 25 g/dm²/h. These precipitation rates correspond with the lower and upper precipitation rate boundaries for very light snow (3 to 4 g/dm²/h), light snow (4 to 10 g/dm²/h), and moderate snow (10 to 25 g/dm²/h) used in the HOT Guidelines. Certain Type II fluid-specific HOT tables do not include information for very light snow or light snow. Correspondingly, no DSHOT values have been provided at these intensities for these fluids.

(4) Fluid-specific DSHOTs have only been determined for snow conditions where the standard HOTs are derived through regression analysis. There are some exceptions where DSHOTs cannot be calculated, these are:

  (a) Snow HOTs below -14°C for fluids with generic snow HOTs below -14°C; and

  (b) Snow HOTs below -25°C for fluids with:

    (i) Fluid-specific snow HOTs below -14°C, and

    (ii) Fluid LOUT colder than -29.0°C.

(5) In the above-mentioned instances, the related data in the DSHOT database has been populated with the applicable standard (i.e. non-temperature specific) HOTs.

Conditions

(1) The DSHOT database reference tables cannot be used in its published form on its own; the data must be incorporated into an operator's approved GIP and meet the requirements set out in the Appendices of this AC. There are several possible methods by which an operator can utilize the published DSHOT data, including:

  (a) Internal publication of a modified paper HOT table;

  (b) Electronic presentation of a HOT table;

  (c) Incorporation of the DSHOT data into a verified digital display (e.g. Electronic Flight Bag App).

(2) The database must be sourced (e.g. downloaded) from the most recent TCCA DSHOT database publication.

(3) The operator must ensure that the DSHOT database is the most current and their applicable means to present the data such as modified paper tables, an electronic presentation of a HOT table, or an electronic application Electronic Flight Bags (EFB) Application (App) are updated accordingly.

(4) The operator must ensure that all applicable notes and cautions found in the TCCA published HOT guidelines are available when using the DSHOT database and its data presentation. An example of applicable notes and cautions is provided for illustrative purposes below; the operator must still ensure all table-specific notes and cautions appear in the tables that will be part of their GIP.

Table A1: Example of notes and cautions

NOTES
1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type IV fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 42) is required.
3 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4 Includes light, moderate and heavy freezing drizzle. 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, small hail and hail (Table 41 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).
8 If the LOUT is unknown, no holdover time guidelines exist below -22.5°C (-9°F).

CAUTIONS
- The responsibility for the application of these data remains with the user.
- The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable 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.

(5) The DSHOT data may be used in full, or in a partial format as required by the operator based on the operator's areas of operation or their operational requirements, such as:

(a) Operators flying exclusively within North America may not need to include Type II data;

(b) Operators who opt not to use fluid-specific holdover time tables may choose not to include them;

(c) Operators who configure their aircraft with deployed flaps or slats may use the adjusted DSHOT.

Appendix B — Data management and security

Operator requirements

1.1 Assignment of DSHOT Data Administrator

(1) The operator shall designate a DSHOT Data Administrator (DSHOTDA) who is suitably qualified, trained and provided with adequate resources to ensure data integrity of the database.

1.2 Data management procedures

(1) The operator shall establish and maintain documented procedures on the acquisition, management and data presentation of the DSHOT database. These procedures must:

(a) clearly document processes for the acquisition, management and distribution of the data;

(b) define access rights for users and administrators;

(c) provide adequate controls to prevent user corruption of data.

1.3 Data security

(1) DSHOT source data must be protected against unauthorized manipulation. The DSHOTDA must add the appropriate level of protection to any DSHOT reference database which is distributed within the operator's organization.

1.4 Data integrity and verification requirements

(1) Data integrity can be compromised when the original data source (e.g. the DSHOT database) is manipulated to provide the data in a different format. Therefore, the operator shall ensure that end-to-end traceability of data is documented. A detailed verification in accordance with Appendix C shall be completed to ensure migration of the data is accurate and complete at each stage of manipulation.

(2) The verification process shall consist of a series of manual checks of the DSHOT database values within a DSHOT data presentation against the corresponding values published in TCCA DSHOT database. Each DSHOT value for each fluid included within the data presentation shall be verified.

(3) A record of the verification process shall be kept and maintained by the DSHOTDA to ensure that all necessary verification has been performed. The verification record shall clearly demonstrate that all DSHOT values have been verified. Additionally, the verification record shall indicate what date the verification was performed and the person(s), who performed the verification, and which version of the TCCA DSHOT database was used for the check. Blank verification record sheets will be provided within the TCCA DSHOT database. Figure B1 below depicts an example of a completed verification record sheet for one table of DSHOTs (Generic Type IV ADF).

Table B1 – Sample verification table for Generic Type IV ADF DSHOT values

Fluid Name	Ambient Temp (°C)	Snow HOT Rate = 3 g/dm²/h	Verification	Snow HOT Rate = 4 g/dm²/h	Verification	Snow HOT Rate = 10 g/dm²/h	Verification	Snow HOT Rate = 25 g/dm²/h	Verification
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	✓
Database Version:	**V1.0**	**Date of Verification:**		**2020-06-10**		**Verification Performed by:**		**TC**	

(4) The operator shall ensure that the verification process is updated and/or repeated on an annual basis or whenever the DSHOT database or its data presentation is updated, whichever comes first.

1.5 Quality assurance of DSHOT data management

(1) The operator shall have a quality assurance process in place which contains at a minimum:

(a) DSHOT data management related checklists;

(b) DSHOT data management process standards;

(c) DSHOT data management process documentation; and

(d) DSHOT data management oversight/audit.

(2) The operator shall have a process in place which assures that in the event of DSHOT data failure, there is a viable alternative to provide guidance to flight crew to establish holdover times, especially where a failure would lead to the presentation of potentially incorrect or misleading information.

1.6 Degree-Specific Holdover Times data presentation

(1) Readability

(a) Text size and font type for the DSHOT data presentation should ensure readability at the intended viewing distance, and the information layout should ensure clarity and prevent any ambiguity.

(2) Interface and data format

(a) Good data presentation is an important safety factor when DSHOT data is being used. The following are essential design guidelines to be considered when developing a DSHOT data presentation:

(i) Fluid names used in any data presentation shall match those used in the HOT Guidelines;

(ii) Notes and cautions provided in any data presentation shall be worded the same as in the HOT Guidelines;

(iii) The data presentation should minimize the risk of misinterpretation of the DSHOT values; and

(iv) The DSHOT data should be presented in a format that is consistent with the training that end users receive. The interface design, including, but not limited to, color-coding philosophies, and symbols, should be consistent with other representations of HOT within the operator's GIP.

Appendix C — Data verification and operator validation

Data verification

(1) General

(a) Operators shall ensure that the degree-specific holdover time (DSHOT) data presentation intended to be provided to flight crew in either physical media (e.g. paper) or via a digital display (e.g. EFB) is verified.

(b) The operator may appoint a third party to carry out the verification process.

(2) Information and data fields to be verified

(a) At a minimum, the operator shall ensure the following information is verified for each individual aircraft de/anti-icing fluid (ADF) that will be used from the DSHOT database as part of its ground icing program (GIP).

(i) ADF name

(ii) Temperature at each degree (°C) decrement beginning at 3°C down to the ADF's lowest operational use temperature (LOUT). For each degree (°C) :

(A) The ADF's HOT for snow at precipitation rate of 3 g/dm²/h (very light snow)

(B) The ADF's HOT for snow at precipitation rate of 4 g/dm²/h (upper threshold of very light snow and lower threshold of light snow)

(C) The ADF's HOT for snow at precipitation rate of 10 g/dm²/h (upper threshold of light snow and lower threshold of moderate snow)

(D) The ADF's HOT for snow at precipitation rate of 25 g/dm²/h (upper threshold of moderate snow)

Operator validation

(1) As part of its GIP, the operator shall confirm that it has validated the DSHOT data verification process to ensure that the DSHOT data presentation intended to be provided to flight crew in either physical media or via a digital display is verified.

Appendix D — Procedures and training requirements

Degree-Specific Holdover Times – crew training and procedures

(1) Workload

(a) The DSHOT data presentation should be designed to minimize flight crew workload. An evaluation of the DSHOT data presentation should include a qualitative assessment of incremental pilot workload, as well as pilot-system interfaces and their safety implications. The use of DSHOT data should not result in any increase to pilot workload when compared to the use of standard HOT guidance.

(2) Crew procedures

(a) Clear limitations on the use of DSHOT data and crew procedures should be provided and documented.

(b) The procedures shall:

(i) be properly integrated with existing Standard Operating Procedures (SOPs);

(ii) contain suitable crew crosschecks for verifying safety critical data; and

(iii) mitigate and/or control any additional workload associated with the use of DSHOT data.

(3) Training program

(a) The operator shall establish suitable training programs on the use of DSHOT for ground staff, crew members and service providers. Once it is established, the training program must be evaluated to determine that:

(i) the training program is fully documented;

(ii) the training methodology matches the level of knowledge and experience of the participants;

(iii) the operator has assigned adequate resources to deliver the training;

(iv) adequate DSHOT data presentations have been provided;

(v) human factors and cockpit resource management are included in the training; and

(vi) the training material matches both the presentation of the DSHOT data in its final form and the published procedures.

Appendix E — DSHOT database checklist

Item	Checklist item	Acceptable Yes/No/NA	Review date	Remarks
1	**Degree-Specific Holdover Time Data Administrator (DSHOTDA)**			
	Is the appointed DSHOTDA suitably qualified and trained?			
	Are there adequate resources assigned to enable the DSHOTDA to carry out functions?			
2	**Data management procedures**			
	Are there documented processes for the acquisition, management and distribution of the data?			
	Are the access rights for users and administrators to manage data clearly defined?			
	Are there adequate controls to prevent user corruption of data?			
3	**Data security**			
	Have appropriate safeguards been applied to all DSHOT reference files?			
4	**Data integrity and verification**			
	Has the operator ensured that end-to-end traceability of data is documented?			
	Have procedures been documented to log all data management activities for audit and traceability purposes?			
	Has verification of the DSHOT values been performed for all HOT values included within the DSHOT data presentation?			
	Is there a record of the verification process?			
	Is the sourced DSHOT database the most recent and has the verification process of its presentation been updated?			

Item	Checklist item	Acceptable Yes/No/NA	Review date	Remarks
5	**Readability**			
	Do the text size and font ensure readability at the intended viewing distance?			
	Is the DSHOT information layout clear and unambiguous?			
6	**Interface and data format**			
	Are the fluid names in the data presentation consistent with the fluid names in the HOT Guidelines?			
	Are the notes and cautions included in the data presentation worded the same as in the HOT Guidelines?			
	Is the data presentation consistent with the training that end users have received?			
	Is the data presentation consistent with other representations of HOTs within the operator's ground icing program?			
7	**Workload**			
	Has the effect overall impact of including DSHOT data in the data presentation on pilot workload been evaluated?			
8	**Crew procedures**			
	Are there appropriate procedures for crew usage of DSHOT data?			
	Are the procedures clearly presented, suitably illustrated and readily understood?			
	Have crew procedures for the use of DSHOT data been integrated with existing SOPs?			
	Is any additional workload mitigated and/ or controlled?			
9	**Training program**			
	Are flight crew members, and (where applicable) ground staff and service provider training programs fully documented?			

Item	Checklist item	Acceptable Yes/No/NA	Review date	Remarks
	Is the training methodology matched appropriately to the participant's level of experience and knowledge?			
	Has the operator assigned adequate resources (time/personnel/facilities) for training?			
	Does the training material match both the presentation of the DSHOT data in its final form and the published procedures?			
	Does the training program include human factors in relation to DSHOT use?			
	Is there a published recurrent training?			
	Comments			

This page intentionally left blank.

APPENDIX H

EXCERPT OF N 8900.594 – GUIDELINES FOR THE USE OF DEGREE-SPECIFIC HOTs (DSHOT) FOR SNOW

Note: Information regarding a specific system can be obtained from the manufacturer's technical literature. SAE Aerospace Information Report (AIR) 6284, Forced Air or Forced Air/Fluid Equipment for Removal of Frozen Contaminants, provides some information on FAS usage, limitations, and precautions. This document is available at https://www.sae.org/standards/content/air6284.

b. Liquid Water Equivalent Systems (LWES). LWES have been in development for a number of years. They include HOT determination systems (HOTDS). At this time, SureHOT and SureHOT+, provided by SureWx Inc., are the only LWES available by operations specification (OpSpec). All of these systems convert snowfall data and other types of winter precipitation data into liquid water equivalent (LWE) data, which is then used to develop a HOT. The precipitation rate determined by these devices is matched with HOT data developed when fluids are tested in natural snow conditions, and artificial conditions for other precipitation types, to determine a HOT for a particular fluid type in the case of Type I fluids, and for a specific fluid name brand and type for Types II, III, and IV fluids. FAA Order 8900.1, Volume 3, Chapter 27, Section 5, Liquid Water Equivalent Systems, describes the approval process for using these devices to determine HOTs as part of an FAA-approved program.

c. Electronic Hand-Held Devices to Determine Electronic HOTs (eHOT). Electronic devices that determine eHOTs may be used as part of an air operator's § 121.629 winter operations plan submitted to the FAA for approval. If for any reason the device or application fails, or if the user has any concern regarding the accuracy of the data being displayed, printed tables sourced from the FAA HOT Guidelines must be used as a fallback information source. Questions regarding the use of these devices should be submitted via email to charles.j.enders@faa.gov or via phone at 202-267-4557.

13. Guidelines for the Use of Degree-Specific HOTs (DSHOT) for Snow.

a. Background and General Information Relating to DSHOTs.

(1) Beginning in Winter 2021–2022, the FAA is publishing an annual database of DSHOTs for snow and snow-related precipitation conditions (including snow, snow grains, and snow pellets). The DSHOT database contains an expanded set of snow precipitation HOTs (very light snow, light snow, and moderate snow) for all undiluted Type II, III and IV anti-icing fluids listed in the FAA HOT Guidelines. The DSHOT data is provided in the form of a set of reference tables ("xls" format) contained within an annually updated FAA DSHOT data publication. The data is obtainable from the following website: https://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/deicing/.

(2) The DSHOT database is an extension of the FAA HOT Guidelines. The data it contains is derived from the same natural snow test data that is used to calculate the snow HOT values within the standard HOT tables. Within a typical HOT table, HOTs are provided for defined temperature ranges (e.g., -3 °C to -8 °C). The HOTs provided within a given temperature range are based on the coldest temperature of that range. Within the DSHOT database, specific HOT values are provided for each Type II, III, and IV fluid at all temperatures decrementing down to a given fluid's LOUT. A 1 °C safeguard is incorporated in all DSHOT calculations

(i.e., all published DSHOT values are calculated using a temperature that is 1 °C colder than the listed temperature).

(3) DSHOTs are provided as single values for precipitation rates of 3, 4, 10, and 25 g/dm²/h. These precipitation rates correspond with the lower and upper precipitation rate boundaries for very light snow (3 to 4 g/dm²/h), light snow (4 to 10 g/dm²/h), and moderate snow (10 to 25 g/dm²/h) used in the HOT Guidelines. Certain Type II fluid-specific HOT tables do not include information for very light snow or light snow. Correspondingly, no DSHOT values have been provided at these intensities for these fluids.

(4) All notes and cautions that would be applicable to standard snow HOTs within a given HOT table in the FAA HOT Guidelines are also applicable to their corresponding DSHOTs. All users of the DSHOT data shall ensure that the applicable notes and cautions are available for reference.

(5) Fluid-specific DSHOTs have only been determined for snow conditions where the standard snow HOTs are derived through regression analysis. There are some exceptions where DSHOTs cannot be calculated, these are:

(a) Snow HOTs below -14 °C for fluids with generic snow HOTs below -14 °C; and

(b) Snow HOTs below -25 °C for fluids with:

(i) Fluid-specific snow HOTs below -14 °C, and

(ii) Fluid LOUTs colder than -29.0 °C.

Note: In the above-mentioned instances, the related data in the DSHOT database has been populated with the applicable standard (i.e., non-degree-specific) HOTs.

(6) In addition to the fluid-specific DSHOT values, the DSHOT database also contains a set of generic DSHOTs for both Type II and Type IV fluids. The generic DSHOT values for a given fluid type and temperature represent the lowest calculated DSHOT value of all fluids of that type at the specified temperature.

(7) Separate sets of DSHOT values are provided for standard anti-icing operations, and for operations where flaps and slats are extended to the takeoff configuration prior to deicing/anti-icing (identified as "Adjusted" DSHOT values).

b. Presentation of DSHOT Data.

(1) The DSHOT database is impractical for direct use in its published format. There are several possible methods by which an air operator can present the published DSHOT data, including:

(a) Internal publication of a modified paper HOT table.

(b) Incorporation of the DSHOT data into a verified digital display (e.g., an eHOT app).

(2) An air operator's chosen DSHOT data presentation can incorporate the DSHOT database in full, or in a customized format as preferred by the operator. For example:

(a) Air operators flying exclusively within North America may choose not to include Type II data.

(b) Air operators who opt not to use fluid-specific HOT tables may choose not to include them.

(c) Air operators who operate with their flaps and slats extended to the takeoff configuration prior to deicing/anti-icing may choose to list only the adjusted DSHOT values.

(3) Any data presentation used must be updated annually (or whenever the DSHOT database is updated) and shall incorporate the relevant notes and cautions that would be found in the corresponding FAA HOT Guidelines tables.

c. Validation of DSHOT Data.

(1) Data integrity can be compromised when the original data source (i.e., the DSHOT database) is manipulated to provide the data in a different format. Any operator making use of the DSHOT data in a modified format shall employ a detailed verification process to ensure that the data presented is accurate and complete. This verification process shall consist of a series of manual checks of the DSHOT data within a DSHOT data presentation (e.g., a modified paper table or an eHOT app) against the corresponding values published in the most recent FAA DSHOT database publication. At a minimum, the air operator shall ensure the following information is verified for each individual anti-icing fluid that will be used from the DSHOT database:

(a) Fluid name.

(b) Temperature at each degree (°C) decrement down to the fluid's LOUT. For each degree (°C):

(i) The DSHOT value at a precipitation rate of 3 g/dm²/h (lower threshold of very light snow).

(ii) The DSHOT value at a precipitation rate of 4 g/dm²/h (upper threshold of very light snow and lower threshold of light snow).

(iii) The DSHOT value at a precipitation rate of 10 g/dm²/h (upper threshold of light snow and lower threshold of moderate snow).

(iv) The DSHOT value at a precipitation rate of 25 g/dm²/h (upper threshold of moderate snow).

(2) A record of the verification process shall be kept and maintained and this record shall clearly demonstrate that all DSHOT values within a data presentation have been verified. The verification process shall be updated and/or repeated on an annual basis (or whenever the DSHOT database or its data presentation is updated, whichever comes first).

d. Temperature Inputs for Use With DSHOTs.

(1) All users of the published DSHOT data must ensure that all temperature inputs used are from an FAA-approved weather source (e.g., METAR/Aviation Selected Special Weather Report (SPECI)/Automatic Terminal Information Service (ATIS)). The current edition of AC 00-45, Aviation Weather Services, provides guidance on appropriate sources of temperature data.

(2) The aircraft commander is responsible to ensure the conditions (including the OAT) used to determine the DSHOT value remain correct until takeoff.

14. Concerns/Conditions.

a. Starting and Stopping the HOT Clock. Once the HOT time clock has been started, it must not be stopped for intermittent precipitation. Intermittent precipitation conditions during ground icing operations are a common occurrence at some airports. As precipitation falls on an aircraft that has been anti-iced, the fluid is diluted. The more diluted the fluid becomes, the more readily it flows off the aircraft, and the higher the freezing point becomes. Even if the precipitation stops, the diluted fluid will continue to flow off the aircraft due to gravity. There is no practical way to determine how much residual anti-icing fluid is on the wing under these circumstances. HOT values under these conditions have not been assessed. Therefore, after the anti-icing HOT clock has been started, it must not be stopped. HOT credit cannot be given due to the fact that the precipitation has temporarily stopped falling.

b. Flightcrew Awareness of Conditions Affecting the Aircraft Anti-Icing Treatment Following Deicing and Anti-Icing Operations. The operator's deicing plan must provide a process that informs the captain of the time of the deicing/anti-icing treatment and conditions that could have affected the aircraft anti-icing treatment since that time. If the flightcrew is not present at the time of the deicing/anti-icing application, the crew will review this information before calculating the HOT.

c. Early Fluid Failure on Extended Slats and Flaps.

(1) Research into HOTs on deployed flaps/slats began in Winter 2009–2010, and since Winter 2011–2012 has included cooperative efforts with industry. Data collected has provided a substantive amount of evidence that demonstrates extended flaps/slats can accelerate anti-icing fluid runoff from aircraft wings, in turn negatively affecting the protection capacity of the fluid. This results in a potential safety risk. The protection capacity of the fluid is affected by many elements: the aircraft design, the slope of the surface, the type of fluid, the aircraft skin and ambient temperature, the type of precipitation, the amount of fluid applied, and the effective wind.

APPENDIX I

PROCEDURE:
VERTICAL SURFACES TESTING – EFFECT OF VIBRATION DURING AIRCRAFT TAXI ON FLUID AND CONTAMINATION

300293

PROCEDURE:

VERTICAL SURFACES TESTING – EFFECT OF VIBRATION DURING AIRCRAFT TAXI ON FLUID AND CONTAMINATION

Winter 2020-21

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

Prepared by: Diana Lalla

Reviewed by: Marco Ruggi

February 23, 2021
Final Version 1.0

VERTICAL SURFACES TESTING – EFFECT OF VIBRATION DURING AIRCRAFT TAXI ON FLUID AND CONTAMINATION

Winter 2020-21

1. BACKGROUND

There is a lack of standardization in the treatment of vertical surfaces. Some operators in the United States and Canada exclude the treatment of vertical surfaces, including the tail, while others only consider treatment in ongoing freezing precipitation. Some reports have also indicated that treatment of the tail may worsen takeoff performance as the anti-icing fluid on the tail may lead to increased accumulation of contamination in active precipitation conditions.

Current Transport Canada (TC) and Federal Aviation Administration (FAA) rules and regulations require that critical surfaces be free of contamination prior to takeoff. The vertical stabilizer is defined as a critical surface by both TC and the FAA. However, from a regulatory implementation and enforcement standpoint, there is currently no standardized guidance that offers inspectors a means to determine if an air operator is complying with operational rules. If current operational rules aim to achieve the clean aircraft concept – which requires the tail to have zero adhering frozen contamination – the question remains: How can this be adequately achieved, or appropriately mitigated by operators, to ensure a satisfactory level of safety?

The research conducted to date has demonstrated the variability in the fluid protection times and characteristics of contamination that can be present on vertical surfaces. Further research would provide a better understanding of the influence of the different variables including the rate and type of precipitation, along with wind conditions and other meteorological conditions.

The effect of vibration during taxiing on fluid adherence to the vertical surfaces has yet to be evaluated. The following describes the preliminary plan to compare contamination on vibrating and stationary vertical surfaces. The results will provide direction for future testing and wind tunnel tests.

2. OBJECTIVE

The objective of this research is the following:

1. Evaluate the effects of vibration during taxiing on fluid adherence to vertical tail with and without contamination.

3. DETERMINATION OF PARAMETERS USED TO SIMULATE VIBRATION DURING TAXI

In order to simulate the effect of taxiing vibration on fluid adherence to vertical surfaces, representative targets were chosen for vibration frequency and amplitude based on available data.

Accelerometer data from two reports was used to calculate average frequency and amplitude of the vibration. The reports referenced were, Airport Pavement Roughness Study conducted by Cherokee CRC, LLC with the FAA, outlined in the report, DOT/FAA/TC 18/8, *Boeing 737-800 Final Surface Roughness Study Data Collection* (1) and DOT/FAA/TC 18/13, *Airbus A330-200 Final Surface Roughness Study Data Collection* (2). The studies modeled profiles from real-world airport surfaces of varying roughness, recording resulting cockpit acceleration in both a Boeing 737-800 and an Airbus A330-200 flight simulator. The data from the taxiway profile with the highest level of roughness and consequently highest vibration acceleration was chosen as the most conservative case to test.

Another study reviewed was conducted on a Dornier DO 228-101 documented in the report *Taxi Vibration Testing – An Alternative Method to Ground Vibration Testing of Large Aircraft* (3). In this case, accelerometers were installed on the aircraft which was pulled by a tractor along the taxiway.

The data from the above-mentioned reports was analyzed and the basic parameters for the proposed testing were derived; this data is included in Table 3.1.

Table 3.1: Summary of APS Calculated Vibration Parameters Based on Literature Review

Aircraft	Taxi speed (km/hr)	Vibration Frequency (Hz)	Vibration Amplitude (mm)
Boeing 737-800 Simulator	37	3.1	5.3
Airbus A330-200 Simulator	37	3.5	2.66
Dornier DO 228-101	"slow speed"	2.33	5

4. PROCEDURE

To evaluate the effects of vibration on the fluid endurance times when applied to vertical surfaces, a test plate positioned at 80° will be made to vibrate by means of a reciprocating linear actuator installed on the test stand, and the fluid performance will be compared to that of fluid applied to a non-vibrating test plate and baseline 10º plate.

4.1 Test Surfaces

Three plates will be used for testing, with the stationary and vibrating plates on separate stands:

- Position 1: 10° Test Plate treated with Type I/Type IV Fluid;
- Position 2: 80° Test Plate treated with Type I/Type IV Fluid; and
- Position 3: 80° Test Plate equipped with actuator (for vibration) treated with Type I/Type IV Fluid.

Figure 4.1 depicts the intended setup.

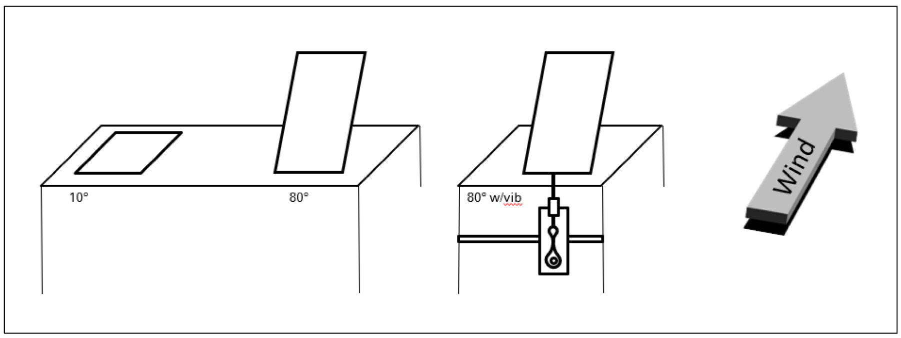


Figure 4.1: Outdoor Testing Setup

4.2 General Procedure

4.2.1 Comparative Fluid Thickness Tests

The objective of this activity is to conduct tests to characterize and compare fluid thickness decay profiles following de/anti-icing on a 10° plate, 80° plate, and vibrating 80° plate. Tests will be conducted with Type I and Type IV fluids and measurements will be taken over a 30-minute period. The standard thickness testing procedure will be followed. The following are some procedural notables:

- For the Type I fluids, 0.5 L of fluid should be applied on a box at 60°C with a warm-soaked 12-hole spreader. The current setup does not allow the use of boxes, therefore consider heated fluid on a plate;

- For the Type IV Fluid, 1 L of fluid should be applied to a test plate at outside air temperature (OAT) using a pour container;
- After fluid application, fluid thickness should be measured at 5, 10, 15 and 30 minutes; and
- Fluid thickness should be measured at the 15 cm line of the plates.

4.2.2 Comparative Endurance Time Tests

Standard endurance time testing procedures for natural snow conditions will be followed. The following are some procedural notables:

- For the Type I fluids, 0.5 L of fluid should be applied on a box at 60ºC with a warm-soaked 12-hole spreader. The current setup does not allow the use of boxes, therefore consider heated fluid on a plate;
- For the Type IV Fluid, 1 L of fluid should be applied to a test plate at OAT using a pour container;
- Measure fluid thickness 5-min after application, and the Brix once contamination covers more than 1/3 of the test plate;
- Fluid protection times should be recorded for the fluid applied to each of the surfaces (1/3 of the test plate);
- After the baseline plate has more than 1/3 of the test plate contaminated, re-measure Brix, and thickness (a ruler may be required if very thick) and characterize the type of contamination present. Adherence inspections should also be conducted and documented if present;
- Rate measurements should be conducted before fluid application, after each standard plate failure, and every 5-10 minutes during the test;
- Fluid protection times and characterization of the contamination should be recorded for the fluid applied to each of the surfaces in Attachment 2: End Condition Data Form; and
- Photos of each plate should be taken at 10-minute intervals.

5. TEST PLAN

Testing is to be conducted in natural conditions. A test thickness testing plan is included in Table 5.1. A fluid endurance time testing plan is included in Table 5.2. The test runs are not specific to precipitation rate or outside temperature; however, a variety of different conditions are preferred.

Table 5.1: Fluid Thickness Test Plan

Fluid Thickness Tests					
Test #	**Plate 1**	**Plate 2**	**Plate 3**	**Fluid Type**	**Temperature**
TH1	10 °	80 °	80 ° w/ vib.	TI	≤ -10°C
TH2	10 °	80 °	80 ° w/ vib.	TIV (EG or PG)	≤ -10°C
TH3	10 °	80 °	80 ° w/ vib.	TI	≥ -5°C
TH4	10 °	80 °	80 ° w/ vib.	TIV (EG or PG)	≥ -5°C

Table 5.2: Fluid Endurance Time Test Plan

Endurance Time Tests					
Test #	**Plate 1**	**Plate 2**	**Plate 3**	**Fluid Type**	**Temperature**
1	10 °	80 °	80 ° w/ vib.	TIV EG	≤ -10°C
2	10 °	80 °	80 ° w/ vib.	TIV PG	≤ -10°C
3	10 °	80 °	80 ° w/ vib.	TIV EG	≥ -5°C
4	10 °	80 °	80 ° w/ vib.	TIV PG	≥ -5°C
5 (Optional)	10 °	80 °	80 ° w/ vib.	TI	any

6. FLUIDS

Testing will primarily be performed with any available commercial fluids of mid-production viscosity (for comparative testing). If in surplus and available, lowest on-wing viscosity (LOWV) or suitable prototype fluids can also be used.

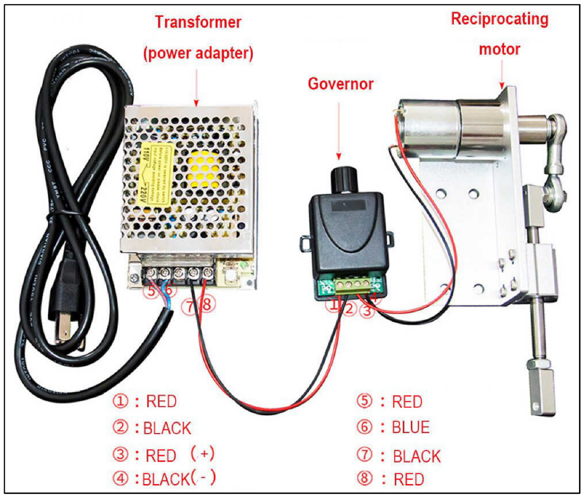
About 24 L of TIV and 3 L of TI are required.

7. EQUIPMENT

Standard equipment used for endurance tests outdoors will be used, except for the stands required to position the test plates at 80° from the horizontal and the reciprocating linear actuator used to generate vibration. An accelerometer will be attached to the test plate to measure the vibration profile.

Photo 7.1: Reciprocating Linear Actuator

Photo 7.2: Reciprocating Linear Actuator Wiring



8. DATA FORMS

The following data forms will be used for testing:

- Attachment 1: Thickness Data Form; and
- Attachment 2: End Condition Data Form.

Rate measurements will be done using the electronic rate form typically used for endurance time testing.

9. PERSONNEL

A minimum of two persons will be required for the conduct of these tests. A third assistant would be beneficial for setup, fluid application, and tear down.

10. REFERENCES

1. Ballew, J., Hudspeth, S., Sparkman, J., Stapleton, D., *Boeing 737-800 Final Surface Roughness Study Data Collection*, FAA, February 2017, DOT/FAA/TC-18/8, 75.

2. Cherokee CRC, LLC, *Airbus A330-200 Final Surface Roughness Study Data Collection*, FAA, May 2020, DOT/FAA/TC 18/13, 55

3. Böswald M., Govers, Y., *Taxi Vibration Testing – An Alternative Method to Ground Vibration Testing of Large Aircraft, ISMA 2008 - International Conference on Noise and Vibration Engineering*, Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Aeroelasticity, Bunsenstr. 10, 37073 Göttingen, Germany, January 2008, 14.

Attachment 1: Thickness Data Form

THICKNESS DATA FORM - VIBRATING VERTICAL SURFACE

DATE ________

TEST MGR ________

Time of Fluid Application: ________ ________ ________

TIME (min)	10° THICKNESS 15 CM LINE	80° THICKNESS 15 CM LINE	80° w/ vib. THICKNESS 15 CM LINE
5			
10			
15			
30			

FLUID INFORMATION

Fluid Name: ________

Fluid Type: ________

Fluid Dilution: ________

Batch #: ________

Initial Brix: ________

Initial Temp: ________

EC HOURLY DATA

RECORDED AT END OF POUR TIME

TEMP _____ °C

WIND SPEED ____km/h

WIND DIRECTION _____.

TEST STAND DIRECTION: ______°

COMMENT:

____

Attachment 2: End Condition Data Form

END CONDITION DATA FORM - VIBRATING VERTICAL SURFACE

DATE ______

TEST MGR ______

Time of Fluid Application:	______	______	______
Time of 1/3 Cont:	______	______	______
	10°	80°	80° w/ vib.
Description of Contamination @ Baseline End (Draw)			
TH @ 5 MINS	/	/	/
BRIX @ FAILURE	/	/	/
TH @BASELINE END		/	/
BRIX @ BASELINE END		/	/
Adherence Present (Check if Yes)	☐	☐	☐

FLUID INFORMATION

Fluid Name: ______

Fluid Type: ______

Fluid Dilution: ______

Batch #: ______

Initial Brix: ______

Initial Temp: ______

EC HOURLY DATA

RECORDED AT END OF POUR TIME

TEMP _____ °C

WIND SPEED ____km/h

WIND DIRECTION _____.

TEST STAND DIRECTION: ______°

COMMENT:

______

APPENDIX J

LOG OF TESTS

Log of Endurance Time Tests

Run #	Date	Condition	Fluid Type	Dilution	Surface	OAT (°C)	Fluid Start Temperature (°C)	Precipitation Rate ($g/dm^2/h$)	Wind Speed (km/h)	Endurance Time (min)	Adjusted Endurance Time (min)	Baseline Endurance Time (min)	Ratio of Endurance Time to Baseline (%)	Thickness @ 5 min (mm)	Brix @ Fail (°)	Thickness @ Baseline End (mm)	Brix @ Baseline End (°)
	24-Feb-21	Natural Snow	IV PG	100%	10° Plate	0.5	1.5	21.5	15.6	76.0	76.0	76.0	100%	1.7	3.00	3.9	3.00
1	24-Feb-21	Natural Snow	IV PG	100%	80° Plate	0.5	1.5	19.9	13.2	45.0	41.7	76.0	55%	0.6	0.00	5.7	0.00
	24-Feb-21	Natural Snow	IV PG	100%	80° Vib Plate	0.4	1.5	19.6	11.8	36.0	32.8	76.0	43%	0.6	0.50	7.0	0.00
	27-Feb-21	Natural Snow	IV PG	100%	10° Plate	0.0	-4.6	11.5	24.2	107.0	107.0	107.0	100%	1.5	3.25	5.7	3.25
2	27-Feb-21	Natural Snow	IV PG	100%	80° Plate	0.0	-4.6	8.0	24.8	76.0	53.2	107.0	50%	0.5	0.25	0.0	0.25
	27-Feb-21	Natural Snow	IV PG	100%	80° Vib Plate	0.0	-4.6	8.0	24.8	76.0	53.2	107.0	50%	0.4	0.00	0.0	0.00
	2-Mar-21	Natural Snow	IV PG	100%	10° Plate	-8.3	-9.6	4.9	9.7	135.0	135.0	135.0	100%	1.1	16.50	2.9	16.50
3	2-Mar-21	Natural Snow	IV PG	100%	80° Plate	-8.5	-9.6	4.7	11.6	58.0	55.5	135.0	41%	0.4	14.75	5.7	0.00
	2-Mar-21	Natural Snow	IV PG	100%	80° Vib Plate	-8.5	-9.6	4.7	11.3	64.0	61.8	135.0	46%	0.4	15.50	5.7	0.00
	1-Apr-21	Natural Snow	IV EG	100%	10° Plate	-1.4	4.5	15.7	26.0	122.8[1]	122.8[1]	122.8[1]	100%	3.3	n/a	n/a	n/a
4	1-Apr-21	Natural Snow	IV EG	100%	80° Plate	-1.4	4.5	15.7	26.0	13.8	13.7	122.8[1]	11%	0.8	3.75	2.2	0.50
	1-Apr-21	Natural Snow	IV EG	100%	80° Vib Plate	-1.4	4.5	15.3	26.0	8.3	8.1	122.8[1]	7%	0.7	3.00	2.5	0.00
	21-Apr-21	Natural Snow	IV EG	100%	10° Plate	-1.4	1.9	9.0	15.6	131.0	131.0	131.0	100%	2.2	4.75	0.2	4.75
5	21-Apr-21	Natural Snow	IV EG	100%	80° Plate	-1.2	1.9	5.4	18.0	41.0	24.7	131.0	19%	0.6	0.50	8.9	0.00
	21-Apr-21	Natural Snow	IV EG	100%	80° Vib Plate	-1.2	1.9	4.9	18.0	35.0	19.2	131.0	15%	0.6	0.25	10.2	0.00
	21-Apr-21	Natural Snow	IV EG	100%	10° Plate	-1.0	2.0	10.8	9.2	170.0	170.0	170.0	100%	3.5	0.50	0.1	0.50
6	21-Apr-21	Natural Snow	IV EG	100%	80° Plate	-1.6	2.0	18.8	11.0	26.0	45.4	170.0	27%	1.0	2.75	0.0	0.00
	21-Apr-21	Natural Snow	IV EG	100%	80° Vib Plate	-1.6	2.0	19.9	11.0	23.0	42.4	170.0	25%	0.8	2.50	0.0	0.00

[1] 10 degree plate did not fail, time is estimated

Log of Thickness Tests

Run #	Date	Condition	Fluid Type	Dilution	Surface	Ambient Temperature (°C)	Fluid Start Temperature (°C)	Measurement Location from top edge (cm)	Thickness @ 5 min (mm)	Thickness @ 10 min (mm)	Thickness @ 15 min (mm)	Thickness @ 30 min (mm)	Thickness @ 60 min (mm)	Thickness @ 90 min (mm)
1	24-Mar-21	Refrigerated Truck	I	42%	10° Plate	-7.4	60	15	0.0	0.0	0.0	0.0	-	-
	24-Mar-21	Refrigerated Truck	I	42%	80° Plate	-7.4	60	15	0.0	0.0	0.0	0.0	-	-
	24-Mar-21	Refrigerated Truck	I	42%	80° Vib Plate	-7.4	60	15	0.0	0.0	0.0	0.0	-	-
2	24-Mar-21	Refrigerated Truck	IV PG	100%	10° Plate	-10.3	-3.9	15	1.1	1.0	0.8	0.6	-	-
	24-Mar-21	Refrigerated Truck	IV PG	100%	80° Plate	-10.3	-3.9	15	0.4	0.3	0.2	0.2	-	-
	24-Mar-21	Refrigerated Truck	IV PG	100%	80° Vib Plate	-10.3	-3.9	15	0.3	0.3	0.2	0.2	-	-
3	24-Mar-21	Refrigerated Truck	IV PG	100%	10° Plate	-3.7	-2.8	15	1.3	1.2	1.0	1.0	-	-
	24-Mar-21	Refrigerated Truck	IV PG	100%	80° Plate	-3.7	-2.8	15	0.3	0.4	0.3	0.3	-	-
	24-Mar-21	Refrigerated Truck	IV PG	100%	80° Vib Plate	-3.7	-2.8	15	0.3	0.4	0.3	0.3	-	-
4	25-Mar-21	Refrigerated Truck	IV EG	100%	10° Plate	-6.9	-7.8	15	2.9	2.2	2.2	1.5	1.2	1.0
	25-Mar-21	Refrigerated Truck	IV EG	100%	10° Plate	-6.9	-7.8	23	3.1	2.5	2.2	1.7	1.3	1.1
	25-Mar-21	Refrigerated Truck	IV EG	100%	10° Plate	-6.9	-7.8	30	3.3	2.9	2.5	1.9	1.5	1.3
	25-Mar-21	Refrigerated Truck	IV EG	100%	10° Plate	-6.9	-7.8	38	3.3	2.7	2.5	2.2	1.7	1.3
	25-Mar-21	Refrigerated Truck	IV EG	100%	10° Plate	-6.9	-7.8	48	3.3	2.9	2.7	2.2	1.9	1.5
	25-Mar-21	Refrigerated Truck	IV EG	100%	80° Plate	-6.9	-7.8	15	0.6	0.5	0.4	0.4	0.4	0.3
	25-Mar-21	Refrigerated Truck	IV EG	100%	80° Plate	-6.9	-7.8	23	0.7	0.5	0.5	0.4	0.4	0.4
	25-Mar-21	Refrigerated Truck	IV EG	100%	80° Plate	-6.9	-7.8	30	0.7	0.5	0.5	0.5	0.4	0.4
	25-Mar-21	Refrigerated Truck	IV EG	100%	80° Plate	-6.9	-7.8	38	1.0	0.6	0.7	0.5	0.5	0.4

Log of Thickness Tests (cont'd)

Run #	Date	Condition	Fluid Type	Dilution	Surface	Ambient Temperature (°C)	Fluid Start Temperature (°C)	Measurement Location from top edge (cm)	Thickness @ 5 min (mm)	Thickness @ 10 min (mm)	Thickness @ 15 min (mm)	Thickness @ 30 min (mm)	Thickness @ 60 min (mm)	Thickness @ 90 min (mm)
4	25-Mar-21	Refrigerated Truck	IV EG	100%	80° Plate	-6.9	-7.8	48	0.8	0.8	0.7	0.5	0.6	0.4
	25-Mar-21	Refrigerated Truck	IV EG	100%	80° Vib Plate	-6.9	-7.8	15	0.5	0.5	0.5	0.4	0.4	0.3
	25-Mar-21	Refrigerated Truck	IV EG	100%	80° Vib Plate	-6.9	-7.8	23	0.7	0.5	0.5	0.5	0.4	0.3
	25-Mar-21	Refrigerated Truck	IV EG	100%	80° Vib Plate	-6.9	-7.8	30	0.7	0.5	0.5	0.5	0.5	0.4
	25-Mar-21	Refrigerated Truck	IV EG	100%	80° Vib Plate	-6.9	-7.8	38	1.0	0.7	0.6	0.5	0.4	0.4
	25-Mar-21	Refrigerated Truck	IV EG	100%	80° Vib Plate	-6.9	-7.8	48	1.0	0.7	0.6	0.6	0.5	0.4

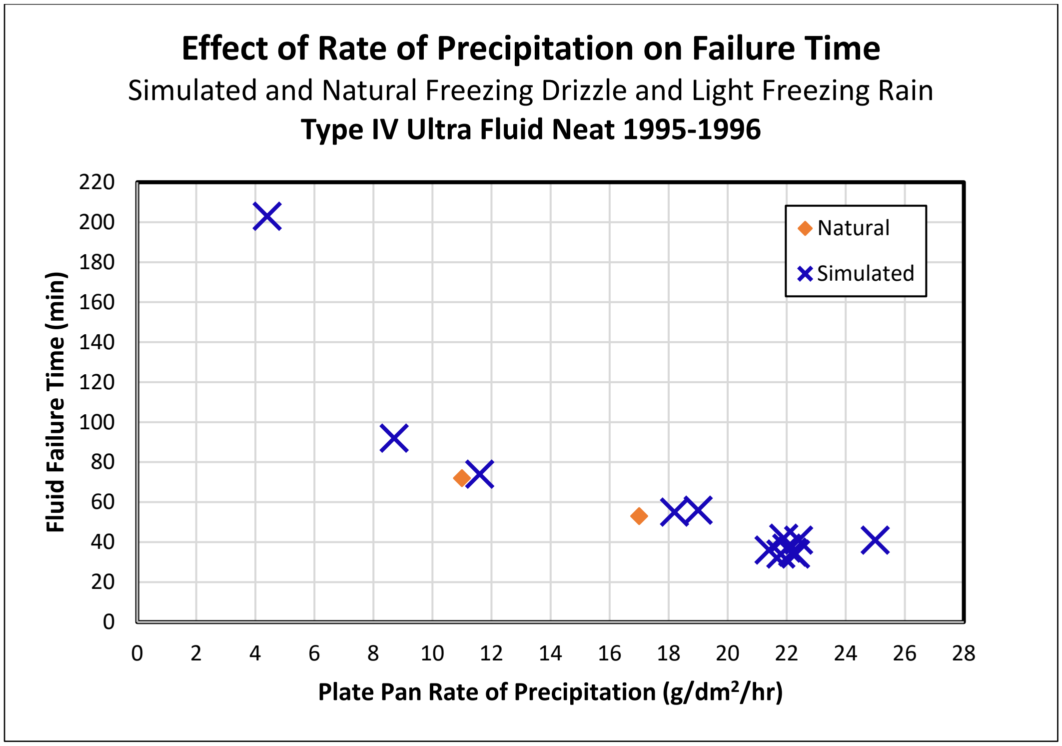
This page intentionally left blank.

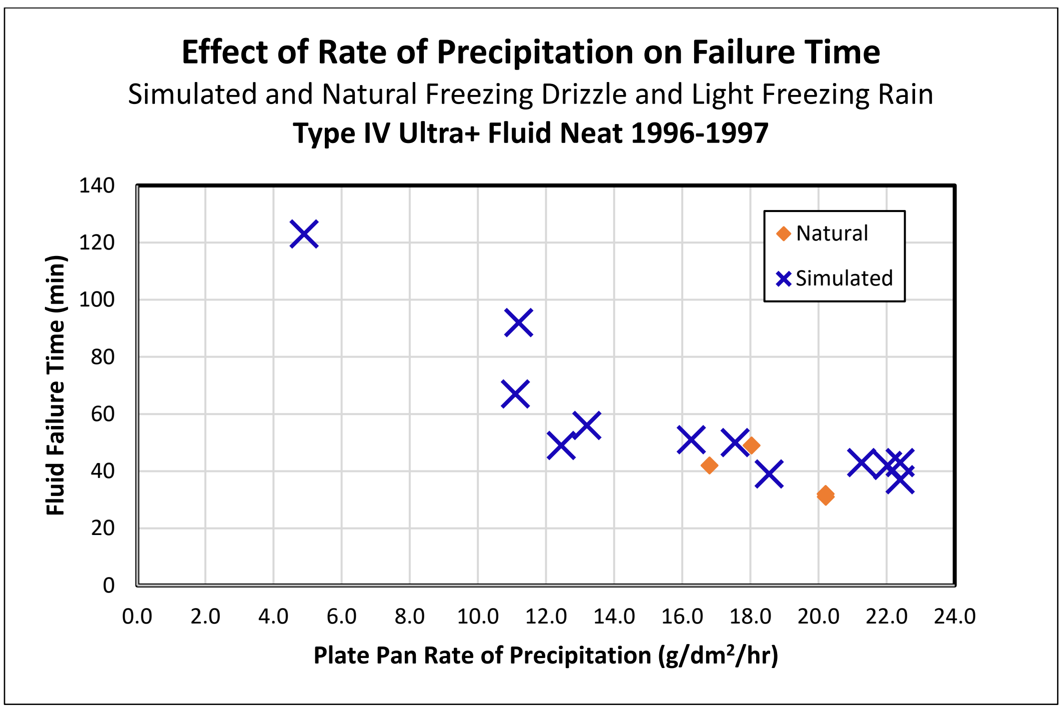
APPENDIX K

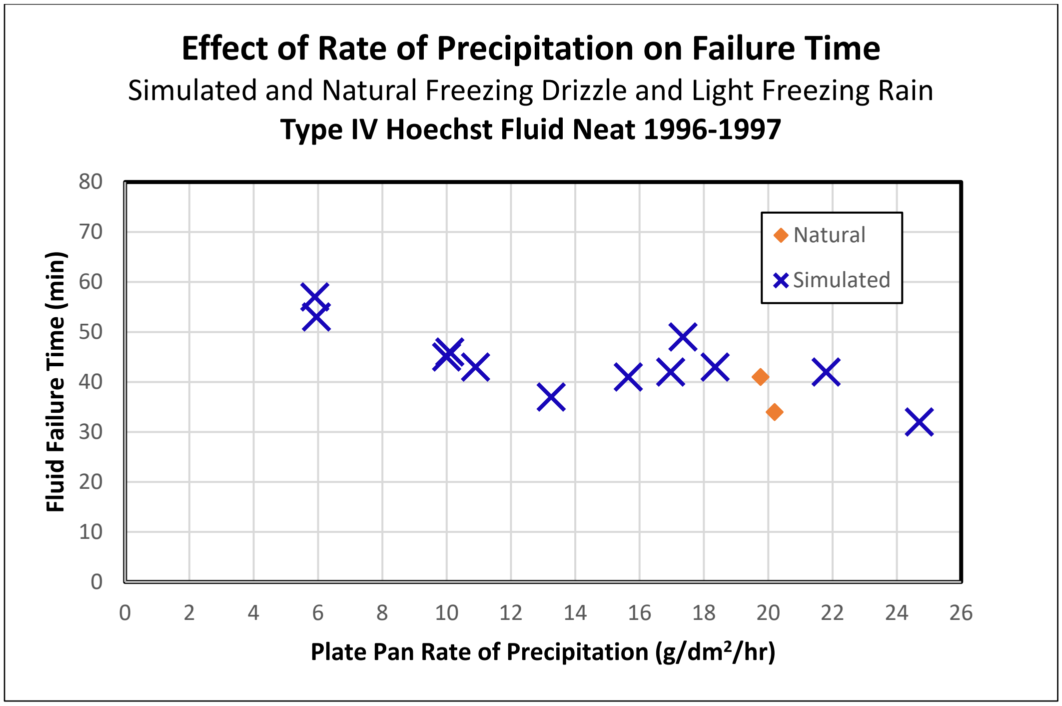
COMPARATIVE TESTING – NATURAL VS. SIMULATED LIGHT FREEZING RAIN CONDITIONS (1995-97)

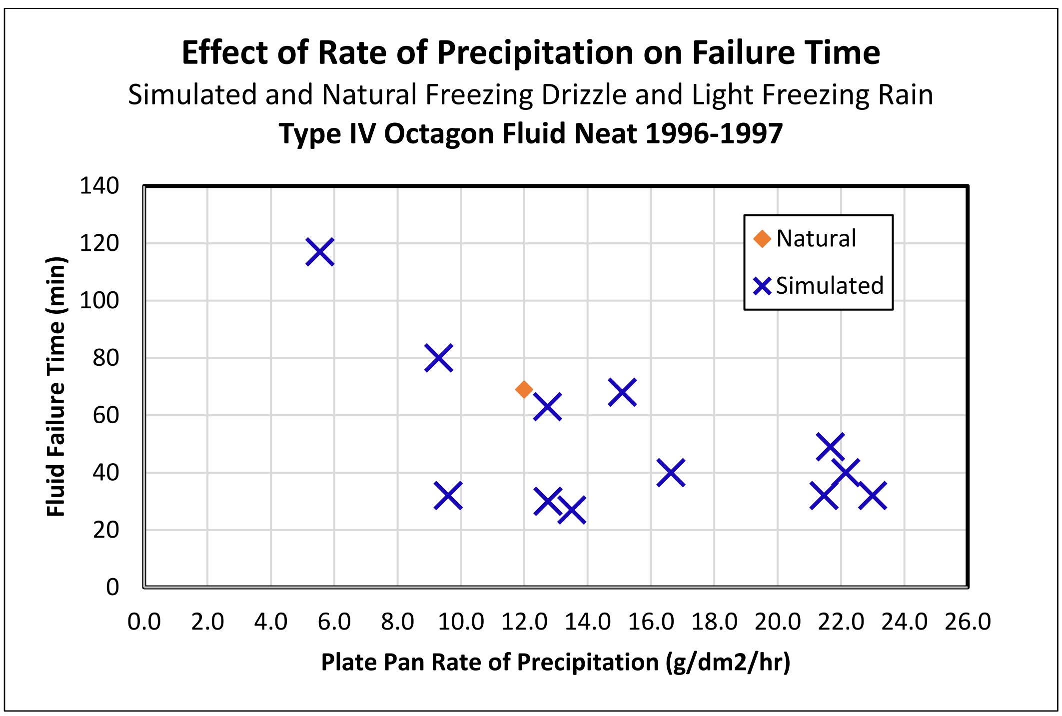
Ultra/Ultra+ Comparison of Holdover Times in –ZR Natural vs. Simulated

Year	1st Step Fluid	2nd Step Fluid	Test Surface	Natural vs. Simulated Precip	Temperature (°C)	Precipitation Rate ($g/dm^2/h$)	Failure Time (min)	Source
1995/96	XL54	Ultra	DC-9-30 Wing	Natural	-1	11	67	TP 12901E
1995/96	XL54	Ultra	Flat Plate	Natural	-1	11	72	
1995/96	XL54	Ultra	DC-9-30 Wing	Natural	-1	17	59	
1995/96	XL54	Ultra	Flat Plate	Natural	-1	17	53	
1995/96	-	Ultra	Flat Plate	CEF	-2.8	18.2	55	TP 12896E
1995/96	-	Ultra	Flat Plate	CEF	-2.8	22.4	41	
1996/97	XL54	Ultra+	B-737	Natural	-3.2	16.1	40	TP 13130E
1996/97	XL54	Ultra+	Flat Plate	Natural	**-3.2**	**16.8**	**42**	
1996/97	-	Ultra+	Flat Plate	CEF	-2.7	17.6	50	TP 13131E
1996/97	-	Ultra+	Flat Plate	CEF	**-2.7**	**16.8**	**48**	*estimate from curve
1996/97	-	Ultra+	Flat Plate	CEF	-2.8	22.4	43	-
1996/97	-	Ultra+	Flat Plate	CEF	-3.3	21.3	43	-
1996/97	-	Ultra+	Flat Plate	CEF	-2.8	22.4	37	-


Effect of Rate of Precipitation on Failure Time
Simulated and Natural Freezing Drizzle and Light Freezing Rain
Type IV Ultra Fluid Neat 1995-1996
Fluid Failure Time (min)
220
200
180
160
140
120
100
80
60
40
20
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Plate Pan Rate of Precipitation (g/dm²/hr)
Natural
Simulated


Effect of Rate of Precipitation on Failure Time
Simulated and Natural Freezing Drizzle and Light Freezing Rain
Type IV Ultra+ Fluid Neat 1996-1997
Fluid Failure Time (min)
140
120
100
80
60
40
20
0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0
Plate Pan Rate of Precipitation (g/dm²/hr)
Natural
Simulated


Effect of Rate of Precipitation on Failure Time
Simulated and Natural Freezing Drizzle and Light Freezing Rain
Type IV Hoechst Fluid Neat 1996-1997
Fluid Failure Time (min)
0
10
20
30
40
50
60
70
80
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Plate Pan Rate of Precipitation (g/dm²/hr)
Natural
Simulated

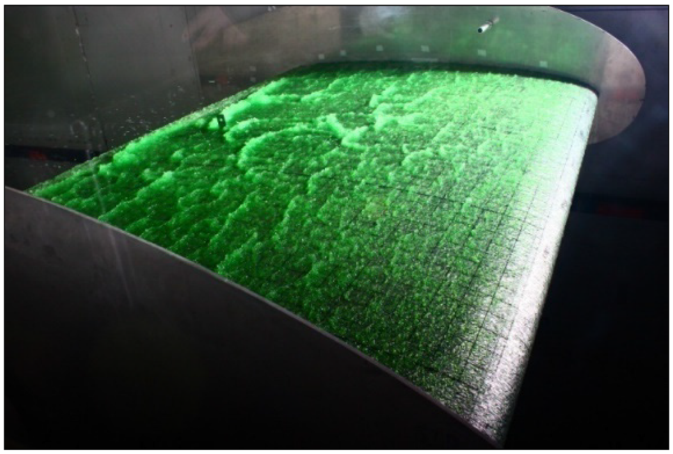

Effect of Rate of Precipitation on Failure Time
Simulated and Natural Freezing Drizzle and Light Freezing Rain
Type IV Octagon Fluid Neat 1996-1997
Fluid Failure Time (min)
0
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
Plate Pan Rate of Precipitation (g/dm2/hr)
Natural
Simulated

This page intentionally left blank.

APPENDIX L

TEST METHODS AND PROTOCOLS FOR THE DEVELOPMENT OF ICE PELLET ALLOWANCE TIMES

Test Methods and Protocols for the Development of Ice Pellet Allowance Times



This document was prepared as working document for reference purposes.

Prepared by: Diana Lalla

Reviewed by: Marco Ruggi

APS Aviation Inc.

September 24, 2021
Final Version 1.0

CONTENTS Page

TABLE OF CONTENTS

LIST OF TABLES Page

LIST OF FIGURES Page

LIST OF EQUATIONS Page

1. SCOPE

Due to their physical characteristics, ice pellets tend to become partially embedded in aircraft ground anti-icing fluids and can take longer to melt compared to snow or other forms of precipitation. For this reason, the visual indicators used in endurance time testing of other precipitation types (which result in holdover times) cannot be applied to develop holdover time guidance for conditions with ice pellets.

As a result, a test protocol for wind tunnel testing was developed to provide operational guidance in ice pellet conditions. The test protocol uses a combination of aerodynamic parameters measuring fluid flow off performance of ice pellet-contaminated fluids in combination with the visual inspection and evaluation of a wing model test surface. The resulting guidance derived from this testing is known as "allowance times." This guidance is also applicable to small hail due to inherent similarities to ice pellets.

Prior to the drafting of this new manual, the testing protocol and procedures were only documented in published technical reports by APS, NRC and NASA. As well, additional information existed only in internal APS procedural documentation or was not documented at all. It was recommended that the ice pellet testing protocols and procedures be formally recorded in this comprehensive document to serve as a reference for on-going research and future historical purposes.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of publication. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE International Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS1424 Fluid, Aircraft Deicing/Anti-Icing, SAE Type 1

AMS1428	Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV
AMS1428/1	Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV Glycol (Conventional and Non-Conventional) Based
AMS1428/2	Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV Non-Glycol Based
ARP5485	Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Type II, III, and IV
ARP5718	Qualifications Required for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluids
AS5900	Standard Test Method for Aerodynamic Acceptance of AMS1424 and AMS1428 Aircraft Deicing/Anti-Icing Fluids
AS9968	Laboratory Viscosity Measurement of Thickened Aircraft Deicing/Anti-icing Fluids with the Brookfield LV Viscometer

2.1.2 ASTM International Publications

Available from ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Tel: 877-909-2786 (inside USA and Canada) or +1 610-832-9500, www.astm.org.

ASTM D1747-09(2019)	Standard Test Method for Refractive Index of Viscous Materials
ASTM D2196-20	Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational Viscometer

2.1.3 Federal Aviation Administration Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

FAA Holdover Time Guidelines. (These are published every winter. Always use the latest issue; search for "FAA Holdover Time" at www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/deicing/.)

FAA-Approved Deicing Program Updates, Winter 20XX-20XX. (This document is published every winter. Always use the latest issue; search for "FAA-Approved Deicing Program" at www.faa.gov/regulations_policies/orders_notices/.)

2.1.4 Transport Canada Publications

Transport Canada documents are available from Transport Canada, Tower C, Place de Ville, 330 Sparks Street Ottawa, Ontario K1A 0N5, Tel: 1-800-305-2059, www.tc.gc.ca.

Transport Canada Holdover Time Guidelines. (These are published every winter. Always use the latest issue.)

Guidelines for Aircraft Ground Icing Operations. TP14052E, April 2005.

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. TP15232E Vol 1-5, November 2013.

2.1.5 Other Publications

Broeren, A., & Riley, J. T. (2012). Scaling of Lift Degradation due to Anti-Icing Fluids Based Upon the Aerodynamic Acceptance Test. *4th AIAA Atmospheric and Space Environments Conference.* New Orleans.

Clark, C. and Ruggi, M., "Evaluation of Visual Failure versus Aerodynamic Limit for a Snow Contaminated Anti-Iced Wing Section during Simulated Takeoff," SAE Technical Paper 2019-01-1972, 2019

Rae, W., & Pope, A. (1984). *Low-Speed Wind Tunnel Testing* (2nd ed.). Toronto: John Wiley & Sons.

2.2 Acronyms

APS	APS Aviation Inc.
AWG	Aerodynamics Working Group
BLDT	Boundary Layer Displacement Thickness
EG	Ethylene Glycol

FAA	Federal Aviation Administration
HOT	Holdover Time
IWT	3 m x 6 m Icing Wind Tunnel
LOUT	Lowest Operational Use Temperature
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NRC	National Research Council Canada
PG	Propylene Glycol
RJ	Regional Jet
RTD	Resistance Temperature Detector
TC	Transport Canada

2.3 Definitions

AERODYNAMIC ACCEPTANCE: A performance test required under 3.2.5 of AMS1428 and defined in AS5900.

ALLOWANCE TIME: Time, from the initial application of fluid, that a fluid is expected to provide protection of an aircraft against contamination from conditions of or mixed with ice pellets or small hail. Allowance times are derived from aerodynamic fluid flow off performance data and visual inspection of fluids exposed to these precipitation types.

ALLOWANCE TIME GUIDELINE: A table giving the generic fluid type based allowance time for various precipitation conditions and temperatures with cautions and notes giving guidance to ground deicing/anti-icing crews and pilots.

ENDURANCE TIME: Time that a fluid can endure defined and controlled temperature and precipitation conditions before visual failure. Endurance time tests are defined in ARP5485.

FAA/TRANSPORT CANADA LISTS OF FLUIDS: Lists published by Transport Canada and the FAA in their Holdover Time Guidelines which include fluids that have been tested for endurance times (according to ARP5485), anti-icing performance (according to 3.2.4 of AMS1428 using the test method in AS5901) and aerodynamic acceptance (3.2.5 of AMS1428 using the test method in AS5900) only.

HOLDOVER TIME (HOT): Time, from the initial application of fluid, that an anti-icing fluid is expected to provide protection of an aircraft against freezing or frozen precipitation. Holdover times are derived primarily from visual inspection of fluids exposed to freezing and frozen precipitation.

HOLDOVER TIME GUIDELINE: A table giving the holdover time for various precipitation conditions and temperatures with cautions and notes giving guidance to ground deicing/anti-icing crews and pilots. The "holdover time guideline" is also often referred to as "holdover time table".

LOWER SALES SPECIFICATION VISCOSITY LIMIT: Viscosity set by the fluid manufacturer for its sales specification. This viscosity must be equal to or higher than the AMS1428 low viscosity and must be higher than the lowest on-wing viscosity (LOWV).

LOWEST ON-WING VISCOSITY (LOWV): Viscosity reported by the laboratory performing the testing. The LOWV is published with the specific holdover time guideline for that fluid. Fluids having an on-wing viscosity less than the LOWV cannot be used with holdover time guidelines. The LOWV must be below the lower sales specification viscosity limit.

LOWEST OPERATIONAL USE TEMPERATURE (LOUT): The lowest operational use temperature of a Type II/III/IV fluid is generally recognized as the higher of:

a. The lowest temperature at which it meets the aerodynamics acceptance test (AS5900) for a given type of aircraft; or
b. The freezing point of the fluid plus the freezing point buffer of 7 °C (about 13 °F).

MAXIMUM ON-WING VISCOSITY (MOWV): Refer to AMS1428 high viscosity. Fluids having a viscosity higher than the MOWV must not be used.

UPPER SALES SPECIFICATION VISCOSITY LIMIT: Viscosity set by the fluid manufacturer for its sales specification. This viscosity must be equal to or lower than the AMS1428 high viscosity or MOWV.

3. GENERAL INFORMATION

This section provides a brief description of general information related to the Ice Pellet Allowance Time research program.

3.1 TC/FAA Supported R&D Activity

Ice Pellet Allowance Time research is supported by TC and the FAA to provide guidance material for operators. Testing is conducted for all new-to-market fluids and guidance is developed to be generic and currently applicable to Type III and IV fluids only. Currently, fluid manufacturers are required to provide fluid for the testing.

3.2 Frequency of Testing

Testing is conducted yearly or bi-yearly dictated by the release of new fluids to market.

3.3 Fluid Types Tested

Ice pellet allowance time testing is performed on AMS1428 Type III and IV de/anti-icing fluids. AMS1424 Type I and AMS1428 Type II fluids are not currently included in the testing program.

3.4 Safety Hazards

This document may refer to procedures involving hazardous materials, operations, and equipment. This document does not purport to address the safety problems associated with its use. It is the responsibility of the user of this document to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

4. TEST FACILITY AND MODEL REQUIREMENTS

This section describes the facility and model requirements for wind tunnel testing of ice pellet allowance times.

4.1 Facility

The research program takes place at the National Research Council (NRC) 3 m × 6 m Icing Wind Tunnel (IWT) in Ottawa, Ontario, Canada. The facility has a 7.9 m diameter, 16-blade fan that draws outdoor air, allowing for naturally cold test section conditions during the winter months. The fan has a high solidity ratio to reduce unsteadiness in the test section due to outdoor wind conditions and is fitted with a set of anti-swirl stators to reduce flow angularity. The fan is powered by the exhaust from a gas-turbine engine to achieve the speeds and ramp times required to simulate an aircraft takeoff profile. An optional electric-drive system is available for lower speed testing, however, has never been used for ice pellet allowance time research.

The settling chamber has a set of fine mesh screens to minimize flow turbulence. The settling chamber is followed by a 6:1 contraction ratio into the test section which is 3.1 m wide, 6.1 m high, and 12.2 m long. The roof insert contains a spray system that provides freezing rain/drizzle conditions, extending and retracting in less than a minute to allow easy access to the system. The floor insert is composed of manually-assembled metal sections, with a large plastic tarp underneath to act as a bladder to contain any fluids that leak into it. The floor has grating parallel to each wall for secure footing when walking in the test section. The test section is followed by a diffuser with a 90°-bend and the tunnel exhausts directly outdoors.

The open-circuit layout, with a fan at entry, permits contaminants associated with the test articles (such as heat or de/anti-icing fluid) to discharge directly, without recirculating or contacting the fan.

4.2 Models

The following subsection describes the different wing section models used in ice pellet allowance time testing.

4.2.1 Thin High-Performance Regional Jet (RJ) Wing Section

The more recent and most commonly used wing section for this test program is a two-dimensional wing section based on the wing of a generic regional commuter aircraft similar to the Bombardier CRJ-200 with a single hinged flap fixed at 20°. The generic coordinates for the model were supplied by Bombardier Aerospace. This model was designed and built in 2009 and has since been used by TC and the FAA to develop the ice pellet allowance time tables. At a typical run temperature of -10°C and speed of 100 kts, the experimental Reynolds number based on wing chord is 7.5×10^6.

A cross sectional view of the thin high-performance wing section used for testing has been included in Figure 4.1; the dimensions indicated are in meters. Some of the pertinent dimensions of the wing section are:

- Chord length not including flap: 1.4 m (4.6 ft.); and
- Width: 2.4 m (8 ft.).

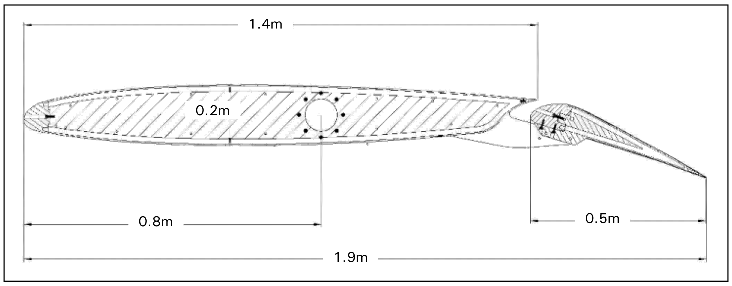


Figure 4.1: Generic "Thin High-Performance" Wing Section

End plates were installed on the wing section to eliminate the "wall effects" from the wind tunnel walls and to provide a better aerodynamic flow-off above the test area. Figure 4.2 demonstrates the end plates installed on the thin high-performance wing section (note: the wing section is depicted without the top wing skin).

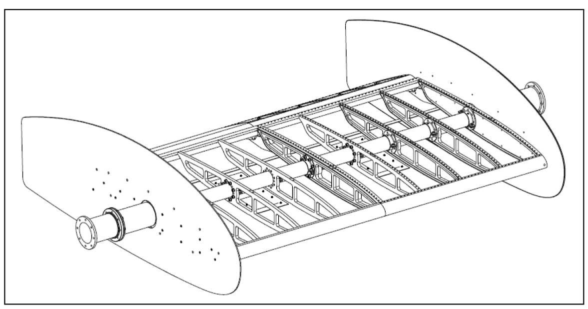


Figure 4.2: End Plates Installed on Thin High-Performance Wing Section

4.2.2 LS0417 Turboprop Regional Airliner Wing Section

Lower speed testing at 80 knots or lower is primarily done using the wing section built according to the National Aeronautics and Space Administration (NASA)

LS(1)-0417 specifications. This wing section can and has been used to conduct testing at 100 knots. The wing section is representative of a turboprop wing section such as a De Havilland Dash 8. As compared to the thin high performance regional jet wing section, the LS(1)-0417 airfoil is best suited for lower speed testing. The general testing methodologies, including fluid application and calibration, remain the same for both wing sections.

A cross sectional view of the NASA LS(1)-0417 wing section used for low-speed testing has been included in Figure 4.3. Some of the pertinent dimensions of the wing section are:

- Chord length not including flap: 1.8 m (6 ft.); and
- Width: 2.4 m (8 ft.).

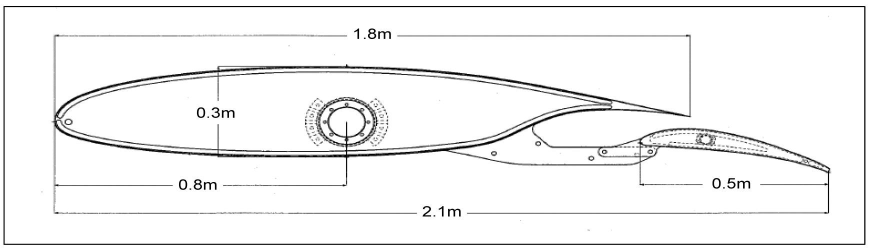


Figure 4.3: NASA LS(1)-0417 Wing Section

The wing section was fitted with a Fowler flap, however, the flap position was fixed at 15° and was could not be changed during testing. No moveable devices were available on the wing section.

End plates were installed on the wing section to eliminate the “wall effects” from the wind tunnel walls (aerodynamic interference caused by the walls on a wing section spanning the wind tunnel) and to provide a better aerodynamic flow-off above the test area. Figure 4.4 demonstrates the end plates installed on the NASA LS(1)-0417 wing section.

The NASA LS(1)-0417 was initially used in 2007-08 to support the expansion of the ice pellet allowance time table and has since been used to support primarily lower speed (80 knots) testing activities.

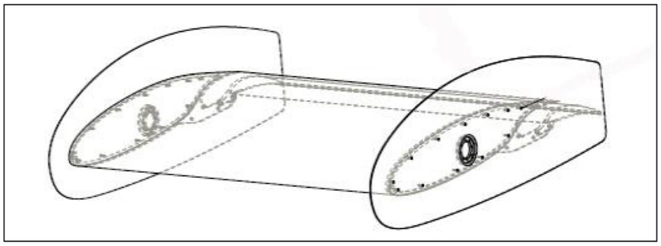


Figure 4.4: End Plates Installed on NASA LS(1)-0417 Wing Section

4.2.3 NACA 23012 Turboprob Utility Aircraft Wing Section

The National Advisory Committee for Aeronautics (NACA) 23012 wing section is a hard wing airfoil similar to that of a Cessna Caravan.

A cross sectional view of the NACA 23012 wing section used for testing is included in Figure 4.5. Some of the pertinent dimensions of the wing section are:

a. Chord length: 1.2 m (4 ft.);
b. Width: 3 m (10 ft.); and
c. Wing surface area: 3.6 m^2 (40 $ft.^2$).

The wing section used did not have slats or flaps. No moveable devices were available on the wing section.

The NACA 23012 wing section was only used in 2006-07 for the initial development of the ice pellet allowance time table.

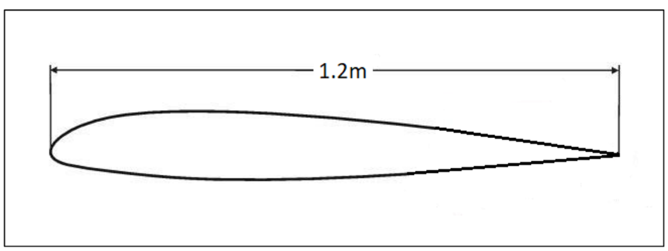


Figure 4.5: Cross Sectional View of NACA 23012 Wing Section

4.3 Instrumentation

The following subsection describes the instrumentation used in ice pellet allowance time testing.

4.3.1 Side-Wall Balances and Model Position

The aerodynamic performance (lift, drag and pitching moment) of the model is measured through the use of external balances mounted on each side of the test section. Each balance rotates with the models and consists of two load cells in the normal direction and one load cell in the axial direction. The combined load cells measure normal force, axial force and pitching moment about the rotation point, which the data reduction code converts to lift, drag and pitching moment about the quarter-chord of the model. The balance on the port side of the test section is driven by a motor and gearbox that control the pitch angle of the model and measures the pitching moment about the point of rotation, while the balance on the starboard side rotates freely on a bearing. The model pitch angle is zeroed aerodynamically at the start of the test and then calculated based on the motor position and known gearbox ratio. Protective covers prevent observers looking through the test section windows from touching the balance and affecting the load measurements.

4.3.2 Temperature

The temperature of the air around the wing and the temperature of the wing skin are key parameters for this test, as anti-icing fluid performance is a function of the air temperature where they are being applied. There are 8 resistance temperature detectors (RTDs) mounted inside the model to measure the skin temperature distribution, as well as an RTD mounted off the port endplate to measure the air temperature just above the model. The temperatures in the settling chamber and the outdoor air temperature are also measured and included in the data set. The RTD calibrations (with the exception of the outdoor air temperature sensor as it is non-essential) are verified prior to the start of the research program.

4.4 Calibration and Tares

All wind tunnel instrumentation must have valid calibrations that are tracked on the facility critical instrumentation list. The following subsection describes the calibration methods used.

4.4.1 Side-Wall Balance Calibration and Tares

All load cells shall be calibrated prior to installation in the side-wall balance and the performance and functionality of the side-wall balances are to be verified using calibrated weights prior to the start of testing. Prior to the start of the tests, a tare is performed by pitching the model through the full range of motion with the wind off and recording the balance response. The load cell responses to the model weight are subtracted from the wind-on balance loads in the data reduction code.

4.4.2 Empty Tunnel Calibration

The test section is calibrated by placing a pitot-static probe in the centre of the empty test section and measuring the probe and wind tunnel pressures through a range of fan speeds. The difference between the probe total and static pressures is measured using a 10-inch H_2O sensor with an accuracy of ±0.05% of reading, and the difference between the probe static pressure and the static pressure tap upstream of the test section is measured using a 1-inch H_2O sensor with an accuracy of ±0.05% of reading. The method to calibrate the empty test section of a wind tunnel is described in Section 3.11 of "Low-Speed Wind Tunnel Testing" (Rae & Pope, 1984). The resulting calibration coefficients are used by the data reduction code to calculate the total and static pressures at the test section centreline.

4.4.3 Clean Wing Calibration

The baseline aerodynamic performance of the clean wing is an average of all the clean-wing runs. The instrumentation accuracy and the standard deviation of the measurements at each angle of attack over the course of multiple runs are analysed.

The average lift generated by the clean wing at $\alpha = 8°$ is the most important measurement from the test, as it is used to quantitatively assess the performance of the anti-icing fluids. The clean wing lift and drag is compared to the values measured for previous years to confirm the aerodynamic performance from year to year is within an acceptable deviation.

4.5 Data Reduction

The raw data from the wind tunnel data acquisition system are acquired using software such as TestSLATE and processed by the NRC using a MATLAB program developed in-house. This program converts the data to engineering units, calculates the non-dimensional aerodynamic parameters and applies standard blockage corrections as described below.

During the application of the fluids and precipitation, the data system records all balance and temperature measurements at a rate of 1 Hz. The high-speed data acquisition system triggers at a tunnel fan speed of 5 RPM and records at a rate of 500 Hz until the end of the run.

4.5.1 Calculation of Aerodynamic Parameters

4.5.1.1 Test Section Operating Conditions

The total and static pressures in the test section are calculated based on the established empty tunnel calibration and are used to calculate the Mach number (see Equation 4.1).

$$M = \sqrt{5\left(\frac{P_T}{P_S}\right)^{\frac{2}{7}} - 1}$$

Equation 4.1: Mach Number

The uncorrected dynamic pressure (see Equation 4.2) in the test section is calculated from the Mach number and static pressure.

$$q = 0.7P_S\, M^2 * 1000$$

Equation 4.2: Uncorrected Dynamic Pressure

The air density (see Equation 4.3) in the test section is calculated based on the static pressure and the static air temperature. The air temperature sensor is mounted upstream of the test section, in the settling chamber.

$$\rho = 1.225\left(\frac{P_S}{101325}\right)\left(\frac{288.15}{T + 273.15}\right)$$

Equation 4.3: Air Density

The uncorrected airspeed (see Equation 4.4) in the test section is calculated using the dynamic pressure and air density.

$$V = \sqrt{\frac{2q}{\rho}}$$

Equation 4.4: Uncorrected Airspeed

4.5.1.2 Balance Data

The balance provides the normal and axial forces on the model as a direct sum of the individual load cell values. The pitching moment about the rotation point of the model is calculated from the difference between the normal load cells on the port side of the model. The angles of the model and balances are then used to convert the normal and axial forces to lift and drag forces in the test section wind axis. The uncorrected lift, drag and pitching moment coefficients are calculated from the measured loads using standard equations for these non-dimensional aerodynamic parameters.

The data reduction code corrects the aerodynamic coefficients to measured values in the wind tunnel to those that would be experienced by the same model in free air. These corrections are based on standard two-dimensional testing corrections (Rae & Pope, 1984) for solid blockage, wake blockage and streamline curvature.

4.5.2 Uncertainty Analysis

The uncertainties in the calculated dynamic pressure and velocity in the test section are functions of the accuracies of the pressure transducers used to measure the pressure differential in the contraction and the barometric pressure. The pressure differential in the contraction is measured using a 12-inch H2O sensor with an accuracy of ±0.01% of the full-scale range (±0.299 Pa). The barometric pressure is measured using an absolute pressure transducer with an accuracy of ±0.1% of reading (±101.325 Pa at standard atmosphere). The uncertainty in the air density is a function of the uncertainty in absolute static pressure and temperature in Kelvin, and is ±0.1% of reading.

Each load cell in the balance has a non-linearity of ±0.1% of full-scale (FS), hysteresis of ±0.1% FS, and repeatability of ±0.05% FS, resulting in a total uncertainty of 0.15% FS. The resulting uncertainties due to the load cell accuracy are ±17.65 N in the normal direction and ±4.72 N in the axial direction. These values, combined with the uncertainty in test section dynamic pressure, result in an uncertainty of ±0.002 in CL for $\alpha = 8°$ at a velocity of 100 knots.

5. TEST FLUID REQUIREMENTS

This section describes the test fluid requirements for in ice pellet allowance time testing.

5.1 General

Fluids submitted for testing shall be representative of mid-production viscosity fluids which lie between the lower and upper sales production viscosity limits. The manufacturer shall mark each fluid sample container with the company name, product name, lot number, location, and date of manufacture. Only fluids having been commercialized for at least one season should be submitted for testing.

5.2 Fluid Parameters

This subsection describes the fluid parameters measured.

5.2.1 Viscosity

Viscosity shall be measured by Brookfield LV viscometer, or equivalent, in accordance with the latest revision of AS9968, using the fluid manufacturer stated method. The viscosity may be measured with the Brookfield small sample adapter; the report shall state whether it was used and detail the spindle size, container size, volume of fluid employed, and the rotation duration. Viscosity measurements will be made for all tested fluid dilutions, if applicable.

5.2.2 Refractive Index

The refractive index of the undiluted fluid shall be determined at 20 °C ± 3 °C in accordance with ASTM D1747.

5.3 Fluid Application

Fluids are generally received from the manufacturers in 20 L containers; however, some fluids are received in large 200 L barrels and larger 1000 L totes and transferred into 20 L containers. The fluids are decanted from the 20 L containers into 2 L pour containers for application. Fluids are poured rather than sprayed as to not change the fluid viscosity due to shearing.

5.4 Quantities

Typically, up to 20 litres of fluid are required for one test run. However, depending on viscosity this can range from 10L to 20L. Generally, a minimum of 400 litres per fluid is required for validation testing for a newly submitted fluid (sufficient for approximately 20 tests).

5.5 Waste Fluid Collection

Waste fluids shall be collected and safely disposed. The services of a specialized waste removal company are recommended.

6. SIMULATED PRECIPITATION

The following types of precipitation are simulated for aerodynamic research in the IWT:

1. Ice Pellets;
2. Snow;
3. Freezing Rain/Rain;
4. Freezing Drizzle/Drizzle; and
5. Other conditions related to HOTs.

6.1 Ice Pellets

Simulated ice pellets shall be produced with diameters ranging from 1.4 mm to 4.0 mm to represent the most common ice pellet sizes observed during natural events. Cubes of ice are crushed and passed through calibrated sieves to obtain the required ice pellet size range. The ice pellets should be applied to the leading and trailing edges of the wing at the same time.

Simulated ice pellets are distributed over a test surface using an ice pellet pitcher (a modified seed dispenser). The speed of the motor is set at 1000 rpm and monitored throughout the application. The rate of precipitation is controlled by applying a measured quantity using a calibrated scoop of ice pellets per minute at each position.

A total of four dispensers are used: two dispensers on each of the leading and trailing edges of wing. Each of the four dispensers are moved to four different positions along each edge during the dispensing process. Ice pellets are manually loaded into the dispenser (see Table 6.1 for quantities) and dispersed over the designated test area.

Table 6.1: Ice Pellet Quantities for Dispensing

Target Ice Pellet Rate	Ice Pellets Dispensed Per Position, Per 5 min Cycle
25 g/dm²/h	81 g
75 g/dm²/h	242 g

6.2 Snow

Snow is produced using the same method for producing ice pellets. The snow shall consist of small ice crystals measuring less than 1.4 mm in diameter. Previous testing conducted by APS investigated the dissolving properties of the artificial snow versus natural snow. The artificial snow was selected as an appropriate substitute for natural snow.

Cubes of ice are crushed and passed through calibrated sieves to obtain the required snow size range. The snow should be applied to the leading and trailing edges of the wing at the same time.

Snow is distributed using the same dispensers as used for ice pellets. The rate of precipitation for snow is controlled by applying a measured quantity using a calibrated scoop of snow per minute at each position.

A total of four dispensers are used: two dispensers on each of the leading and trailing edges of wing. Each of the four dispensers are moved to four different positions along each edge during the dispensing process. Snow is manually loaded into the dispenser (see Table 6.2 for quantities) and dispersed over the designated test area.

Table 6.2: Snow Quantities for Dispensing

Target Snow Rate	Snow Dispensed Per Position, Per 5 min Cycle
10 g/dm²/h	31 g

6.3 Freezing Rain/Rain and Freezing Drizzle/Drizzle

A sprayer system uses compressed air and distilled water to produce freezing rain or drizzle. The sprayer system consists of a scanner and sprayer head with interchangeable nozzles for generating the required droplet sizes. The temperature of the water is controlled and is kept just above freezing temperature to produce freezing rain. To produce rain, the temperature of the water is raised until the precipitation no longer freezes on the test surfaces.

Freezing rain and rain are defined by a water droplet median volume diameter of 1000 µm ± 100 µm. Freezing drizzle and drizzle are defined by a water droplet median volume diameter of 300 µm ± 100 µm. A summary of the sprayer settings used as of January 2021 is provided in Table 6.1 for reference. However, settings may need to be adjusted following the annual calibration performed prior to the start of testing.

Table 6.3: Sprayer System Settings (as of Jan 2021)

Precipitation Type	Precipitation Rate (g/dm²/h)	Water Flow Rate (mL/min)	Sprayer Nozzle	Sprayer Quantity	Pressure Setting (psi)
Freezing Drizzle (ZD)	25	250	#20	2	45
Freezing Rain (ZR)	13	180	#23	2	45
Rain (R)	75	865	#17	2	45

6.4 Definition of Precipitation Rates

The precipitation generated is applied within the following ranges:

1. Light Ice Pellets: 13-25 g/dm²/h;
2. Moderate Ice Pellets: 25-75 g/dm²/h;
3. Light Freezing Rain: 13-25 g/dm²/h;
4. Freezing Drizzle*: 5-13 g/dm²/h;
5. Light Rain: 13-25 g/dm²/h;
6. Moderate Rain: 25-75 g/dm²/h;
7. Light Snow: 4-10 g/dm²/h; and
8. Moderate Snow: 10-25 g/dm²/h.

*includes light, moderate and heavy freezing drizzle

Figure 6.1 indicates the precipitation limits as applicable to the holdover time guidelines, a subset of which also apply to ice pellet allowance times.

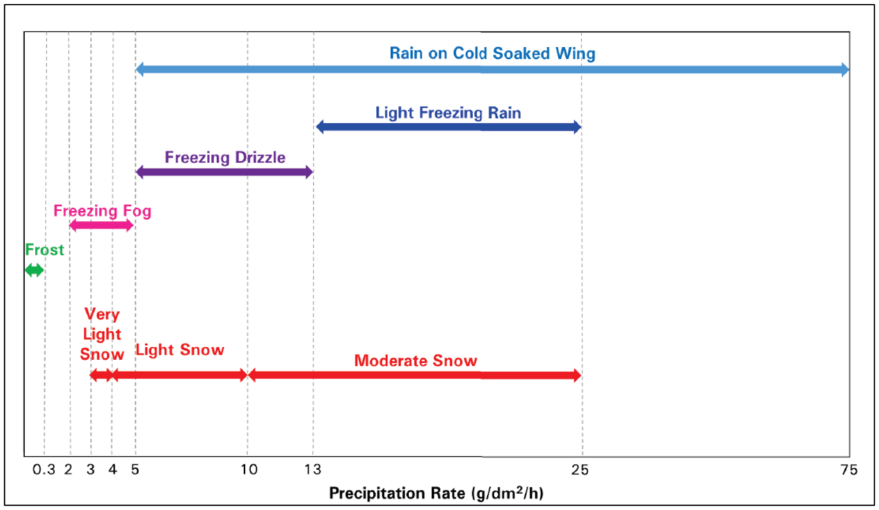


Figure 6.1: Precipitation Rate Limits Used in Endurance Time Testing

7. TEST PROCEDURE

This section describes the test procedure for used for ice pellet allowance time testing.

7.1 Run Schedule

The length of each test (from start of set-up to end of last measurement) may vary largely due to the length of exposure to precipitation (if applicable). Time required for set-up and teardown as well as preparing and configuring the wing section is relatively consistent. Figure 7.1 demonstrates a sample time line for a typical wind tunnel test. It should be noted that a precipitation exposure time of 30 minutes is used for illustration purposes; this varies for each test depending on the objective.

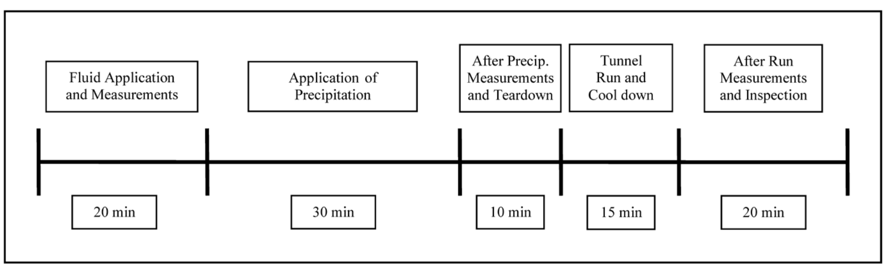


Figure 7.1 Typical Wind Tunnel Test Timeline

The procedure for each fluid test is described below.

a. The clean wing section is treated with anti-icing fluid, poured in a one-step operation (no Type I fluid is to be used during the tests).
b. When applicable, contamination in the form of simulated precipitation is applied to the wing section. Test parameters are measured at the beginning and end of the exposure to contamination.
c. At the end of the contamination period, the tunnel shall be cleared of all equipment and scaffolding.
d. The wind tunnel is operated through a simulated takeoff and climb-out, with the wind tunnel data systems acquiring aerodynamic loading and test section operation condition measurements.
e. The visual behaviour of the fluid during takeoff and climb-out are recorded with digital high-speed still cameras. In addition, windows overlooking the wing section allow observers to document the fluid elimination performance in real-time. The wing is inspected after the test for any residual fluid and contamination.

7.2 Fluid Application and Measurements

The wing section is treated with anti-icing fluid, poured in a one-step operation (no Type I fluid is to be used during the tests). A pre-wash with fluid and wipe down should be done for each fluid brand changeover to avoid cross contamination. Fluid thickness and brix (refractive index of the fluid) shall be recorded 5-minutes after the fluid is applied at predetermined locations mid span along the chord length.

In the case of the thin high performance wing section, the wing section should be tilted to a geometric pitch angle of -2° to represent a typical outboard wing section on a commuter aircraft. For a select number of runs, the flap on the model is adjusted manually from its set position of 20° to 0° for the application of fluid and precipitation (it is then returned to 20° for the simulated takeoff run) to simulate different aircraft configurations for de/anti-icing.

Note: for the thin high-performance regional jet (RJ) wing section, the wing section is tilted to a geometric pitch angle of -10º for a period of 1 minute following fluid application to allow for the fluid to properly coat the surface of the wing. This is done because the fluid is poured rather than sprayed and to ensure an even and thorough fluid distribution.

7.3 Precipitation Application

Precipitation is applied as per the requirements outlined in Section 6.

7.4 Survey of Fluid Condition After Contamination Period

At the end of the contamination period, the fluid thickness and brix shall be recorded again to document any changes. In addition, a visual evaluation of the fluid condition is to be performed by a minimum of two trained persons to document fluid failure.

7.5 Takeoff Profiles

Three different takeoff ramp profiles are used to simulate takeoff runs for ice pellet allowance time testing. In general, acceleration from 0-40 kts is achieved in 15 seconds, and acceleration increases as the fan blade rotation gains momentum. The ramp-up time and acceleration in this range is not of particular interest as fluid generally does not begin to shear until 40 kts is achieved.

The acceleration from 40 kts to the final speed is more linear in shape as the fan continues to accelerate. The wind speed data is corrected for blockage from the wing section and represents approximately a 3 kt increase in speed at the time of rotation (see Section 4.5 for additional details).

The details of the different takeoff profiles are given in Table 7.1 below.

Table 7.1: Target Takeoff Profile Parameters

Rotation Speed (kts)	Time from 40 kts to Rotation Speed (s)	Average Acceleration (kt/s)
80	17	2.4
100	19	3.2
115	21	3.6

7.6 Survey of Fluid During Takeoff Run

During the takeoff run, a visual evaluation of the fluid condition is to be performed by a minimum of two trained persons to document the flow off performance. At the end of the takeoff run, the fluid thickness and brix shall be recorded again to document residual fluid and contamination present on the wing. An example of the visual evaluation rating form is provided in Figure 8.1 below.

8. ANALYSIS METHODOLOGY

The following provides a brief description of the analysis methodology.

8.1 General Methodology

Each ice pellet test is analysed in detail using the following objectives:

1. Test parameters;
2. Visual ratings at the start of the test;
3. Visual ratings at rotation;
4. 8° lift loss; and
5. Overall test status.

The evaluation grades for each criterion are "good," "review," or "bad." These grades are determined based on whether the criterion satisfied each test objective requirement.

Several test parameters shall be evaluated, such as tunnel temperature before the start of the test, rate of precipitation, and exposure time of precipitation. These parameters are compared to the target parameters described in the test plan. The actual recorded ramp-up time should also be evaluated and compared to the target ramp-up time to ensure representative flow-off results.

8.2 Visual Evaluation of Fluid Condition at the Start of Test

During each of the tests conducted, visual contamination ratings shall be determined by minimum of two trained observers. The level of contamination present on the leading edge and trailing edge of the wing, as well as on the flap, is quantified using a scale of one-to-five with five being the worst-case scenario; partial numbers are assigned when cases are marginally above or below a specific rating.

The visual contamination rating criteria at the start of the test on both the leading and trailing edges must be equal to 3 or less to pass. The flap must have a rating of 4 or less. For a review grade to be given, the leading and trailing edges must have a rating between 3 and 3.5, and the flap must have a rating between 4 and 4.5. Any rating greater than 3.5 on the leading and trailing edges is considered a fail, while anything greater than 4.5 on the flap is considered a fail. An example of the visual evaluation rating form is provided in Figure 8.1 below.

VISUAL EVALUATION RATING OF CONDITION OF WING

Date: ____________________ Run Number: _______

Ratings:
1 - Contamination not very visible, fluid still clean.
2 - Contamination is visible, but lots of fluid still present
3 - Contamination visible, spots of bridging contamination
4 - Contamination visible, lots of dry bridging present
5 - Contamination visible, adherence of contamination

Note: Ratings can include decimals i.e. 1.4 or 3.5

Before Take-off Run

Area	Visual Severity Rating (1-5)	
Leading Edge		*>3 = Review, >3.5=Bad*
Trailing Edge		*>3 = Review, >3.5=Bad*
Flap		*>4 = Review, >4.5=Bad*

At Rotation

Area	Visual Severity Rating (1-5)		Expected Lift Loss (%) *>5.4 = Review* *>9.2 = Bad*
Leading Edge		*>1= Review >1.5 = Bad*	
Trailing Edge			
Flap			

After Take-off Run

Area	Visual Severity Rating (1-5)
Leading Edge	
Trailing Edge	
Flap	

Additional Observations: ____________________

OBSERVER: ____________________

Figure 8.1: Visual Evaluation Rating Form

8.3 Visual Evaluation of Fluid Condition at Rotation Test

The visual contamination rating criteria at the time of rotation on the leading edge must be equal to 1 or less to pass. For a review grade to be given, the leading edge must have a rating between 1 and 1.5. Any rating on the leading edge greater than 1.5 is considered a fail. An example of the visual evaluation rating form is provided in Figure 8.1.

8.4 Evaluation of Aerodynamic Limit

The aerodynamic penalty associated with a fluid or fluid and precipitation application is quantified as the percent lift-loss relative to the average clean wing lift at $\alpha = 8°$, as shown in Equation 8.1 below.

$$Lift\ Loss = \frac{C_{l(Clean\ Wing)} - C_{l(Fluid\ or\ Fluid+Snow)}}{C_{l(Clean\ Wing)}} \times 100\%$$

Equation 8.1: Percent Lift-Loss Relative to the Average Clean Wing Lift

Based on previous wing characterization work and the interpretation by Broeren & Riley (2012), the lift-loss at α = 8° has been correlated to boundary layer displacement thickness (BLDT) measurements from the Aerodynamic Acceptance Test from AS5900. This work categorized clean fluid lift-losses less than 5.4% as aerodynamically acceptable, lift-losses between 5.4% and 9.2% as needing further review, and lift-losses greater than 9.2% exceeding the aerodynamic limit. For this research program, the aerodynamic limit was defined using the 9.2% lift loss criteria.

Due to industry concern with the validity of the results obtained, and the relevance of the test methods to operational aircraft, it was recommended that testing during the winter of 2011-12 focus on surveying and characterizing the wind tunnel to obtain a better sense of the repeatability of results. With the support and under the direction of NASA, a large series of test runs (both dry and with fluid) were conducted to better understand the performance characteristics of the wind tunnel and airfoil. During the winter 2011-12 testing, the back-to-back fluid only runs demonstrated excellent repeatability of test methods, and this was reflected in the aerodynamic data collected. Variation in year-to-year fluid only test runs demonstrated some differences, which can be attributed to differences in ramp-up time, temperature, and fluid viscosity. The additional variable of contamination generated slightly more variation in the test results; however, this variation is considered acceptable given the number of variables such as temperature, ramp-up time, fluid viscosity, and contamination. The repeatability of the testing was considered acceptable for this type of aerodynamic testing work and was not indicative of systematic errors in procedures or equipment.

8.5 Overall Test Status

An overall status is given a “good,” “review,” or “bad” evaluation. This serves as an overall summary for each test. The overall status is determined by the worst-case scenario from any of the test objectives; if any of the criteria are given a “bad” grade, the overall status is considered “bad” and the test considered a fail. A visual example of the Ice Pellet Test Analysis Criteria is provided in Figure 8.1.

1. TEST PARAMETERS

2. VISUAL RATINGS AT START OF TEST

CRITERIA:	LE / TE	≤ 3
	Flap	≤ 4

≤ 3, 3, 4	GOOD
> 3, 3, 4 to 3.5, 3.5, 4.5	REVIEW
> 3.5, 3.5, 4.5	BAD

3. VISUAL RATINGS AT ROTATION

CRITERIA:	LE	= 1

1	GOOD
1 to 1.5	REVIEW
> 1.5	BAD

4. LIFT LOSS AT 8°

CRITERIA:

< -2 σ	< 5.4%	GOOD
-2 σ to 2σ	5.4% to 9.2%	REVIEW
> +2 σ	> 9.2%	BAD

OVERALL STATUS

IF ANY OF THE ABOVE CRITERIA ARE RED, TEST IS NOT ACCEPTABLE

THEREFORE WORST OF ABOVE 3 CRITERIA, ORDER IS:

GREEN
YELLOW
RED

Figure 8.2: Ice Pellet Test Analysis Criteria

8.6 Dry Wing Calibration

To ensure the accuracy of the testing results, a dry wing calibration test shall be conducted at the start of each day. The dry wing test allows the research team to ensure that the model aerodynamics do not change due to mechanical, communication, or analytical errors. Dry wing tests are also conducted following any mechanical modification to the wing section (i.e., after applying the ice phobic wing skins).

8.7 Exceptional Cases

The following subsection describes exceptional testing cases which require additional protocol.

8.7.1 Flap Up vs. Flap Down Tests for the RJ Wing Model

In operations, aircraft will typically have fluid from the trailing edge of the wing feeding onto the flap. Feeding does not occur on the thin high performance regional jet model. As a result, the condition of the fluid on the flap is conservative, and in some instances, a test may be considered "bad" as a result of the visual evaluation of the flap during the test. This can occur in freezing precipitation whereby adherence may be present on the flap, or in frozen precipitation when the build-up of ice on the layer of the fluid may be excessive.

Historical testing has indicated that if the test is re-run with the flap configured to 0º instead of 20º, the condition of the fluid will significantly improve and the aerodynamic results will reflect this as well. As this is well documented, the following protocol can be used to evaluate the acceptance of each test when the flap is considered visually failed.

1. If the Lift loss (LL) is less than 9.2%, then the test is satisfactory and considered to be conservative, particularly if the LL is less than 5.4%. (Even though it is a visual fail due to adherence or buildup of contamination on the flap at the start or at rotation). Historical testing has been done to demonstrate that there is not an issue.
2. If the LL is higher than 9.2%, then the flap should be raised for the test and then run again. If the lift loss of the new run is less than 5.4%, then this re-run test is considered to be acceptable. If the lift loss of the new run is between 5.4-9.2%, then the test is considered marginal, and further investigation is suggested. If the lift loss is above 9.2%, the test is not acceptable.

8.7.2 100 vs. 115 knots

Historical data has demonstrated that the measured lift losses for PG fluids will increase at colder temperatures. Allowance times have been limited at those lower temperatures and can require higher rotation speeds to compensate for the flow-off performance at those temperatures. Testing is typically conducted at 100 knots, however some conditions require 115 knots for PG fluids in the -10ºC to -16ºC range, and operations below -16 are not allowed for PG fluids.

Guidance material has been updated to indicated that no allowance times exist for propylene glycol (PG) fluids when used on aircraft with rotation speeds less than 115 knots, and if the glycol type is unknown, no allowance times exist for aircraft with rotation speeds of less than 115 knots.

8.7.3 EG vs. PG Type IV Fluids

Historical data has demonstrated fluid flow off performance differences between EG and PG fluids when operating with ice pellets. As such the allowance times can be different at specific temperatures. For this reason, the Type IV allowance times have been separated into two table for Type IV EG and Type IV PG fluids. This allows operators to benefit from the longest allowance times when the specific fluid type is known.

9. DEVELOPMENT OF ICE PELLET ALLOWANCE TIME GUIDANCE MATERIAL

This section describes the development of ice pellet allowance time guidance material.

9.1 Allowance Time Guideline Format

This subsection provides details on the content and format of allowance time guidelines tables.

9.1.1 Columns

Allowance time tables for Type III fluids have columns corresponding to the following temperature ranges: -5 °C and above, below -5 to -10 °C, and below -10 °C.

Allowance time tables for Type IV EG and PG fluids have columns corresponding to the following temperature ranges: -5 °C and above, below -5 to -10 °C, below -10 to -16 °C, and below -16 to -22 °C.

9.1.2 Rows

Allowance time tables for Type III and IV fluids have six and eight rows, respectively, representing categories of freezing or frozen precipitation:

a. Light ice pellets;
b. Light ice pellets mixed with snow;
c. Light ice pellets mixed with freezing drizzle;
d. Light ice pellets mixed with freezing rain;

e. Light ice pellets mixed with rain;
f. Moderate ice pellets (or small hail);
g. Moderate ice pellets (or small hail) mixed with freezing drizzle (Type IV tables only); and
h. Moderate ice pellets (or small hail) mixed with rain (Type IV tables only).

9.1.3 Cells

Each cell provides a fixed allowance time for a particular temperature range in a particular category of freezing or frozen precipitation. These allowance times cannot be extended with the use of a pre-takeoff contamination check.

9.1.4 Notes

Notes are added to the allowance time tables to provide additional information and restrictions on the use of specific allowance times.

9.1.5 Cautions

Cautions are added to the allowance time tables to advise users of potential limitations to published allowance time values.

9.1.6 Additional Guidance Material

Additional guidance material related to ice pellet allowance times is included in TC's TP 14052 and the FAA's N8900.

9.1.7 Date

Allowance time guidelines will have an issue date and/or a revision date. These guidelines are typically updated annually. When a new issue of the guidelines is published, all previous issues become obsolete.

9.2 Restrictions

Fluid manufacturers must inform the FAA and Transport Canada or their designated delegate of the restrictions on use of their fluid, for instance, if the fluid cannot be used below a certain temperature.

9.3 Allowance Time Values Derived from Wind Tunnel Data

The allowance time guidelines produced are generic. The allowance time for each cell is the most conservative (worst case) pass time of the group of fluids tested.

9.3.1 Methodology for Developing or Expanding New Allowance Times

Initial testing to first develop the allowance times is done with representative "grandfather" fluids (fluids with a long history of data). Testing is conducted at different temperatures and rates, and the allowance times are based on the limits where tests fail the acceptance criteria (based on visual ratings and aerodynamic performance). Much "trial and error" is needed to determine the limits of the allowance times (i.e., it may require running tests with a grandfather fluid at 15, 20, and 25 minutes to determine that the allowance time should be limited to 20 minutes). Once the target allowance times are determined, they are validated using limited spot checks with multiple fluids.

9.3.2 Generic Guidelines per Fluid Type

Fluid-specific allowance time guidelines are not currently produced. An allowance time guideline is produced per fluid type.

Allowance time guidelines are produced for Type III and Type IV fluids only, with separate allowance times for Type IV EG and PG fluids. There are currently no ice pellet allowance times for Type I or Type II fluids, however some preliminary limited research has been conducted.

9.3.3 Allowance Time Values

Allowance time values above 10.0 minutes are developed to the nearest integer of "5." Allowance time values below 10.0 minutes are developed to the nearest integer of "1."

9.4 Validating New Fluids for Use with Allowance Times

Within one to two years of a new fluid becoming commercially available, the fluid must undergo ice pellet allowance time testing to ensure the fluid is safe to use with the published guidelines. Testing is conducted in a subset of conditions (typically 10 or more tests). The allowance times are generic, so this process is satisfactory and provides a "first alert" in the event that a fluid may be underperforming, in which case further action and testing would be required.

9.5 Obligation for Manufacturers to Submit Fluids for Testing

In the case of allowance time testing, only commercialized fluids actively used on the market should be tested in order ensure efficient use of R&D resources. TC and the FAA strive to have fluids tested within two years of being commercialized and sold.

9.5.1 Identification of Fluids Approved for Use with Allowance Times

Currently ice pellet allowance time testing is performed as an R&D activity with the voluntary participation of fluid manufacturers. To date, all fluid manufacturers have opted to submit commercialized fluids for allowance time testing. In the event a fluid manufacturer chooses not to submit a fluid for allowance time testing, regulators may opt to specifically identify fluids approved for use with the allowance time guidelines.

9.6 Removal of Obsolete Fluids from Allowance Time Guidelines

If a fluid is removed from the FAA and Transport Canada published lists of fluids, the allowance times should be re-evaluated to identify the impact that fluid may have had on the generic allowance times. In the event a fluid being removed is a main driver for past allowance time reductions, those allowance times may be revisited to identify the potential to re-expand the times given the current generation of fluids.

10. ROLE OF THE SAE G-12 HOLDOVER TIME COMMITTEE

The following sections describe the role of the SAE G-12 Holdover Time Committee. It should be noted that allowance times are included in the Holdover Time guidelines and as such are under the jurisdiction of the Holdover Time Committee.

10.1 Holdover Time Committee Co-Chairs

The co-chairs of the SAE G-12 Holdover Time Committee are representatives of the FAA and Transport Canada. In the absence of an FAA or Transport Canada chair during an SAE G-12 HOT meeting, an EASA representative may sit-in as acting co-chair.

10.2 Holdover Time Committee Advisory Role

In addition to its normal role of preparing and maintaining standards such as this ARP5718, ARP6207, ARP5485 and ARP5945, the SAE G-12 Holdover Time Committee acts as an advisory body to the FAA and Transport Canada, who publish the holdover time guidelines, which includes the ice pellet allowance times. The SAE G-12 Holdover Time Committee is a normal path for recommendations to regulators on matters related to holdover time guidelines.

New draft holdover time guidelines, including any changes to the ice pellet allowance times, should be presented for review to the SAE G-12 Holdover Time Committee at least annually during the annual general meeting of the SAE G-12.

11. PUBLICATION OF ICE PELLET ALLOWANCE TIME GUIDELINES

The holdover time guidelines are published yearly in the month of August by Transport Canada and the FAA. Whenever required, Transport Canada and the FAA may publish interim holdover time guidelines due to updated information or special issues.

Ice pellet allowance times are published as part of the Holdover Time Guidelines and updated as required, based on fluids tested.

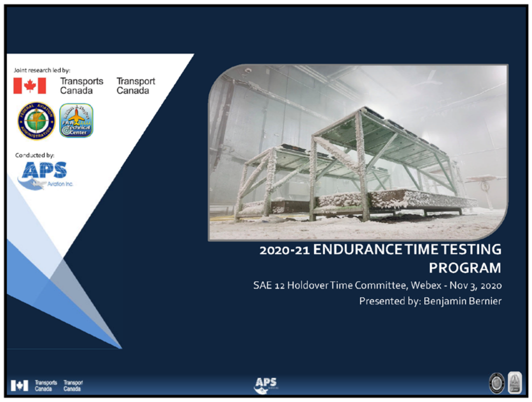
This page intentionally left blank.

APPENDIX M

PRESENTATIONS, FLUID MANUFACTURER REPORTS, AND TEST PROCEDURES FOR 2020-21

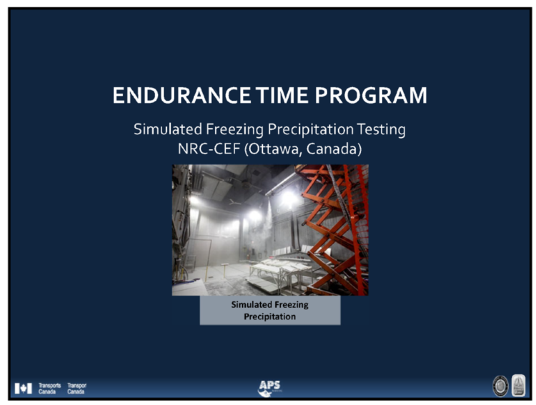
SAE G-12 HOLDOVER TIME COMMITTEE MEETING, ONLINE (VIA WEBEX)
NOVEMBER 2020

PRESENTATION:
2020-21 ENDURANCE TIME TESTING PROGRAM

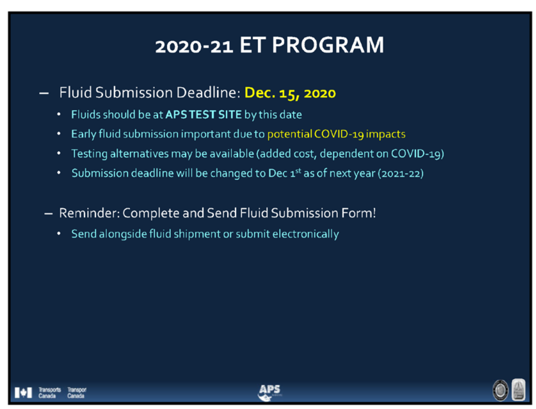

Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS
2020-21 ENDURANCE TIME TESTING PROGRAM
SAE 12 Holdover Time Committee, Webex - Nov 3, 2020
Presented by: Benjamin Bernier

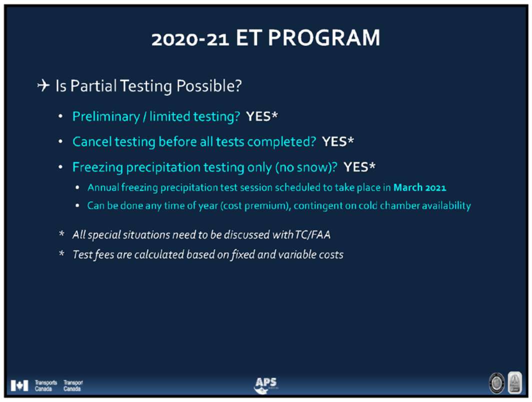

ENDURANCE TIME PROGRAM
APS Aviation is contracted to conduct HOT Testing on behalf of TC/FAA

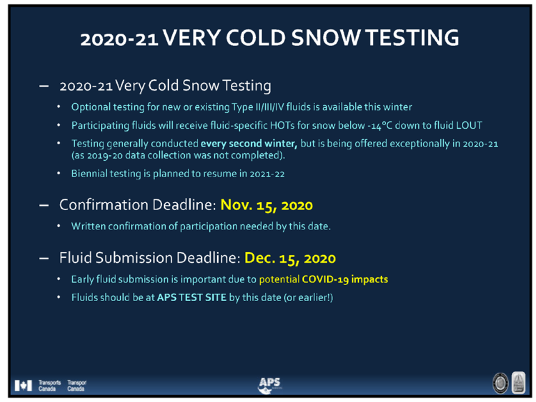

ENDURANCE TIME PROGRAM
Natural Snow and Natural Frost Testing
APS Test Site (Montreal, Canada)
Natural Snow
Natural Frost

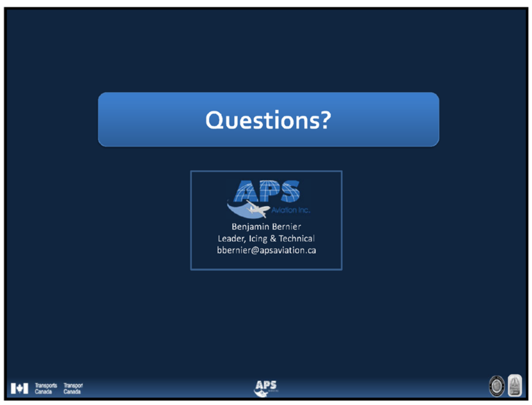

ENDURANCE TIME PROGRAM
Simulated Freezing Precipitation Testing
NRC-CEF (Ottawa, Canada)
Simulated Freezing Precipitation


2020-21 ET PROGRAM
– 2020-21 testing season is starting soon!
– HOT Fluid Request Letter: emailed Oct 15, 2020
– Contains info on:
• Testing Fees
• Fluid Sample Preparation
• Shipping Details
• Plus: Fluid Submission Forms and FAQ Sheet


2020-21 ET PROGRAM
– Fluid Submission Deadline: Dec. 15, 2020
• Fluids should be at APS TEST SITE by this date
• Early fluid submission important due to potential COVID-19 impacts
• Testing alternatives may be available (added cost, dependent on COVID-19)
• Submission deadline will be changed to Dec 1st as of next year (2021-22)
– Reminder: Complete and Send Fluid Submission Form!
• Send alongside fluid shipment or submit electronically


2020-21 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 scheduled to take place in March 2021
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


2020-21 VERY COLD SNOW TESTING
2020-21 Very Cold Snow Testing
Optional testing for new or existing Type II/III/IV fluids is available this winter
Participating fluids will receive fluid-specific HOTs for snow below -14°C down to fluid LOUT
Testing generally conducted every second winter, but is being offered exceptionally in 2020-21 (as 2019-20 data collection was not completed).
Biennial testing is planned to resume in 2021-22
Confirmation Deadline: Nov. 15, 2020
Written confirmation of participation needed by this date.
Fluid Submission Deadline: Dec. 15, 2020
Early fluid submission is important due to potential COVID-19 impacts
Fluids should be at APS TEST SITE by this date (or earlier!)
Transports Canada Transport Canada
APS


Questions?
APS
Aviation Inc.
Benjamin Bernier
Leader, Icing & Technical
bbernier@apsaviation.ca
Transports Canada Transport Canada
APS

SAE G-12 HOLDOVER TIME COMMITTEE MEETING, ONLINE (VIA WEBEX)
NOVEMBER 2020

PRESENTATION:
UPDATE: NATURAL SNOW CHARACTERIZATION SUPPORTING ARTIFICIAL SNOW RESEARCH

Joint research led by:
Transports Canada Transport Canada

Conducted by:
APS

UPDATE: NATURAL SNOW CHARACTERIZATION SUPPORTING ARTIFICIAL SNOW RESEARCH

SAE 12 Holdover Time Committee, Webex, November 3rd, 2020
Dany Posteraro, B. Eng., M. Eng., PhD

Purpose

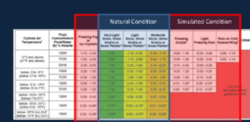
- To provide an update on the artificial snow research activities conducted by APS in 2019-20
- To provide information on future planned artificial snow research activities

Outline

- Project Background and Research Goals
- Testing Methodology, Summary and Data Processing
- Analysis and Findings
  - Point to Point Comparison
  - Global Data Set Approach
- Way Forward
  - Upcoming Artificial Snow Research Activities

Project Background

- Natural snow testing is a major component of the yearly HOT testing activities
- Gathering natural snow data must be done at specific times of the year Dec-April
  - In contrast, simulated precipitation testing can be done at the NRC CEF in Ottawa year round
- A suitable artificial surrogate for natural snow would be beneficial to:
  - Allow testing year round
  - Allow testing at colder temperatures and higher rates not readily encountered

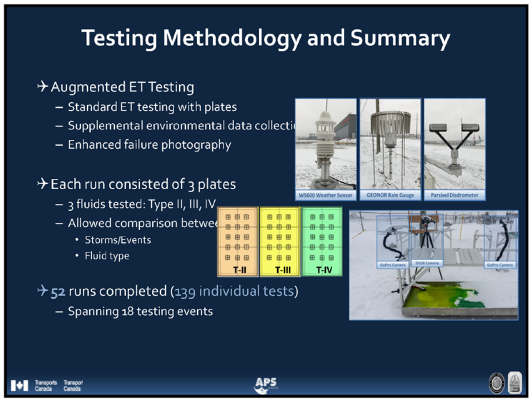


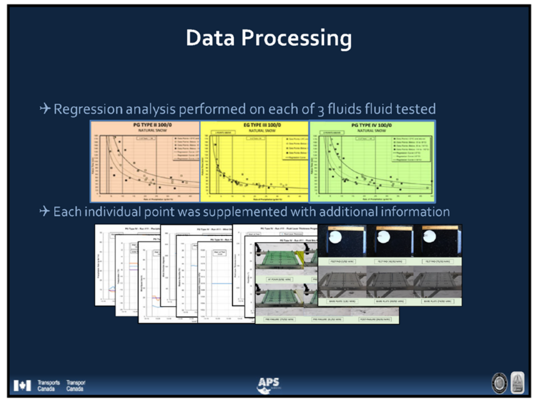
Project Background and Research Goals

- Long Term Objective:
  - Develop artificial snow testing platform for HOT development
- Challenge:
  - Correlation of artificial snow data to natural snow results
- 2019-20 Goal:
  - Identify and characterize environmental parameters influencing anti-icing fluid performance in natural snow
  - Understand data variance that occur in natural conditions

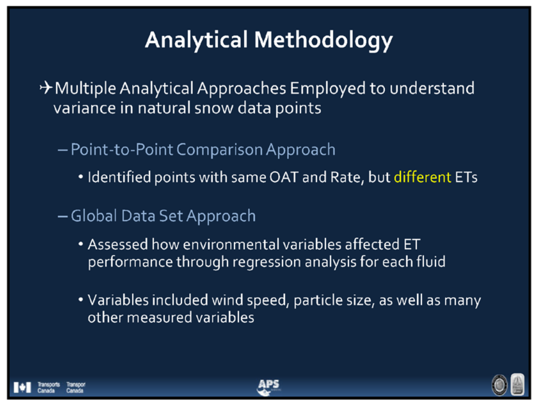
Outline

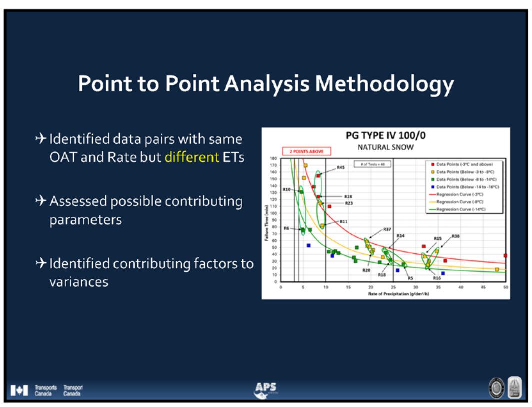
- Project Background and Research Goals
- Testing Methodology, Summary and Data Processing
- Analysis and Findings
  - Point to Point Comparison
  - Global Data Set Approach
- Way Forward
  - Upcoming Artificial Snow Research Activities

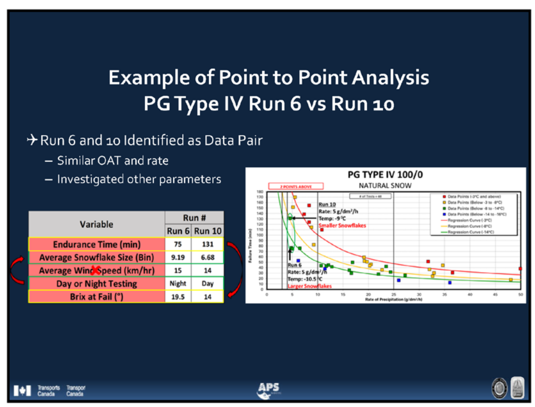

Testing Methodology and Summary
Augmented ET Testing
– Standard ET testing with plates
– Supplemental environmental data collecti
– Enhanced failure photography
Each run consisted of 3 plates
– 3 fluids tested: Type II, III, IV
– Allowed comparison betwee
• Storms/Events
• Fluid type
52 runs completed (139 individual tests)
– Spanning 18 testing events
WS600 Weather Sensor
GEONOR Rain Gauge
Parsivel Disdrometer
T-II
T-III
T-IV
GoPro Camera
DSLR Camera
GoPro Camera
Transports Canada
APS

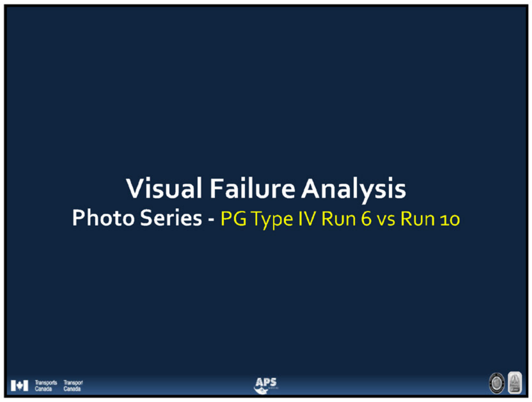

Data Processing
Regression analysis performed on each of 3 fluids fluid tested
Each individual point was supplemented with additional information
APS

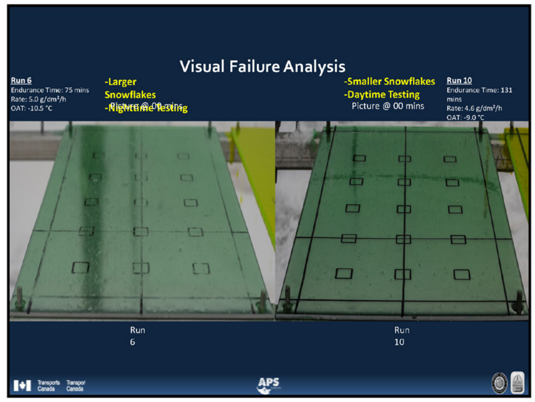

Outline
Project Background and Research Goals
Testing Methodology, Summary and Data Processing
Analysis and Findings
– Point to Point Comparison
– Global Data Set Approach
Way Forward
– Upcoming Artificial Snow Research Activities
APS

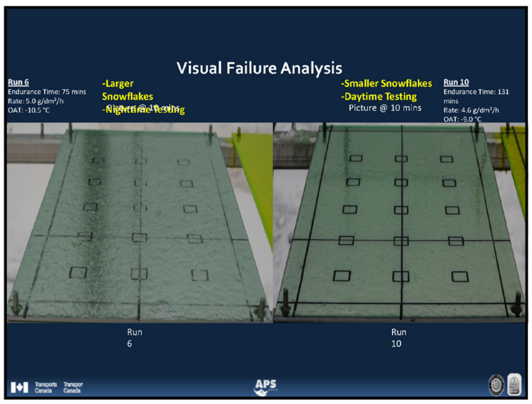

Analytical Methodology
Multiple Analytical Approaches Employed to understand variance in natural snow data points
– Point-to-Point Comparison Approach
• Identified points with same OAT and Rate, but different ETs
– Global Data Set Approach
• Assessed how environmental variables affected ET performance through regression analysis for each fluid
• Variables included wind speed, particle size, as well as many other measured variables
APS

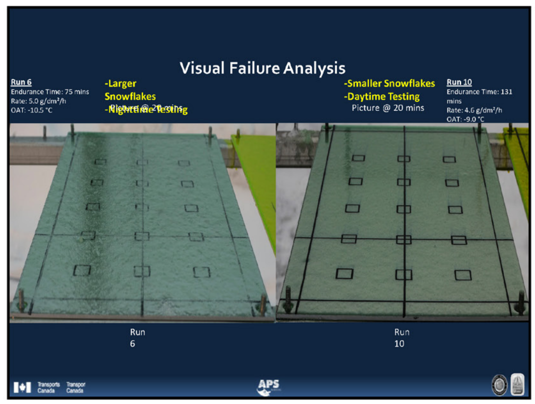

Point to Point Analysis Methodology
Identified data pairs with same OAT and Rate but different ETs
Assessed possible contributing parameters
Identified contributing factors to variances
PG TYPE IV 100/0
NATURAL SNOW
APS

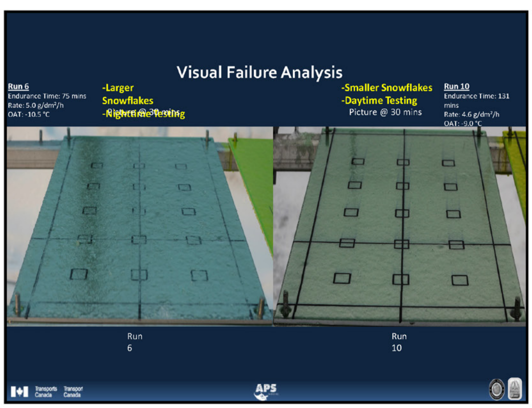

Example of Point to Point Analysis
PG Type IV Run 6 vs Run 10
Run 6 and 10 Identified as Data Pair
– Similar OAT and rate
– Investigated other parameters
Variable | Run # Run 6 | Run 10
Endurance Time (min) | 75 | 131
Average Snowflake Size (Bin) | 9.19 | 6.68
Average Wind Speed (km/hr) | 15 | 14
Day or Night Testing | Night | Day
Brix at Fail (°) | 19.5 | 14
PG TYPE IV 100/0
NATURAL SNOW
2 POINTS ABOVE
Run 10
Rate: 5 g/dm²/h
Temp: -9 °C
Smaller Snowflakes
Run 6
Rate: 5 g/dm²/h
Temp: -10.5 °C
Larger Snowflakes
Rate of Precipitation (g/dm²/h)
Failure Time (min)
APS

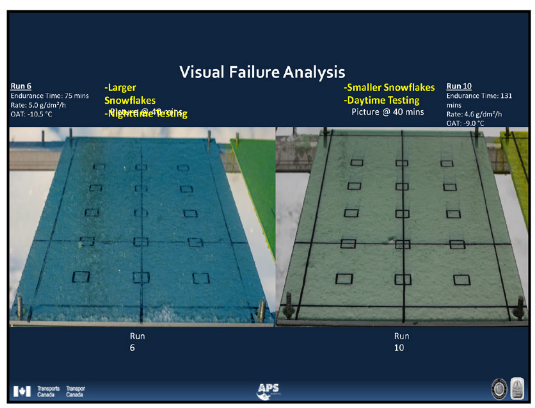

Visual Failure Analysis
Photo Series - PG Type IV Run 6 vs Run 10
APS

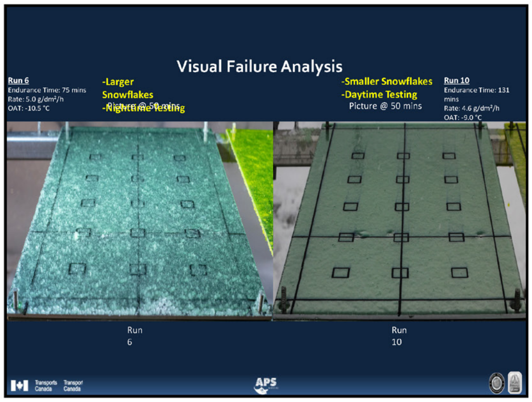

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
-Smaller Snowflakes
-Daytime Testing
Picture @ 00 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS

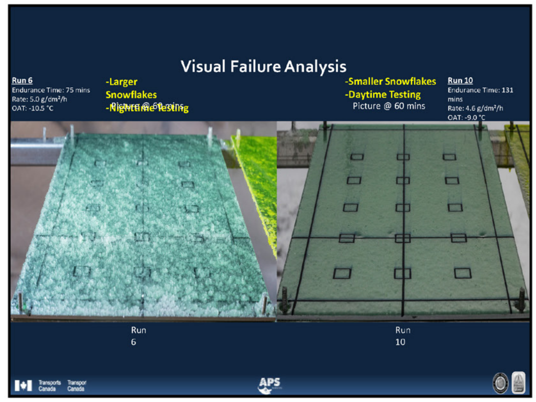

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
-Smaller Snowflakes
-Daytime Testing
Picture @ 10 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS

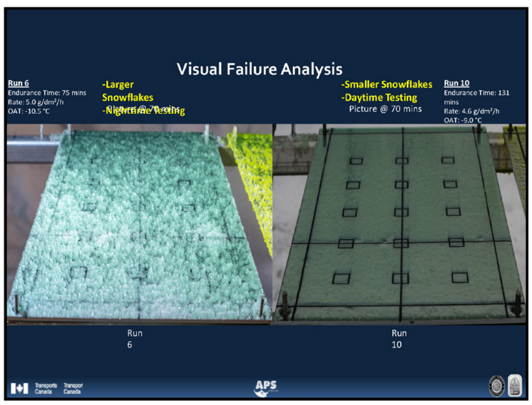

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
-Smaller Snowflakes
-Daytime Testing
Picture @ 20 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS

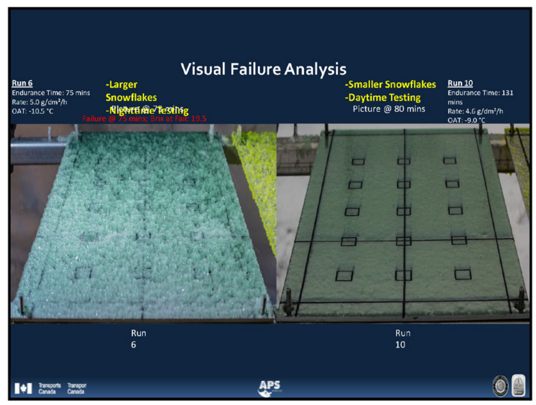

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
-Smaller Snowflakes
-Daytime Testing
Picture @ 30 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS

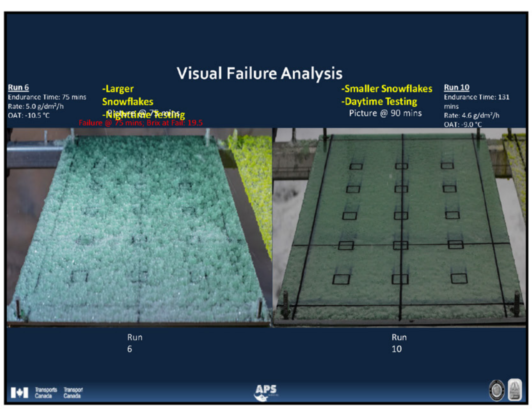

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
-Smaller Snowflakes
-Daytime Testing
Picture @ 40 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS

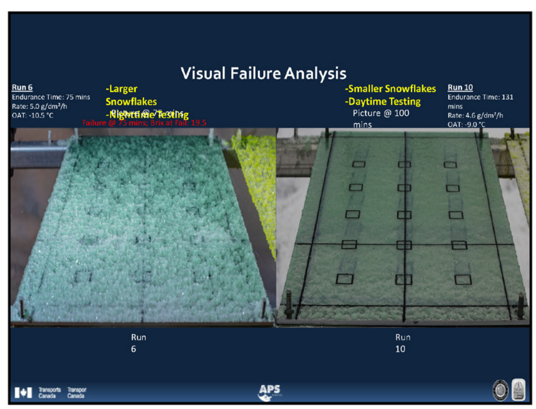

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
Picture @ 50 mins
-Smaller Snowflakes
-Daytime Testing
Picture @ 50 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10

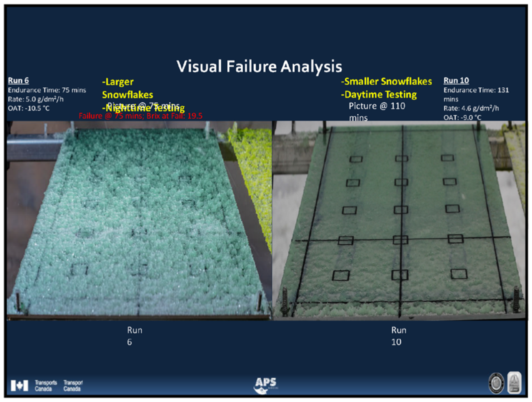

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
Picture @ 60 mins
-Smaller Snowflakes
-Daytime Testing
Picture @ 60 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10

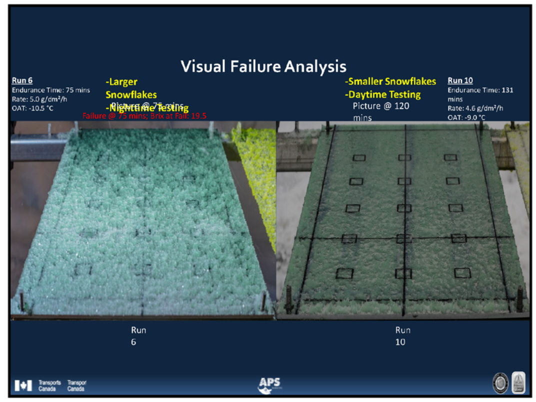

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
Picture @ 70 mins
-Smaller Snowflakes
-Daytime Testing
Picture @ 70 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10

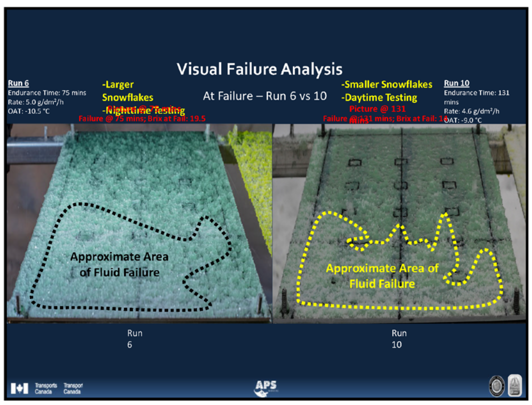

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
Picture @ 75 mins
Failure @ 75 mins; Brix at Fail: 19.5
-Smaller Snowflakes
-Daytime Testing
Picture @ 80 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10

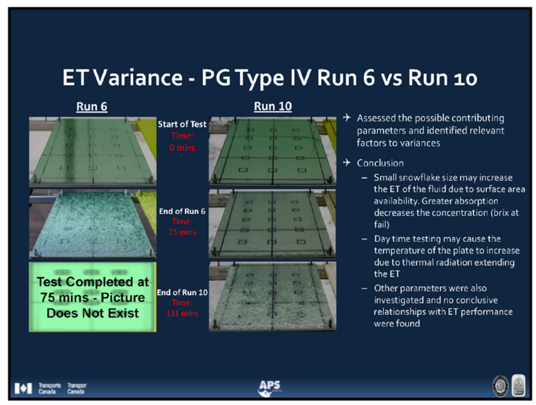

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
Picture @ 75 mins
Failure @ 75 mins; Brix at Fail: 19.5
-Smaller Snowflakes
-Daytime Testing
Picture @ 90 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10

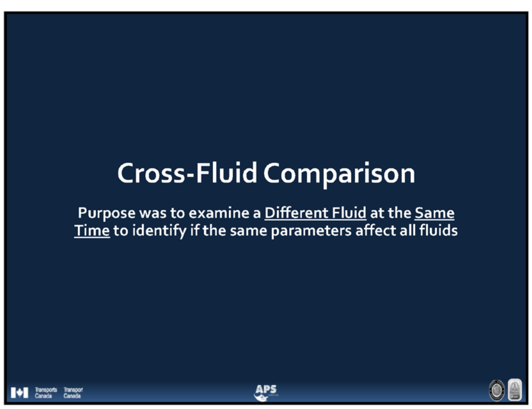

Visual Failure Analysis
Run 6
Endurance Time: 75 mins
Rate: 5.0 g/dm²/h
OAT: -10.5 °C
-Larger Snowflakes
-Nighttime Testing
Picture @ 75 mins
Failure @ 75 mins; Brix at Fail: 19.5
-Smaller Snowflakes
-Daytime Testing
Picture @ 100 mins
Run 10
Endurance Time: 131 mins
Rate: 4.6 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10

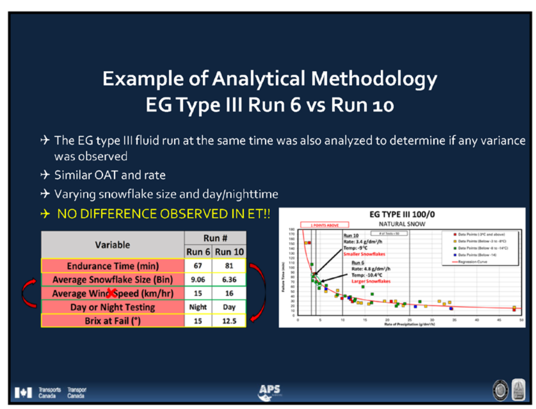




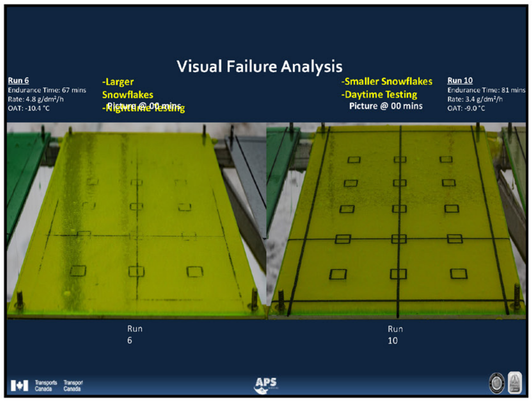


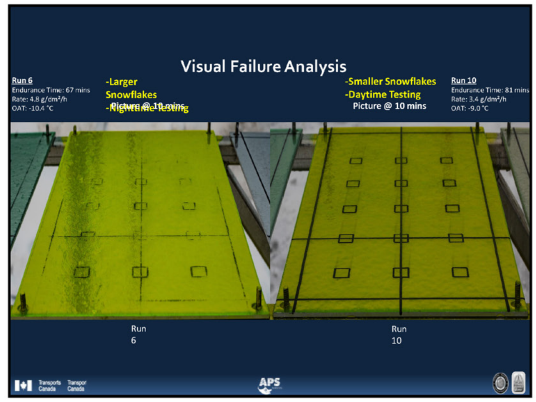


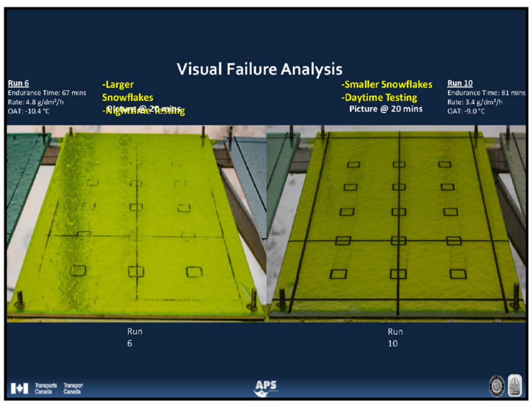


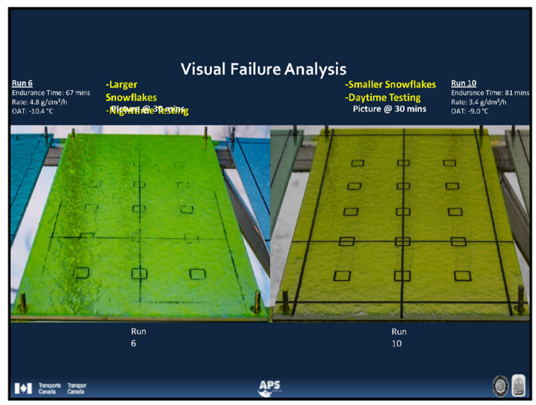


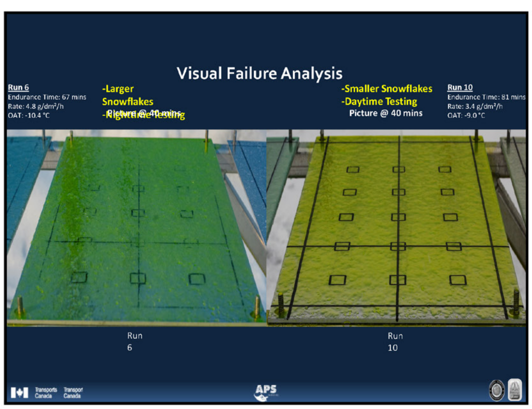
Variable	Run #	
	Run 6	Run 10
Endurance Time (min)	67	81
Average Snowflake Size (Bin)	9.06	6.36
Average Wind Speed (km/hr)	15	16
Day or Night Testing	Night	Day
Brix at Fail (°)	15	12.5

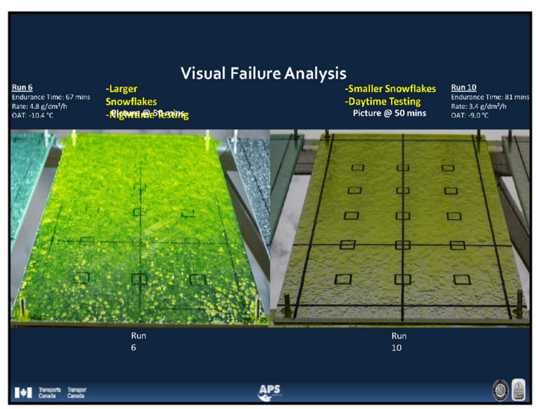

Visual Failure Analysis
Run 6
Endurance Time: 67 mins
Rate: 4.8 g/dm²/h
OAT: -10.4 °C
-Larger Snowflakes
-Nighttime Testing
Picture @ 00 mins
-Smaller Snowflakes
-Daytime Testing
Picture @ 00 mins
Run 10
Endurance Time: 81 mins
Rate: 3.4 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS

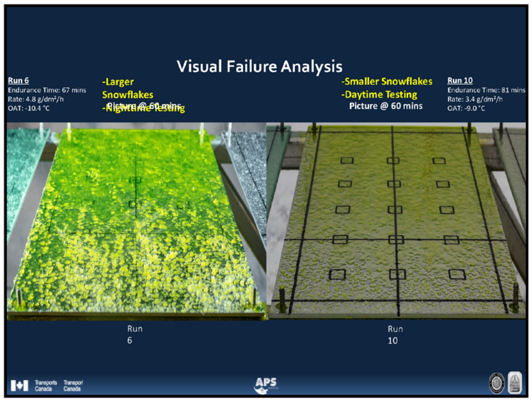

Visual Failure Analysis
Run 6
Endurance Time: 67 mins
Rate: 4.8 g/dm²/h
OAT: -10.4 °C
-Larger Snowflakes
-Nighttime Testing
-Smaller Snowflakes
-Daytime Testing
Picture @ 10 mins
Run 10
Endurance Time: 81 mins
Rate: 3.4 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS

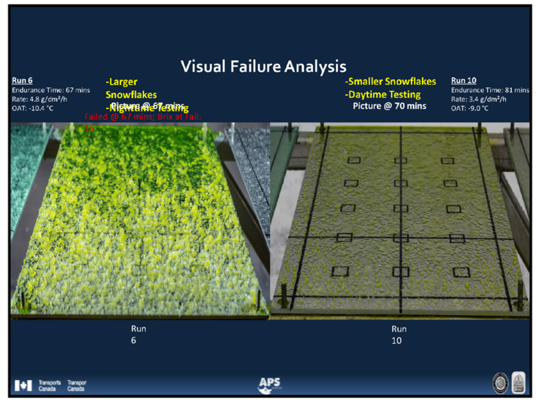

Visual Failure Analysis
Run 6
Endurance Time: 67 mins
Rate: 4.8 g/dm²/h
OAT: -10.4 °C
-Larger Snowflakes
-Nighttime Testing
-Smaller Snowflakes
-Daytime Testing
Picture @ 20 mins
Run 10
Endurance Time: 81 mins
Rate: 3.4 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS

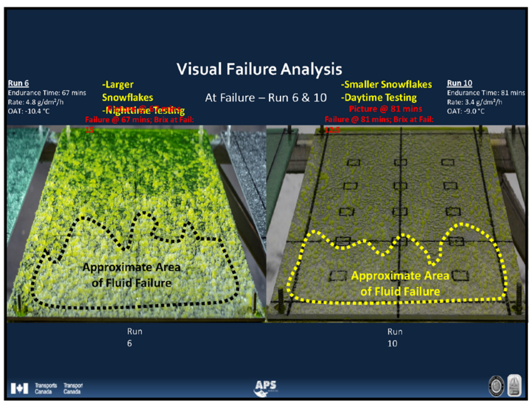

Visual Failure Analysis
Run 6
Endurance Time: 67 mins
Rate: 4.8 g/dm²/h
OAT: -10.4 °C
-Larger Snowflakes
-Nighttime Testing
-Smaller Snowflakes
-Daytime Testing
Picture @ 30 mins
Run 10
Endurance Time: 81 mins
Rate: 3.4 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS

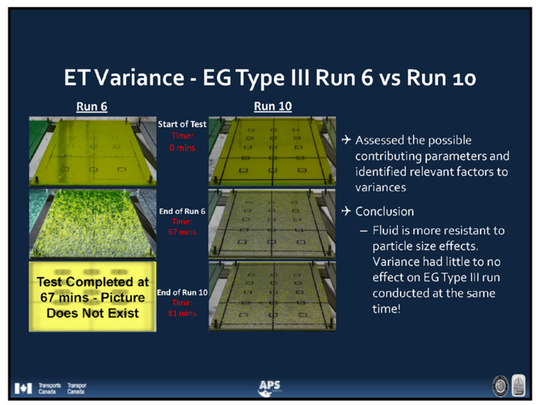

Visual Failure Analysis
Run 6
Endurance Time: 67 mins
Rate: 4.8 g/dm²/h
OAT: -10.4 °C
-Larger Snowflakes
-Nighttime Testing
-Smaller Snowflakes
-Daytime Testing
Picture @ 40 mins
Run 10
Endurance Time: 81 mins
Rate: 3.4 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS

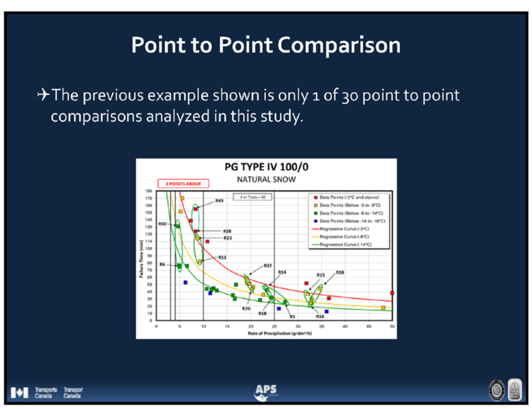

Visual Failure Analysis
Run 6
Endurance Time: 67 mins
Rate: 4.8 g/dm²/h
OAT: -10.4 °C
-Larger Snowflakes
-Nighttime Testing
-Smaller Snowflakes
-Daytime Testing
Picture @ 50 mins
Run 10
Endurance Time: 81 mins
Rate: 3.4 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS


Visual Failure Analysis
Run 6
Endurance Time: 67 mins
Rate: 4.8 g/dm²/h
OAT: -10.4 °C
-Larger
Snowflakes
-Nighttime Testing
Picture @ 60 mins
-Smaller Snowflakes
-Daytime Testing
Picture @ 60 mins
Run 10
Endurance Time: 81 mins
Rate: 3.4 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS


Visual Failure Analysis
Run 6
Endurance Time: 67 mins
Rate: 4.8 g/dm²/h
OAT: -10.4 °C
-Larger
Snowflakes
Picture @ 67 mins
Failed @ 67 mins; Brix at Fail:
-Smaller Snowflakes
-Daytime Testing
Picture @ 70 mins
Run 10
Endurance Time: 81 mins
Rate: 3.4 g/dm²/h
OAT: -9.0 °C
Run 6
Run 10
APS


Visual Failure Analysis
Run 6
Endurance Time: 67 mins
Rate: 4.8 g/dm²/h
OAT: -10.4 °C
-Larger
Snowflakes
-Nighttime Testing
Picture @ 67 mins
Failure @ 67 mins; Brix at Fail: 15
At Failure – Run 6 & 10
-Smaller Snowflakes
-Daytime Testing
Picture @ 81 mins
Failure @ 81 mins; Brix at Fail: 12.5
Run 10
Endurance Time: 81 mins
Rate: 3.4 g/dm²/h
OAT: -9.0 °C
Approximate Area of Fluid Failure
Approximate Area of Fluid Failure
Run 6
Run 10
APS

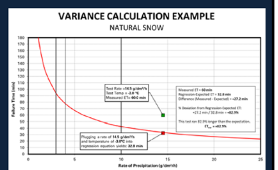

ET Variance - EG Type III Run 6 vs Run 10
Run 6
Run 10
Start of Test
Time: 0 mins
End of Run 6
Time: 67 mins
End of Run 10
Time: 81 mins
Test Completed at 67 mins - Picture Does Not Exist
Assessed the possible contributing parameters and identified relevant factors to variances
Conclusion
– Fluid is more resistant to particle size effects. Variance had little to no effect on EG Type III run conducted at the same time!
Transports Canada
Transport Canada
APS


Point to Point Comparison
The previous example shown is only 1 of 30 point to point comparisons analyzed in this study.
PG TYPE IV 100/0
NATURAL SNOW
APS


Outline
Project Background and Research Goals
Testing Methodology, Summary and Data Processing
Analysis and Findings
– Point to Point Comparison
– Global Data Set Approach
Way Forward
– Upcoming Artificial Snow Research Activities
APS

Global Data Set Analysis

- Multi variable regression analysis performed using
  - Environmental factors as inputs
  - ET variance from predicted ET as output
- The significance of each of the environmental variables measured during testing was evaluated
- Analysis supported the variance findings of the point to point analysis



Preliminary General Findings - Overall

- Both analytical approaches identified wind speed and particle size as parameters affecting endurance time performance in natural snow
  - Higher winds was associated with longer than expected endurance times
  - Smaller particle size was associated with longer than expected endurance times
- Magnitude of effect dependent on the fluid being tested
  - EG Type III ET performance was not affected by either wind speed or particle size

Fluids:	PG Type II	EG Type III	PG Type IV
Significant Variables	Wind Speed	None	Wind Speed Particle Size

Significance of Variance

- OAT and Rate are still major variables and drivers for ET
- Some variance comes from the other environmental factors (wind, snow size, etc)
- The variance is accounted for in current HOT testing methodology by
  - Multiple storms
  - Large data set
  - Conducting regression analysis on the large data set
- Challenge is how to account for this variance in artificial snow setup if:
  - Wind and snow particle cannot be easily modified
  - Adding additional parameters potentially increases testing requirements

Recommendations

- Need to better understand significance of variables (wind and snow size) and how they will affect artificial snow testing

Outline

- Project Background and Research Goals
- Testing Methodology, Summary and Data Processing
- Analysis and Findings
  - Point to Point Comparison
  - Global Data Set Approach
- Way Forward
  - Upcoming Artificial Snow Research Activities

Upcoming Artificial Snow Research Activities

- Artificial/Natural Snow Comparison Testing
  - Conduct natural snow testing
    - Warm snow at APS test facility
    - Very cold snow where weather permits; mainly in northern Canada
  - Replicate natural snow data sets with artificial snow testing systems
    - Compare holdover times derived from each data set to assess correlation
  - Expected to be complete over 2 testing seasons


Thank
You
APS
Aviation Inc.
Dany Posteraro
dposteraro@apsaviation.ca

This page intentionally left blank.

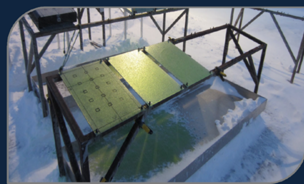
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX)
MAY 2021

PRESENTATION:
WINTER 2019-20 + 2020-21 ENDURANCE TIME TESTING UPDATE

Joint research led by:

Transports Canada Transport Canada

Conducted by: APS Aviation Inc.



WINTER 2019-20 + 2020-21
ENDURANCE TIME TESTING UPDATE

SAE 12 Holdover Time Committee, Webex, May 18, 2021
Benjamin Bernier, Project Leader

Purpose

- To provide an overview of the new fluids tested for inclusion in the HOT guidelines
  - Includes fluids tested in 2019-20 and 2020-21
- Notes:
  - HOTs and fluid info are not official until published by TC/FAA
  - All data/charts included in an Appendix for brevity.
  - Appendix slides will be available on the SAE website, but not shown at meeting unless requested.

Outline

- 2019-20 + 2020-21 Testing Overview
- Methodology
- Standard HOT Test Results Summary: 10 Fluids
- Very Cold Snow Test Results Summary: 11 Fluids
- Supplemental Testing: Cleanwing II
- Summary
- Appendix: Detailed Test Results

Testing Overview

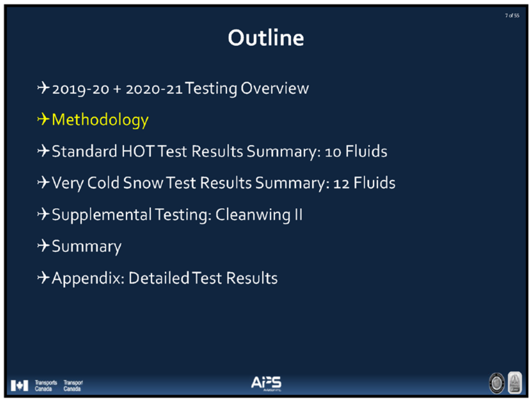
- 1872 total endurance time (ET) tests were conducted with fluids submitted in 2019-20 + 2020-21
  - 2019-20 ET testing activities conducted over two years due to COVID-19
- Of the fluids submitted, ten new fluids are expected to be added to the HOT Guidelines for the 2021-22 winter season

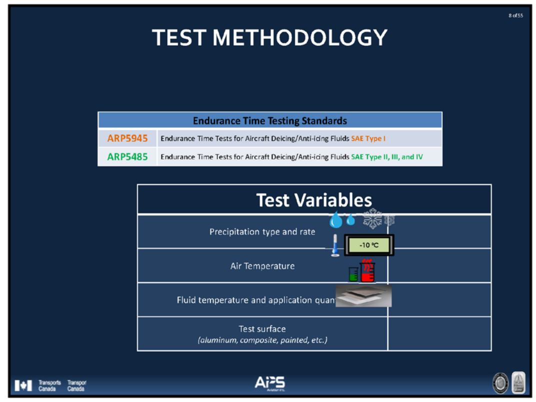
Tests Conducted

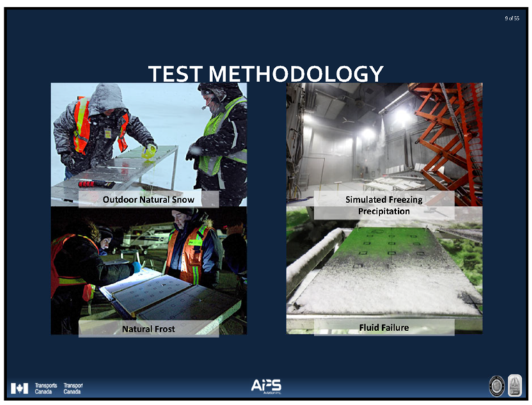
Fluid Type	Fluid Dilution	Natural Snow	Artificial Snow	Freezing Fog	Freezing Drizzle	Light Freezing Rain	Cold-Soak Surface	Frost	Total
Type I	Alum.	0	0	0	0	0	0	0	0
	Comp.	0	0	0	0	0	0	0	0
Type II	100/0	75	9	24	16	16	8	26	174
	75/25	110	0	18	16	16	8	10	178
	50/50	28	0	4	4	4	0	6	46
Type III	100/0	0	0	0	0	0	0	0	0
	75/25	0	0	0	0	0	0	0	0
	50/50	0	0	0	0	0	0	0	0
Type IV	100/0	772	211	172	96	96	48	79	1474
	75/25	0	0	0	0	0	0	0	0
	50/50	0	0	0	0	0	0	0	0
Total		985	220	218	132	132	64	121	1872

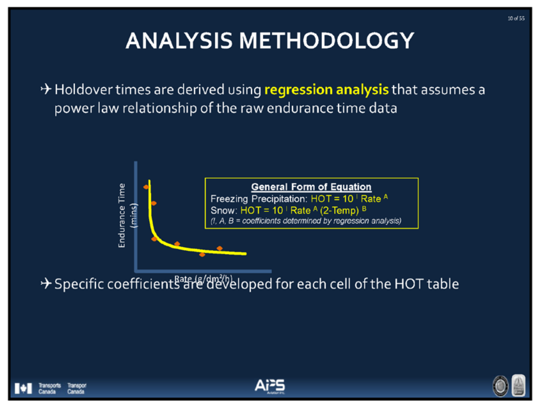
New Fluids

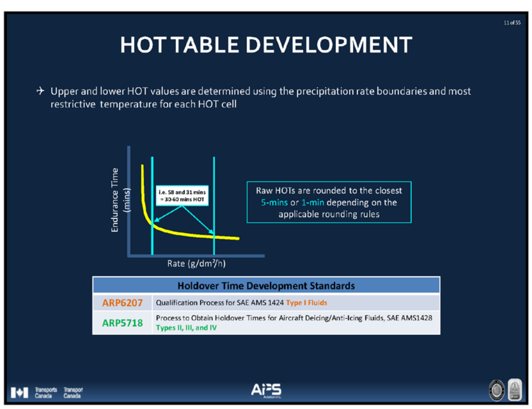
Kilfrost	Type II	Kilfrost Ice Clear II (Fluid Reformulated)	AVIAFLUID	Type IV	AVIAFlight EG
Romchim	Type II	ADD-PROTECT NG	AVIAFLUID	Type IV	AVIAFlight PG
ALLCLEAR SYSTEMS	Type IV	ClearWing ECO	CHEMR Deicing products	Type IV	ChemR Nordik IV
ASGLOBAL	Type IV	4Flite EG	NEWAVE	Type IV	FCY-EGIV
ASGLOBAL	Type IV	4Flite PG	NORDIX	Type IV	Defrost North 4

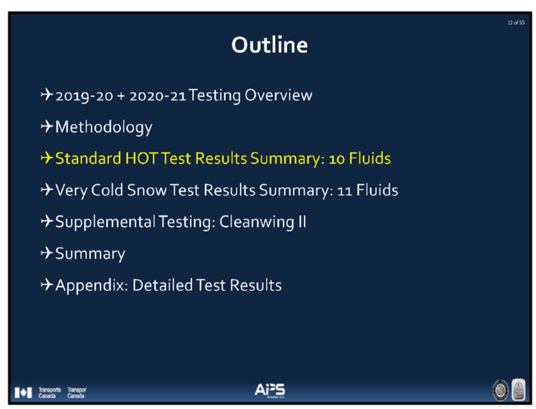

Outline
2019-20 + 2020-21 Testing Overview
Methodology
Standard HOT Test Results Summary: 10 Fluids
Very Cold Snow Test Results Summary: 12 Fluids
Supplemental Testing: Cleanwing II
Summary
Appendix: Detailed Test Results

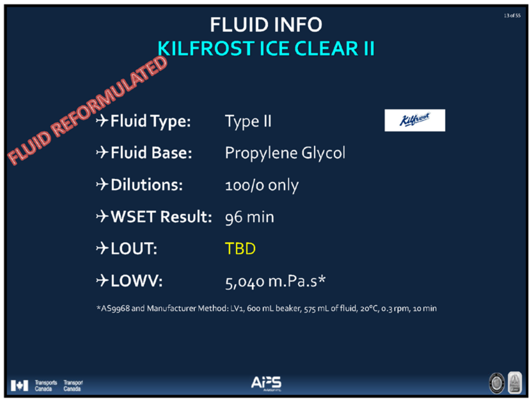

TEST METHODOLOGY
Endurance Time Testing Standards
ARP5945
Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type I
ARP5485
Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type II, III, and IV
Test Variables
Precipitation type and rate
Air Temperature
-10 °C
Fluid temperature and application quan
Test surface
(aluminum, composite, painted, etc.)

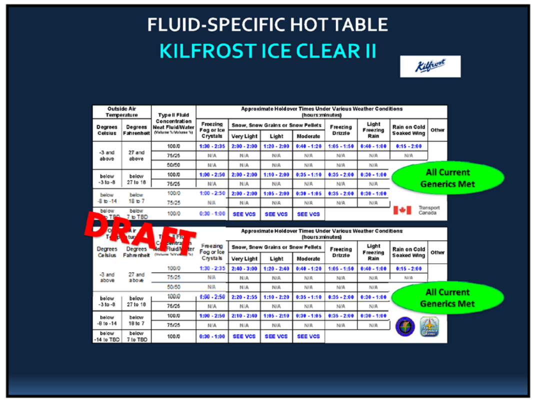

TEST METHODOLOGY
Outdoor Natural Snow
Simulated Freezing Precipitation
Natural Frost
Fluid Failure

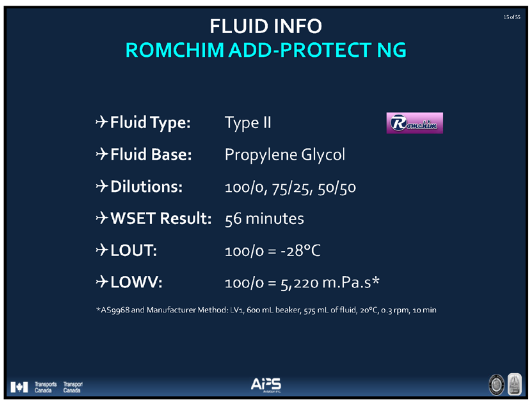

ANALYSIS METHODOLOGY
Holdover times are derived using regression analysis that assumes a power law relationship of the raw endurance time data
Endurance Time (mins)
Rate (g/dm²/h)
General Form of Equation
Freezing Precipitation: HOT = 10 I Rate A
Snow: HOT = 10 I Rate A (2-Temp) B
(I, A, B = coefficients determined by regression analysis)
Specific coefficients are developed for each cell of the HOT table

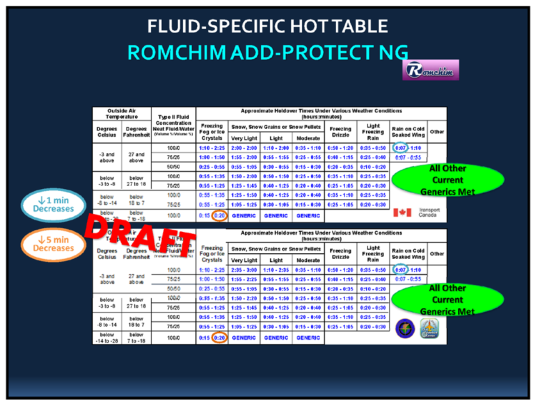

HOT TABLE DEVELOPMENT
Upper and lower HOT values are determined using the precipitation rate boundaries and most restrictive temperature for each HOT cell
Endurance Time (mins)
Rate (g/dm²/h)
Raw HOTs are rounded to the closest 5-mins or 1-min depending on the applicable rounding rules
Holdover Time Development Standards
ARP6207
Qualification Process for SAE AMS 1424 Type I Fluids
ARP5718
Process to Obtain Holdover Times for Aircraft Deicing/Anti-Icing Fluids, SAE AMS1428 Types II, III, and IV

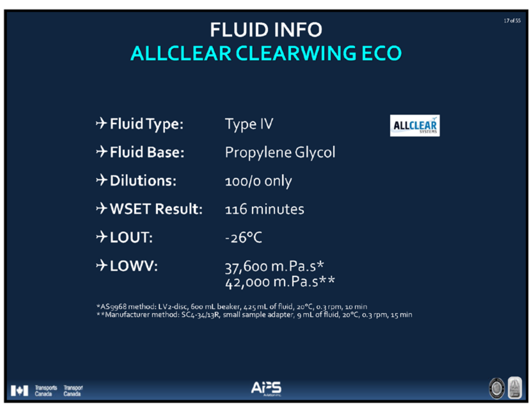

Outline
2019-20 + 2020-21 Testing Overview
Methodology
Standard HOT Test Results Summary: 10 Fluids
Very Cold Snow Test Results Summary: 11 Fluids
Supplemental Testing: Cleanwing II
Summary
Appendix: Detailed Test Results

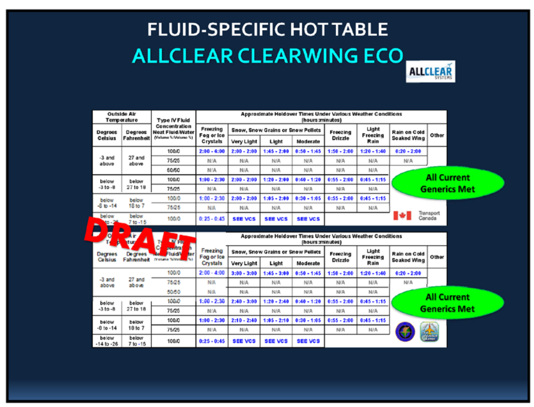

FLUID INFO
KILFROST ICE CLEAR II
FLUID REFORMULATED
Fluid Type: Type II
Fluid Base: Propylene Glycol
Dilutions: 100/0 only
WSET Result: 96 min
LOUT: TBD
LOWV: 5,040 m.Pa.s*
*AS9968 and Manufacturer Method: LV1, 600 mL beaker, 575 mL of fluid, 20°C, 0.3 rpm, 10 min
Transports Canada Transport Canada
APS

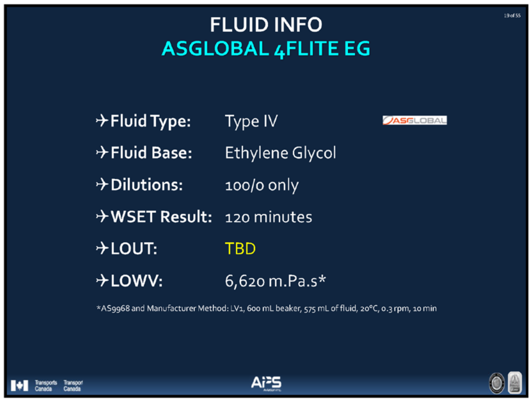

FLUID-SPECIFIC HOT TABLE
KILFROST ICE CLEAR II
DRAFT
All Current Generics Met
All Current Generics Met

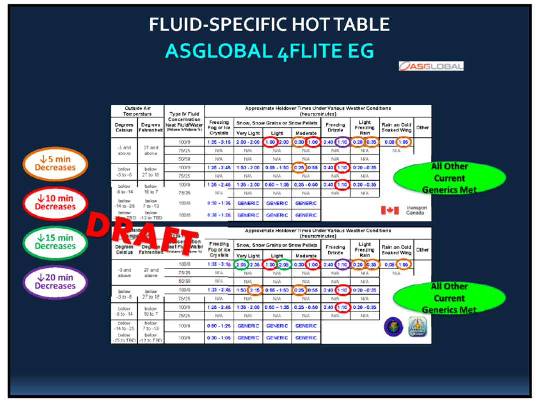

FLUID INFO
ROMCHIM ADD-PROTECT NG
Fluid Type: Type II
Fluid Base: Propylene Glycol
Dilutions: 100/0, 75/25, 50/50
WSET Result: 56 minutes
LOUT: 100/0 = -28°C
LOWV: 100/0 = 5,220 m.Pa.s*
*AS9968 and Manufacturer Method: LV1, 600 mL beaker, 575 mL of fluid, 20°C, 0.3 rpm, 10 min
Transports Canada Transport Canada
APS

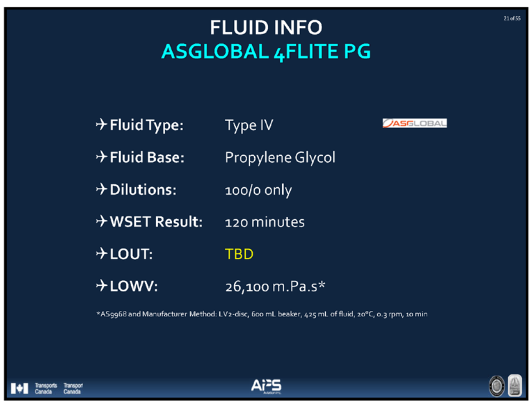

FLUID-SPECIFIC HOT TABLE
ROMCHIM ADD-PROTECT NG
DRAFT
1 min Decreases
5 min Decreases
All Other Current Generics Met
All Other Current Generics Met

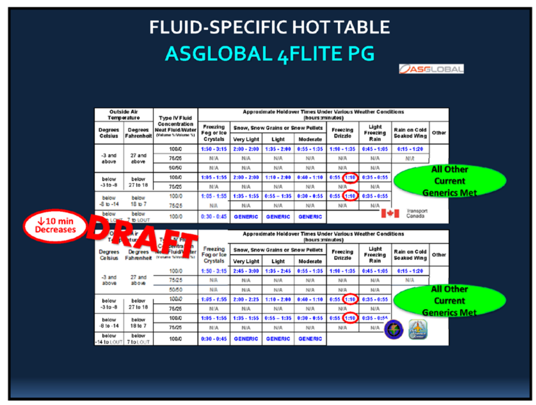

FLUID INFO
ALLCLEAR CLEARWING ECO
Fluid Type: Type IV
Fluid Base: Propylene Glycol
Dilutions: 100/0 only
WSET Result: 116 minutes
LOUT: -26°C
LOWV: 37,600 m.Pa.s*
42,000 m.Pa.s**
*AS9968 method: LV2-disc, 600 mL beaker, 425 mL of fluid, 20°C, 0.3 rpm, 10 min
**Manufacturer method: SC4-34/13R, small sample adapter, 9 mL of fluid, 20°C, 0.3 rpm, 15 min
Transports Canada Transport Canada
APS

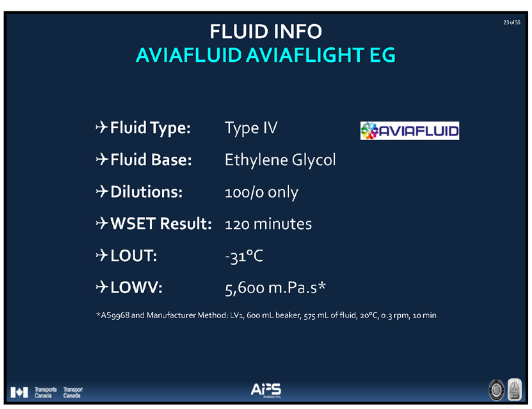

FLUID-SPECIFIC HOT TABLE
ALLCLEAR CLEARWING ECO
ALLCLEAR
DRAFT
All Current Generics Met
All Current Generics Met

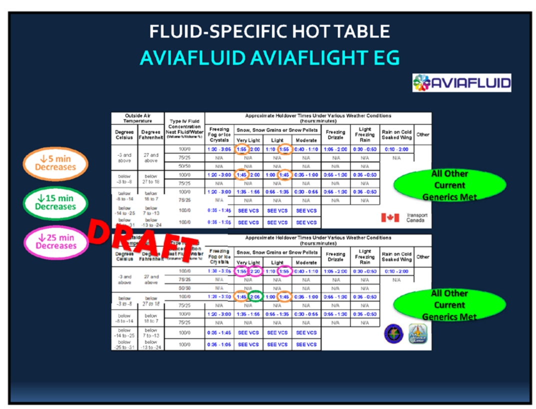

FLUID INFO
ASGLOBAL 4FLITE EG
ASGLOBAL
Fluid Type: Type IV
Fluid Base: Ethylene Glycol
Dilutions: 100/0 only
WSET Result: 120 minutes
LOUT: TBD
LOWV: 6,620 m.Pa.s*
*AS5968 and Manufacturer Method: LV1, 600 mL beaker, 575 mL of fluid, 20°C, 0.3 rpm, 10 min
APS

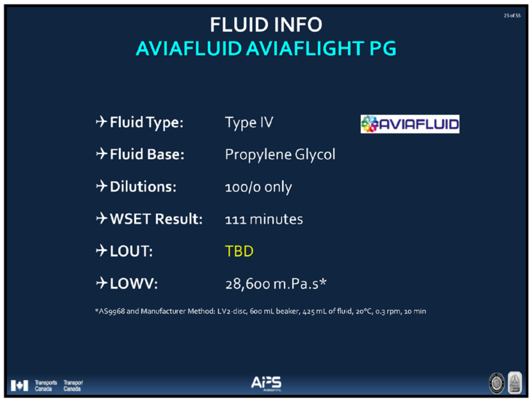

FLUID-SPECIFIC HOT TABLE
ASGLOBAL 4FLITE EG
ASGLOBAL
5 min Decreases
10 min Decreases
15 min Decreases
20 min Decreases
DRAFT
All Other Current Generics Met
All Other Current Generics Met

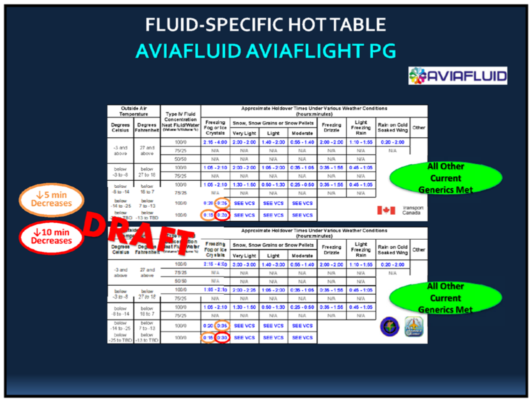

FLUID INFO
ASGLOBAL 4FLITE PG
ASGLOBAL
Fluid Type: Type IV
Fluid Base: Propylene Glycol
Dilutions: 100/0 only
WSET Result: 120 minutes
LOUT: TBD
LOWV: 26,100 m.Pa.s*
*AS5968 and Manufacturer Method: LV2-disc, 600 mL beaker, 425 mL of fluid, 20°C, 0.3 rpm, 10 min
APS

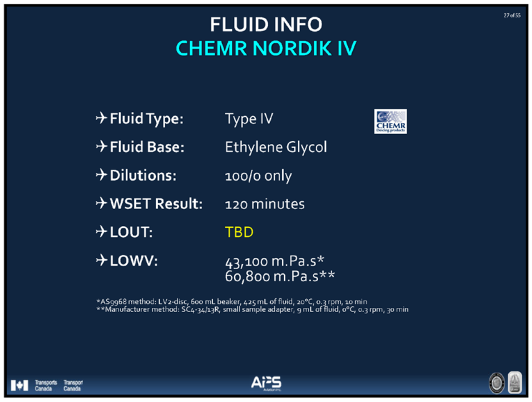

FLUID-SPECIFIC HOT TABLE
ASGLOBAL 4FLITE PG
ASGLOBAL
10 min Decreases
DRAFT
All Other Current Generics Met
All Other Current Generics Met

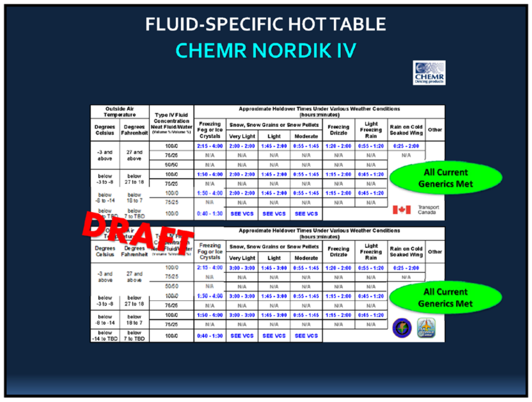

FLUID INFO
AVIAFLUID AVIAFLIGHT EG
AVIAFLUID
Fluid Type: Type IV
Fluid Base: Ethylene Glycol
Dilutions: 100/0 only
WSET Result: 120 minutes
LOUT: -31°C
LOWV: 5,600 m.Pa.s*
*AS5968 and Manufacturer Method: LV1, 600 mL beaker, 575 mL of fluid, 20°C, 0.3 rpm, 10 min
APS

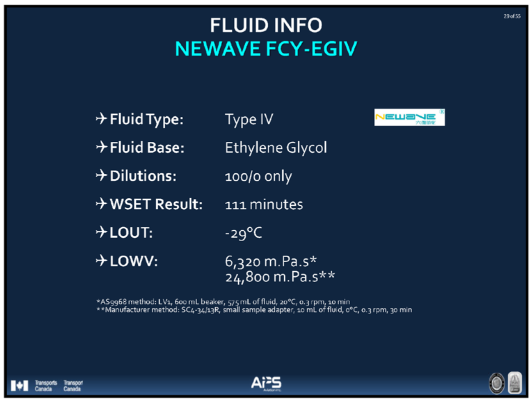

FLUID-SPECIFIC HOT TABLE
AVIAFLUID AVIAFLIGHT EG
AVIAFLUID
5 min Decreases
15 min Decreases
25 min Decreases
DRAFT
All Other Current Generics Met
All Other Current Generics Met

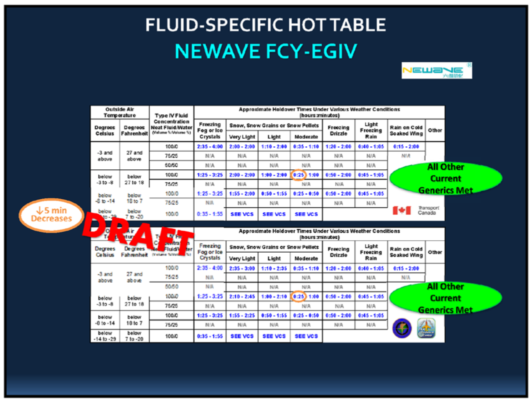

FLUID INFO
AVIAFLUID AVIAFLIGHT PG
AVIAFLUID
Fluid Type: Type IV
Fluid Base: Propylene Glycol
Dilutions: 100/0 only
WSET Result: 111 minutes
LOUT: TBD
LOWV: 28,600 m.Pa.s*
*AS9968 and Manufacturer Method: LV2-disc, 600 mL beaker, 425 mL of fluid, 20°C, 0.3 rpm, 10 min
Transports Canada Transport Canada
AiPS

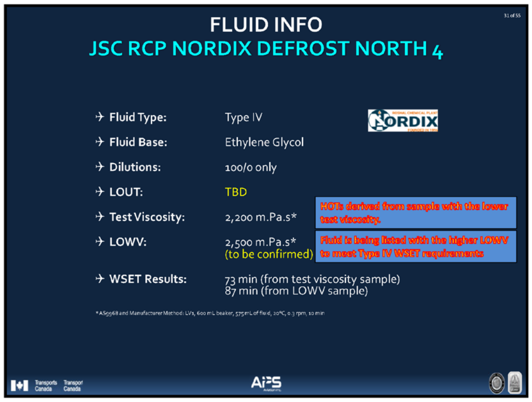

FLUID-SPECIFIC HOT TABLE
AVIAFLUID AVIAFLIGHT PG
AVIAFLUID
5 min Decreases
10 min Decreases
DRAFT
All Other Current Generics Met
All Other Current Generics Met

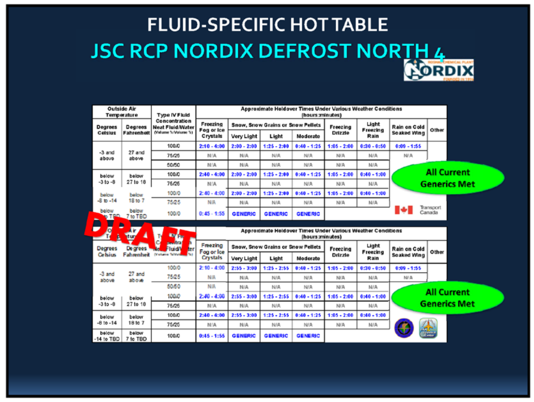

FLUID INFO
CHEMR NORDIK IV
CHEMR
Fluid Type: Type IV
Fluid Base: Ethylene Glycol
Dilutions: 100/0 only
WSET Result: 120 minutes
LOUT: TBD
LOWV: 43,100 m.Pa.s*
60,800 m.Pa.s**
*AS9968 method: LV2-disc, 600 mL beaker, 425 mL of fluid, 20°C, 0.3 rpm, 10 min
**Manufacturer method: SC4-34/13R, small sample adapter, 9 mL of fluid, 0°C, 0.3 rpm, 30 min
Transports Canada Transport Canada
AiPS


FLUID-SPECIFIC HOT TABLE
CHEMR NORDIK IV
CHEMR
DRAFT
All Current Generics Met
All Current Generics Met


FLUID INFO
NEWAVE FCY-EGIV
NEWAVE
Fluid Type: Type IV
Fluid Base: Ethylene Glycol
Dilutions: 100/0 only
WSET Result: 111 minutes
LOUT: -29°C
LOWV: 6,320 m.Pa.s*
24,800 m.Pa.s**
*AS9968 method: LV1, 600 mL beaker, 575 mL of fluid, 20°C, 0.3 rpm, 10 min
**Manufacturer method: SC4-34/13R, small sample adapter, 10 mL of fluid, 0°C, 0.3 rpm, 30 min
Transports Canada Transport Canada
AiPS

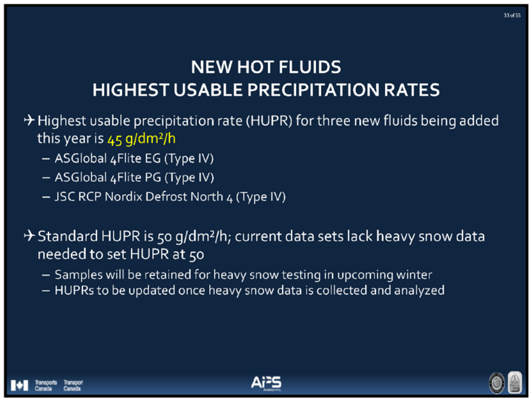

FLUID-SPECIFIC HOT TABLE
NEWAVE FCY-EGIV
NEWAVE
5 min Decreases
DRAFT
All Other Current Generics Met
All Other Current Generics Met

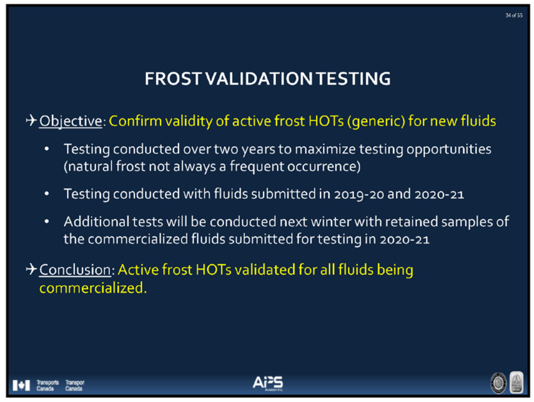


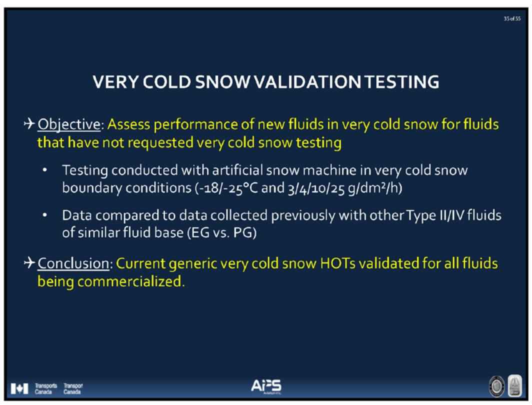


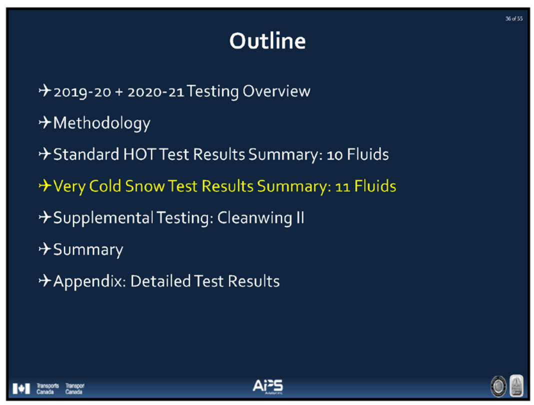
Outside Air Temperature Degrees Celsius	Outside Air Temperature Degrees Fahrenheit	Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets: Very Light	Snow, Snow Grains or Snow Pellets: Light	Snow, Snow Grains or Snow Pellets: Moderate	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 and above	27 and above	100/0	2:10 - 4:00	2:00 - 2:00	1:25 - 2:00	0:40 - 1:25	1:05 - 2:00	0:30 - 0:50	0:09 - 1:55	
		75/25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
		50/50	N/A	N/A	N/A	N/A	N/A	N/A		
below -3 to -8	below 27 to 18	100/0	2:40 - 4:00	2:00 - 2:00	1:25 - 2:00	0:40 - 1:25	1:05 - 2:00	0:40 - 1:00		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -8 to -14	below 18 to 7	100/0	2:40 - 4:00	2:00 - 2:00	1:25 - 2:00	0:40 - 1:25	1:05 - 2:00	0:40 - 1:00		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below ... to TBD	below 7 to TBD	100/0	0:45 - 1:55	GENERIC	GENERIC	GENERIC				

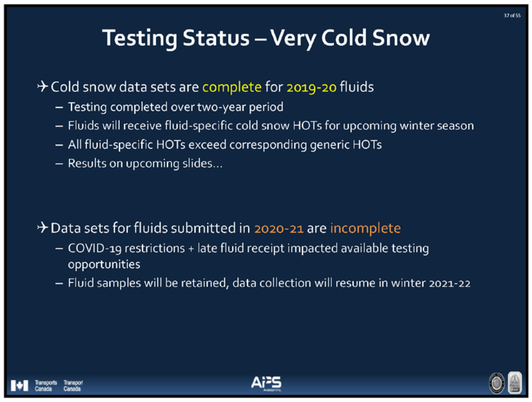
Outside Air Temperature Degrees Celsius	Outside Air Temperature Degrees Fahrenheit	Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets: Very Light	Snow, Snow Grains or Snow Pellets: Light	Snow, Snow Grains or Snow Pellets: Moderate	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 and above	27 and above	100/0	2:10 - 4:00	2:55 - 3:00	1:25 - 2:55	0:40 - 1:25	1:05 - 2:00	0:30 - 0:50	0:09 - 1:55	
		75/25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
		50/50	N/A	N/A	N/A	N/A	N/A	N/A		
below -3 to -8	below 27 to 18	100/0	2:40 - 4:00	2:55 - 3:00	1:25 - 2:55	0:40 - 1:25	1:05 - 2:00	0:40 - 1:00		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -8 to -14	below 18 to 7	100/0	2:40 - 4:00	2:55 - 3:00	1:25 - 2:55	0:40 - 1:25	1:05 - 2:00	0:40 - 1:00		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to TBD	below 7 to TBD	100/0	0:45 - 1:55	GENERIC	GENERIC	GENERIC				

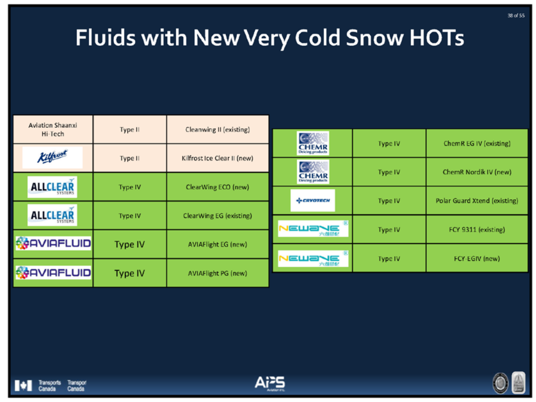




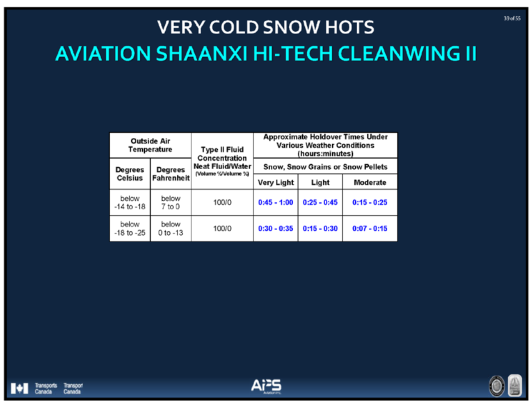




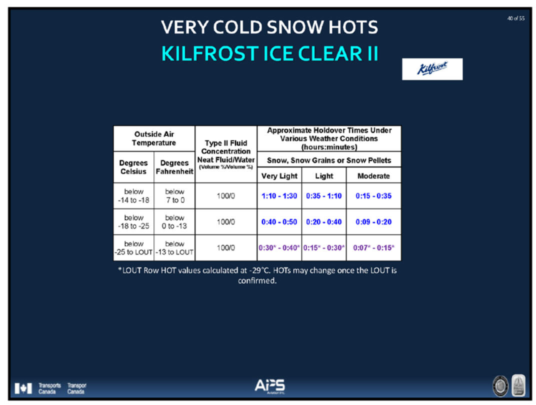




Aviation Shaanxi Hi-Tech	Type II	Cleanwing II (existing)
Kilfrost	Type II	Kilfrost Ice Clear II (new)
ALLCLEAR	Type IV	ClearWing ECO (new)
ALLCLEAR	Type IV	ClearWing EG (existing)
AVIAFLUID	Type IV	AVIAFlight EG (new)
AVIAFLUID	Type IV	AVIAFlight PG (new)
CHEMR	Type IV	ChemR EG IV (existing)
CHEMR	Type IV	ChemR Nordik IV (new)
CRYOTECH	Type IV	Polar Guard Xtend (existing)
NEWAVE	Type IV	FCY 9311 (existing)
NEWAVE	Type IV	FCY-EGIV (new)

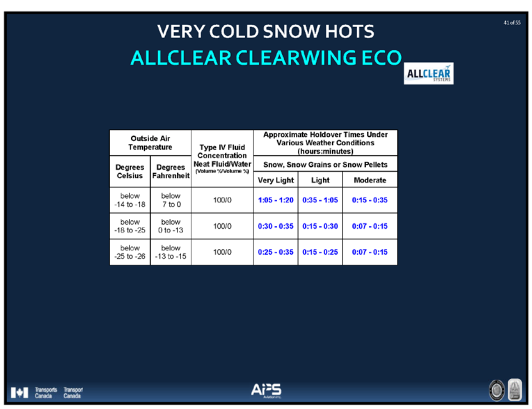


Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	0:45 - 1:00	0:25 - 0:45	0:15 - 0:25
below -18 to -25	below 0 to -13	100/0	0:30 - 0:35	0:15 - 0:30	0:07 - 0:15

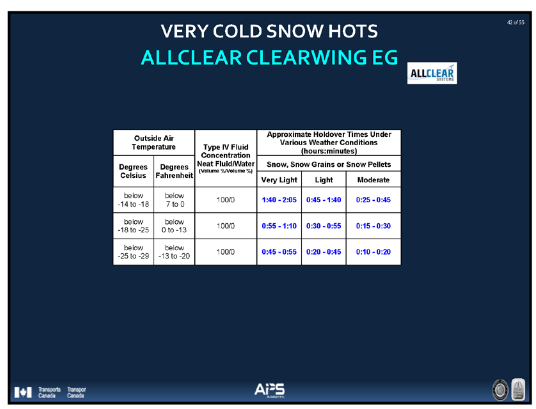


Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:10 - 1:30	0:35 - 1:10	0:15 - 0:35
below -18 to -25	below 0 to -13	100/0	0:40 - 0:50	0:20 - 0:40	0:09 - 0:20
below -25 to LOUT	below -13 to LOUT	100/0	0:30* - 0:40*	0:15* - 0:30*	0:07* - 0:15*

*LOUT Row HOT values calculated at -29°C. HOTs may change once the LOUT is confirmed.



Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:05 - 1:20	0:35 - 1:05	0:15 - 0:35
below -18 to -25	below 0 to -13	100/0	0:30 - 0:35	0:15 - 0:30	0:07 - 0:15
below -25 to -26	below -13 to -15	100/0	0:25 - 0:35	0:15 - 0:25	0:07 - 0:15



Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:40 - 2:05	0:45 - 1:40	0:25 - 0:45
below -18 to -25	below 0 to -13	100/0	0:55 - 1:10	0:30 - 0:55	0:15 - 0:30
below -25 to -29	below -13 to -20	100/0	0:45 - 0:55	0:20 - 0:45	0:10 - 0:20

VERY COLD SNOW HOTS
AVIAFLUID AVIAFLIGHT EG

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:40 - 2:00	0:50 -1:40	0:25 - 0:50
below -18 to -25	below 0 to -13	100/0	1:20 - 1:35	0:40 - 1:20	0:20 - 0:40
below -25 to -31	below -13 to -24	100/0	0:35 - 0:45	0:20 - 0:35	0:09 - 0:20

VERY COLD SNOW HOTS
AVIAFLUID AVIAFLIGHT PG

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	0:50 - 1:00	0:25 - 0:50	0:15 - 0:25
below -18 to -25	below 0 to -13	100/0	0:25 - 0:30	0:15 - 0:25	0:06 - 0:15
below -25 to LOUT	below -13 to LOUT	100/0	0:15* - 0:20*	0:08* - 0:15*	0:04* - 0:08*

*LOUT Row HOT values based on testing at -30°C. HOTs may change once the LOUT is confirmed.

VERY COLD SNOW HOTS
CHEMR EG IV

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:25 - 1:45	0:45 - 1:25	0:20 - 0:45
below -18 to -25	below 0 to -13	100/0	1:25 - 1:45	0:45 - 1:25	0:20 - 0:45
below -25 to -27	below -13 to -17	100/0	1:25 - 1:45	0:45 - 1:25	0:20 - 0:45

VERY COLD SNOW HOTS
CHEMR NORDIK IV

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	3:00 - 3:00	1:35 - 3:00	0:50 - 1:35
below -18 to -25	below 0 to -13	100/0	2:10 - 2:40	1:05 - 2:10	0:35 - 1:05
below -25 to LOUT	below -13 to LOUT	100/0	1:50* - 2:15*	0:55* - 1:50*	0:30* - 0:55*

*LOUT Row HOT values calculated at -29°C. HOTs may change once the LOUT is confirmed.

VERY COLD SNOW HOTS
CRYOTECH POLAR GUARD XTEND

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:20 - 1:40	0:40 - 1:20	0:20 - 0:40
below -18 to -25	below 0 to -13	100/0	0:30 - 0:40	0:15 - 0:30	0:06 - 0:15
below -25 to -29	below -13 to -20	100/0	0:20 - 0:25	0:09 - 0:20	0:04 - 0:09

VERY COLD SNOW HOTS
NEWAVE FCY 9311

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:00 - 1:15	0:30 - 1:00	0:15 - 0:30
below -18 to -25	below 0 to -13	100/0	0:35 - 0:40	0:15 - 0:35	0:07 - 0:15
below -25 to -29.5	below -13 to -21	100/0	0:30 - 0:40	0:15 - 0:30	0:06 - 0:15

VERY COLD SNOW HOTS
NEWAVE FCY-EGIV

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:35 - 2:05	0:40 - 1:35	0:15 - 0:40
below -18 to -25	below 0 to -13	100/0	1:10 - 1:35	0:30 - 1:10	0:15 - 0:30
below -25 to -29	below -13 to -20	100/0	1:00 - 1:20	0:25 - 1:00	0:10 - 0:25

Outline

- 2019-20 + 2020-21 Testing Overview
- Methodology
- Standard HOT Test Results Summary: 10 Fluids
- Very Cold Snow Test Results Summary: 11 Fluids
- Supplemental Testing: Cleanwing II
- Summary
- Appendix: Detailed Test Results

SUPPLEMENTAL TESTING – CLEANWING II

- Additional natural snow data collected with Cleanwing II to support expansion of the fluid-specific snow HOTs + change to fluid LUPRs
- Supplemental data allowed for development of light snow + very light snow HOTs
- Fluid-specific snow HOTs for Cleanwing II changed to three-column format
- LUPR decreased to 3 g/dm²/h for 100/0 dilution (below -14°C) and 50/50 dilution (-3°C and above)

MODIFIED SNOW HOTS
AVIATION SHAANXI HI-TECH CLEANWING II

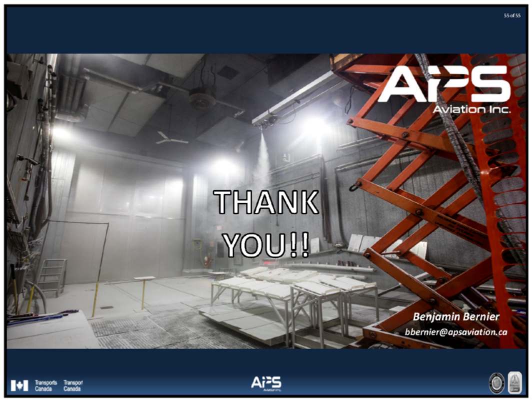
Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
-3 and above	27 and above	100/0	1:35 - 2:00	0:55 - 1:35	0:30 - 0:55
		75/25	1:20 - 1:40	0:45 - 1:20	0:25 - 0:45
		50/50	0:50 - 1:05	0:25 - 0:50	0:15 - 0:25
below -3 to -8	below 27 to 18	100/0	1:20 - 1:35	0:45 - 1:20	0:25 - 0:45
		75/25	1:20 - 1:35	0:45 - 1:20	0:25 - 0:45
below -8 to -14	below 18 to 7	100/0	1:10 - 1:25	0:40 - 1:10	0:20 - 0:40
		75/25	1:20 - 1:35	0:45 - 1:20	0:25 - 0:45
below -14	below 7	100/0	SEE VCS	SEE VCS	SEE VCS

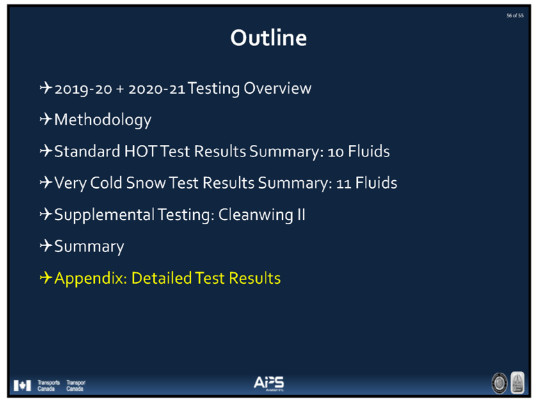
Outline

- 2019-20 + 2020-21 Testing Overview
- Methodology
- Standard HOT Test Results Summary: 10 Fluids
- Very Cold Snow Test Results Summary: 11 Fluids
- Supplemental Testing: Cleanwing II
- Summary
- Appendix: Detailed Test Results

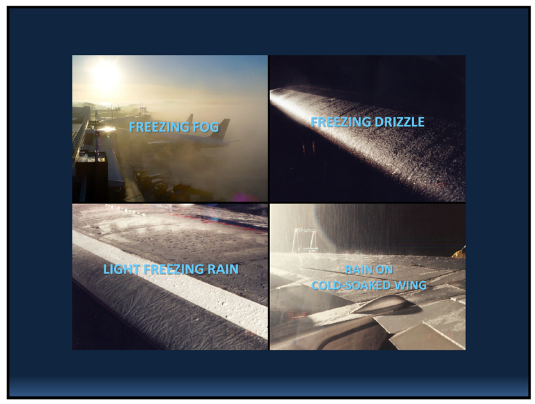
SUMMARY

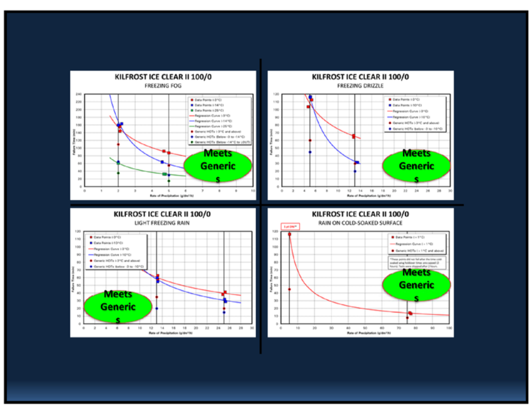
- Fluids Tested
  - Tests carried out with new fluids; ten fluids expected to be commercialized
- Results
  - Ten new fluid specific HOT tables
  - Generic frost/very cold snow HOTs substantiated
  - New fluid-specific VCS HOTs for six new Type II/IV fluids, five existing Type II/IV fluids
  - Snow HOTs expanded for Cleanwing II
  - Moderate impacts to existing generic Type II/IV HOTs


AiPS
Aviation Inc.
THANK
YOU!!
Benjamin Bernier
bbernier@apsaviation.ca

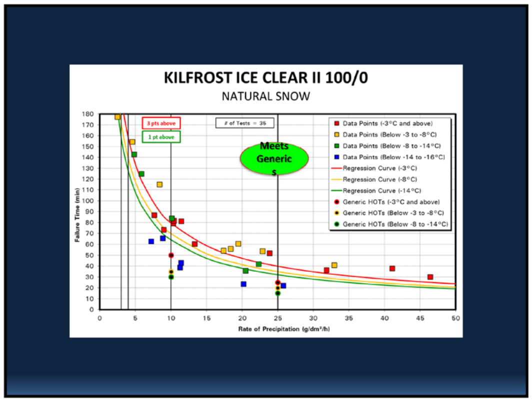

Outline
2019-20 + 2020-21 Testing Overview
Methodology
Standard HOT Test Results Summary: 10 Fluids
Very Cold Snow Test Results Summary: 11 Fluids
Supplemental Testing: Cleanwing II
Summary
Appendix: Detailed Test Results

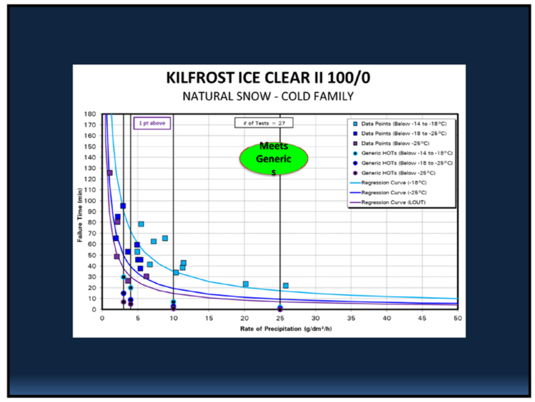

KILFROST
KILFROST ICE CLEAR II


FREEZING FOG
FREEZING DRIZZLE
LIGHT FREEZING RAIN
RAIN ON
COLD-SOAKED WING

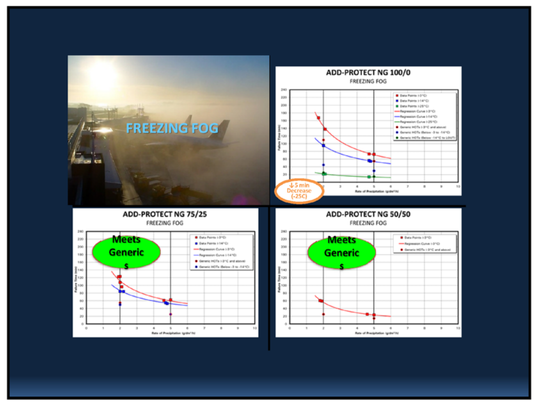

KILFROST ICE CLEAR II 100/0
FREEZING FOG
Meets
Generic
KILFROST ICE CLEAR II 100/0
FREEZING DRIZZLE
Meets
Generic
KILFROST ICE CLEAR II 100/0
LIGHT FREEZING RAIN
Meets
Generic
KILFROST ICE CLEAR II 100/0
RAIN ON COLD-SOAKED SURFACE
Meets
Generic

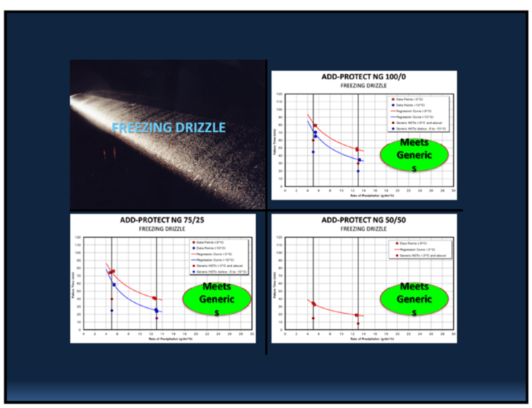

NATURAL SNOW

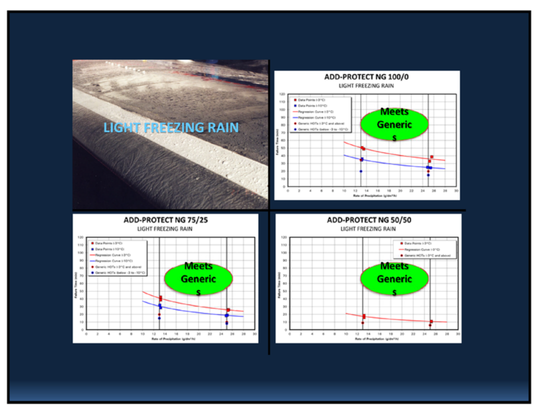

KILFROST ICE CLEAR II 100/0
NATURAL SNOW
3 pts above
1 pt above
# of Tests = 36
Meets Generic s
Data Points (-3°C and above)
Data Points (Below -3 to -8°C)
Data Points (Below -8 to -14°C)
Data Points (Below -14 to -16°C)
Regression Curve (-3°C)
Regression Curve (-8°C)
Regression Curve (-14°C)
Generic HOTs (-3°C and above)
Generic HOTs (Below -3 to -8°C)
Generic HOTs (Below -8 to -14°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

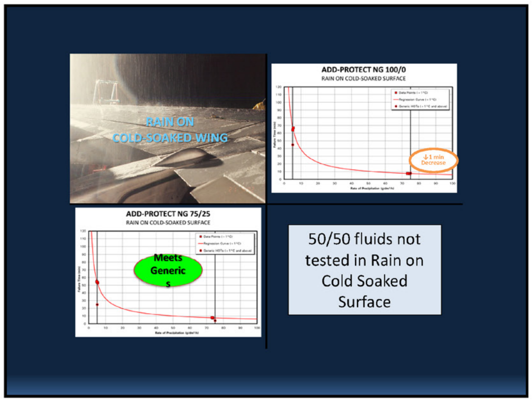

KILFROST ICE CLEAR II 100/0
NATURAL SNOW - COLD FAMILY
1 pt above
# of Tests = 27
Meets Generic s
Failure Time (min)
Rate of Precipitation (g/dm²/h)

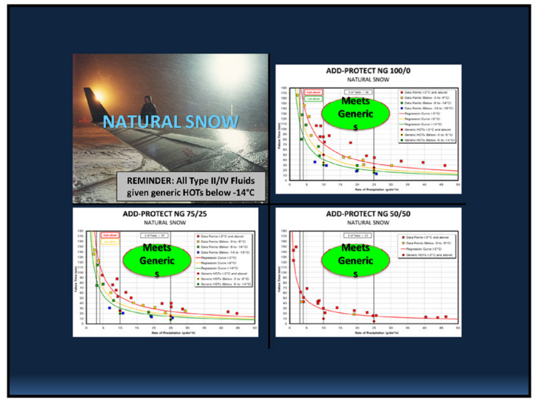

ROMCHIM
ADD-PROTECT NG

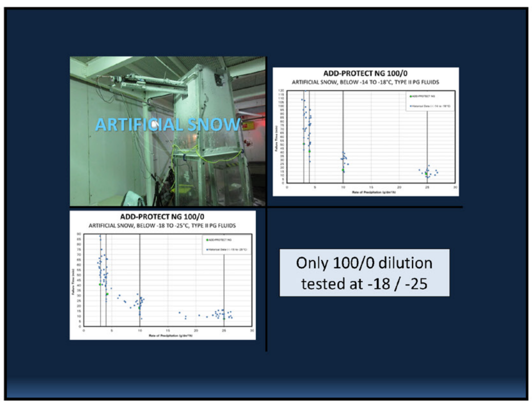

FREEZING FOG
ADD-PROTECT NG 100/0
FREEZING FOG
ADD-PROTECT NG 75/25
FREEZING FOG
Meets Generic s
ADD-PROTECT NG 50/50
FREEZING FOG
Meets Generic s


FREEZING DRIZZLE
ADD-PROTECT NG 100/0
FREEZING DRIZZLE
Meets Generic s
ADD-PROTECT NG 75/25
FREEZING DRIZZLE
Meets Generic s
ADD-PROTECT NG 50/50
FREEZING DRIZZLE
Meets Generic s


LIGHT FREEZING RAIN
ADD-PROTECT NG 100/0
LIGHT FREEZING RAIN
Meets Generic s
ADD-PROTECT NG 75/25
LIGHT FREEZING RAIN
Meets Generic s
ADD-PROTECT NG 50/50
LIGHT FREEZING RAIN
Meets Generic s

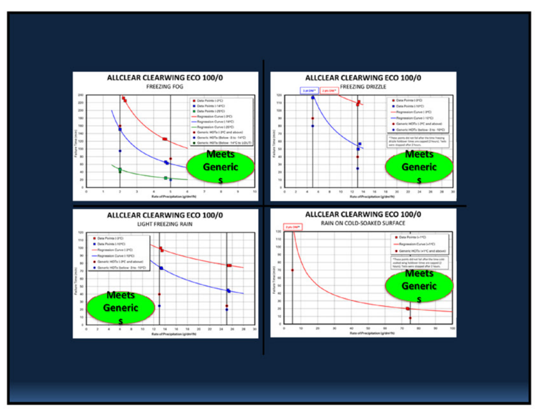

RAIN ON
COLD-SOAKED WING
ADD-PROTECT NG 100/0
RAIN ON COLD-SOAKED SURFACE
ADD-PROTECT NG 75/25
RAIN ON COLD-SOAKED SURFACE
Meets
Generic
s
50/50 fluids not
tested in Rain on
Cold Soaked
Surface


NATURAL SNOW
REMINDER: All Type II/IV Fluids
given generic HOTs below -14°C
ADD-PROTECT NG 100/0
NATURAL SNOW
Meets
Generic
s
ADD-PROTECT NG 75/25
NATURAL SNOW
Meets
Generic
s
ADD-PROTECT NG 50/50
NATURAL SNOW
Meets
Generic
s

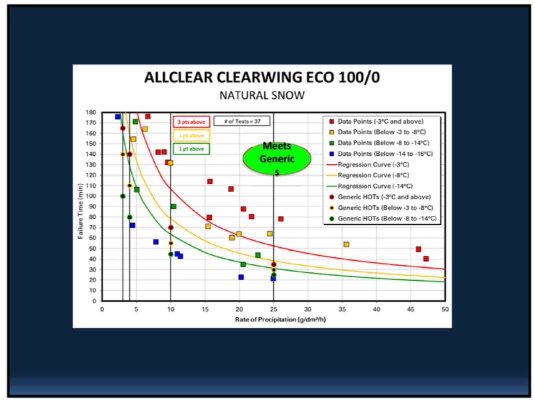

ARTIFICIAL SNOW
ADD-PROTECT NG 100/0
ARTIFICIAL SNOW, BELOW -14 TO -18°C, TYPE II PG FLUIDS
ADD-PROTECT NG 100/0
ARTIFICIAL SNOW, BELOW -18 TO -25°C, TYPE II PG FLUIDS
Only 100/0 dilution
tested at -18 / -25

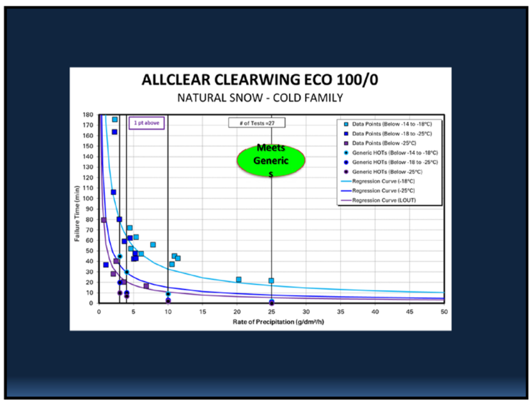

ALLCLEAR
CLEARWING ECO


FREEZING FOG
FREEZING DRIZZLE
LIGHT FREEZING RAIN
RAIN ON
COLD-SOAKED WING

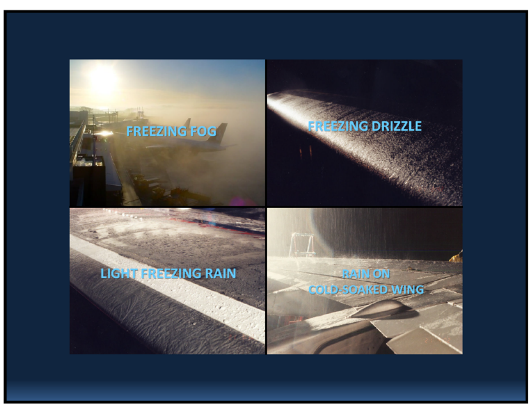

ALLCLEAR CLEARWING ECO 100/0
FREEZING FOG
Meets
Generic
s
ALLCLEAR CLEARWING ECO 100/0
FREEZING DRIZZLE
Meets
Generic
s
ALLCLEAR CLEARWING ECO 100/0
LIGHT FREEZING RAIN
Meets
Generic
s
ALLCLEAR CLEARWING ECO 100/0
RAIN ON COLD-SOAKED SURFACE
Meets
Generic
s

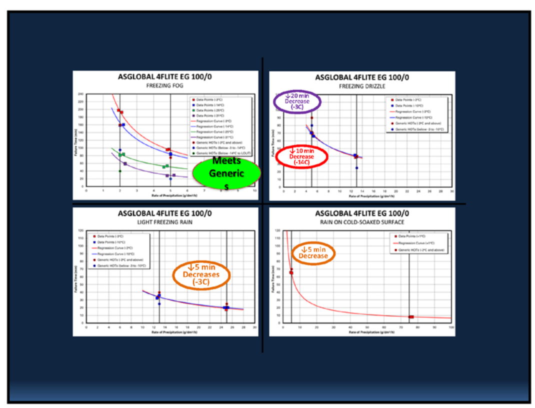

NATURAL SNOW


ALLCLEAR CLEARWING ECO 100/0
NATURAL SNOW
3 pts above
# of Tests = 37
1 pt above
1 pt above
Meets Generic
Data Points (-3°C and above)
Data Points (Below -3 to -8°C)
Data Points (Below -8 to -14°C)
Data Points (Below -14 to -16°C)
Regression Curve (-3°C)
Regression Curve (-8°C)
Regression Curve (-14°C)
Generic HOTs (-3°C and above)
Generic HOTs (Below -3 to -8°C)
Generic HOTs (Below -8 to -14°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

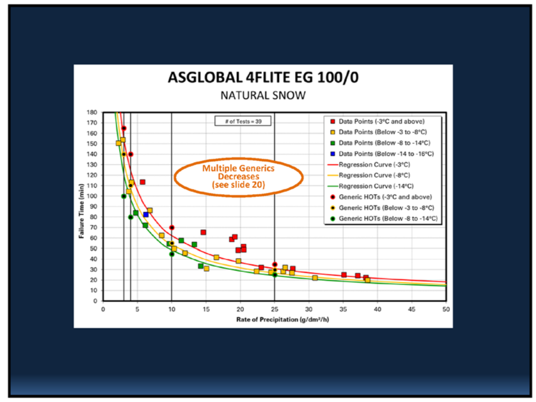

ALLCLEAR CLEARWING ECO 100/0
NATURAL SNOW - COLD FAMILY
1 pt above
# of Tests =27
Meets Generic
Data Points (Below -14 to -18°C)
Data Points (Below -18 to -25°C)
Data Points (Below -25°C)
Generic HOTs (Below -14 to -18°C)
Generic HOTs (Below -18 to -25°C)
Generic HOTs (Below -25°C)
Regression Curve (-18°C)
Regression Curve (-25°C)
Regression Curve (LOUT)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

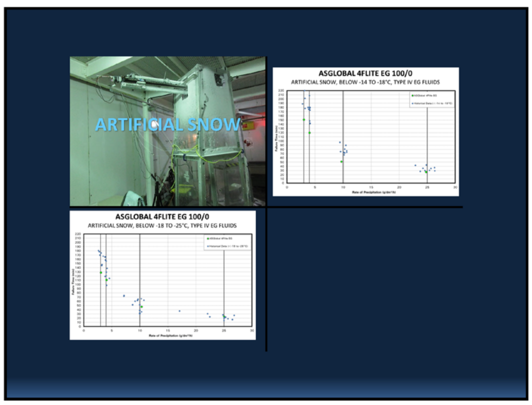

ASGLOBAL
4FLITE EG


FREEZING FOG
FREEZING DRIZZLE
LIGHT FREEZING RAIN
RAIN ON
COLD-SOAKED WING


ASGLOBAL 4FLITE EG 100/0
FREEZING FOG
Meets Generic
ASGLOBAL 4FLITE EG 100/0
FREEZING DRIZZLE
↓20 min Decrease (-3C)
↓10 min Decrease (-5C)
ASGLOBAL 4FLITE EG 100/0
LIGHT FREEZING RAIN
↓5 min Decreases (-3C)
ASGLOBAL 4FLITE EG 100/0
RAIN ON COLD-SOAKED SURFACE
↓5 min Decrease

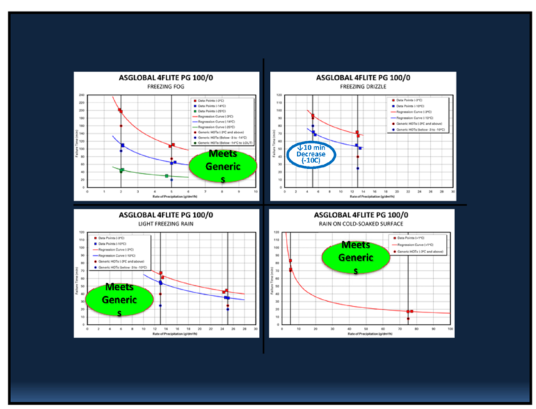

NATURAL SNOW


ASGLOBAL 4FLITE EG 100/0
NATURAL SNOW
# of Tests = 30
Multiple Generics Decreases (see slide 20)
Data Points (-3°C and above)
Data Points (Below -3 to -8°C)
Data Points (Below -8 to -14°C)
Data Points (Below -14 to -16°C)
Regression Curve (-3°C)
Regression Curve (-8°C)
Regression Curve (-14°C)
Generic HOTs (-3°C and above)
Generic HOTs (Below -3 to -8°C)
Generic HOTs (Below -8 to -14°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

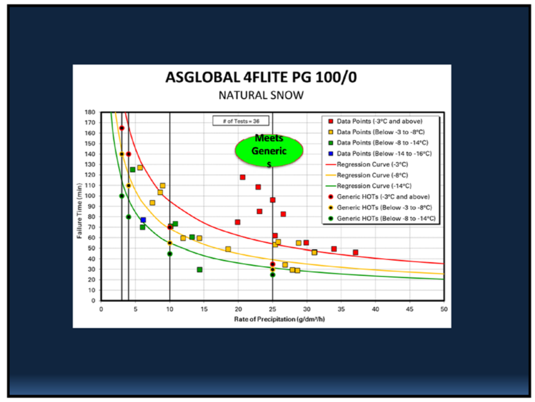

ARTIFICIAL SNOW
ASGLOBAL 4FLITE EG 100/0
ARTIFICIAL SNOW, BELOW -14 TO -18°C, TYPE IV EG FLUIDS
ASGLOBAL 4FLITE EG 100/0
ARTIFICIAL SNOW, BELOW -18 TO -25°C, TYPE IV EG FLUIDS

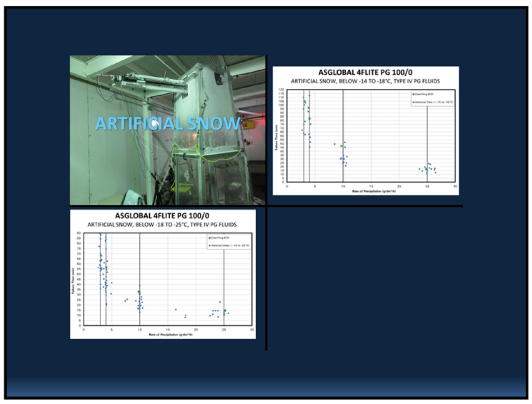

ASGLOBAL
4FLITE PG


FREEZING FOG
FREEZING DRIZZLE
LIGHT FREEZING RAIN
RAIN ON COLD-SOAKED WING

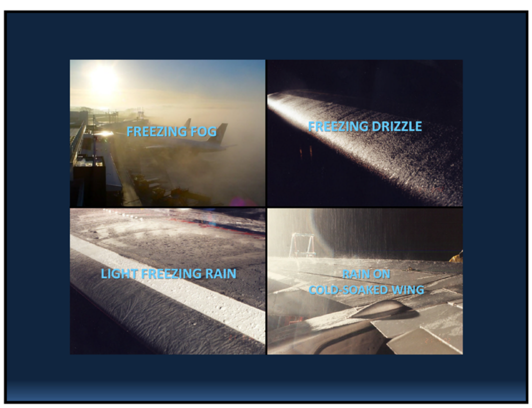

ASGLOBAL 4FLITE PG 100/0
FREEZING FOG
Meets Generics
ASGLOBAL 4FLITE PG 100/0
FREEZING DRIZZLE
≥10 min Decrease (-10C)
ASGLOBAL 4FLITE PG 100/0
LIGHT FREEZING RAIN
Meets Generics
ASGLOBAL 4FLITE PG 100/0
RAIN ON COLD-SOAKED SURFACE
Meets Generics

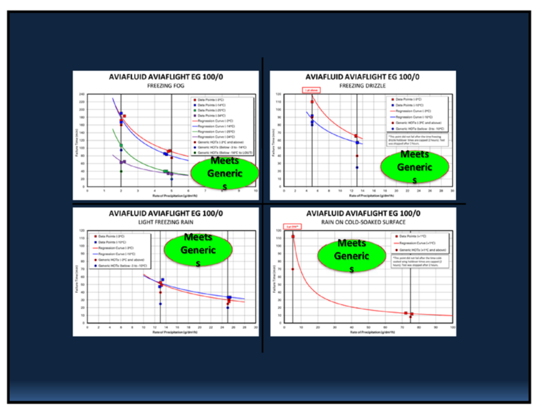

NATURAL SNOW


ASGLOBAL 4FLITE PG 100/0
NATURAL SNOW
# of Tests = 38
Meets Generic
Data Points (-3°C and above)
Data Points (Below -3 to -8°C)
Data Points (Below -8 to -14°C)
Data Points (Below -14 to -16°C)
Regression Curve (-3°C)
Regression Curve (-8°C)
Regression Curve (-14°C)
Generic HOTs (-3°C and above)
Generic HOTs (Below -3 to -8°C)
Generic HOTs (Below -8 to -14°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

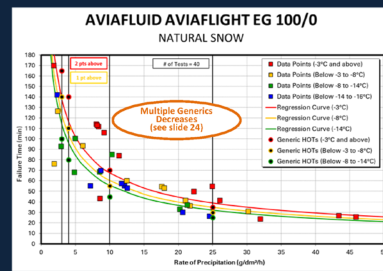

ARTIFICIAL SNOW
ASGLOBAL 4FLITE PG 100/0
ARTIFICIAL SNOW, BELOW -14 TO -18°C, TYPE IV PG FLUIDS
ASGLOBAL 4FLITE PG 100/0
ARTIFICIAL SNOW, BELOW -18 TO -25°C, TYPE IV PG FLUIDS

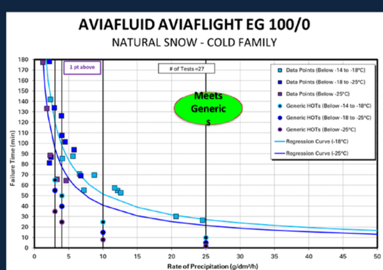

AVIAFLUID
AVIAFLIGHT EG


FREEZING FOG
FREEZING DRIZZLE
LIGHT FREEZING RAIN
RAIN ON COLD-SOAKED WING


AVIAFLUID AVIAFLIGHT EG 100/0
FREEZING FOG
Meets Generic
AVIAFLUID AVIAFLIGHT EG 100/0
FREEZING DRIZZLE
Meets Generic
AVIAFLUID AVIAFLIGHT EG 100/0
LIGHT FREEZING RAIN
Meets Generic
AVIAFLUID AVIAFLIGHT EG 100/0
RAIN ON COLD-SOAKED SURFACE
Meets Generic

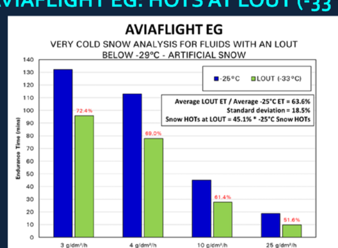
NATURAL SNOW



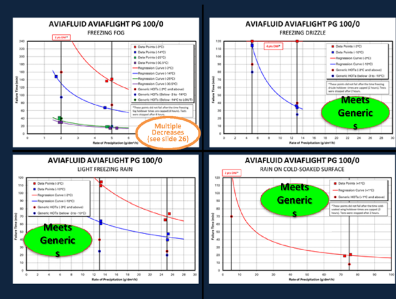


ARTIFICAL SNOW

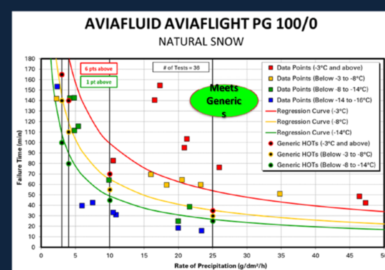
AVIAFLIGHT EG: HOTS AT LOUT (-33°C)

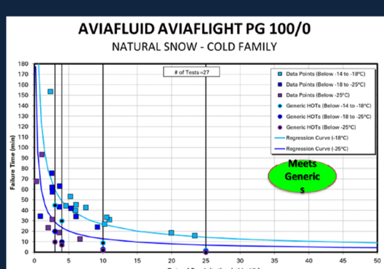


AVIAFLUID
AVIAFLIGHT PG



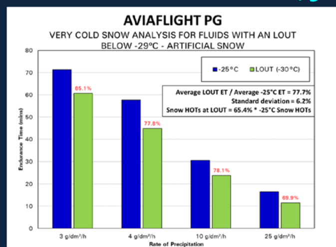
NATURAL SNOW



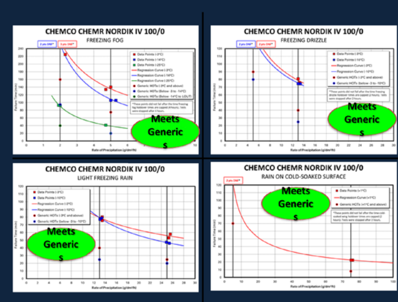


ARTIFICAL SNOW

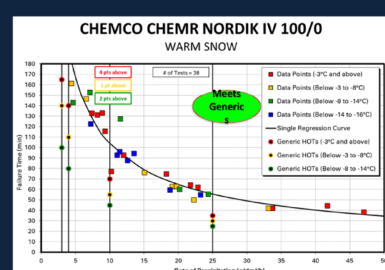
AVIAFLIGHT PG: HOTS AT LOUT (-30°C)

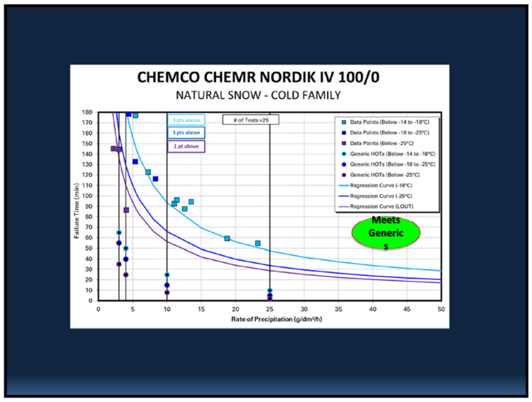


CHEMCO
CHEMR NORDIK IV

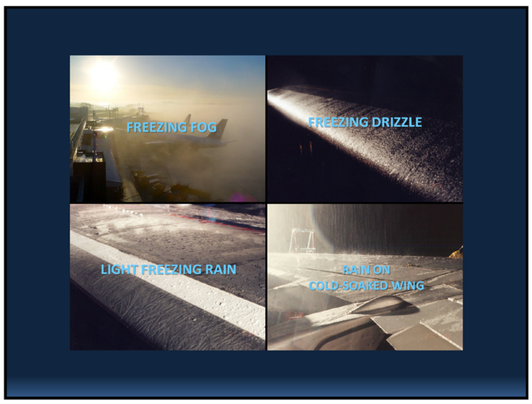


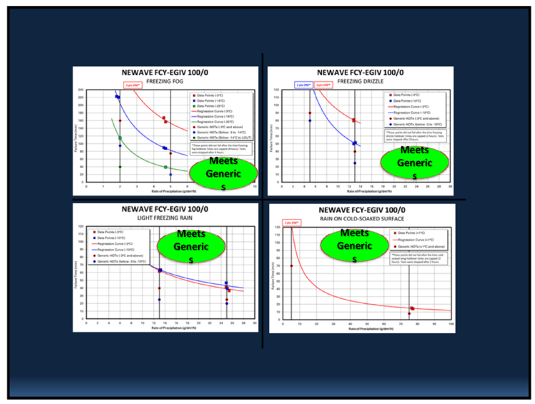
NATURAL SNOW



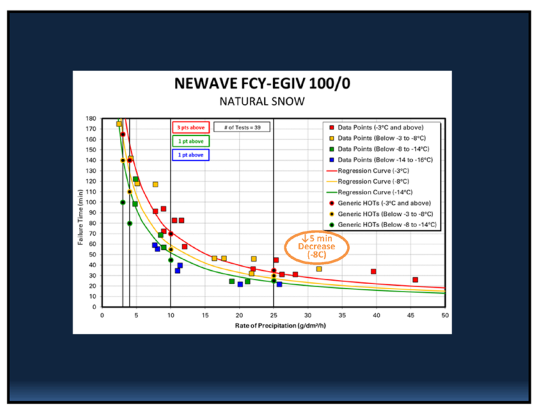

CHEMCO CHEMR NORDIK IV 100/0
NATURAL SNOW - COLD FAMILY
Meets Generic
Rate of Precipitation (g/dm²/h)
Failure Time (min)

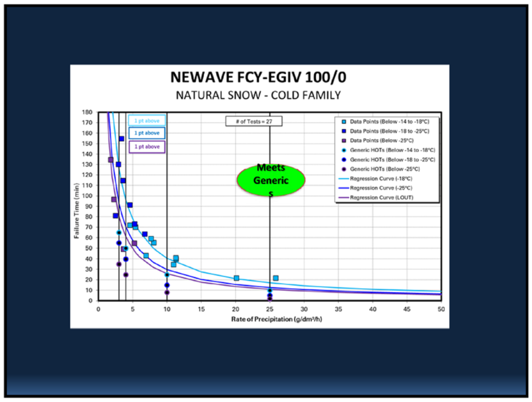

NEWAVE
FCY-EGIV


FREEZING FOG
FREEZING DRIZZLE
LIGHT FREEZING RAIN
RAIN ON
COLD-SOAKED WING

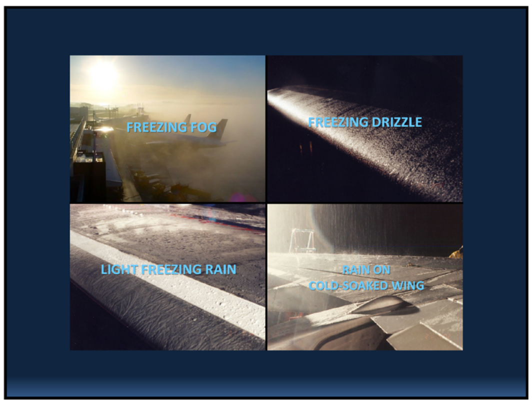

NEWAVE FCY-EGIV 100/0
FREEZING FOG
NEWAVE FCY-EGIV 100/0
FREEZING DRIZZLE
NEWAVE FCY-EGIV 100/0
LIGHT FREEZING RAIN
NEWAVE FCY-EGIV 100/0
RAIN ON COLD-SOAKED SURFACE
Meets Generic

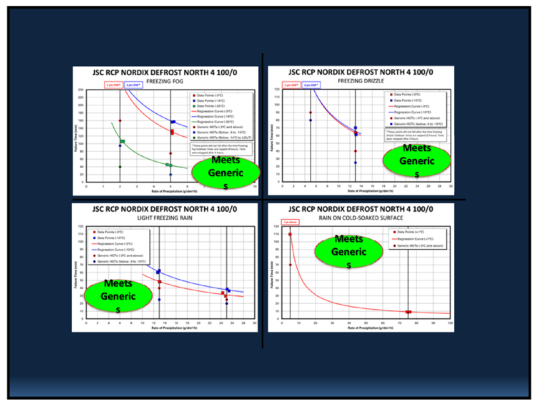

NATURAL SNOW


NEWAVE FCY-EGIV 100/0
NATURAL SNOW
↓5 min Decrease (-8C)
Rate of Precipitation (g/dm²/h)
Failure Time (min)

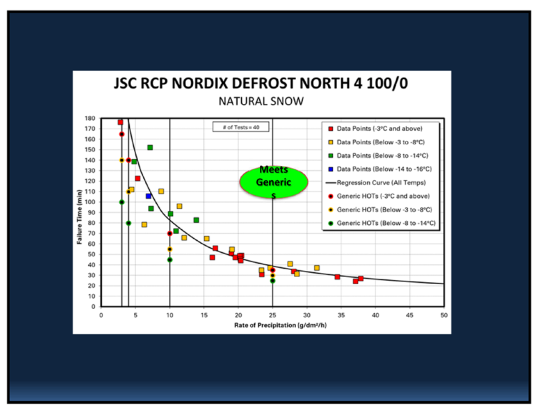


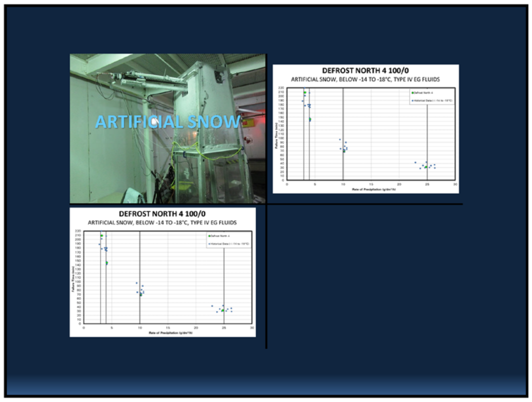
JSC RCP NORDIX
DEFROST NORTH 4



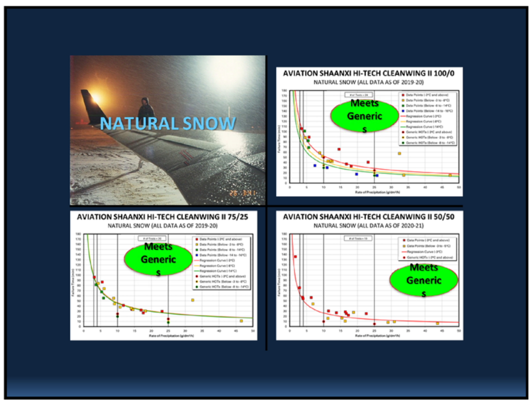


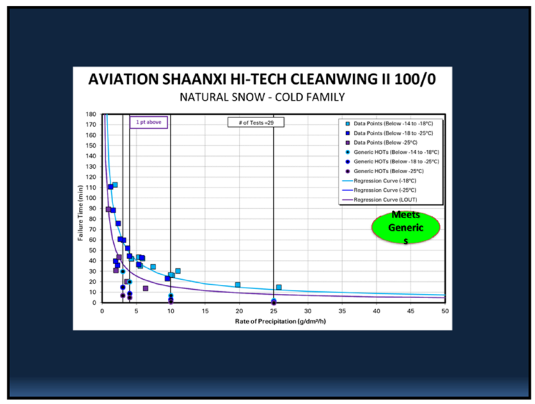
NATURAL SNOW





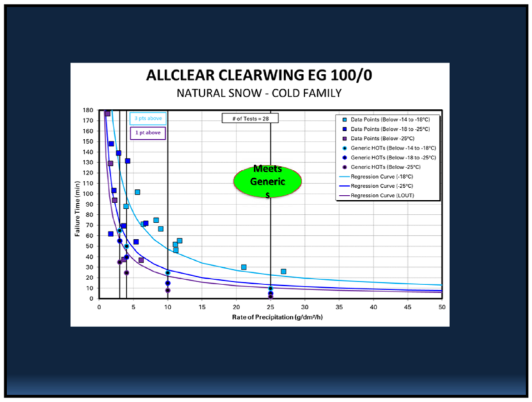
AVIATION SHAANXI HI-TECH
CLEANWING II





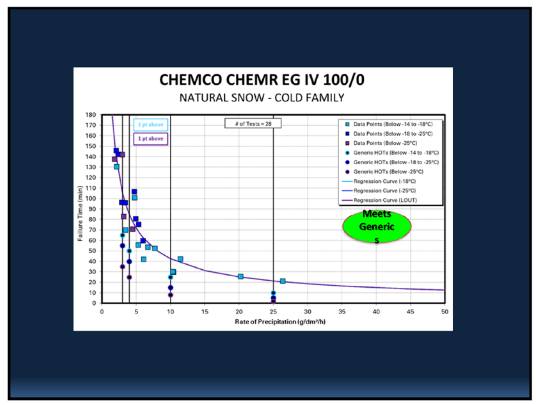
ALLCLEAR
CLEARWING EG

NATURAL SNOW


ALLCLEAR CLEARWING EG 100/0
NATURAL SNOW - COLD FAMILY
Meets Generic
Failure Time (min)
Rate of Precipitation (g/dm²/h)

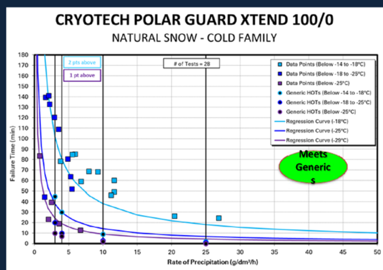

CHEMCO
CHEMR EG IV


NATURAL SNOW


CHEMCO CHEMR EG IV 100/0
NATURAL SNOW - COLD FAMILY
Meets Generic
Failure Time (min)
Rate of Precipitation (g/dm²/h)

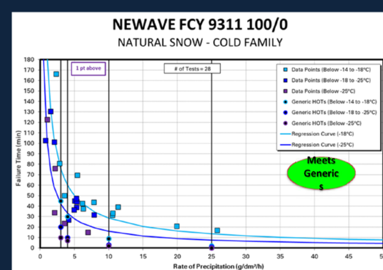

CRYOTECH
POLAR GUARD XTEND


NATURAL SNOW



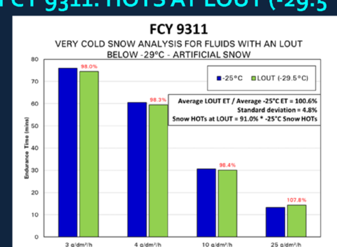
NEWAVE
FCY 9311

NATURAL SNOW



ARTIFICAL SNOW

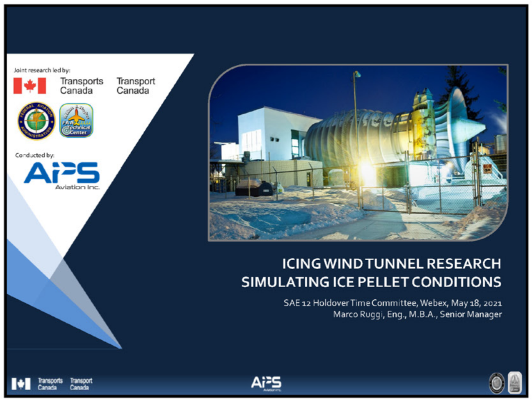
FCY 9311: HOTS AT LOUT (-29.5°C)

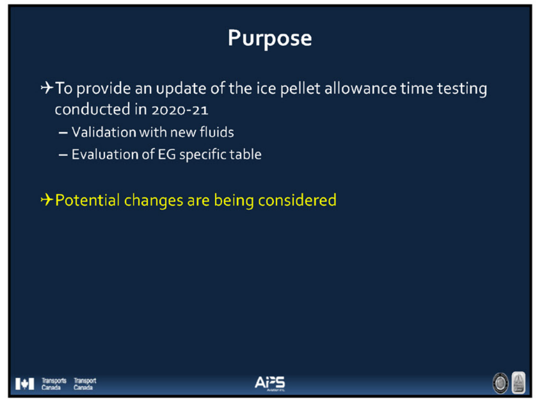


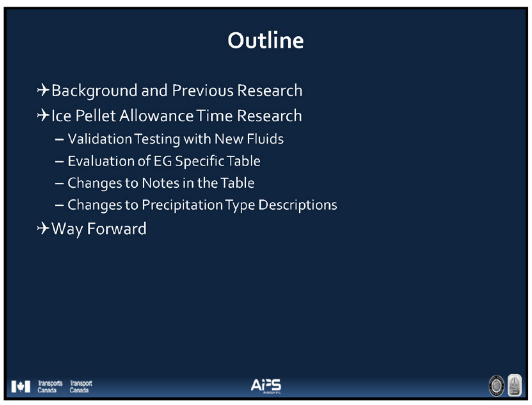
This page intentionally left blank.

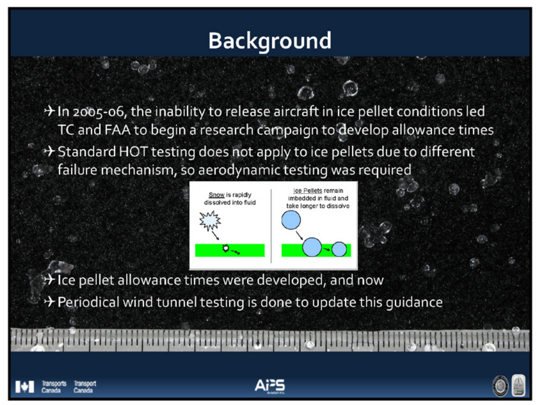
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX)
MAY 2021

PRESENTATION:
ICING WIND TUNNEL RESEARCH SIMULATING ICE PELLET CONDITIONS

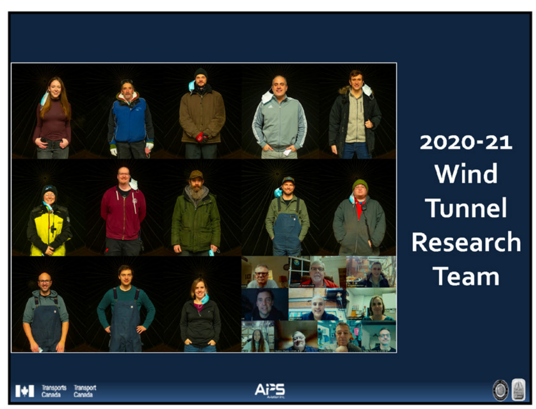

Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS Aviation Inc.
ICING WIND TUNNEL RESEARCH
SIMULATING ICE PELLET CONDITIONS
SAE 12 Holdover Time Committee, Webex, May 18, 2021
Marco Ruggi, Eng., M.B.A., Senior Manager

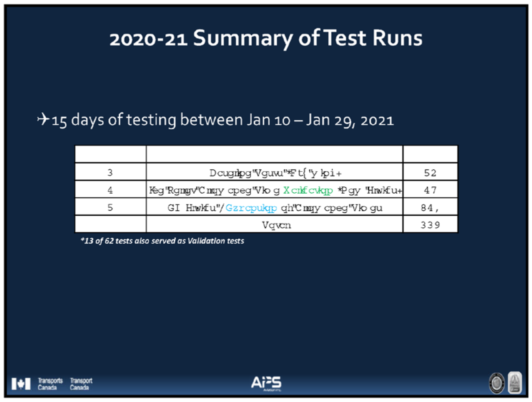

Purpose
To provide an update of the ice pellet allowance time testing conducted in 2020-21
– Validation with new fluids
– Evaluation of EG specific table
Potential changes are being considered

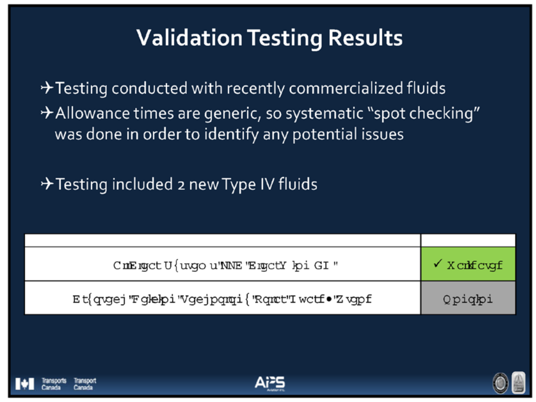

Outline
Background and Previous Research
Ice Pellet Allowance Time Research
– Validation Testing with New Fluids
– Evaluation of EG Specific Table
– Changes to Notes in the Table
– Changes to Precipitation Type Descriptions
Way Forward

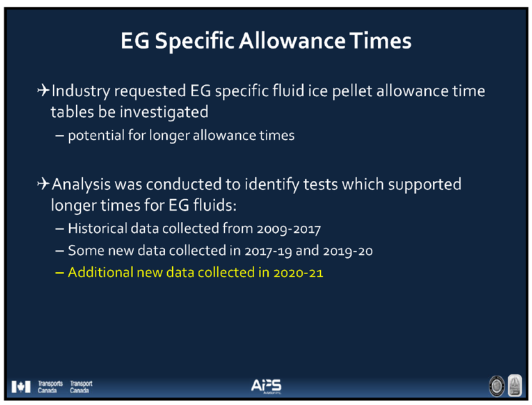

Background
In 2005-06, the inability to release aircraft in ice pellet conditions led TC and FAA to begin a research campaign to develop allowance times
Standard HOT testing does not apply to ice pellets due to different failure mechanism, so aerodynamic testing was required
Snow is rapidly dissolved into fluid
Ice Pellets remain imbedded in fluid and take longer to dissolve
Ice pellet allowance times were developed, and now
Periodical wind tunnel testing is done to update this guidance

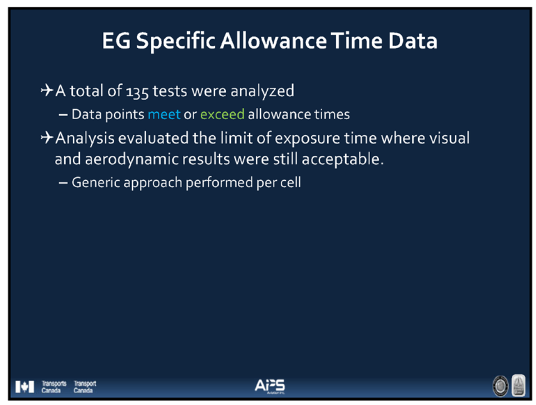

COLLABORATORS
Transport Canada
NASA
NRC CNRC
AMIL
APS Aviation Inc.
SUPPORTERS
ABAX
ALLCLEAR SYSTEMS
CHEMCO
CLARIANT
CRYOTECH
DOW
Inland
Kilfrost
LNT Solutions
NEWAVE
NORDIX
SAE INTERNATIONAL

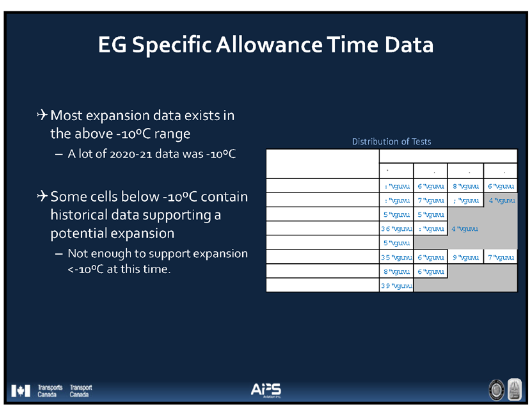

2020-21 Wind Tunnel Research Team

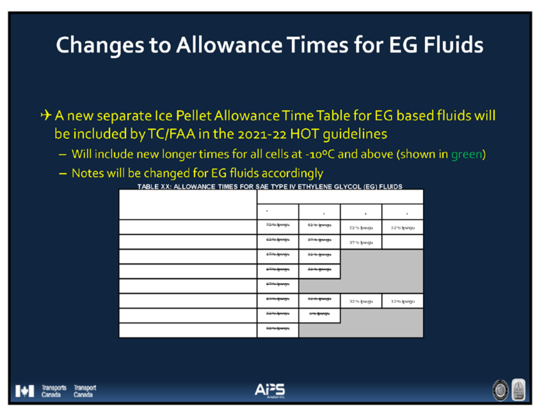

2020-21 Summary of Test Runs
15 days of testing between Jan 10 – Jan 29, 2021
*13 of 62 tests also served as Validation tests

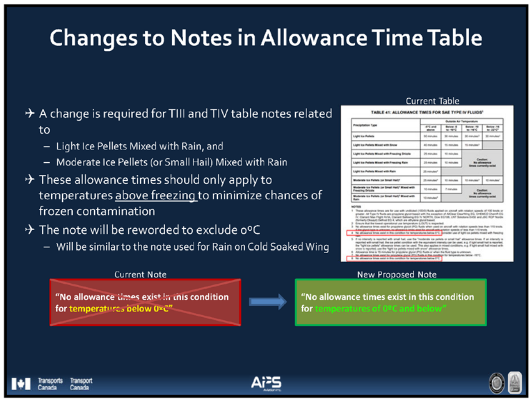

Validation Testing Results
Testing conducted with recently commercialized fluids
Allowance times are generic, so systematic "spot checking" was done in order to identify any potential issues
Testing included 2 new Type IV fluids

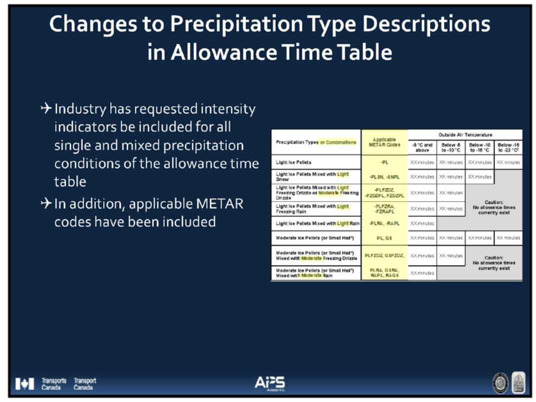

EG Specific Allowance Times
Industry requested EG specific fluid ice pellet allowance time tables be investigated
– potential for longer allowance times
Analysis was conducted to identify tests which supported longer times for EG fluids:
– Historical data collected from 2009-2017
– Some new data collected in 2017-19 and 2019-20
– Additional new data collected in 2020-21

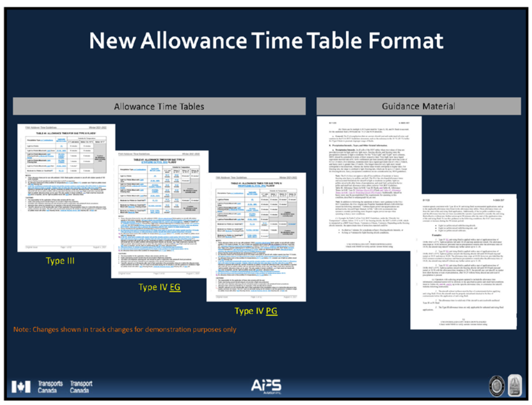

EG Specific Allowance Time Data
A total of 135 tests were analyzed
– Data points meet or exceed allowance times
Analysis evaluated the limit of exposure time where visual and aerodynamic results were still acceptable.
– Generic approach performed per cell

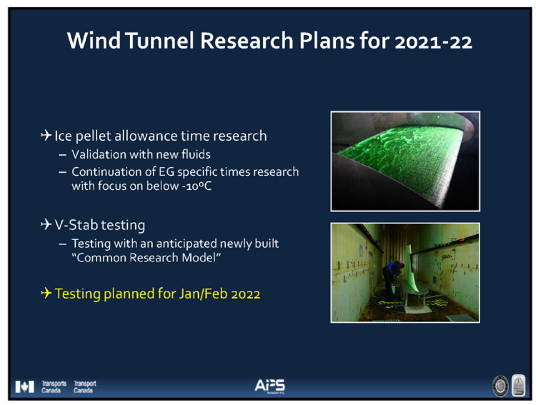

EG Specific Allowance Time Data
Most expansion data exists in the above -10°C range
– A lot of 2020-21 data was -10°C
Some cells below -10°C contain historical data supporting a potential expansion
– Not enough to support expansion <-10°C at this time.
Distribution of Tests

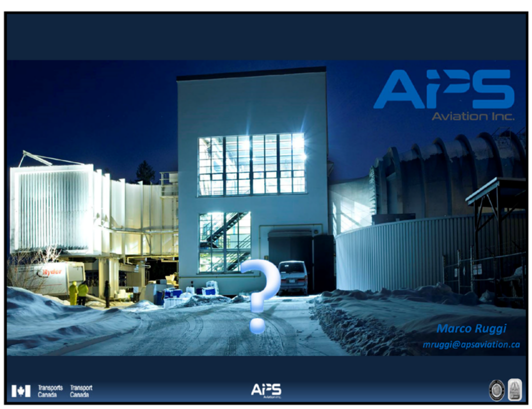

Changes to Allowance Times for EG Fluids
A new separate Ice Pellet Allowance Time Table for EG based fluids will be included by TC/FAA in the 2021-22 HOT guidelines
– Will include new longer times for all cells at -10°C and above (shown in green)
– Notes will be changed for EG fluids accordingly
TABLE XX: ALLOWANCE TIMES FOR SAE TYPE IV ETHYLENE GLYCOL (EG) FLUIDS


Changes to Notes in Allowance Time Table
A change is required for TIII and TIV table notes related to
– Light Ice Pellets Mixed with Rain, and
– Moderate Ice Pellets (or Small Hail) Mixed with Rain
These allowance times should only apply to temperatures above freezing to minimize chances of frozen contamination
The note will be reworded to exclude 0°C
– Will be similar to the note used for Rain on Cold Soaked Wing
Current Table
Current Note
"No allowance times exist in this condition for temperatures below 0°C"
New Proposed Note
"No allowance times exist in this condition for temperatures of 0°C and below"


Changes to Precipitation Type Descriptions in Allowance Time Table
Industry has requested intensity indicators be included for all single and mixed precipitation conditions of the allowance time table
In addition, applicable METAR codes have been included


New Allowance Time Table Format
Allowance Time Tables
Guidance Material
Type III
Type IV EG
Type IV PG
Note: Changes shown in track changes for demonstration purposes only


Wind Tunnel Research Plans for 2021-22
Ice pellet allowance time research
– Validation with new fluids
– Continuation of EG specific times research with focus on below -10°C
V-Stab testing
– Testing with an anticipated newly built "Common Research Model"
Testing planned for Jan/Feb 2022

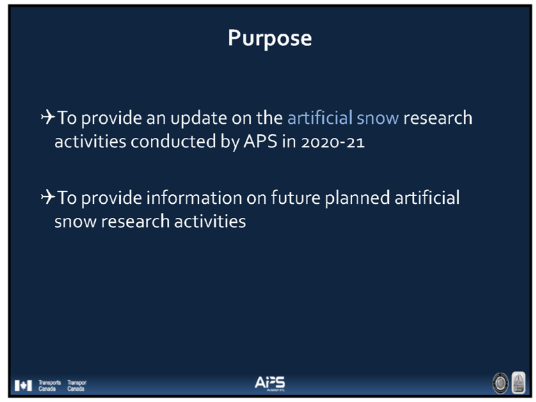

APS
Aviation Inc.
Marco Ruggi
mruggi@apsaviation.ca

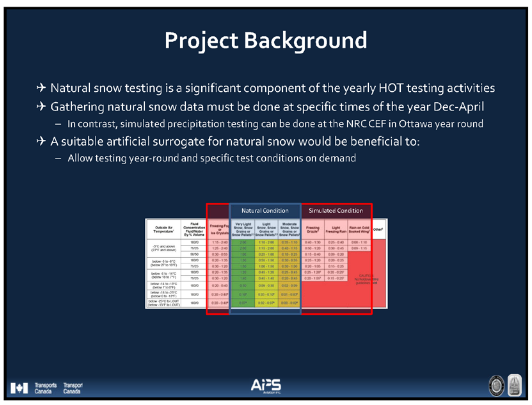
This page intentionally left blank.

SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX)
MAY 2021

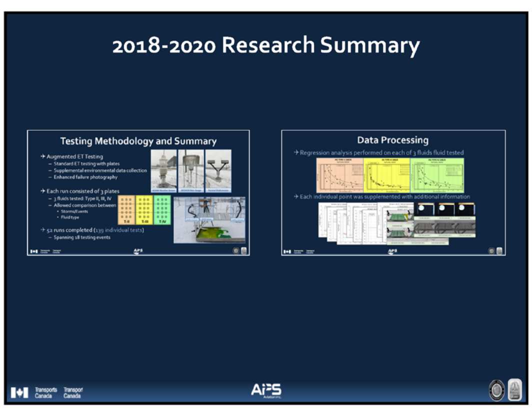
PRESENTATION:
UPDATE: ARTIFICIAL VS. NATURAL SNOW COMPARISON SUPPORTING ARTIFICIAL SNOW RESEARCH

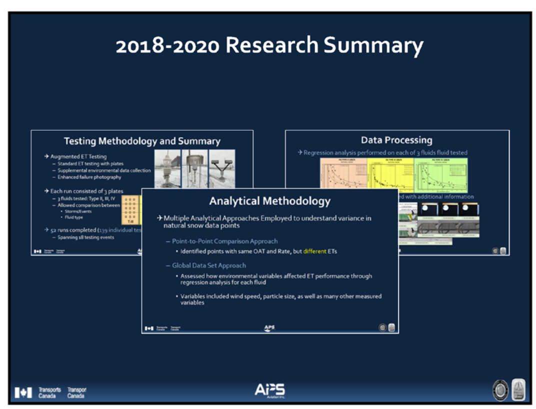

Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS Aviation Inc.
UPDATE: ARTIFICAL Vs. NATURAL SNOW COMPARISON
SUPPORTING ARTIFICIAL SNOW RESEARCH
SAE 12 Holdover Time Committee, Webex, May 18th, 2021
Dany Posteraro, B. Eng., M. Eng., PhD

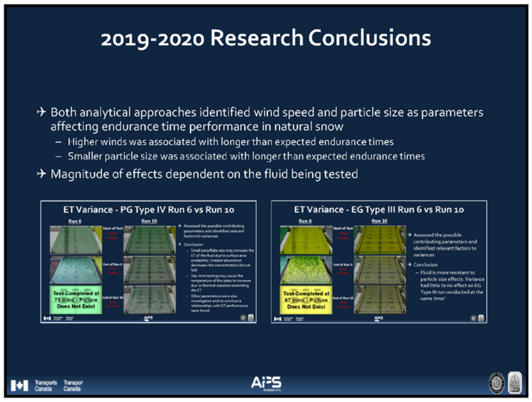

Purpose
To provide an update on the artificial snow research activities conducted by APS in 2020-21
To provide information on future planned artificial snow research activities

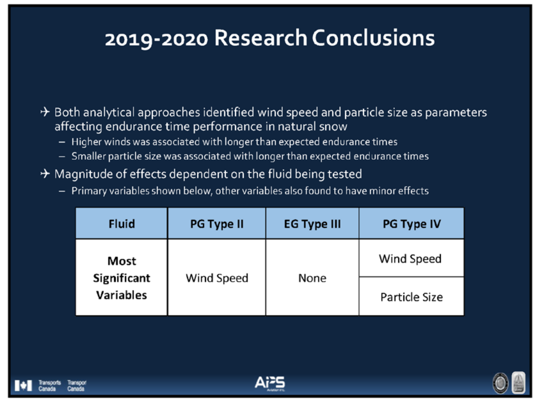

Project Background
Natural snow testing is a significant component of the yearly HOT testing activities
Gathering natural snow data must be done at specific times of the year Dec-April
– In contrast, simulated precipitation testing can be done at the NRC CEF in Ottawa year round
A suitable artificial surrogate for natural snow would be beneficial to:
– Allow testing year-round and specific test conditions on demand
Natural Condition
Simulated Condition


Project Background and Research Goals
Long Term Objective:
– Develop artificial snow testing platform for HOT development
Challenge:
– Correlation of artificial snow data to natural snow results
2020-21 Goal:
– Collect warm and cold snow data sets to be used for snow machine development.

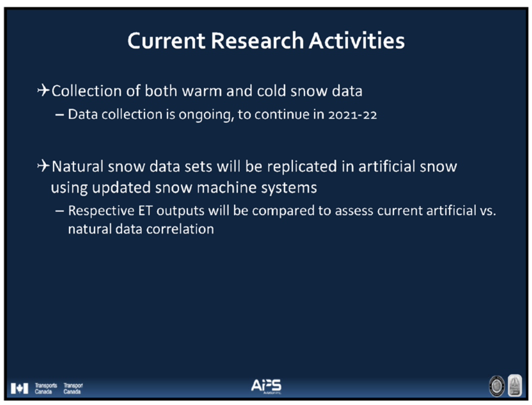

2018-2020 Research Summary
Testing Methodology and Summary
Data Processing

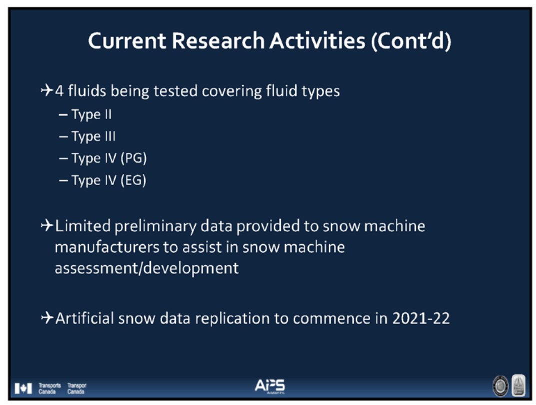

2018-2020 Research Summary
Testing Methodology and Summary
Data Processing
Analytical Methodology
Multiple Analytical Approaches Employed to understand variance in natural snow data points
– Point-to-Point Comparison Approach
• Identified points with same OAT and Rate, but different ETs
– Global Data Set Approach
• Assessed how environmental variables affected ET performance through regression analysis for each fluid
• Variables included wind speed, particle size, as well as many other measured variables





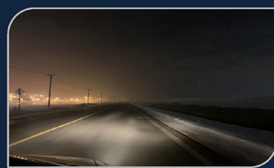
Fluid	PG Type II	EG Type III	PG Type IV
Most Significant Variables	Wind Speed	None	Wind Speed
			Particle Size





SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX)
MAY 2021

PRESENTATION:
INVESTIGATION OF MIST DEPOSITION RATES



INVESTIGATION OF MIST DEPOSITION RATES

SAE 12 Holdover Time Committee, Webex, May 18, 2021
Presented by: Dany Posteraro, B.Eng., M.Eng., PhD
Prepared by: Diana Lalla, Jr. Eng.

OUTLINE

- Background
- Methodology
- Results
- Summary
- Impact for METAR Interpretation
- Way Forward

OUTLINE

- Background
- Methodology
- Results
- Summary
- Impact for METAR Interpretation
- Way Forward

BACKGROUND

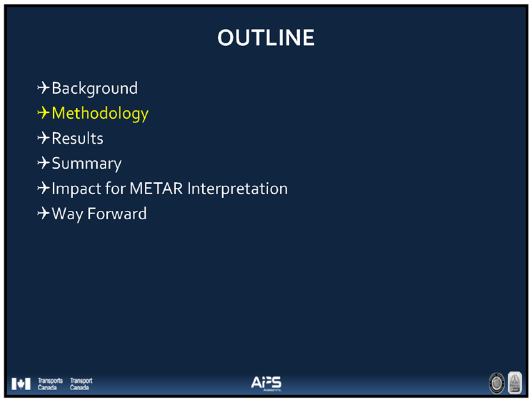
- Mist (METAR code BR) is a commonly reported weather phenomenon:
  - Considered an obscuration rather than precipitation
  - Can occur alone or with other conditions i.e. snow, freezing rain, etc
- Both mist and freezing fog are considered obscurations, however, HOTs exist specifically for freezing fog, but not for mist

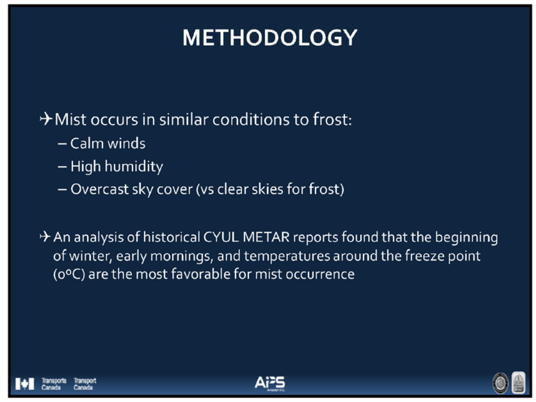
BACKGROUND

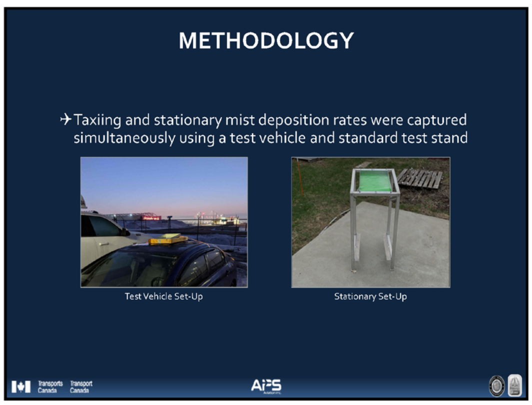
- Visibility:
  - Mist: between 5/8 and 7 (FMH1) or 6 (MANOBS) statute miles
  - Fog: <5/8 statute mile
- Historical research simulating an aircraft taxi in freezing fog indicated that the deposition rates can increase significantly when in motion;
  - consequently, simulated freezing fog rates of 2 to 5 g/dm²/h were selected for developing HOTs
- The deposition rates for mist have never been quantified from a HOT perspective

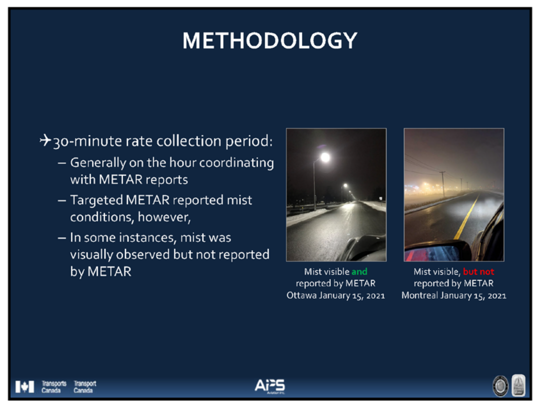
OBJECTIVE

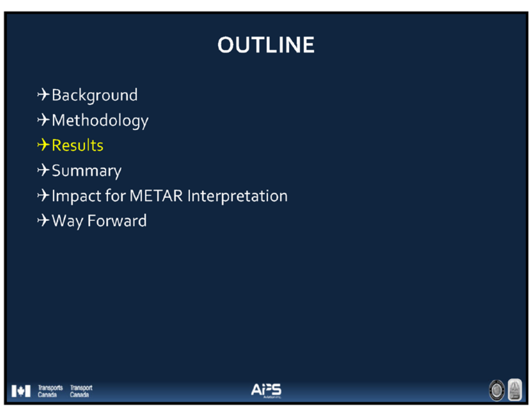
- The objective is to determine the range of deposition rates that occur naturally in mist
- This research is required to develop guidance for the appropriate treatment of mist for HOT determination

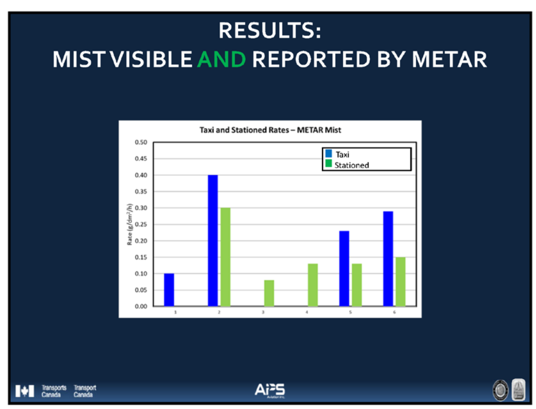

OUTLINE
Background
Methodology
Results
Summary
Impact for METAR Interpretation
Way Forward

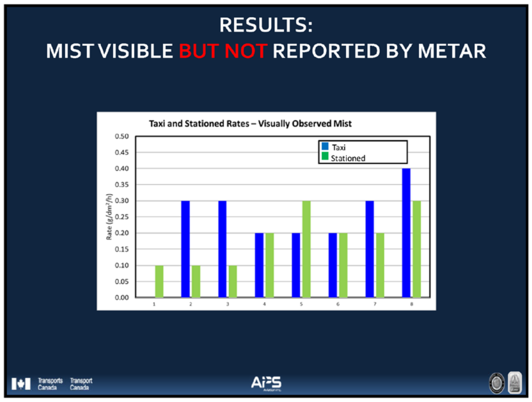

METHODOLOGY
Mist occurs in similar conditions to frost:
– Calm winds
– High humidity
– Overcast sky cover (vs clear skies for frost)
An analysis of historical CYUL METAR reports found that the beginning of winter, early mornings, and temperatures around the freeze point (0°C) are the most favorable for mist occurrence


METHODOLOGY
Taxiing and stationary mist deposition rates were captured simultaneously using a test vehicle and standard test stand
Test Vehicle Set-Up
Stationary Set-Up

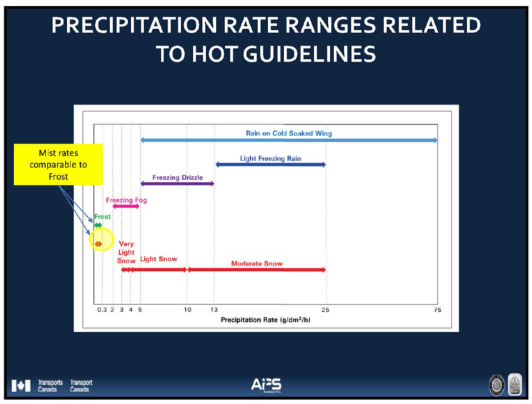

METHODOLOGY
30-minute rate collection period:
– Generally on the hour coordinating with METAR reports
– Targeted METAR reported mist conditions, however,
– In some instances, mist was visually observed but not reported by METAR
Mist visible and reported by METAR Ottawa January 15, 2021
Mist visible, but not reported by METAR Montreal January 15, 2021

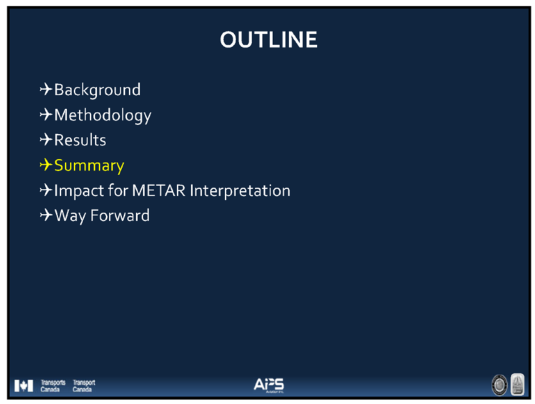

OUTLINE
Background
Methodology
Results
Summary
Impact for METAR Interpretation
Way Forward

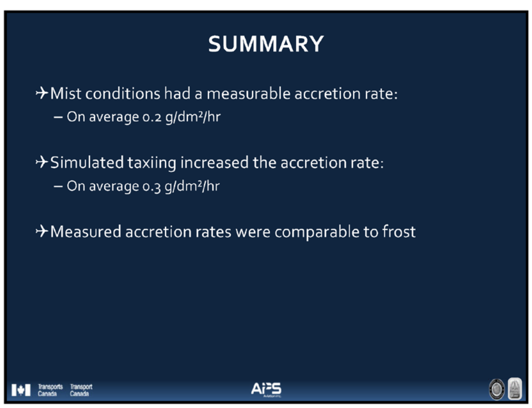

RESULTS:
MIST VISIBLE AND REPORTED BY METAR
Taxi and Stationed Rates – METAR Mist
Taxi
Stationed

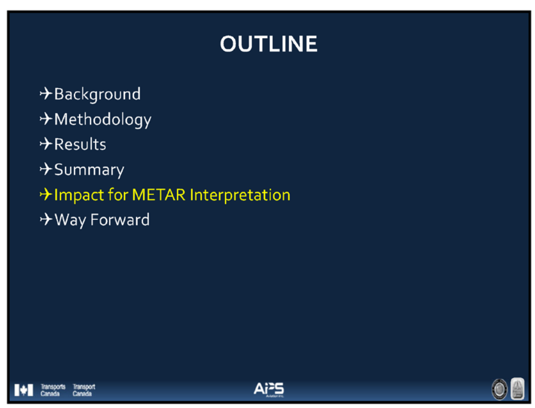


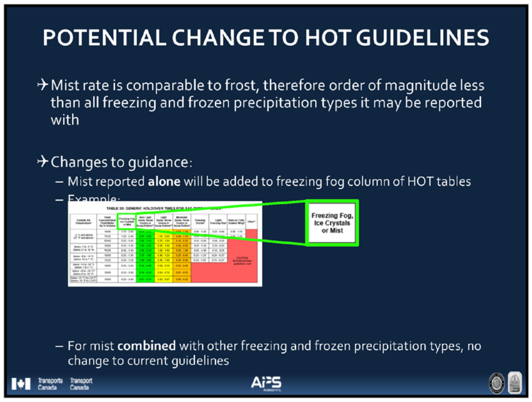
	Simulated Taxi Average Rate (Rate (g/dm²/h)	Stationed Average Rate (Rate (g/dm²/h)
Mist visible and reported by METAR	0.26	0.13
Mist visible, but not reported by METAR	0.27	0.19
Combined Average (Rounded)	0.3	0.2

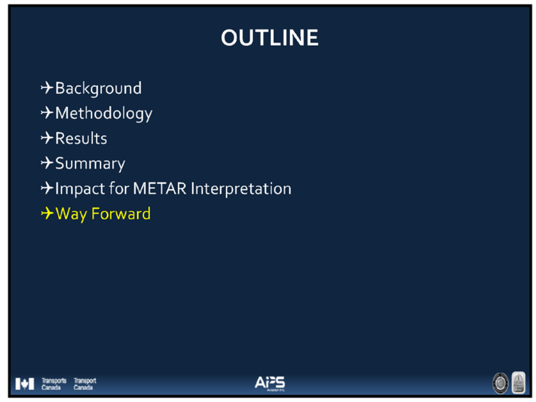


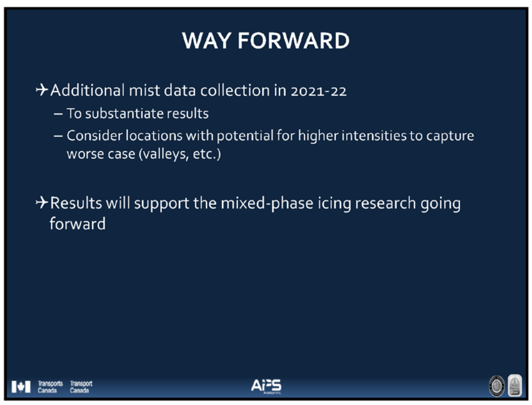







POTENTIAL CHANGE TO HOT GUIDELINES
Mist rate is comparable to frost, therefore order of magnitude less than all freezing and frozen precipitation types it may be reported with
Changes to guidance:
– Mist reported alone will be added to freezing fog column of HOT tables
– Example:
Freezing Fog, Ice Crystals or Mist
– For mist combined with other freezing and frozen precipitation types, no change to current guidelines

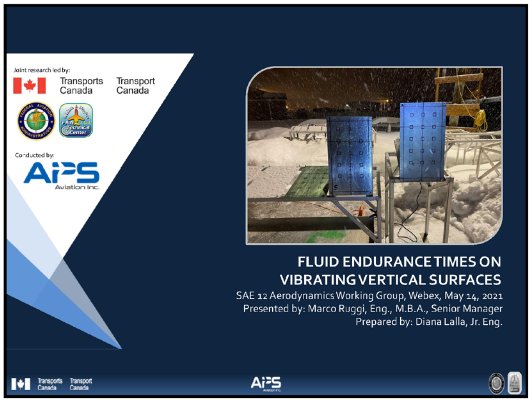

OUTLINE
Background
Methodology
Results
Summary
Impact for METAR Interpretation
Way Forward

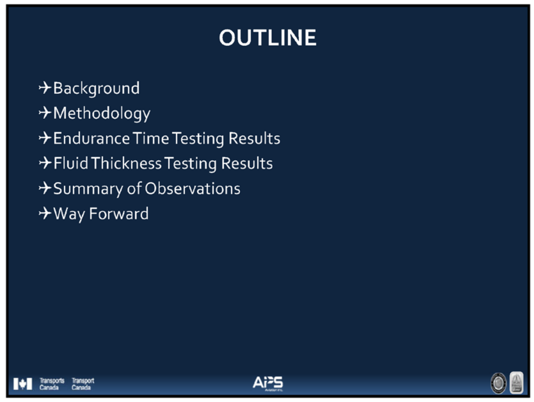

WAY FORWARD
Additional mist data collection in 2021-22
– To substantiate results
– Consider locations with potential for higher intensities to capture worse case (valleys, etc.)
Results will support the mixed-phase icing research going forward

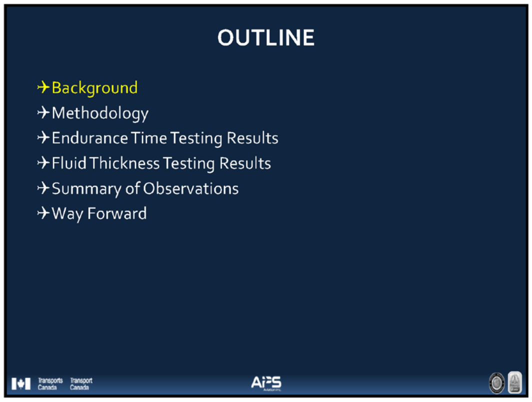

Thank You
Dany Posteraro
dposteraro@apsaviation.ca

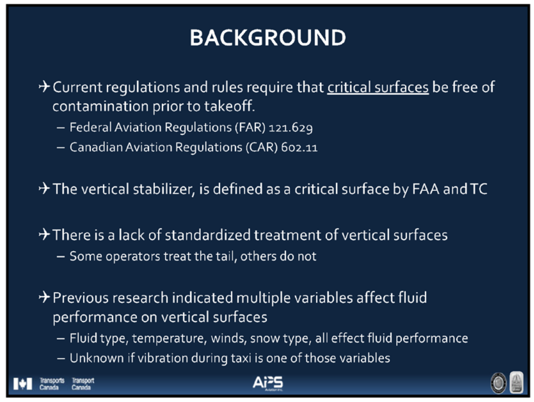
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX)
MAY 2021

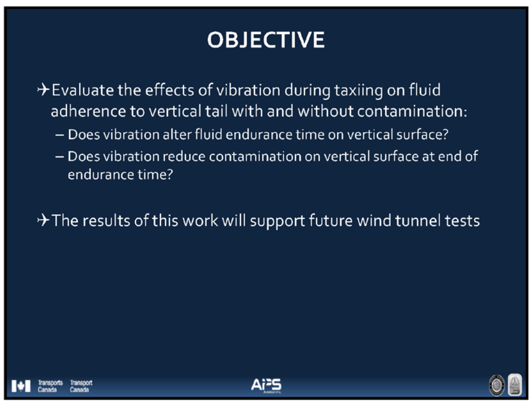
PRESENTATION:
FLUID ENDURANCE TIMES ON VIBRATING VERTICAL SURFACES

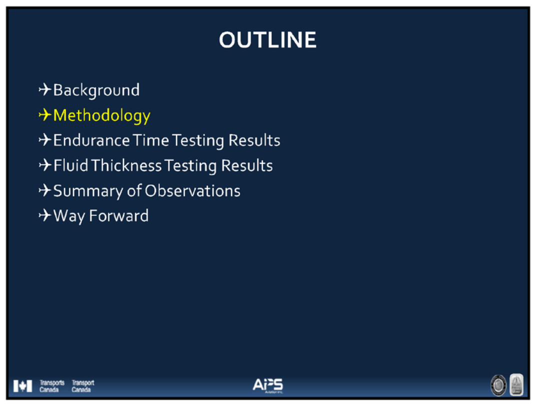

Joint research led by:
Transports Canada Transport Canada
Conducted by:
APS Aviation Inc.
FLUID ENDURANCE TIMES ON VIBRATING VERTICAL SURFACES
SAE 12 Aerodynamics Working Group, Webex, May 14, 2021
Presented by: Marco Ruggi, Eng., M.B.A., Senior Manager
Prepared by: Diana Lalla, Jr. Eng.

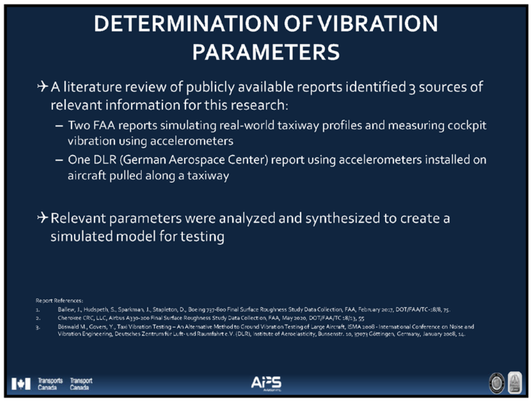

OUTLINE
Background
Methodology
Endurance Time Testing Results
Fluid Thickness Testing Results
Summary of Observations
Way Forward

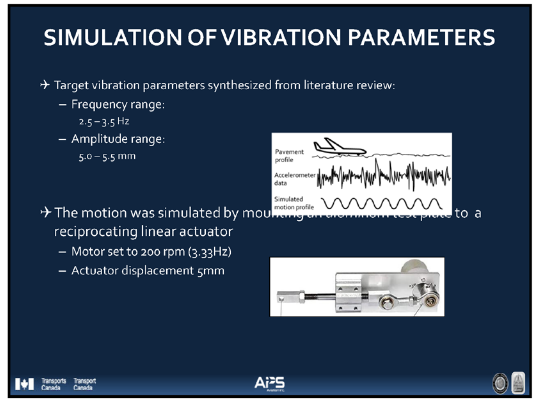

OUTLINE
Background
Methodology
Endurance Time Testing Results
Fluid Thickness Testing Results
Summary of Observations
Way Forward

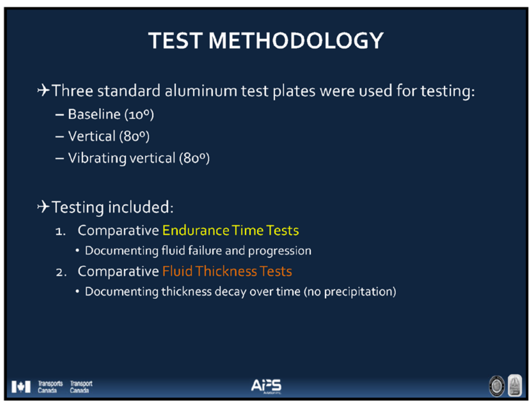

BACKGROUND
Current regulations and rules require that critical surfaces be free of contamination prior to takeoff.
– Federal Aviation Regulations (FAR) 121.629
– Canadian Aviation Regulations (CAR) 602.11
The vertical stabilizer, is defined as a critical surface by FAA and TC
There is a lack of standardized treatment of vertical surfaces
– Some operators treat the tail, others do not
Previous research indicated multiple variables affect fluid performance on vertical surfaces
– Fluid type, temperature, winds, snow type, all effect fluid performance
– Unknown if vibration during taxi is one of those variables

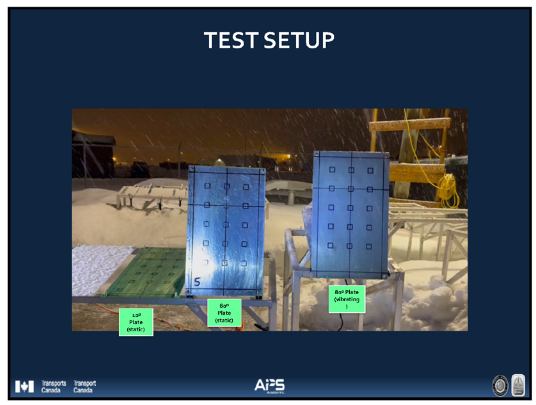

OBJECTIVE
Evaluate the effects of vibration during taxiing on fluid adherence to vertical tail with and without contamination:
– Does vibration alter fluid endurance time on vertical surface?
– Does vibration reduce contamination on vertical surface at end of endurance time?
The results of this work will support future wind tunnel tests

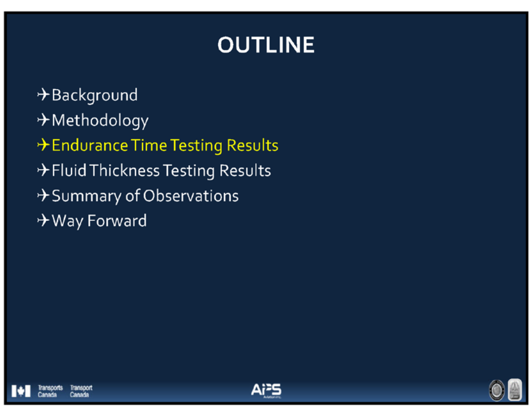

OUTLINE
Background
Methodology
Endurance Time Testing Results
Fluid Thickness Testing Results
Summary of Observations
Way Forward

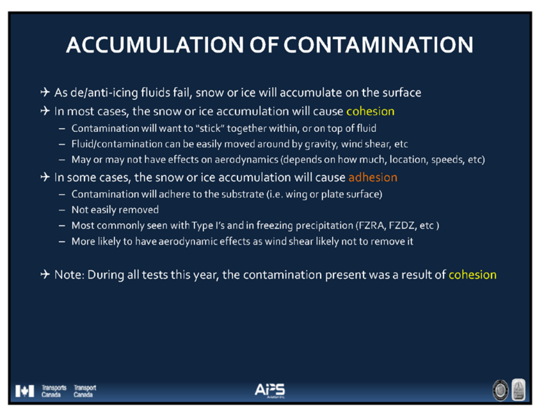

DETERMINATION OF VIBRATION PARAMETERS
A literature review of publicly available reports identified 3 sources of relevant information for this research:
– Two FAA reports simulating real-world taxiway profiles and measuring cockpit vibration using accelerometers
– One DLR (German Aerospace Center) report using accelerometers installed on aircraft pulled along a taxiway
Relevant parameters were analyzed and synthesized to create a simulated model for testing
Report References:
1. Ballew, J., Hudspeth, S., Sparkman, J., Stapleton, D., Boeing 737-800 Final Surface Roughness Study Data Collection, FAA, February 2017, DOT/FAA/TC-18/8, 75.
2. Cherokee CRC, LLC, Airbus A330-200 Final Surface Roughness Study Data Collection, FAA, May 2020, DOT/FAA/TC 18/13, 55
3. Böswald M., Govers, Y., Taxi Vibration Testing – An Alternative Method to Ground Vibration Testing of Large Aircraft, ISMA 2008 - International Conference on Noise and Vibration Engineering, Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Aeroelasticity, Bunsenstr. 10, 37073 Göttingen, Germany, January 2008, 14.
Transports Canada Transport Canada
AiPS

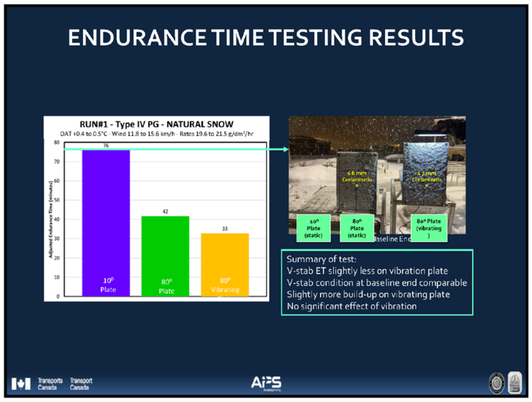

SIMULATION OF VIBRATION PARAMETERS
Target vibration parameters synthesized from literature review:
– Frequency range:
2.5 – 3.5 Hz
– Amplitude range:
5.0 – 5.5 mm
Pavement profile
Accelerometer data
Simulated motion profile
The motion was simulated by mou... to a reciprocating linear actuator
– Motor set to 200 rpm (3.33Hz)
– Actuator displacement 5mm
Transports Canada Transport Canada
AiPS

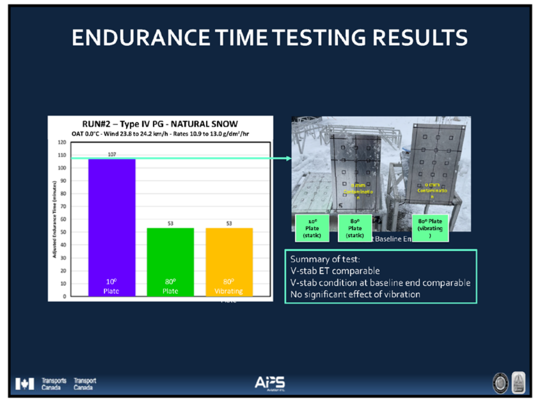

TEST METHODOLOGY
Three standard aluminum test plates were used for testing:
– Baseline (10º)
– Vertical (80º)
– Vibrating vertical (80º)
Testing included:
1. Comparative Endurance Time Tests
• Documenting fluid failure and progression
2. Comparative Fluid Thickness Tests
• Documenting thickness decay over time (no precipitation)
Transports Canada Transport Canada
AiPS

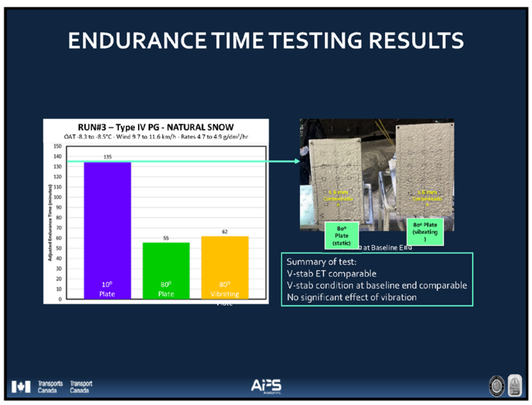

TEST SETUP
10º Plate (static)
80º Plate (static)
80º Plate (vibrating)
Transports Canada Transport Canada
AiPS

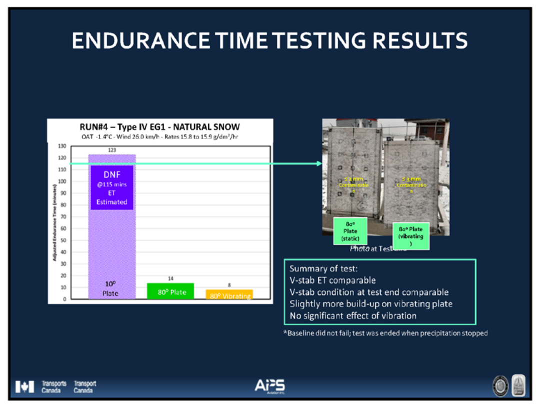

OUTLINE
Background
Methodology
Endurance Time Testing Results
Fluid Thickness Testing Results
Summary of Observations
Way Forward
Transports Canada Transport Canada
AiPS

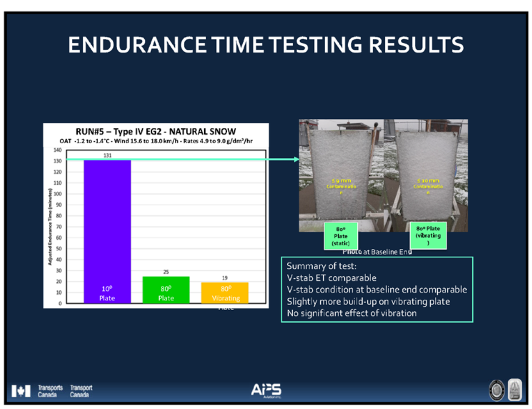

ACCUMULATION OF CONTAMINATION
As de/anti-icing fluids fail, snow or ice will accumulate on the surface
In most cases, the snow or ice accumulation will cause cohesion
– Contamination will want to "stick" together within, or on top of fluid
– Fluid/contamination can be easily moved around by gravity, wind shear, etc
– May or may not have effects on aerodynamics (depends on how much, location, speeds, etc)
In some cases, the snow or ice accumulation will cause adhesion
– Contamination will adhere to the substrate (i.e. wing or plate surface)
– Not easily removed
– Most commonly seen with Type I's and in freezing precipitation (FZRA, FZDZ, etc)
– More likely to have aerodynamic effects as wind shear likely not to remove it
Note: During all tests this year, the contamination present was a result of cohesion
Transports Canada Transport Canada
AiPS

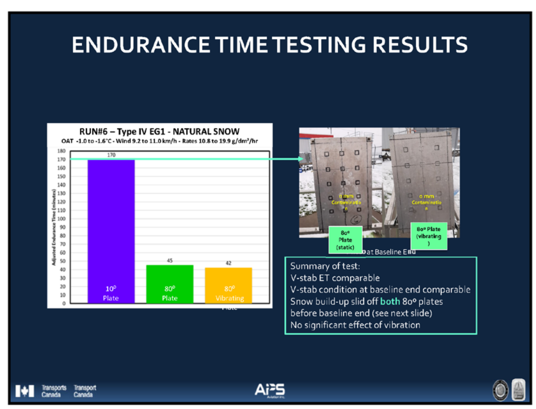

ENDURANCE TIME TESTING RESULTS
RUN#1 - Type IV PG - NATURAL SNOW
OAT +0.4 to 0.5°C - Wind 11.8 to 15.6 km/h - Rates 19.6 to 21.5 g/dm²/hr
Adjusted Endurance Time (minutes)
76
42
33
10° Plate
80° Plate
80° Vibrating
≤ 6 mm Contamination
≤ 7 mm Contamination
10° Plate (static)
80° Plate (static)
80° Plate (vibrating)
Summary of test:
V-stab ET slightly less on vibration plate
V-stab condition at baseline end comparable
Slightly more build-up on vibrating plate
No significant effect of vibration
Transports Canada Transport Canada
APS

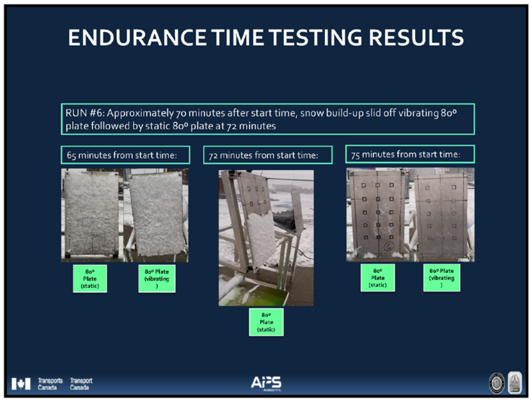

ENDURANCE TIME TESTING RESULTS
RUN#2 – Type IV PG - NATURAL SNOW
OAT 0.0°C - Wind 23.8 to 24.2 km/h - Rates 10.9 to 13.0 g/dm²/hr
Adjusted Endurance Time (minutes)
107
53
53
10° Plate
80° Plate
80° Vibrating
0 mm Contamination
0 mm Contamination
10° Plate (static)
80° Plate (static)
80° Plate (vibrating)
Summary of test:
V-stab ET comparable
V-stab condition at baseline end comparable
No significant effect of vibration
Transports Canada Transport Canada
APS

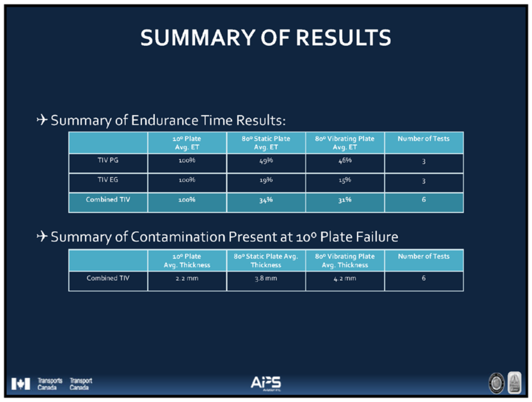

ENDURANCE TIME TESTING RESULTS
RUN#3 – Type IV PG - NATURAL SNOW
OAT -8.3 to -8.5°C - Wind 9.7 to 11.6 km/h - Rates 4.7 to 4.9 g/dm²/hr
Adjusted Endurance Time (minutes)
135
55
62
10° Plate
80° Plate
80° Vibrating
≤ 6 mm Contamination
≤ 6 mm Contamination
80° Plate (static)
80° Plate (vibrating)
at Baseline End
Summary of test:
V-stab ET comparable
V-stab condition at baseline end comparable
No significant effect of vibration
Transports Canada Transport Canada
APS


ENDURANCE TIME TESTING RESULTS
RUN#4 – Type IV EG1 - NATURAL SNOW
OAT -1.4°C - Wind 26.0 km/h - Rates 15.8 to 15.9 g/dm²/hr
Adjusted Endurance Time (minutes)
123
DNF @115 mins ET Estimated
14
8
10° Plate
80° Plate
80° Vibrating
≤ 2 mm Contamination
≤ 3 mm Contamination
80° Plate (static)
80° Plate (vibrating)
Summary of test:
V-stab ET comparable
V-stab condition at test end comparable
Slightly more build-up on vibrating plate
No significant effect of vibration
*Baseline did not fail; test was ended when precipitation stopped
Transports Canada Transport Canada
APS


ENDURANCE TIME TESTING RESULTS
RUN#5 – Type IV EG2 - NATURAL SNOW
OAT -1.2 to -1.4°C - Wind 15.6 to 18.0 km/h - Rates 4.9 to 9.0 g/dm²/hr
Adjusted Endurance Time (minutes)
131
25
19
10° Plate
80° Plate
80° Vibrating
≤ 9 mm Contamination
≤ 10 mm Contamination
80° Plate (static)
80° Plate (vibrating)
at Baseline End
Summary of test:
V-stab ET comparable
V-stab condition at baseline end comparable
Slightly more build-up on vibrating plate
No significant effect of vibration
Transports Canada Transport Canada
APS


ENDURANCE TIME TESTING RESULTS
RUN#6 – Type IV EG1 - NATURAL SNOW
OAT -1.0 to -1.6°C - Wind 9.2 to 11.0 km/h - Rates 10.8 to 19.9 g/dm²/hr
Adjusted Endurance Time (minutes)
170
45
42
10° Plate
80° Plate
80° Vibrating
0 mm Contamination
0 mm Contamination
80° Plate (static)
80° Plate (vibrating)
Summary of test:
V-stab ET comparable
V-stab condition at baseline end comparable
Snow build-up slid off both 80° plates
before baseline end (see next slide)
No significant effect of vibration
Transports Canada Transport Canada
APS


ENDURANCE TIME TESTING RESULTS
RUN #6: Approximately 70 minutes after start time, snow build-up slid off vibrating 80° plate followed by static 80° plate at 72 minutes
65 minutes from start time:
80° Plate (static)
80° Plate (vibrating)
72 minutes from start time:
80° Plate (static)
75 minutes from start time:
80° Plate (static)
80° Plate (vibrating)
Transports Canada Transport Canada
APS

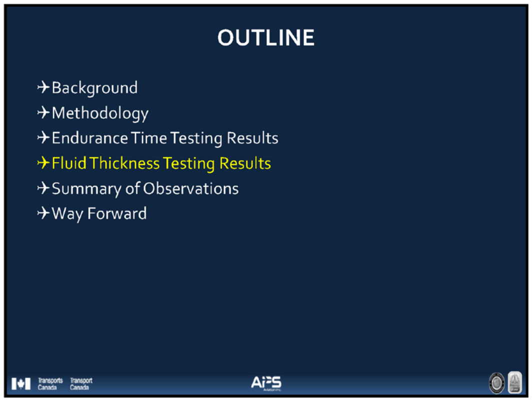

SUMMARY OF RESULTS
Summary of Endurance Time Results:

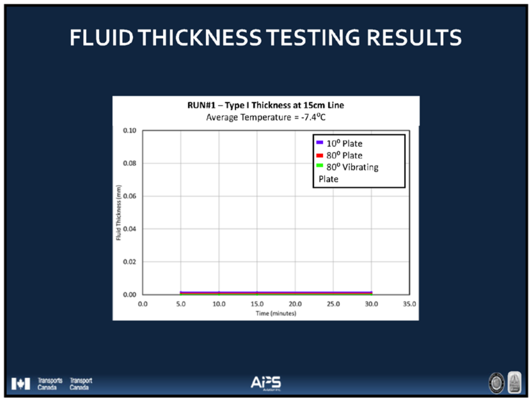
	10° Plate Avg. ET	80° Static Plate Avg. ET	80° Vibrating Plate Avg. ET	Number of Tests
TIV PG	100%	49%	46%	3
TIV EG	100%	19%	15%	3
Combined TIV	100%	34%	31%	6

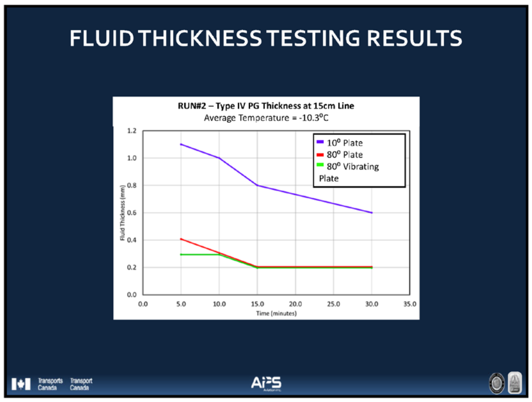
Summary of Contamination Present at 10° Plate Failure

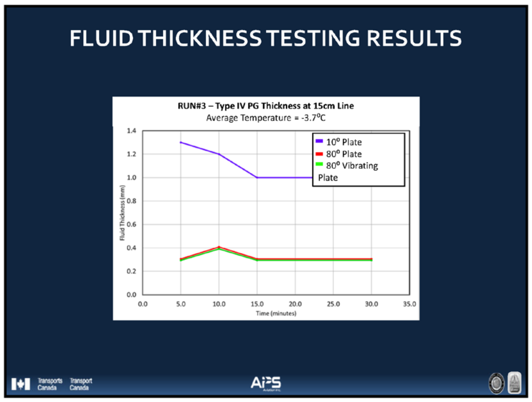
	10° Plate Avg. Thickness	80° Static Plate Avg. Thickness	80° Vibrating Plate Avg. Thickness	Number of Tests
Combined TIV	2.2 mm	3.8 mm	4.2 mm	6

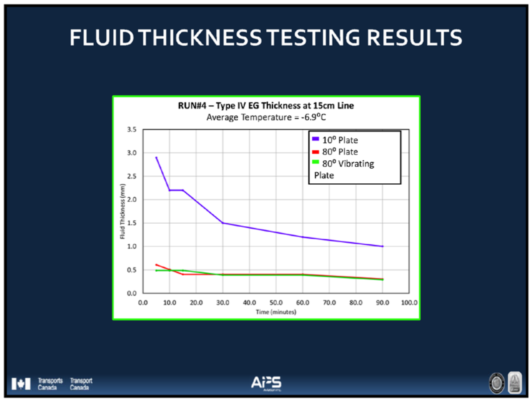
Transports Canada Transport Canada
APS

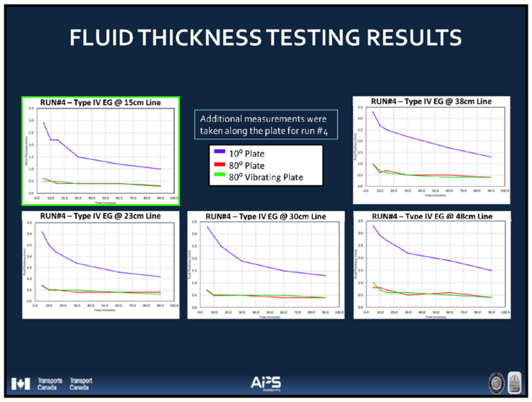

OUTLINE
Background
Methodology
Endurance Time Testing Results
Fluid Thickness Testing Results
Summary of Observations
Way Forward
Transports Canada Transport Canada
APS

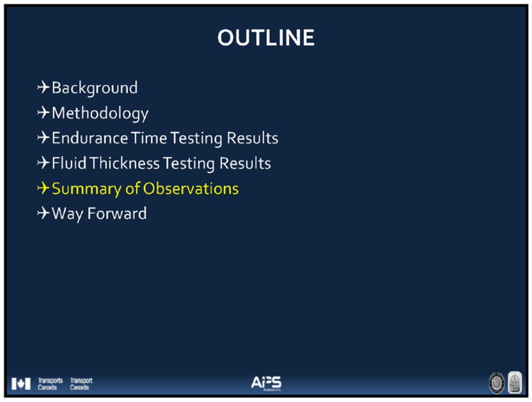

FLUID THICKNESS TESTING RESULTS
RUN#1 – Type I Thickness at 15cm Line
Average Temperature = -7.4°C
10° Plate
80° Plate
80° Vibrating Plate
Fluid Thickness (mm)
Time (minutes)
Transports Canada Transport Canada
APS

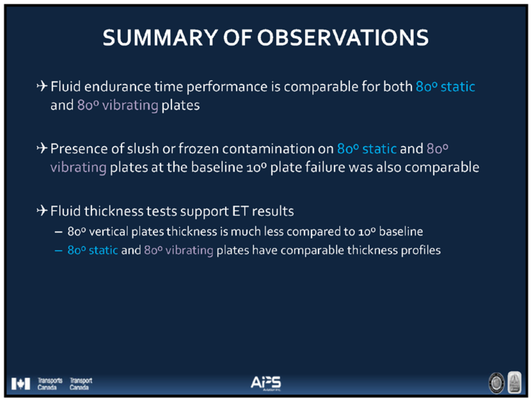

FLUID THICKNESS TESTING RESULTS
RUN#2 – Type IV PG Thickness at 15cm Line
Average Temperature = -10.3°C
10° Plate
80° Plate
80° Vibrating Plate
Fluid Thickness (mm)
Time (minutes)
Transports Canada Transport Canada
APS

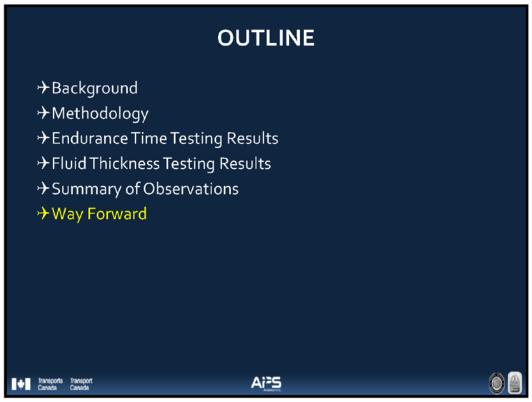

FLUID THICKNESS TESTING RESULTS
RUN#3 – Type IV PG Thickness at 15cm Line
Average Temperature = -3.7°C
10° Plate
80° Plate
80° Vibrating Plate
Fluid Thickness (mm)
Time (minutes)
Transports Canada Transport Canada
APS

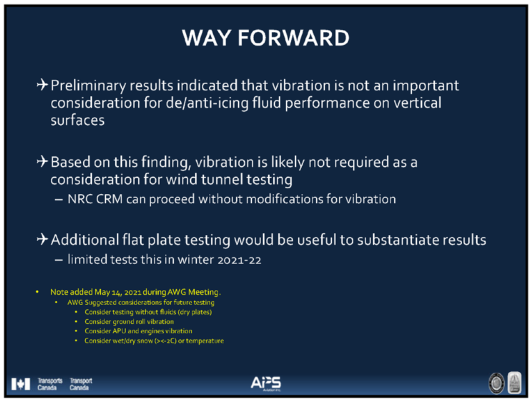

FLUID THICKNESS TESTING RESULTS
RUN#4 – Type IV EG Thickness at 15cm Line
Average Temperature = -6.9°C
10° Plate
80° Plate
80° Vibrating Plate
Fluid Thickness (mm)
Time (minutes)
Transports Canada
Transport Canada
AiPS


FLUID THICKNESS TESTING RESULTS
RUN#4 – Type IV EG @ 15cm Line
Additional measurements were taken along the plate for run #4
10° Plate
80° Plate
80° Vibrating Plate
RUN#4 – Type IV EG @ 38cm Line
RUN#4 – Type IV EG @ 23cm Line
RUN#4 – Type IV EG @ 30cm Line
RUN#4 – Type IV EG @ 48cm Line
Transports Canada
Transport Canada
AiPS


OUTLINE
Background
Methodology
Endurance Time Testing Results
Fluid Thickness Testing Results
Summary of Observations
Way Forward
Transports Canada
Transport Canada
AiPS


SUMMARY OF OBSERVATIONS
Fluid endurance time performance is comparable for both 80° static and 80° vibrating plates
Presence of slush or frozen contamination on 80° static and 80° vibrating plates at the baseline 10° plate failure was also comparable
Fluid thickness tests support ET results
– 80° vertical plates thickness is much less compared to 10° baseline
– 80° static and 80° vibrating plates have comparable thickness profiles
Transports Canada
Transport Canada
AiPS


OUTLINE
Background
Methodology
Endurance Time Testing Results
Fluid Thickness Testing Results
Summary of Observations
Way Forward
Transports Canada
Transport Canada
AiPS


WAY FORWARD
Preliminary results indicated that vibration is not an important consideration for de/anti-icing fluid performance on vertical surfaces
Based on this finding, vibration is likely not required as a consideration for wind tunnel testing
– NRC CRM can proceed without modifications for vibration
Additional flat plate testing would be useful to substantiate results
– limited tests this in winter 2021-22
Note added May 14, 2021 during AWG Meeting.
AWG Suggested considerations for future testing
Consider testing without fluids (dry plates)
Consider ground roll vibration
Consider APU and engines vibration
Consider wet/dry snow (><-2C) or temperature
Transports Canada
Transport Canada
AiPS


APS
Aviation Inc
Thank
You
5
Marco Ruggi
mruggi@apsaviation.ca
Transports Canada
Transport Canada
APS